BHUTAN CIVIL AVIATION REQUIREMENT

BCAR-10

AERONAUTICAL TELECOMMUNICATION

VOLUME IV

SURVEILLANCE AND COLLISION AVODIANCE SYSTEM

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Bhutan Civil Aviation Authority

RECORD OF AMENDMENTS AND CORRIGENDA

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FOREWORD

Section 59 of the Civil Aviation Act of Bhutan 2016 empowers the Head of Authority, in this case the Director General of Civil Aviation Authority of Bhutan (BCAA), to make Rules and Regulations concerning the use of the airspace, air navigation facilities and services. Accordingly, BCAR-10 Volume IV (Surveillance and collision avoidance system) containing provision incorporating the standard and recommended practices of ICAO Annex 10 Volume IV has been developed.

BCAR-10 or BCAR – Aeronautical Telecommunication, which are to be used interchangeably and construed to refer to this document, is hereby published in accordance with section 56 of the act.

During the transposing of the standard and recommended practices of ICAO Annex 10 Volume IV to this BCAR, some provisions that are not applicable or currently irrelevant have been left out and marked as "Reserved". These provisions will be incorporated as and when appropriate.

Any difference existing in this BCAR and the related ICAO Standards and Recommended Practices and any amendments thereto will be notified to the ICAO and the same shall be published in the Aeronautical Information Publication (AIP).

BCAR-10 Volume IV hereby supersedes the BCAR-Aeronautical Telecommunication Volume IV that was published on October 1, 2010.

This BCAR is a controlled document and the provisions contained herein are subject to change through amendments.

Wangdi Gyaltshen
Director General
Bhutan Civil Aviation Authority
Date: 07/12/2017

CHAPTER 1. DEFINITIONS

Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radio communication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies *(ICAO Doc 9718).*

Airborne collision avoidance system (ACAS). An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

Note.— SSR transponders referred to above are those operating in Mode C or Mode S.

Aircraft address. A unique combination of twenty-four bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Note.— SSR Mode S transponders transmit extended squitters to support the broadcast of aircraft-derived position for surveillance purposes. The broadcast of this type of information is a form of automatic dependent surveillance (ADS) known as ADS-broadcast (ADS-B).

Automatic dependent surveillance-broadcast (ADS-B) OUT. A function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers.

Automatic dependent surveillance-broadcast (ADS-B) IN. A function that receives surveillance data from ADS-B OUT data sources.

Collision avoidance logic. The sub-system or part of ACAS that analyses data relating to an intruder and own aircraft, decides whether or not advisories are appropriate and, if so, generates the advisories. It includes the following functions: range and altitude tracking, threat detection and RA generation. It excludes surveillance.

Human Factors principles. Principles which apply to design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

Secondary surveillance radar (SSR). A surveillance radar system which uses transmitters/receivers (interrogators) and transponders.

Note.— The requirements for interrogators and transponders are specified in Chapter 3.

Surveillance radar. Radar equipment used to determine the position of an aircraft in range and azimuth.

Traffic information service – broadcast (TIS-B) IN. A surveillance function that receives and processes surveillance data from TIS-B OUT data sources.

Traffic information service – broadcast (TIS-B) OUT. A function on the ground that periodically broadcasts the surveillance information made available by ground sensors in a format suitable for TIS-B IN capable receivers.

Note.— This technique can be achieved through different data links. The requirements for Mode S extended squitters are specified in BCAR-10, Volume IV, Chapter 5. The requirements for VHF digital link (VDL) Mode 4 and universal access transceiver (UAT) are specified in BCAR-10, Volume III, Part I.

Transponder occupancy. A state of unavailability of the transponder from the time it detects an incoming signal that appears to cause some action or from the time of a self-initiated transmission, to the time that it is capable of replying to another interrogation.

Note.— Signals from various systems that contribute to transponder occupancy are described in the Aeronautical Surveillance Manual *(Doc 9924), Appendix M.*

CHAPTER 2. GENERAL

2.1 (Reserved) Secondary Surveillance Radar (SSR)

2.2 (Reserved) Human Factors Considerations

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CHAPTER 3. SURVEILLANCE SYSTEMS

3.1 (Reserved) Secondary Surveillance Radar (SSR) System Characteristics.

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CHAPTER 4. AIRBORNE COLLISION AVOIDANCE SYSTEM

Note 1.— Guidance material relating to the airborne collision avoidance system is contained in the Airborne Collision Avoidance System (ACAS) Manual *(ICAO Doc 9863).*

Note 2.— Non-SI alternative units are used as permitted by BCAR - 5, Chapter 3, 3.2.2. In limited cases, to ensure consistency at the level of the logic calculations, units such as ft/s, NM/s and kt/s are used.

Note 3.— The system that is compliant with Chapter 4 in its entirety is the one that incorporates the traffic alert and collision avoidance systems (TCAS) Version 7.1 and therefore meets the RTCA/DO-185B or EUROCAE/ED-143 specification.

Note 4.— Equipment complying with RTCA/DO-185A standards (also known as TCAS Version 7.0) is not compliant with Chapter 4 in its entirety.

4.1 Definitions Relating to Airborne Collision Avoidance System

ACAS I. An ACAS which provides information as an aid to "see and avoid" action but does not include the capability for generating resolution advisories (RAs).

Note.— ACAS I is not intended for international implementation and standardization by ICAO. Therefore, only ACAS I characteristics required to ensure compatible operation with other ACAS configurations and interference limiting are defined in 4.2.

ACAS II. An ACAS which provides vertical resolution advisories (RAs) in addition to traffic advisories (TAs).

ACAS III. An ACAS which provides vertical and horizontal resolution advisories (RAs) in addition to traffic advisories (TAs).

ACAS broadcast. A long Mode S air-air surveillance interrogation (UF = 16) with the broadcast address.

Active RAC. An RAC is active if it currently constrains the selection of the RA. RACs that have been received within the last six seconds and have not been explicitly cancelled are active.

Altitude crossing RA. A resolution advisory is altitude crossing if own ACAS aircraft is currently at least 30 m (100 ft) below or above the threat aircraft for upward or downward sense advisories, respectively.

Climb RA. A positive RA recommending a climb but not an increased climb.

Closest approach. The occurrence of minimum range between own ACAS aircraft and the intruder. Thus range at closest approach is the smallest range between the two aircraft and time of closest approach is the time at which this occurs.

Coordination. The process by which two ACAS-equipped aircraft select compatible resolution advisories (RAs) by the exchange of resolution advisory complements (RACs).

Coordination interrogation. A Mode S interrogation (uplink transmission) radiated by ACAS II or III and containing a resolution message.

Coordination reply. A Mode S reply (downlink transmission) acknowledging the receipt of a coordination interrogation by the Mode S transponder that is part of an ACAS II or III installation.

Corrective RA. A resolution advisory that advises the pilot to deviate from the current flight path.

Cycle. The term "cycle" used in this chapter refers to one complete pass through the sequence of functions executed by ACAS II or ACAS III, nominally once a second.

Descend RA. A positive RA recommending a descent but not an increased descent.

Established track. A track generated by ACAS air-air surveillance that is treated as the track of an actual aircraft.

Increased rate RA. A resolution advisory with a strength that recommends increasing the altitude rate to a value exceeding that recommended by a previous climb or descend RA.

Intruder. An SSR transponder-equipped aircraft within the surveillance range of ACAS for which ACAS has an established track.

Own aircraft. The aircraft fitted with the ACAS that is the subject of the discourse, which ACAS is to protect against possible collisions, and which may enter a manoeuvre in response to an ACAS indication.

Positive RA. A resolution advisory that advises the pilot either to climb or to descend (applies to ACAS II).

Potential threat. An intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near-collision course with own aircraft. The warning time provided against a potential threat is sufficiently small that a traffic advisory (TA) is justified but not so small that a resolution advisory (RA) would be justified.

Preventive RA. A resolution advisory that advises the pilot to avoid certain deviations from the current flight path but does not require any change in the current flight path.

RA sense. The sense of an ACAS II RA is "upward" if it requires climb or limitation of descent rate and "downward" if it requires descent or limitation of climb rate. It can be both upward and downward simultaneously if it requires limitation of the vertical rate to a specified range.

Note.— The RA sense may be both upward and downward when, having several simultaneous threats, ACAS generates an RA aimed at ensuring adequate separation below some threat(s) and above some other threat(s).

Resolution advisory (RA). An indication given to the flight crew recommending:

a) a manoeuvre intended to provide separation from all threats; or

b) a manoeuvre restriction intended to maintain existing separation.

Resolution advisory complement (RAC). Information provided by one ACAS to another via a Mode S interrogation in order to ensure complementary manoeuvres by restricting the choice of manoeuvres available to the ACAS receiving the RAC.

Resolution advisory complements record (RAC record). A composite of all currently active vertical RACs (VRCs) and horizontal RACs (HRCs) that have been received by ACAS. This information is provided by one ACAS to another ACAS or to a Mode S ground station via a Mode S reply.

Resolution advisory strength. The magnitude of the manoeuvre indicated by the RA. An RA may take on several successive strengths before being cancelled. Once a new RA strength is issued, the previous one automatically becomes void.

Resolution message. The message containing the resolution advisory complement (RAC).

Reversed sense RA. A resolution advisory that has had its sense reversed.

Sensitivity level (S). An integer defining a set of parameters used by the traffic advisory (TA) and collision avoidance algorithms to control the warning time provided by the potential threat and threat detection logic, as well as the values of parameters relevant to the RA selection logic.

Threat. An intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near-collision course with own aircraft. The warning time provided against a threat is sufficiently small that an RA is justified.

Track. A sequence of at least three measurements representing positions that could reasonably have been occupied by an aircraft.

Traffic advisory (TA). An indication given to the flight crew that a certain intruder is a potential threat.

Vertical speed limit (VSL) RA. A resolution advisory advising the pilot to avoid a given range of altitude rates. A VSL RA can be either corrective or preventive.

Warning time. The time interval between potential threat or threat detection and closest approach when neither aircraft accelerates.

4.2 ACAS I General Provisions and Characteristics

4.2.1 Functional requirements. ACAS I shall perform the following functions:

a) surveillance of nearby SSR transponder-equipped aircraft; and

b) provide indications to the flight crew identifying the approximate position of nearby aircraft as an aid to visual acquisition.

Note.— ACAS I is intended to operate using Mode A/C interrogations only. Furthermore, it does not coordinate with other ACAS. Therefore, a Mode S transponder is not required as a part of an ACAS I installation.

4.2.2 Signal format. The RF characteristics of all ACAS I signals shall conform to the provisions of Chapter 3, 3.1.1.1 through 3.1.1.6 and 3.1.2.1 through 3.1.2.4.

4.2.3 Interference control

4.2.3.1 Maximum radiated RF power. The effective radiated power of an ACAS I transmission at 0 degree elevation relative to the longitudinal axis of the aircraft shall not exceed 24 dBW.

4.2.3.2 Unwanted radiated power. When ACAS I is not transmitting an interrogation, the effective radiated power in any direction shall not exceed –70 dBm.

Note.— This requirement is to ensure that, when not transmitting an interrogation, ACAS I does not radiate RF energy that could interfere with, or reduce the sensitivity of, the SSR transponder or radio equipment in other nearby aircraft or ground facilities.

4.2.3.3 Interference limiting. Each ACAS I interrogator shall control its interrogation rate or power or both in all SSR modes to minimize interference effects (4.2.3.3.3 and 4.2.3.3.4).

Note.— These limits are a means of ensuring that all interference effects resulting from these interrogations, together with the interrogations from all other ACAS I, ACAS II and ACAS III interrogators in the vicinity are kept to a low level.

4.2.3.3.1 Determination of own transponder reply rate. ACAS I shall monitor the rate that own transponder replies to interrogations to ensure that the provisions in 4.2.3.3.3 are met.

4.2.3.3.2 Determination of the number of ACAS II and ACAS III interrogators. ACAS I shall count the number of ACAS II and ACAS III interrogators in the vicinity to ensure that the provisions in 4.2.3.3.3 or 4.2.3.3.4 are met. This count shall be obtained by monitoring ACAS broadcasts (UF = 16), (4.3.7.1.2.4) and shall be updated as the number of distinct ACAS aircraft addresses received within the previous 20-s period at a nominal frequency of at least 1 Hz.

4.2.3.3.3 Mode A/C ACAS I interference limits. The interrogator power shall not exceed the following limits:

	Upper limit for $\{\sum_{k=1}^{k_t} P_a(k)\}$	
n_a	If $f_r \leq 240$	If $f_r > 240$
0	250	118
1	250	113
2	250	108
3	250	103
4	250	98
5	250	94
6	250	89
7	250	84
8	250	79
9	250	74
10	245	70
11	228	65
12	210	60
13	193	55
14	175	50
15	158	45
16	144	41
17	126	36
18	109	31
19	91	26
20	74	21
21	60	17
≥22	42	12

where:

n_a = number of operating ACAS II and ACAS III equipped aircraft near own (based on ACAS broadcasts received with a transponder receiver threshold of –74 dBm);

{ } = average value of the expression within the brackets over last 8 interrogation cycles;

$P_a(k)$ = peak power radiated from the antenna in all directions of the pulse having the largest amplitude in the group of pulses comprising a single interrogation during the *k*th Mode A/C interrogation in a 1 s interrogation cycle, W;

k = index number for Mode A/C interrogations, $k = 1, 2, \ldots, k_t$;

k_t = number of Mode A/C interrogations transmitted in a 1 s interrogation cycle;

f_r = Mode A/C reply rate of own transponder.

4.2.3.3.4 *Mode S ACAS I interference limits.* An ACAS I that uses Mode S interrogations shall not cause greater interference effects than an ACAS I using Mode A/C interrogations only.

4.3 General Provisions Relating to ACAS II and ACAS III

4.2.3.3.4 Mode S ACAS I interference limits. An ACAS I that uses Mode S interrogations shall not cause greater interference effects than an ACAS I using Mode A/C interrogations only.

Note 1.— The acronym ACAS is used in this section to indicate either ACAS II or ACAS III.

Note 2.— Carriage requirements for ACAS equipment are addressed in ICAO Annex 6.

Note 3.— The term "equipped threat" is used in this section to indicate a threat fitted with ACAS II or ACAS III.

4.3.1 Functional requirements

4.3.1.1 ACAS functions. ACAS shall perform the following functions:

a) surveillance;

b) generation of TAs;

c) threat detection;

d) generation of RAs;

e) coordination; and

f) communication with ground stations.

The equipment shall execute functions b) through e) on each cycle of operation.

Note.— Certain features of these functions must be standardized to ensure that ACAS units cooperate satisfactorily with other ACAS units, with Mode S ground stations and with the ATC system. Each of the features that are standardized is discussed below. Certain other features are given herein as recommendations.

4.3.1.1.1 The duration of a cycle shall not exceed 1.2 s.

4.3.2 Surveillance performance requirements

4.3.2.1 General surveillance requirements. ACAS shall interrogate SSR Mode A/C and Mode S transponders in other aircraft and detect the transponder replies. ACAS shall measure the range and relative bearing of responding aircraft. Using these measurements and information conveyed by transponder replies, ACAS shall estimate the relative positions of each responding aircraft. ACAS shall include provisions for achieving such position determination in the presence of ground reflections, interference and variations in signal strength.

4.3.2.1.1 Track establishment probability. ACAS shall generate an established track, with at least a 0.90 probability that the track is established 30 s before closest approach, on aircraft equipped with transponders when all of the following conditions are satisfied:

a) the elevation angles of these aircraft are within ±10 degrees relative to the ACAS aircraft pitch plane;

b) the magnitudes of these aircraft's rates of change of altitude are less than or equal to 51 m/s (10 000 ft/min);

c) the transponders and antennas of these aircraft meet the Standards of Chapter 3, 3.1.1 and 3.1.2;

d) the closing speeds and directions of these aircraft, the local density of SSR transponder-equipped aircraft and the number of other ACAS interrogators in the vicinity (as determined by monitoring ACAS broadcasts, 4.3.7.1.2.4) satisfy the conditions specified in Table 4-1; and

e) the minimum slant range is equal to or greater than 300 m (1 000 ft).

Table 4-1. ACAS design assumptions

Conditions									*Performance*
Quadrant						*Maximum traffic density*		*Maximum number of other ACAS within 56 km (30 NM)*	*Probability of success*
Forward		*Side*		*Back*					
Maximum closing speed						*aircraft/ km²*	*aircraft/ NM²*		
m/s	*Kt*	*m/s*	*Kt*	*m/s*	*kt*				
260	500	150	300	93	180	0.087	0.30	30	0.90
620	1 200	390	750	220	430	0.017	0.06	30	0.90

Note.— Table 4-1 shows the design assumption upon which the development of ACAS was based. Operational experience and simulation show that ACAS provides adequate surveillance for collision avoidance even when the maximum number of other ACAS within 56 km (30 NM) is somewhat higher than that shown in Table 4-1. Future ACAS designs will take account of current and expected ACAS densities.

4.3.2.1.1.1 ACAS shall continue to provide surveillance with no abrupt degradation in track establishment probability as any one of the condition bounds defined in 4.3.2.1.1 is exceeded.

4.3.2.1.1.2 ACAS shall not track Mode S aircraft that report that they are on the ground.

Note.— A Mode S aircraft may report that it is on the ground by coding in the capability (CA) field in a DF = 11 or DF = 17 transmission (Chapter 3, 3.1.2.5.2.2.1) or by coding in the vertical status (VS) field in a DF = 0 transmission (Chapter 3, 3.1.2.8.2.1). Alternatively, if the aircraft is under Mode S ground surveillance, ground status may be determined by monitoring the flight status (FS) field in downlink formats DF = 4, 5, 20 or 21 (Chapter 3, 3.1.2.6.5.1).

4.3.2.1.1.3 ACAS should achieve the required tracking performance when the average SSR Mode A/C asynchronous reply rate from transponders in the vicinity of the ACAS aircraft is 240 replies per second and when the peak interrogation rate received by the individual transponders under surveillance is 500 per second.

Note.— The peak interrogation rate mentioned above includes interrogations from all sources.

4.3.2.1.2 False track probability. The probability that an established Mode A/C track does not correspond in range and altitude, if reported, to an actual aircraft shall be less than 10^{-2}. For an established Mode S track this probability shall be less than 10^{-6}. These limits shall not be exceeded in any traffic environment.

4.3.2.1.3 Range and Bearing Accuracy

4.3.2.1.3.1 Range shall be measured with a resolution of 14.5 m (1/128 NM) or better.

4.3.2.1.3.2 The errors in the relative bearings of the estimated positions of intruders should not exceed 10 degrees rms.

Note.— This accuracy in the relative bearing of intruders is practicable and sufficient as an aid to the visual acquisition of potential threats. In addition, such relative bearing information has been found useful in threat detection, where it can indicate that an intruder is a threat. However, this accuracy is not sufficient as a basis for horizontal RAs, nor is it sufficient for reliable predictions of horizontal miss distance.

4.3.2.2 Interference Control

4.3.2.2.1 Maximum radiated RF power. The effective radiated power of an ACAS transmission at 0 degree elevation relative to the longitudinal axis of the aircraft shall not exceed 27 dBW.

4.3.2.2.1.1 Unwanted radiated power. When ACAS is not transmitting an interrogation, the effective radiated power in any direction shall not exceed –70 dBm.

4.3.2.2.2 Interference limiting. Each ACAS interrogator operating below a pressure-altitude of 5 490 m (18 000 ft) shall control its interrogation rate or power or both so as to conform with specific inequalities (4.3.2.2.2.2).

4.3.2.2.2.1 Determination of the number of other ACAS. ACAS shall count the number of other ACAS II and III interrogators in the vicinity to ensure that the interference limits are met. This count shall be obtained by monitoring ACAS broadcasts (UF = 16), (4.3.7.1.2.4). Each ACAS shall monitor such broadcast interrogations to determine the number of other ACAS within detection range.

4.3.2.2.2.2 ACAS interference limiting inequalities. ACAS shall adjust its interrogation rate and interrogation power such that the following three inequalities remain true, except as provided in 4.3.2.2.2.2.1.

$$\{\sum_{i=1}^{i_t}\left[\frac{p(i)}{250}\right]^{\alpha}\} < minimum\left[\frac{280}{1+n_a}, \frac{11}{\alpha^2}\right] \qquad (1)$$

$$\{\sum_{i=1}^{i_t} m(i)\} < 0.01 \qquad (2)$$

$$\{\frac{1}{B}\sum_{k=1}^{k_t}\frac{P_a(k)}{250}\} < minimum\left[\frac{80}{1+n_a}, 3\right] \qquad (3)$$

The variables in these inequalities shall be defined as follows:

i_t = number of interrogations (Mode A/C and Mode S) transmitted in a 1 s interrogation cycle. This shall include all Mode S interrogations used by the ACAS functions, including those in addition to UF = 0 and UF = 16 interrogations, except as provided in 4.3.2.2.2.2.1;

Note.— UF = 19 interrogations are included in i_t as specified in 3.1.2.8.9.4.

i = index number for Mode A/C and Mode S interrogations, $i = 1, 2, ..., i_t$;

α = the minimum of α_1 calculated as 1/4 $[n_b/n_c]$ subject to the special conditions given below and α_2 calculated as Log_{10} $[n_a/n_b]$ / Log_{10} 25, where n_b and n_c are defined as the number of operating ACAS II and ACAS III equipped aircraft (airborne or on the ground) within 11.2 km (6 NM) and 5.6 km (3 NM) respectively, of own ACAS (based on ACAS surveillance). ACAS aircraft operating on the ground or at or below a radio altitude of 610 m (2 000 ft) AGL shall include both airborne and on-ground ACAS II and ACAS III aircraft in the value for n_b and n_c. Otherwise, ACAS shall include only airborne ACAS II and ACAS III aircraft in the value for n_b and n_c. The values of α, α_1 and α_2 are further constrained to a minimum of 0.5 and a maximum of 1.0.

In addition;

IF $[(n_b \leq 1)$ OR $(n_b \leq 4$ AND $n_c \leq 2$ AND $n_a > 25)]$ THEN $\alpha_1 = 1.0$,

IF $[(n_c > 2)$ AND $(n_b > 2\, n_c)$ AND $(n_a < 40)]$ THEN $\alpha_1 = 0.5$;

$p(i)$ = peak power radiated from the antenna in all directions of the pulse having the largest amplitude in the group of pulses comprising a single interrogation during the ith interrogation in a 1 s interrogation cycle, W;

$m(i)$ = duration of the mutual suppression interval for own transponder associated with the ith interrogation in a 1 s interrogation cycle, s;

B = beam sharpening factor (ratio of 3 dB beam width to beamwidth resulting from interrogation side-lobe suppression). For ACAS interrogators that employ transmitter side-lobe suppression (SLS), the appropriate beamwidth shall be the extent in azimuth angle of the Mode A/C replies from one transponder as limited by SLS, averaged over the transponder population;

{ } see 4.2.3.3.3

$P_a(k)$ "
k "
k_t "
n_a "

Note.— RA and ACAS broadcasts (4.3.6.2.1 and 4.3.7.1.2.4) are interrogations.

4.3.2.2.2.2.1 Transmissions during RAs. All air-to-air coordination interrogations shall be transmitted at full power and these interrogations shall be excluded from the summations of Mode S interrogations in the left-hand terms of inequalities (1) and (2) in 4.3.2.2.2.2 for the duration of the RA.

4.3.2.2.2.2.2 Transmissions from ACAS units on the ground. Whenever the ACAS aircraft indicates that it is on the ground, ACAS interrogations shall be limited by setting the number of other ACAS II and III

aircraft (n_a) count in the interference limiting inequalities to a value that is three times the value obtained based on ACAS broadcasts received with a transponder receiver threshold of –74 dBm. Whenever Mode A/C interrogation power is reduced because of interference limiting, the Mode A/C interrogation power in the forward beam shall be reduced first until the forward sequence matches the right and left sequences. The forward, right and left interrogation powers shall then sequentially be reduced until they match the rear interrogation power. Further reduction of Mode A/C power shall be accomplished by sequentially reducing the forward, side and rear interrogation powers.

4.3.2.2.2.2.3 Transmissions from ACAS units above 5 490 m (18 000 ft) altitude. Each ACAS interrogator operating above a pressure-altitude of 5 490 m (18 000 ft) shall control its interrogation rate or power or both such that inequalities (1) and (3) in 4.3.2.2.2.2 remain true when n_a and α are equal to 1, except as provided in 4.3.2.2.2.2.1.

4.3.3 Traffic advisories (TAs)

4.3.3.1 TA function. ACAS shall provide TAs to alert the flight crew to potential threats. Such TAs shall be accompanied by an indication of the approximate relative position of potential threats to facilitate visual acquisition.

4.3.3.1.1 Display of potential threats. If potential threats are shown on a traffic display, they shall be displayed in amber or yellow.

Note 1.— These colors are generally considered suitable for indicating a cautionary condition.

Note 2.—Additional information assisting in the visual acquisition such as vertical trend and relative altitude may be displayed as well.

Note 3.— Traffic situational awareness is improved when tracks can be supplemented by display of heading information (e.g. as extracted from received ADS-B messages).

4.3.3.2 Proximate Traffic Display

4.3.3.2.1 While any RA and/or TA are displayed, proximate traffic within 11 km (6 NM) range and, if altitude reporting, ±370 m (1 200 ft) altitude should be displayed. This proximate traffic should be distinguished (e.g. by color or symbol type) from threats and potential threats, which should be more prominently displayed.

4.3.3.2.2 While any RA and/or TA are displayed, visual acquisition of the threats and/or potential threat should not be adversely affected by the display of proximate traffic or other data (e.g. contents of received ADS-B messages) unrelated to collision avoidance.

4.3.3.3 TAs as RA precursors. The criteria for TAs shall be such that they are satisfied before those for an RA.

4.3.3.3.1 TA warning time. For intruders reporting altitude, the nominal TA warning time shall not be greater than (T+20 s) where T is the nominal warning time for the generation of the resolution advisory.

Note.— Ideally, RAs would always be preceded by a TA but this is not always possible, e.g. the RA criteria might be already satisfied when a track is first established, or a sudden and sharp manoeuvre by the intruder could cause the TA lead time to be less than a cycle.

4.3.4 Threat detection

4.3.4.1 Declaration of threat. ACAS shall evaluate appropriate characteristics of each intruder to determine whether or not it is a threat.

4.3.4.1.1 Intruder characteristics. As a minimum, the characteristics of an intruder that are used to identify a threat shall include:

a) tracked altitude;

b) tracked rate of change of altitude;

c) tracked slant range;

d) tracked rate of change of slant range; and

e) sensitivity level of intruder's ACAS, S_i.

For an intruder not equipped with ACAS II or ACAS III, S_i shall be set to 1.

4.3.4.1.2 Own aircraft characteristics. As a minimum, the characteristics of own aircraft that are used to identify a threat shall include:

a) altitude;

b) rate of change of altitude; and

c) sensitivity level of own ACAS (4.3.4.3).

4.3.4.2 Sensitivity levels. ACAS shall be capable of operating at any of a number of sensitivity levels. These shall include:

a) $S = 1$, a "standby" mode in which the interrogation of other aircraft and all advisories are inhibited;

b) $S = 2$, a "TA only" mode in which RAs are inhibited; and

c) $S = 3\text{-}7$, further levels that enable the issue of RAs that provide the warning times indicated in Table 4-2 as well as TAs.

4.3.4.3 Selection of own sensitivity level (S_o). The selection of own ACAS sensitivity level shall be determined by sensitivity level control (SLC) commands which shall be accepted from a number of sources as follows:

a) SLC command generated automatically by ACAS based on altitude band or other external factors;

b) SLC command from pilot input; and

c) SLC command from Mode S ground stations.

Table 4-2

Sensitivity level	*2*	*3*	*4*	*5*	*6*	*7*
Nominal warning time	no RAs	15s	20s	25s	30s	35s

4.3.4.3.1 Permitted SLC command codes. As a minimum, the acceptable SLC command codes shall include:

	Coding
for SLC based on altitude band	2-7
for SLC from pilot input	0,1,2
for SLC from Mode S ground stations	0,2-6

4.3.4.3.2 Altitude-band SLC command. Where ACAS selects an SLC command based on altitude, hysteresis shall be applied to the nominal altitude thresholds at which SLC command value changes are required as follows: for a climbing ACAS aircraft the SLC command shall be increased at the appropriate altitude threshold plus the hysteresis value; for a descending ACAS aircraft the SLC command shall be decreased at the appropriate altitude threshold minus the hysteresis value.

4.3.4.3.3 Pilot SLC command. For the SLC command set by the pilot the value 0 shall indicate the selection of the “automatic” mode for which the sensitivity level selection shall be based on the other commands.

4.3.4.3.4 Mode S ground station SLC command. For SLC commands transmitted via Mode S ground stations (4.3.8.4.2.1.1), the value 0 shall indicate that the station concerned is not issuing an SLC command and that sensitivity level selection shall be based on the other commands, including non-0 commands from other Mode S ground stations. ACAS shall not process an uplinked SLC value of 1.

4.3.4.3.4.1 ATS selection of SLC command code. ATS authorities shall ensure that procedures are in place to inform pilots of any ATS selected SLC command code other than 0 (4.3.4.3.1).

4.3.4.3.5 Selection rule. Own ACAS sensitivity level shall be set to the smallest non-0 SLC command received from any of the sources listed in 4.3.4.3.

4.3.4.4 Selection of parameter values for RA generation. When the sensitivity level of own ACAS is 3 or greater, the parameter values used for RA generation that depend on sensitivity level shall be based on the greater of the sensitivity level of own ACAS, S_o, and the sensitivity level of the intruder's ACAS, S_i.

4.3.4.5 Selection of parameter values for TA generation. The parameter values used for TA generation that depend on sensitivity level shall be selected on the same basis as those for RAs (4.3.4.4) except when an SLC command with a value of 2 ("TA only" mode) has been received from either the pilot or a Mode S ground station. In this case, the parameter values for TA generation shall retain the values they would have had in the absence of the SLC command from the pilot or Mode S ground station.

4.3.5 Resolution advisories (RAs)

4.3.5.1 RA generation. For all threats, ACAS shall generate an RA except where it is not possible to select an RA that can be predicted to provide adequate separation either because of uncertainty in the diagnosis of the intruder's flight path or because there is a high risk that a manoeuvre by the threat will negate the RA.

4.3.5.1.1 Display of threats. If threats are shown on a traffic display, they shall be displayed in red.

Note.— This color is generally considered suitable for indicating a warning condition.

4.3.5.1.2 RA cancellation. Once an RA has been generated against a threat or threats it shall be maintained or modified until tests that are less stringent than those for threat detection indicate on two consecutive cycles that the RA may be cancelled, at which time it shall be cancelled.

4.3.5.2 RA selection. ACAS shall generate the RA that is predicted to provide adequate separation from all threats and that has the least effect on the current flight path of the ACAS aircraft consistent with the other provisions in this chapter.

4.3.5.3 RA effectiveness. The RA shall not recommend or continue to recommend a manoeuvre or manoeuvre restriction that, considering the range of probable threat trajectories, is more likely to reduce separation than increase it, subject to the provisions in 4.3.5.5.1.1 and 4.3.5.6.

Note.— See also 4.3.5.8.

4.3.5.3.1 New ACAS installations after 1 January 2014 shall monitor own aircraft's vertical rate to verify compliance with the RA sense. If non-compliance is detected, ACAS shall stop assuming compliance, and instead shall assume the observed vertical rate.

Note 1.— This overcomes the retention of an RA sense that would work only if followed. The revised vertical rate assumption is more likely to allow the logic to select the opposite sense when it is consistent with the non-complying aircraft's vertical rate.

Note 2.— Equipment complying with RTCA/DO-185 or DO-185A standards (also known as TCAS Version 6.04A or TCAS Version 7.0) do not comply with this requirement.

Note 3.— Compliance with this requirement can be achieved through the implementation of traffic alert and collision avoidance system (TCAS) Version 7.1 as specified in RTCA/DO-185B or EUROCAE/ED-143.

4.3.5.3.2 All ACAS should be compliant with the requirement in 4.3.5.3.1.

4.3.5.3.3 After 1 January 2017, all ACAS units shall comply with the requirements stated in 4.3.5.3.1.

4.3.5.4 Aircraft capability. The RA generated by ACAS shall be consistent with the performance capability of the aircraft.

4.3.5.4.1 Proximity to the ground. Descend RAs shall not be generated or maintained when own aircraft is below 300 m (1 000 ft) AGL.

4.3.5.4.2 ACAS shall not operate in sensitivity levels 3-7 when own aircraft is below 300 m (1 000 ft) AGL.

4.3.5.5 Reversals of sense. ACAS shall not reverse the sense of an RA from one cycle to the next, except as permitted in 4.3.5.5.1 to ensure coordination or when the predicted separation at closest approach for the existing sense is inadequate.

4.3.5.5.1 Sense reversals against equipped threats. If an RAC received from an equipped threat is incompatible with the current RA sense, ACAS shall modify the RA sense to conform with the received RAC if own aircraft address is higher in value than that of the threat.

Note.— 4.3.6.1.3 requires that the own ACAS RAC for the threat is also reversed.

4.3.5.5.1.1 ACAS shall not modify an RA sense in a way that makes it incompatible with an RAC received from an equipped threat if own aircraft address is higher in value than that of the threat.

4.3.5.6 RA strength retention. Subject to the requirement that a descend RA is not generated at low altitude (4.3.5.4.1), an RA shall not be modified if the time to closest approach is too short to achieve a significant response or if the threat is diverging in range.

4.3.5.7 Weakening an RA. An RA shall not be weakened if it is likely that it would subsequently need to be strengthened.

4.3.5.8 ACAS-equipped threats. The RA shall be compatible with all the RACs transmitted to threats (4.3.6.1.3). If an RAC is received from a threat before own ACAS generates an RAC for that threat, the RA generated shall be compatible with the RAC received unless such an RA is more likely to reduce separation than increase it and own aircraft address is lower in value than that of the threat.

Note.— In encounters with more than one threat where it is necessary to pass above some threats and below other threats, this standard can be interpreted as referring to the whole duration of the RA. Specifically, it is permissible to retain an RA to climb (descend) towards a threat that is above (below) own aircraft provided there is a calculated intention to provide adequate separation from all threats by subsequently levelling-off.

4.3.5.9 Encoding of ARA subfield. On each cycle of an RA, the RA sense, strength and attributes shall be encoded in the active RA (ARA) subfield (4.3.8.4.2.2.1.1). If the ARA subfield has not been refreshed for an interval of 6 s, it shall be set to 0, along with the MTE subfield in the same message (4.3.8.4.2.2.1.3).

4.3.5.10 System response time. The system delay from receipt of the relevant SSR reply to presentation of an RA sense and strength to the pilot shall be as short as possible and shall not exceed 1.5 s.

4.3.6 Coordination and communication

4.3.6.1 Provisions For Coordination With ACAS-Equipped Threats

4.3.6.1.1 Multi-aircraft coordination. In a multi-aircraft situation, ACAS shall coordinate with each equipped threat individually.

4.3.6.1.2 Data protection during coordination. ACAS shall prevent simultaneous access to stored data by concurrent processes, in particular, during resolution message processing.

4.3.6.1.3 Coordination interrogation. Each cycle ACAS shall transmit a coordination interrogation to each equipped threat, unless generation of an RA is delayed because it is not possible to select an RA that can be predicted to provide adequate separation (4.3.5.1). The resolution message transmitted to a threat shall include an RAC selected for that threat. If an RAC has been received from the threat before ACAS selects an RAC for that threat, the selected RAC shall be compatible with the received RAC unless no more than three cycles have elapsed since the RAC was received, the RAC is altitude-crossing, and own aircraft address is lower in value than that of the threat in which case ACAS shall select its RA independently. If an RAC received from an equipped threat is incompatible with the RAC own ACAS has selected for that threat, ACAS shall modify the selected RAC to be compatible with the received RAC if own aircraft address is higher in value than that of the threat.

Note.— The RAC included in the resolution message is in the form of a vertical RAC (VRC) for ACAS II (4.3.8.4.2.3.2.2) and a vertical RAC (VRC) and/or horizontal RAC (HRC) for ACAS III.

4.3.6.1.3.1 Coordination termination. Within the cycle during which an intruder ceases to be a reason for maintaining the RA, ACAS shall send a resolution message to that intruder by means of a coordination interrogation. The resolution message shall include the cancellation code for the last RAC sent to that intruder while it was a reason for maintaining the RA.

Note.— During an encounter with a single threat, the threat ceases to be a reason for the RA when the conditions for cancelling the RA are met. During an encounter with multiple threats, a threat ceases to be a reason for the RA when the conditions for cancelling the RA are met in respect of that threat, even though the RA may have to be maintained because of other threats.

4.3.6.1.3.2 ACAS coordination interrogations shall be transmitted until a coordination reply is received from the threat, up to a maximum of not less than six and not more than twelve attempts. The successive interrogations shall be nominally equally spaced over a period of 100 ±5 ms. If the maximum number of attempts is made and no reply is received, ACAS shall continue its regular processing sequence.

4.3.6.1.3.3 ACAS shall provide parity protection (4.3.8.4.2.3.2.6 and 4.3.8.4.2.3.2.7) for all fields in the coordination interrogation that convey RAC information.

Note.— This includes the vertical RAC (VRC), the cancel vertical RAC (CVC), the horizontal RAC (HRC) and the cancel horizontal RAC (CHC).

4.3.6.1.3.4 Whenever own ACAS reverses its sense against an equipped threat, the resolution message that is sent on the current and subsequent cycles to that threat shall contain both the newly selected RAC and the cancellation code for the RAC sent before the reversal.

4.3.6.1.3.5 When a vertical RA is selected, the vertical RAC (VRC) (4.3.8.4.2.3.2.2) that own ACAS includes in a resolution message to the threat shall be as follows:

a) "do not pass above" when the RA is intended to provide separation above the threat;

b) "do not pass below" when the RA is intended to provide separation below the threat.

4.3.6.1.4 Resolution message processing. Resolution messages shall be processed in the order in which they are received and with delay limited to that required to prevent possible concurrent access to stored data and delays due to the processing of previously received resolution messages. Resolution messages that are being delayed shall be temporarily queued to prevent possible loss of messages. Processing a resolution message shall include decoding the message and updating the appropriate data structures with the information extracted from the message.

Note.— According to 4.3.6.1.2, resolution message processing must not access any data whose usage is not protected by the coordination lock state.

4.3.6.1.4.1 An RAC or an RAC cancellation received from another ACAS shall be rejected if the encoded sense bits indicate the existence of a parity error or if undefined value(s) are detected in the resolution message. An RAC or an RAC cancellation received without parity errors and without undefined resolution message values shall be considered valid.

4.3.6.1.4.2 RAC storage. A valid RAC received from another ACAS shall be stored or shall be used to update the previously stored RAC corresponding to that ACAS. A valid RAC cancellation shall cause the previously stored RAC to be deleted. A stored RAC that has not been updated for an interval of 6 s shall be deleted.

4.3.6.1.4.3 RAC record update. A valid RAC or RAC cancellation received from another ACAS shall be used to update the RAC record. If a bit in the RAC record has not been refreshed for an interval of 6 s by any threat, that bit shall be set to 0.

4.3.6.2 Provisions for ACAS Communication With Ground Stations

4.3.6.2.1 Air-initiated downlink of ACAS RAs. When an ACAS RA exists, ACAS shall:

a) transfer to its Mode S transponder an RA report for transmission to the ground in a Comm-B reply (4.3.11.4.1); and

b) transmit periodic RA broadcasts (4.3.7.3.2).

4.3.6.2.2 Sensitivity level control (SLC) command. ACAS shall store SLC commands from Mode S ground stations. An SLC command received from a Mode S ground station shall remain effective until replaced by an SLC command from the same ground station as indicated by the site number contained in the IIS subfield of the interrogation. If an existing stored command from a Mode S ground station is not refreshed within 4 minutes, or if the SLC command received has the value 15 (4.3.8.4.2.1.1), the stored SLC command for that Mode S ground station shall be set to 0.

4.3.6.3 Provisions for Data Transfer Between ACAS and its Mode -S Transponder

4.3.6.3.1 Data transfer from ACAS to its Mode S transponder:

a) ACAS shall transfer RA information to its Mode S transponder for transmission in an RA report (4.3.8.4.2.2.1) and in a coordination reply (4.3.8.4.2.4.2);

b) ACAS shall transfer current sensitivity level to its Mode S transponder for transmission in a sensitivity level report (4.3.8.4.2.5); and

c) ACAS shall transfer capability information to its Mode S transponder for transmission in a data link capability report (4.3.8.4.2.2.2).

4.3.6.3.2 Data transfer from Mode S transponder to its ACAS:

a) ACAS shall receive from its Mode S transponder sensitivity level control commands (4.3.8.4.2.1.1) transmitted by Mode S ground stations;

b) ACAS shall receive from its Mode S transponder ACAS broadcast messages (4.3.8.4.2.3.3) transmitted by other ACAS; and

c) ACAS shall receive from its Mode S transponder resolution messages (4.3.8.4.2.3.2) transmitted by other ACAS for air-air coordination purposes.

4.3.7 ACAS protocols

4.3.7.1 Surveillance Protocols

4.3.7.1.1 Surveillance of Mode A/C Transponders

4.3.7.1.1.1 ACAS shall use the Mode C-only all-call interrogation (Chapter 3, 3.1.2.1.5.1.2) for surveillance of aircraft equipped with Mode A/C transponders.

4.3.7.1.1.2 Using a sequence of interrogations with increasing power, surveillance interrogations shall be preceded by an S_1-pulse (Chapter 3, 3.1.1.7.4.3) to reduce interference and improve Mode A/C target detection.

4.3.7.1.2 Surveillance of Mode S Transponders

4.3.7.1.2.1 Detection. ACAS shall monitor 1 090 MHz for Mode S acquisition squitters (DF = 11). ACAS shall detect the presence and determine the address of Mode S-equipped aircraft using their Mode S acquisition squitters (DF = 11) or extended squitters (DF = 17).

Note 1.— It is acceptable to acquire individual aircraft using either acquisition or extended squitters (DF = 11 or DF = 17), and to monitor for both squitters. However, ACAS must monitor for acquisition squitters because, at any time, not all aircraft will transmit the extended squitter.

Note 2.— If, in the future, it becomes permitted for aircraft not to transmit the acquisition squitter, relying instead on continual transmission of the extended squitter, it would become essential for all ACAS units to monitor for both the acquisition and the extended squitters.

4.3.7.1.2.2 Surveillance interrogations. On first receipt of a 24-bit aircraft address from an aircraft that is determined to be within the reliable surveillance range of ACAS based on reception reliability and that is within an altitude band 3 050 m (10 000 ft) above and below own aircraft, ACAS shall transmit a short air-air interrogation (UF = 0) for range acquisition. Surveillance interrogations shall be transmitted at least once every five cycles when this altitude condition is satisfied. Surveillance interrogations shall be transmitted each cycle if the range of the detected aircraft is less than 5.6 km (3 NM) or the calculated time to closest approach is less than 60 s, assuming that both the detected and own aircraft proceed from their current positions with unaccelerated motion and that the range at closest approach equals 5.6 km (3 NM). Surveillance interrogations shall be suspended for a period of five cycles if:

a) a reply was successfully received; and

b) own aircraft and intruder aircraft are operating below a pressure-altitude of 5 490 m (18 000 ft); and

c) the range of the detected aircraft is greater than 5.6 km (3 NM) and the calculated time to closest approach exceeds 60 seconds, assuming that both the detected and own aircraft proceed from their current positions with unaccelerated motion and that the range at closest approach equals 5.6 km (3 NM).

4.3.7.1.2.2.1 Range acquisition interrogations. ACAS shall use the short air-air surveillance format (UF = 0) for range acquisition. ACAS shall set AQ = 1 (Chapter 3, 3.1.2.8.1.1) and RL = 0 (Chapter 3, 3.1.2.8.1.2) in an acquisition interrogation.

Note 1.— Setting AQ = 1 results in a reply with bit 14 of the RI field equal to 1 and serves as an aid in distinguishing the reply to own interrogation from replies elicited from other ACAS units (4.3.7.1.2.2.2).

Note 2.— In the acquisition interrogation RL is set to 0 to command a short acquisition reply (DF = 0).

4.3.7.1.2.2.2 Tracking interrogations. ACAS shall use the short air-air surveillance format (UF = 0) with RL = 0 and AQ = 0 for tracking interrogations.

4.3.7.1.2.3 Surveillance replies. These protocols are described in 4.3.11.3.1.

4.3.7.1.2.4 ACAS broadcast. An ACAS broadcast shall be made nominally every 8 to 10 s at full power from the top antenna. Installations using directional antennas shall operate such that complete circular coverage is provided nominally every 8 to 10 s.

Note.— A broadcast causes other Mode S transponders to accept the interrogation without replying and to present the interrogation content containing the MU field at the transponder output data interface. The UDS1 = 3, UDS2 = 2 combination identifies the data as an ACAS broadcast containing the 24-bit address of the interrogating ACAS aircraft. This provides each ACAS with a means of determining the number of other ACAS within its detection range for limiting interference. The format of the MU field is described in 4.3.8.4.2.3.

4.3.7.2 Air-Air Coordination Protocols

4.3.7.2.1 Coordination interrogations. ACAS shall transmit UF = 16 interrogations (Chapter 3, 3.1.2.3.2, Figure 3-7) with AQ = 0 and RL = 1 when another aircraft reporting RI = 3 or 4 is declared a threat (4.3.4). The MU field shall contain the resolution message in the subfields specified in 4.3.8.4.2.3.2.

Note 1.— A UF = 16 interrogation with AQ = 0 and RL = 1 is intended to cause a DF = 16 reply from the other aircraft.

Note 2.— An aircraft reporting RI = 3 or RI = 4 is an aircraft equipped with an operating ACAS which has vertical only or vertical and horizontal resolution capability, respectively.

4.3.7.2.2 Coordination reply. These protocols are described in 4.3.11.3.2.

4.3.7.3 Protocols for ACAS Communication with Ground Stations

4.3.7.3.1 RA reports to Mode S ground stations. These protocols are described in 4.3.11.4.1.

4.3.7.3.2 RA broadcasts. RA broadcasts shall be transmitted at full power from the bottom antenna at jittered, nominally 8 s intervals for the period that the RA is indicated. The RA broadcast shall include the MU field as specified in 4.3.8.4.2.3.4. The RA broadcast shall describe the most recent RA that existed during the preceding 8 s period. Installations using directional antennas shall operate such that complete circular coverage is provided nominally every 8 s and the same RA sense and strength is broadcast in each direction.

4.3.7.3.3 Data link capability report. These protocols are described in 4.3.11.4.2.

4.3.7.3.4 ACAS sensitivity level control. ACAS shall act upon an SLC command if and only if TMS (Chapter 3,
3.1.2.6.1.4.1) has the value 0 and DI is either 1 or 7 in the same interrogation.

4.3.8 Signal formats

4.3.8.1 The RF characteristics of all ACAS signals shall conform to the Standards of Chapter 3, 3.1.1.1 through 3.1.1.6, 3.1.2.1 through 3.1.2.3, 3.1.2.5 and 3.1.2.8.

4.3.8.2 Relationship Between ACAS and Mode S Signal Formats

Note.— ACAS uses Mode S transmissions for surveillance and communications. ACAS air-air communication functions permit RA decisions to be coordinated with ACAS-equipped threats. ACAS air-ground communication functions permit the reporting of RAs to ground stations and the uplinking of commands to ACAS-equipped aircraft to control parameters of the collision avoidance algorithms.

4.3.8.3 Signal format conventions. The data encoding of all ACAS signals shall conform to the Standards of Chapter 3, 3.1.2.3.

Note.— In air-air transmissions used by ACAS, interrogations transmitted at 1 030 MHz are designated as uplink transmissions and contain uplink format (UF) codes. Replies received at 1 090 MHz are designated as downlink transmissions and contain downlink format (DF) codes.

4.3.8.4 Field Description

Note 1.— The air-air surveillance and communication formats which are used by ACAS but not fully described in Chapter 3, 3.1.2 are given in Figure 4-1.

Note 2.— This section defines the Mode S fields (and their subfields) that are processed by ACAS to accomplish ACAS functions. Some of the ACAS fields (those also used for other SSR Mode S functions) are described with unassigned ACAS codes in Chapter 3, 3.1.2.6. Such codes are assigned in 4.3.8.4.1. Fields and subfields used only by ACAS equipment are assigned in 4.3.8.4.2.

Note 3.— The bit numbering convention used in 4.3.8.4 reflects the bit numbering within the entire uplink or downlink format rather than the bits within individual fields or subfields.

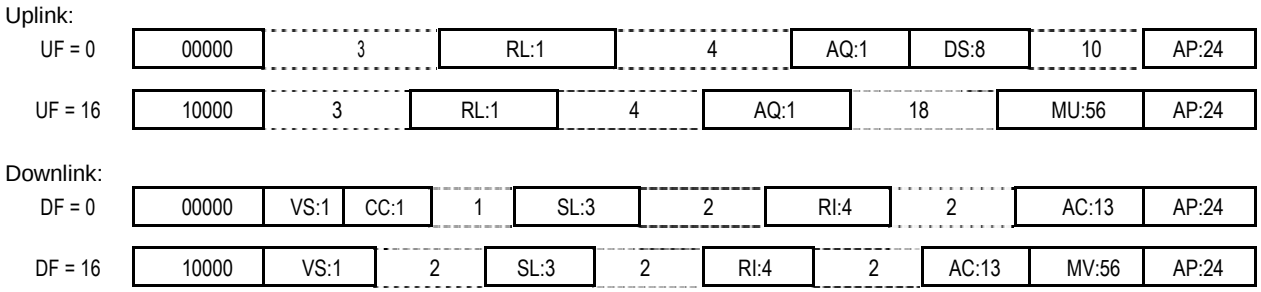

Figure 4-1. Surveillance and communication formats used by ACAS

4.3.8.4.1 Fields and Subfields Introduced In Chapter 3, 3.1.2

Note.— Codes for mission fields and subfields that are designated "reserved for ACAS" in Chapter 3, 3.1.2, are specified in this section.

4.3.8.4.1.1 DR (downlink request). The significance of the coding of the downlink request field shall be as follows:

Coding

0-1 See Chapter 3, 3.1.2.6.5.2
2 ACAS message available
3 Comm-B message available and ACAS message available 4-5 See Chapter 3, 3.1.2.6.5.2
6 Comm-B broadcast message 1 available and ACAS message available
7 Comm-B broadcast message 2 available and ACAS message available
8-31 See Chapter 3, 3.1.2.6.5.2

4.3.8.4.1.2 RI (air-air reply information). The significance of the coding in the RI field shall be as follows:

Coding
0 No operating ACAS
1 Not assigned
2 ACAS with resolution capability inhibited
3 ACAS with vertical-only resolution capability
4 ACAS with vertical and horizontal resolution capability
5-7 Not assigned
8-15 See Chapter 3, 3.1.2.8.2.2

Bit 14 of the reply format containing this field shall replicate the AQ bit of the interrogation. The RI field shall report "no operating ACAS" (RI = 0) if the ACAS unit has failed or is in standby. The RI field shall report "ACAS with resolution capability inhibited" (RI = 2) if sensitivity level is 2 or TA only mode has been selected.

Note.— Codes 0-7 in the RI field indicate that the reply is a tracking reply and also give the ACAS capability of the interrogated aircraft. Codes 8-15 indicate that the reply is an acquisition reply and also give the maximum true airspeed capability of the interrogated aircraft.

4.3.8.4.1.3 RR (reply request). The significance of the coding in the reply request field shall be as follows:

Coding
0-18 See Chapter 3, 3.1.2.6.1.2
19 Transmit a resolution advisory report
20-31 See Chapter 3, 3.1.2.6.1.2

4.3.8.4.2 ACAS Fields and Subfields

Note.— The following paragraphs describe the location and coding of those fields and subfields that are not defined in Chapter 3, 3.1.2 but are used by aircraft equipped with ACAS.

4.3.8.4.2.1 Subfield in MA

4.3.8.4.2.1.1 ADS (A-definition subfield). This 8-bit (33-40) subfield shall define the remainder of MA.

Note.— For convenience of coding, ADS is expressed in two groups of four bits each, ADS1 and ADS2.

4.3.8.4.2.1.2 When ADS1 = 0 and ADS2 = 5, the following subfield shall be contained in MA:

4.3.8.4.2.1.3 SLC (ACAS sensitivity level control (SLC) command). This 4-bit (41-44) subfield shall denote a sensitivity level command for own ACAS.

Coding

0 No command issued
1 Not assigned
2 Set ACAS sensitivity level to 2
3 Set ACAS sensitivity level to 3
4 Set ACAS sensitivity level to 4
5 Set ACAS sensitivity level to 5
6 Set ACAS sensitivity level to
6 7-14 Not assigned
15 Cancel previous SLC command from this ground station

Note.— Structure of MA for a sensitivity level control command:

33–36	37–40	41–44	45–88
ADS1 = 0	ADS2 = 5	SLC	- - - - - 44 - - - - -

4.3.8.4.2.2 Subfields in MB

4.3.8.4.2.2.1 Subfields in MB for an RA report. When BDS1=3 and BDS2=0, the subfields indicated below shall be contained in MB.

Note.— The requirements for communication of information relating to the current or recent RAs is described in 4.3.11.4.1.

4.3.8.4.2.2.1.1 *ARA (active RAs).* This 14-bit (41-54) subfield shall indicate the characteristics of the RA, if any, generated by the ACAS associated with the transponder transmitting the subfield (4.3.6.2.1 a)). The bits in ARA shall have meanings determined by the value of the MTE subfield (4.3.8.4.2.2.1.4) and, for vertical RAs, the value of bit 41 of ARA. The meaning of bit 41 of ARA shall be as follows:

Coding

0 There is more than one threat and the RA is intended to provide separation below some threat(s) and above some other threat(s) or no RA has been generated (when MTE = 0)

1 Either there is only one threat or the RA is intended to provide separation in the same direction for all threats

When ARA bit 41 = 1 and MTE = 0 or 1, bits 42-47 shall have the following meanings:

Bit	*Coding*	
42	0	RA is preventive
	1	RA is corrective
43	0	Upward sense RA has been generated
	1	Downward sense RA has been generated
44	0	RA is not increased rate
	1	RA is increased rate
45	0	RA is not a sense reversal
	1	RA is a sense reversal
46	0	RA is not altitude crossing
	1	RA is altitude crossing
47	0	RA is vertical speed limit
	1	RA is positive
48-54		Reserved for ACAS III

When ARA bit 41 = 0 and MTE = 1, bits 42-47 shall have the following meanings:

Bit	*Coding*	
42	0	RA does not require a correction in the upward sense
	1	RA requires a correction in the upward sense
43	0	RA does not require a positive climb
	1	RA requires a positive climb
44	0	RA does not require a correction in the downward sense
	1	RA requires a correction in the downward sense
45	0	RA does not require a positive descend
	1	RA requires a positive descend
46	0	RA does not require a crossing
	1	RA requires a crossing
47	0	RA is not a sense reversal
	1	RA is a sense reversal
48-54		Reserved for ACAS III

Note.— When ARA bit 41 = 0 and MTE = 0, no vertical RA has been generated.

4.3.8.4.2.2.1.2 RAC (RACs record). This 4-bit (55-58) subfield shall indicate all the currently active RACs, if any, received from other ACAS aircraft. The bits in RAC shall have the following meanings:

Bit	*Resolution advisory complement*
55	Do not pass below
56	Do not pass above
57	Do not turn left
58	Do not turn right

A bit set to 1 shall indicate that the associated RAC is active. A bit set to 0 shall indicate that the associated RAC is inactive.

4.3.8.4.2.2.1.3 RAT (RA terminated indicator). This 1-bit (59) subfield shall indicate when an RA previously generated by ACAS has ceased being generated.

Coding

0	ACAS is currently generating the RA indicated in the ARA subfield
1	The RA indicated by the ARA subfield has been terminated (4.3.11.4.1)

Note 1.— After an RA has been terminated by ACAS, it is still required to be reported by the Mode S transponder for 18±1 s (4.3.11.4.1). The RA terminated indicator may be used, for example, to permit timely removal of an RA indication from an air traffic controller's display, or for assessments of RA duration within a particular airspace.

Note 2.— RAs may terminate for a number of reasons: normally, when the conflict has been resolved and the threat is diverging in range; or when the threat's Mode S transponder for some reason ceases to report altitude during the conflict. The RA terminated indicator is used to show that the RA has been removed in each of these cases.

4.3.8.4.2.2.1.4 MTE (multiple threat encounter). This 1-bit (60) subfield shall indicate whether two or more simultaneous threats are currently being processed by the ACAS threat resolution logic.

Coding

0	One threat is being processed by the resolution logic (when ARA bit 41 = 1); or no threat is being processed by the resolution logic (when ARA bit 41 = 0)
1	Two or more simultaneous threats are being processed by the resolution logic

4.3.8.4.2.2.1.5 TTI (threat type indicator subfield). This 2-bit subfield (61-62) shall define the type of identity data contained in the TID subfield.

Coding

0	No identity data in TID
1	TID contains a Mode S transponder address
2	TID contains altitude, range and bearing data
3	Not assigned

4.3.8.4.2.2.1.6 TID (threat identity data subfield). This 26-bit subfield (63-88) shall contain the Mode S address of the threat or the altitude, range, and bearing if the threat is not Mode S equipped. If two or more threats are simultaneously processed by the ACAS resolution logic, TID shall contain the identity or position data for the most recently declared threat. If TTI = 1, TID shall contain in bits 63-86 the aircraft address of the threat, and bits 87 and 88 shall be set to 0. If TTI = 2, TID shall contain the following three subfields.

4.3.8.4.2.2.1.6.1 TIDA (threat identity data altitude subfield). This 13-bit subfield (63-75) shall contain the most recently reported Mode C altitude code of the threat.

Coding

Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

4.3.8.4.2.2.1.6.2 TIDR (threat identity data range subfield). This 7-bit subfield (76-82) shall contain the most recent threat range estimated by ACAS.

Coding (n)

n	*Estimated range (NM)*
0	No range estimate available
1	Less than 0.05
2-126	$(n-1)/10 \pm 0.05$
127	Greater than 12.55

4.3.8.4.2.2.1.6.3 TIDB (threat identity data bearing subfield). This 6-bit subfield (83-88) shall contain the most recent estimated bearing of the threat aircraft, relative to the ACAS aircraft heading.

Coding (n)

n	*Estimated bearing (degrees)*
0	No bearing estimate available
1-60	Between $6(n-1)$ and $6n$
61-63	*Not assigned*

Note.— Structure of MB for an RA report:

33–36	37–40	41–54	55–58	59–59	60–60	61–62	63–88
BDS1 = 3	BDS2 = 0	ARA	RAC	RAT	MTE	TTI = 1	TID

33–36	37–40	41–54	55–58	59–59	60–60	61–62	63–75	76–82	83–88
BDS1 = 3	BDS2 = 0	ARA	RAC	RAT	MTE	TTI = 2	TIDA	TIDR	TIDB

4.3.8.4.2.2.2 Subfields in MB for the data link capability report. When BDS1 = 1 and BDS2 = 0, the following bit patterns shall be provided to the transponder for its data link capability report:

Bit	*Coding*
48	0 ACAS failed or on standby
	1 ACAS operating
69	0 Hybrid surveillance not operational
	1 Hybrid surveillance fitted and operational
70	0 ACAS generating TAs only
	1 ACAS generating TAs and RAs

Bit 72	Bit 71	ACAS version
0	0	RTCA/DO-185 (pre-ACAS)
0	1	RTCA/DO-185A
1	0	RTCA/DO-185B & EUROCAE ED 143
1	1	Reserved for future versions (see *Note 3*)

Note 1.— A summary of the MB subfields for the data link capability report structure is described in Chapter 3, 3.1.2.6.10.2.2.

Note 2.— The use of hybrid surveillance to limit ACAS active interrogations is described in 4.5.1. The ability only to support decoding of DF = 17 extended squitter messages is not sufficient to set bit 69.

Note 3.— Future versions of ACAS will be identified using part numbers and software version numbers specified in registers $E5_{16}$ and $E6_{16}$.

4.3.8.4.2.3 MU field. This 56-bit (33-88) field of long air-air surveillance interrogations (Figure 4-1) shall be used to transmit resolution messages, ACAS broadcasts and RA broadcasts.

4.3.8.4.2.3.1 UDS (U-definition subfield). This 8-bit (33-40) subfield shall define the remainder of MU.

Note.— For convenience in coding, UDS is expressed in two groups of four bits each, UDS1 and UDS2.

4.3.8.4.2.3.2 Subfields in MU for a resolution message. When UDS1 = 3 and UDS2 = 0 the following subfields shall be contained in MU:

4.3.8.4.2.3.2.1 MTB (multiple threat bit). This 1-bit (42) subfield shall indicate the presence or absence of multiple threats.

Coding	
0	Interrogating ACAS has one threat
1	Interrogating ACAS has more than one threat

4.3.8.4.2.3.2.2 VRC (vertical RAC). This 2-bit (45-46) subfield shall denote a vertical RAC relating to the addressed aircraft.

Coding	
0	No vertical RAC sent
1	Do not pass below
2	Do not pass above
3	Not assigned

4.3.8.4.2.3.2.3 CVC (cancel vertical RAC). This 2-bit (43-44) subfield shall denote the cancellation of a vertical RAC previously sent to the addressed aircraft. This subfield shall be set to 0 for a new threat.

Coding

0 No cancellation
1 Cancel previously sent “Do not pass below”
2 Cancel previously sent “Do not pass above”
3 Not assigned

4.3.8.4.2.3.2.4 HRC (horizontal RAC). This 3-bit (50-52) subfield shall denote a horizontal RAC relating to the addressed aircraft.

Coding

0 No horizontal RAC or no horizontal resolution capability
1 Other ACAS sense is turn left; do not turn left
2 Other ACAS sense is turn left; do not turn right
3 Not assigned
4 Not assigned
5 Other ACAS sense is turn right; do not turn left
6 Other ACAS sense is turn right; do not turn right
7 Not assigned

4.3.8.4.2.3.2.5 CHC (cancel horizontal RAC). This 3-bit (47-49) subfield shall denote the cancellation of a horizontal RAC previously sent to the addressed aircraft. This subfield shall be set to 0 for a new threat.

Coding

0 No cancellation or no horizontal resolution capability
1 Cancel previously sent “Do not turn left”
2 Cancel previously sent “Do not turn right”
3-7 Not assigned

4.3.8.4.2.3.2.6 VSB (vertical sense bits subfield). This 4-bit (61-64) subfield shall be used to protect the data in the CVC and VRC subfields. For each of the 16 possible combinations of bits 43-46 the following VSB code shall be transmitted:

	CVC		VRC		VSB			
Coding	43	44	45	46	61	62	63	64
0	0	0	0	0	0	0	0	0
1	0	0	0	1	1	1	1	0
2	0	0	1	0	0	1	1	1
3	0	0	1	1	1	0	0	1
4	0	1	0	0	1	0	1	1
5	0	1	0	1	0	1	0	1
6	0	1	1	0	1	1	0	0
7	0	1	1	1	0	0	1	0
8	1	0	0	0	1	1	0	1
9	1	0	0	1	0	0	1	1
10	1	0	1	0	1	0	1	0
11	1	0	1	1	0	1	0	0
12	1	1	0	0	0	1	1	0
13	1	1	0	1	1	0	0	0
14	1	1	1	0	0	0	0	1
15	1	1	1	1	1	1	1	1

Note.— The rule used to generate the VSB subfield bit setting is a distance 3 Hamming code augmented with a parity bit, producing the ability to detect up to three errors in the eight transmitted bits.

4.3.8.4.2.3.2.7 HSB (horizontal sense bits subfield). This 5-bit (56-60) subfield shall be used to protect the data in the CHC and HRC subfields. For each of the 64 possible combinations of bits 47-52 the following HSB code shall be transmitted:

	CHC				HRC		HSB				
Coding	47	48	49	50	51	52	56	57	58	59	60
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	0	1	0	1	1
2	0	0	0	0	1	0	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0
4	0	0	0	1	0	0	1	1	1	0	0
5	0	0	0	1	0	1	1	0	1	1	1
6	0	0	0	1	1	0	0	1	1	1	1
7	0	0	0	1	1	1	0	0	1	0	0
8	0	0	1	0	0	0	0	1	1	0	1
9	0	0	1	0	0	1	0	0	1	1	0
10	0	0	1	0	1	0	1	1	1	1	0
11	0	0	1	0	1	1	1	0	1	0	1
12	0	0	1	1	0	0	1	0	0	0	1
13	0	0	1	1	0	1	1	1	0	1	0
14	0	0	1	1	1	0	0	0	0	1	0
15	0	0	1	1	1	1	0	1	0	0	1
16	0	1	0	0	0	0	1	0	1	0	1
17	0	1	0	0	0	1	1	1	1	1	0
18	0	1	0	0	1	0	0	0	1	1	0
19	0	1	0	0	1	1	0	1	1	0	1
20	0	1	0	1	0	0	0	1	0	0	1
21	0	1	0	1	0	1	0	0	0	1	0
22	0	1	0	1	1	0	1	1	0	1	0
23	0	1	0	1	1	1	1	0	0	0	1

24	0	1	1	0	0	0	1	1	0	0	0
25	0	1	1	0	0	1	1	0	0	1	1
26	0	1	1	0	1	0	0	1	0	1	1
27	0	1	1	0	1	1	0	0	0	0	0
28	0	1	1	1	0	0	0	0	1	0	0
29	0	1	1	1	0	1	0	1	1	1	1
30	0	1	1	1	1	0	1	0	1	1	1
31	0	1	1	1	1	1	1	1	1	0	0
32	1	0	0	0	0	0	1	1	0	0	1
33	1	0	0	0	0	1	1	0	0	1	0
34	1	0	0	0	1	0	0	1	0	1	0
35	1	0	0	0	1	1	0	0	0	0	1
36	1	0	0	1	0	0	0	0	1	0	1
37	1	0	0	1	0	1	0	1	1	1	0
38	1	0	0	1	1	0	1	0	1	1	0
39	1	0	0	1	1	1	1	1	1	0	1
40	1	0	1	0	0	0	1	0	1	0	0
41	1	0	1	0	0	1	1	1	1	1	1
42	1	0	1	0	1	0	0	0	1	1	1
43	1	0	1	0	1	1	0	1	1	0	0
44	1	0	1	1	0	0	0	1	0	0	0
45	1	0	1	1	0	1	0	0	0	1	1
46	1	0	1	1	1	0	1	1	0	1	1
47	1	0	1	1	1	1	1	0	0	0	0
48	1	1	0	0	0	0	0	1	1	0	0
49	1	1	0	0	0	1	0	0	1	1	1
50	1	1	0	0	1	0	1	1	1	1	1
51	1	1	0	0	1	1	1	0	1	0	0
52	1	1	0	1	0	0	1	0	0	0	0
53	1	1	0	1	0	1	1	1	0	1	1
54	1	1	0	1	1	0	0	0	0	1	1
55	1	1	0	1	1	1	0	1	0	0	0
56	1	1	1	0	0	0	0	0	0	0	1
57	1	1	1	0	0	1	0	1	0	1	0
58	1	1	1	0	1	0	1	0	0	1	0
59	1	1	1	0	1	1	1	1	0	0	1
60	1	1	1	1	0	0	1	1	1	0	1
61	1	1	1	1	0	1	1	0	1	1	0
62	1	1	1	1	1	0	0	1	1	1	0
63	1	1	1	1	1	1	0	0	1	0	1

Note.— The rule used to generate the HSB subfield bit setting is a distance 3 Hamming code augmented with a parity bit, producing the ability to detect up to three errors in the eleven transmitted bits.

4.3.8.4.2.3.2.8 MID (Aircraft address). This 24-bit (65-88) subfield shall contain the 24-bit aircraft address of the interrogating ACAS aircraft.

Note.— Structure of MU for a resolution message:

33–36	37–40	41	42–44	45–46	47–49	50–52	53–55	56–60	61–64	65–88
UDS1 = 3	UDS2 = 0	-1-	MTB	CVC	VRC	CHC	HRC	-3-	HSB	VSB	MID

4.3.8.4.2.3.3 Subfield in MU for an ACAS broadcast. When UDS1 = 3 and UDS2 = 2, the following subfield shall be contained in MU:

4.3.8.4.2.3.3.1 MID (Aircraft address). This 24-bit (65-88) subfield shall contain the 24-bit aircraft address of the interrogating ACAS aircraft.

Note.— Structure of MU for an ACAS broadcast:

33–36	37–40	41–64	65–88
UDS1 = 3	UDS2 = 2	- - - - - - 24 - - - - - -	MID

4.3.8.4.2.3.4 Subfields in MU for an RA broadcast. When UDS1 = 3 and UDS2 = 1, the following subfields shall be contained in MU:

4.3.8.4.2.3.4.1 ARA (active RAs). This 14-bit (41-54) subfield shall be coded as defined in 4.3.8.4.2.2.1.1.

4.3.8.4.2.3.4.2 RAC (RACs record). This 4-bit (55-58) subfield shall be coded as defined in 4.3.8.4.2.2.1.2.

4.3.8.4.2.3.4.3 RAT (RA terminated indicator). This 1-bit (59) subfield shall be coded as defined in 4.3.8.4.2.2.1.3.

4.3.8.4.2.3.4.4 MTE (multiple threat encounter). This 1-bit (60) subfield shall be coded as defined in 4.3.8.4.2.2.1.4.

4.3.8.4.2.3.4.5 AID (Mode A identity code). This 13-bit (63-75) subfield shall denote the Mode A identity code of the reporting aircraft.

Coding

Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode A code bit	A_4	A_2	A_1	B_4	B_2	B_1	0	C_4	C_2	C_1	D_4	D_2	D_1

4.3.8.4.2.3.4.6 *CAC (Mode C altitude code).* This 13-bit (76-88) subfield shall denote the Mode C altitude code of the reporting aircraft.

Coding

Bit	76	77	78	79	80	81	82	83	84	85	86	87	88
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

Note.— Structure of MU for an RA broadcast:

33–36	37–40	41–54	55–58	59	60	61–62	63–75	76–88
UDS1 = 3	UDS2 = 1	ARA	RAC	RAT	MTE	-2-	AID	CAC

4.3.8.4.2.4 MV field. This 56-bit (33-88) field of long air-air surveillance replies (Figure 4-1) shall be used to transmit air-air coordination reply messages.

4.3.8.4.2.4.1 VDS (V-definition subfield). This 8-bit (33-40) subfield shall define the remainder of MV.

Note.— For convenience in coding, VDS is expressed in two groups of four bits each, VDS1 and VDS2.

4.3.8.4.2.4.2 Subfields in MV for a coordination reply. When VDS1 = 3 and VDS2 = 0, the following subfields shall be contained in MV:

4.3.8.4.2.4.2.1 ARA (active RAs). This 14-bit (41-54) subfield shall be coded as defined in 4.3.8.4.2.2.1.1.

4.3.8.4.2.4.2.2 RAC (RACs record). This 4-bit (55-58) subfield shall be coded as defined in 4.3.8.4.2.2.1.2.

4.3.8.4.2.4.2.3 RAT (RA terminated indicator). This 1-bit (59) subfield shall be coded as defined in 4.3.8.4.2.2.1.3.

4.3.8.4.2.4.2.4 MTE (multiple threat encounter). This 1-bit (60) subfield shall be coded as defined in 4.3.8.4.2.2.1.4.

Note.— Structure of MV for a coordination reply:

33–36	37–40	41–54	55–58	59	60	61–88
VDS1 = 3	VDS2 = 0	ARA	RAC	RAT	MTE	-28-

4.3.8.4.2.5 SL (sensitivity level report). This 3-bit (9-11) downlink field shall be included in both short and long air-air reply formats (DF = 0 and 16). This field shall denote the sensitivity level at which ACAS is currently operating.

Coding

0 ACAS inoperative
1 ACAS is operating at sensitivity level 1
2 ACAS is operating at sensitivity level 2
3 ACAS is operating at sensitivity level 3
4 ACAS is operating at sensitivity level 4
5 ACAS is operating at sensitivity level 5
6 ACAS is operating at sensitivity level 6
7 ACAS is operating at sensitivity level 7

4.3.8.4.2.6 CC: Cross-link capability. This 1-bit (7) downlink field shall indicate the ability of the transponder to support the cross-link capability, i.e. decode the contents of the DS field in an interrogation with UF equals 0 and respond with the contents of the specified GICB register in the corresponding reply with DF equals 16.

Coding

0 signifies that the transponder cannot support the cross-link capability.
1 signifies that the transponder supports the cross-link capability.

4.3.9 ACAS equipment characteristics

4.3.9.1 Interfaces. As a minimum, the following input data shall be provided to the ACAS:

a) aircraft address code;

b) air-air and ground-air Mode S transmissions received by the Mode S transponder for use by ACAS (4.3.6.3.2);

c) own aircraft's maximum cruising true airspeed capability (Chapter 3, 3.1.2.8.2.2);

d) pressure-altitude; and

e) radio altitude.

Note.— Specific requirements for additional inputs for ACAS II and III are listed in the appropriate sections below.

4.3.9.2 Aircraft antenna system. ACAS shall transmit interrogations and receive replies via two antennas, one mounted on the top of the aircraft and the other on the bottom of the aircraft. The top-mounted antenna shall be directional and capable of being used for direction finding.

4.3.9.2.1 Polarization. Polarization of ACAS transmissions shall be nominally vertical.

4.3.9.2.2 Radiation pattern. The radiation pattern in elevation of each antenna when installed on an aircraft shall be nominally equivalent to that of a quarter-wave monopole on a ground plane.

4.3.9.2.3 Antenna Selection

4.3.9.2.3.1 Squitter reception. ACAS shall be capable of receiving squitters via the top and bottom antennas.

4.3.9.2.3.2 Interrogations. ACAS interrogations shall not be transmitted simultaneously on both antennas.

4.3.9.3 Pressure-altitude source. The altitude data for own aircraft provided to ACAS shall be obtained from the source that provides the basis for own Mode C or Mode S reports and they shall be provided at the finest quantization available.

4.3.9.3.1 A source providing a resolution finer than 7.62 m (25 ft) should be used.

4.3.9.3.2 Where a source providing a resolution finer than 7.62 m (25 ft) is not available, and the only altitude data available for own aircraft is Gilham encoded, at least two independent sources shall be used and compared continuously in order to detect encoding errors.

4.3.9.3.3 Two altitude data sources should be used and compared in order to detect errors before provision to ACAS.

4.3.9.3.4 The provisions of 4.3.10.3 shall apply when the comparison of the two altitude data sources indicates that one of the sources is in error.

4.3.10 Monitoring

4.3.10.1 Monitoring function. ACAS shall continuously perform a monitoring function in order to provide a warning if any of the following conditions at least are satisfied:

a) there is no interrogation power limiting due to interference control (4.3.2.2.2) and the maximum radiated power is reduced to less than that necessary to satisfy the surveillance requirements specified in 4.3.2; or

b) any other failure in the equipment is detected which results in a reduced capability of providing TAs or RAs; or

c) data from external sources indispensable for ACAS operation are not provided, or the data provided are not credible.

4.3.10.2 Effect on ACAS operation. The ACAS monitoring function shall not adversely affect other ACAS functions.

4.3.10.3 Monitoring response. When the monitoring function detects a failure (4.3.10.1), ACAS shall:

a) indicate to the flight crew that an abnormal condition exists;

b) prevent any further ACAS interrogations; and

c) cause any Mode S transmission containing own aircraft's resolution capability to indicate that ACAS is not operating.

4.3.11 Requirements for a Mode S transponder used in conjunction with ACAS

4.3.11.1 Transponder capabilities. In addition to the minimum transponder capabilities defined in Chapter 3, 3.1, the Mode S transponder used in conjunction with ACAS shall have the following capabilities:

a) ability to handle the following formats:

Format No.	*Format name*
UF = 16	Long air-air surveillance interrogation
DF = 16	Long air-air surveillance reply

b) ability to receive long Mode S interrogations (UF = 16) and generate replies as per 3.1.2.10.3.7.3;
c) means for delivering the ACAS data content of all accepted interrogations addressed to the ACAS equipment;

d) antenna diversity (as specified in Chapter 3, 3.1.2.10.4);

e) mutual suppression capability; and

f) inactive state transponder output power restriction.

When the Mode S transponder transmitter is in the inactive state, the peak pulse power at 1 090 MHz ±3 MHz at the terminals of the Mode S transponder antenna shall not exceed –70 dBm.

4.3.11.2 Data Transfer Between ACAS and Its Mode S Transponder

4.3.11.2.1 Data transfer from ACAS to its Mode S transponder:

a) The Mode S transponder shall receive from its ACAS RA information for transmission in an RA report (4.3.8.4.2.2.1) and in a coordination reply (4.3.8.4.2.4.2);

b) the Mode S transponder shall receive from its ACAS current sensitivity level for transmission in a sensitivity level report (4.3.8.4.2.5);

c) the Mode S transponder shall receive from its ACAS capability information for transmission in a data link capability report (4.3.8.4.2.2.2) and for transmission in the RI field of air-air downlink formats DF = 0 and DF = 16 (4.3.8.4.1.2); and

d) the Mode S transponder shall receive from its ACAS an indication that RAs are enabled or inhibited for transmission in the RI field of downlink formats 0 and 16.

4.3.11.2.2 Data transfer from Mode S transponder to its ACAS:

a) The Mode S transponder shall transfer to its ACAS received sensitivity level control commands (4.3.8.4.2.1.1) transmitted by Mode S stations;

b) the Mode S transponder shall transfer to its ACAS received ACAS broadcast messages (4.3.8.4.2.3.3) transmitted by other ACASs;

c) the Mode S transponder shall transfer to its ACAS received resolution messages (4.3.8.4.2.3.2) transmitted by other ACASs for air-air coordination purposes; and

d) the Mode S transponder shall transfer to its ACAS own aircraft's Mode A identity data for transmission in an RA broadcast (4.3.8.4.2.3.4.5).

4.3.11.3Communication of ACAS Information to Other ACAS

4.3.11.3.1 Surveillance reply. The ACAS Mode S transponder shall use the short (DF = 0) or long (DF = 16) surveillance formats for replies to ACAS surveillance interrogations. The surveillance reply shall include the VS field as specified in Chapter 3, 3.1.2.8.2, the RI field as specified in Chapter 3, 3.1.2.8.2 and in 4.3.8.4.1.2, and the SL field as specified in 4.3.8.4.2.5.

4.3.11.3.2 Coordination reply. The ACAS Mode S transponder shall transmit a coordination reply upon receipt of a coordination interrogation from an equipped threat subject to the conditions of 4.3.11.3.2.1. The coordination reply shall use the long air-air surveillance reply format, DF = 16, with the VS field as specified in Chapter 3, 3.1.2.8.2, the RI field as specified in Chapter 3, 3.1.2.8.2 and in 4.3.8.4.1.2, the SL field as specified in 4.3.8.4.2.5 and the MV field as specified in 4.3.8.4.2.4.

4.3.11.3.2.1 The ACAS Mode S transponder shall reply with a coordination reply to a coordination interrogation received from another ACAS if and only if the transponder is able to deliver the ACAS data content of the interrogation to its associated ACAS.

4.3.11.4 Communication of ACAS Information T0 Ground Stations

4.3.11.4.1 RA reports to Mode S ground stations. During the period of an RA and for 18±1 s following the end of the RA, the ACAS Mode S transponder shall indicate that it has an RA report by setting the appropriate DR field code in replies to a Mode S sensor as specified in 4.3.8.4.1.1. The RA report shall include the MB field as specified in 4.3.8.4.2.2.1. The RA report shall describe the most recent RA that existed during the preceding 18±1 s period.

Note 1.— The last sentence of 4.3.11.4.1 means that for 18±1 s following the end of an RA, all MB subfields in the RA report with the exception of bit 59 (RA terminated indicator) will retain the information reported at the time the RA was last active.

Note 2.— Upon receipt of a reply with DR = 2, 3, 6 or 7, a Mode S ground station may request downlink of the RA report by setting RR = 19 and either DI = 7, or DI = 7 and RRS = 0 in a surveillance or Comm-A interrogation to the ACAS aircraft. When this interrogation is received, the transponder replies with a Comm-B reply whose MB field contains the RA report.

4.3.11.4.2 Data link capability report. The presence of an ACAS shall be indicated by its Mode S transponder to a ground station in the Mode S data link capability report.

Note.— This indication causes the transponder to set codes in a data link capability report as specified in 4.3.8.4.2.2.2.

4.3.12 Indications to the flight crew

4.3.12.1 Corrective and Preventive RAS

Indications to the flight crew should distinguish between preventive and corrective RAs.

4.3.12.2 Altitude Crossing RAS

If ACAS generates an altitude crossing RA, a specific indication should be given to the flight crew that it is crossing.

4.4 Performance of the ACAS II Collision Avoidance Logic

Note.— Caution is to be observed when considering potential improvements to the reference ACAS II system described in Section 4 of the guidance material in the Attachment since changes may affect more than one aspect of the system performance. It is essential that alternative designs would not degrade the performances of other designs and that such compatibility is demonstrated with a high degree of confidence.

4.4.1 Definitions relating to the performance of the collision avoidance logic

Note.— The notation [t_1, t_2] is used to indicate the interval between t_1 and t_2.

Altitude layer. Each encounter is attributed to one of six altitude layers as follows:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
from		2 300 ft	5 000 ft	10 000 ft	20 000 ft	41 000 ft
to	2 300 ft	5 000 ft	10 000 ft	20 000 ft	41 000 ft	

The altitude layer of an encounter is determined by the average altitude of the two aircraft at closest approach.

Note.— For the purposes of defining the performance of the collision avoidance logic, there is no need to specify the physical basis of the altitude measurement or the relationship between altitude and ground level.

Approach angle. The difference in the ground headings of the two aircraft at closest approach, with 180 degrees defined as head on and 0 degrees defined as parallel.

Crossing encounter. An encounter in which the altitude separation of the two aircraft exceeds 100 ft at the beginning and at the end of the encounter window, and the relative vertical position of two aircraft at the end of the encounter window is reversed from that at the beginning of the encounter window.

Encounter. For the purposes of defining the performance of the collision avoidance logic, an encounter consists of two simulated aircraft trajectories. The horizontal coordinates of the aircraft represent the actual position of the aircraft but the vertical coordinate represents an altimeter measurement of altitude.

Encounter class. Encounters are classified according to whether or not the aircraft are transitioning at the beginning and end of the encounter window, and whether or not the encounter is crossing.

Encounter window. The time interval [tca – 40 s, tca + 10 s].

Horizontal miss distance (hmd). The minimum horizontal separation observed in an encounter.

Level aircraft. An aircraft that is not transitioning.

Original trajectory. The original trajectory of an ACAS-equipped aircraft is that followed by the aircraft in the same encounter when it was not ACAS equipped.

Original rate. The original rate of an ACAS-equipped aircraft at any time is its altitude rate at the same time when it followed the original trajectory.

Required rate. For the standard pilot model, the required rate is that closest to the original rate consistent with the RA.

tca. Nominally, the time of closest approach. For encounters in the standard encounter model (4.4.2.6), a reference time for the construction of the encounter at which various parameters, including the vertical and horizontal separation (vmd and hmd), are specified.

Note.— Encounters in the standard encounter model (4.4.2.6) are constructed by building the trajectories of the two aircraft outwards starting at tca. When the process is complete, tca may not be the precise time of closest approach and differences of a few seconds are acceptable.

Transitioning aircraft. An aircraft having an average vertical rate with a magnitude exceeding 400 feet per minute (ft/min), measured over some period of interest.

Turn extent. A heading difference defined as an aircraft's ground heading at the end of a turn minus its ground heading at the beginning of the turn.

Vertical miss distance (vmd). Notionally, the vertical separation at closest approach. For encounters in the standard encounter model (4.4.2.6), by construction the vertical separation at the time tca.

4.4.2 Conditions under which the requirements apply

4.4.2.1 The following assumed conditions shall apply to the performance requirements specified in 4.4.3 and 4.4.4:

a) range and bearing measurements and an altitude report are available for the intruder each cycle as long as it is within 14 NM, but not when the range exceeds 14 NM;

b) the errors in the range and bearing measurements conform to standard range and bearing error models (4.4.2.2 and 4.4.2.3);

c) the intruder's altitude reports, which are its Mode C replies, are expressed in 100 ft quanta;

d) an altitude measurement that has not been quantized and is expressed with a precision of 1 ft or better is available for own aircraft;

e) errors in the altitude measurements for both aircraft are constant throughout any particular encounter;

f) the errors in the altitude measurements for both aircraft conform to a standard altimetry error model (4.4.2.4);

g) the pilot responses to RAs conform to a standard pilot model (4.4.2.5);

h) the aircraft operate in an airspace in which close encounters, including those in which ACAS generates an RA, conform to a standard encounter model (4.4.2.6);

i) ACAS-equipped aircraft are not limited in their ability to perform the manoeuvres required by their RAs; and

j) as specified in 4.4.2.7:

   1) the intruder involved in each encounter is not equipped (4.4.2.7 a)); or

   2) the intruder is ACAS-equipped but follows a trajectory identical to that in the unequipped encounter (4.4.2.7 b)); or

   3) the intruder is equipped with an ACAS having a collision avoidance logic identical to that of own ACAS (4.4.2.7 c)).

Note.— The phrase "altitude measurement" refers to a measurement by an altimeter prior to any quantization.

4.4.2.1.1 The performance of the collision avoidance logic shall not degrade abruptly as the statistical distribution of the altitude errors or the statistical distributions of the various parameters that characterize the standard encounter model or the response of pilots to the advisories are varied, when surveillance reports are not available on every cycle or when the quantization of the altitude measurements for the intruder is varied or the altitude measurements for own aircraft are quantized.

4.4.2.2 Standard Range Error Model

The errors in the simulated range measurements shall be taken from a Normal distribution with mean 0 ft and standard deviation 50 ft.

4.4.2.3 Standard Bearing Error Model

The errors in the simulated bearing measurements shall be taken from a Normal distribution with mean 0.0 degrees and standard deviation 10.0 degrees.

4.4.2.4 Standard Altimetry Error Model

4.4.2.4.1 The errors in the simulated altitude measurements shall be assumed to be distributed as a Laplacian distribution with zero mean having probability density

$$p(e) = \frac{1}{2\lambda}\exp\left(-\frac{|e|}{\lambda}\right)$$

4.4.2.4.2 The parameter λ required for the definition of the statistical distribution of altimeter error for each aircraft shall have one of two values, λ_1 and λ_2, which depend on the altitude layer of the encounter as follows:

Layer	*1*		*2*		*3*		*4*		*5*		*6*	
	m	*Ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*
λ_1	10	35	11	38	13	43	17	58	22	72	28	94
λ_2	18	60	18	60	21	69	26	87	30	101	30	101

4.4.2.4.3 For an aircraft equipped with ACAS the value of λ shall be λ_1.

4.4.2.4.4 For aircraft not equipped with ACAS, the value of λ shall be selected randomly using the following probabilities:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
prob(λ_1)	0.391	0.320	0.345	0.610	0.610	0.610
prob(λ_2)	0.609	0.680	0.655	0.390	0.390	0.390

4.4.2.5 Standard Pilot Model

The standard pilot model used in the assessment of the performance of the collision avoidance logic shall be that:

a) any RA is complied with by accelerating to the required rate (if necessary) after an appropriate delay;

b) when the aircraft's current rate is the same as its original rate and the original rate complies with the RA, the aircraft continues at its original rate, which is not necessarily constant due to the possibility of acceleration in the original trajectory;

c) when the aircraft is complying with the RA, its current rate is the same as the original rate and the original rate changes and consequently becomes inconsistent with the RA, the aircraft continues to comply with the RA;

d) when an initial RA requires a change in altitude rate, the aircraft responds with an acceleration of 0.25 *g* after a delay of 5 s from the display of the RA;

e) when an RA is modified and the original rate complies with the modified RA, the aircraft returns to its original rate (if necessary) with the acceleration specified in g) after the delay specified in h);

f) when an RA is modified and the original rate does not comply with the modified RA, the aircraft responds to comply with the RA with the acceleration specified in g) after the delay specified in h);

g) the acceleration used when an RA is modified is 0.25 *g* unless the modified RA is a reversed sense RA or an increased rate RA in which case the acceleration is 0.35 *g*;

h) the delay used when an RA is modified is 2.5 s unless this results in the acceleration starting earlier than 5 s from the initial RA in which case the acceleration starts 5 s from the initial RA; and

i) when an RA is cancelled, the aircraft returns to its original rate (if necessary) with an acceleration of 0.25 *g* after a delay of 2.5 s.

4.4.2.6 Standard Encounter Model

4.4.2.6.1 Elements of the Standard Encounter Model

4.4.2.6.1.1 In order to calculate the effect of ACAS on the risk of collision (4.4.3) and the compatibility of ACAS with air traffic management (ATM) (4.4.4), sets of encounters shall be created for each of:

a) the two aircraft address orderings;

b) the six altitude layers;

c) nineteen encounter classes; and

d) nine or ten *vmd* bins as specified in 4.4.2.6.2.4.

The results for these sets shall be combined using the relative weightings given in 4.4.2.6.2.

4.4.2.6.1.1.1 Each set of encounters shall contain at least 500 independent, randomly generated encounters.

4.4.2.6.1.1.2 The two aircraft trajectories in each encounter shall be constructed with the following randomly selected characteristics:

a) in the vertical plane:

   1) a *vmd* from within the appropriate *vmd* bin;

   2) a vertical rate for each aircraft at the beginning of the encounter window, $\dot{z}_1$, and at the end of the encounter window, $\dot{z}_2$;

   3) a vertical acceleration; and

   4) a start time for the vertical acceleration; and

b) and in the horizontal plane:

   1) an *hmd*;

   2) an approach angle;

   3) a speed for each aircraft at closest approach;

   4) a decision for each aircraft whether or not it turns;

   5) the turn extent; the bank angle; and the turn end time;

   6) a decision for each aircraft whether or not its speed changes; and

   7) the magnitude of the speed change.

Note.— It is possible for the selections made for the various characteristics of an encounter to be irreconcilable. When this occurs, the problem can be resolved by discarding either the selection for a particular characteristic or the whole encounter, as most appropriate.

4.4.2.6.1.3 Two models shall be used for the statistical distribution of *hmd* (4.4.2.6.4.1). For calculations of the effect of ACAS on the risk of collision (4.4.3), *hmd* shall be constrained to be less than 500 ft. For calculations of the compatibility of ACAS with ATM (4.4.4), *hmd* shall be selected from a larger range of values (4.4.2.6.4.1.2).

Note.— 4.4.2.6.2 and 4.4.2.6.3 specify vertical characteristics for the aircraft trajectories in the standard encounter model that depend on whether the hmd *is constrained to be small ("for calculating risk ratio") or can take larger values ("for ATM compatibility"). Otherwise, the characteristics of the encounters in the vertical and horizontal planes are independent.*

4.4.2.6.2 Encounter Classes and Weights

4.4.2.6.2.1 Aircraft address. Each aircraft shall be equally likely to have the higher aircraft address.

4.4.2.6.2.2 Altitude layers. The relative weights of the altitude layers shall be as follows:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
prob(layer)	0.13	0.25	0.32	0.22	0.07	0.01

4.4.2.6.2.3 Encounter classes

4.4.2.6.2.3.1 The encounters shall be classified according to whether the aircraft are level (L) or transitioning (T) at the beginning *(*before *tca*) and end (after *tca*) of the encounter window and whether or not the encounter is crossing, as follows:

	Aircraft No. 1		*Aircraft No. 2*		
Class	*before* tca	*after* tca	*before* tca	*after* tca	*Crossing*
1	L	L	T	T	yes
2	L	L	L	T	yes
3	L	L	T	L	yes
4	T	T	T	T	yes
5	L	T	T	T	yes
6	T	T	T	L	yes
7	L	T	L	T	yes
8	L	T	T	L	yes
9	T	L	T	L	yes
10	L	L	L	L	no
11	L	L	T	T	no
12	L	L	L	T	no
13	L	L	T	L	no
14	T	T	T	T	no
15	L	T	T	T	no
16	T	T	T	L	no
17	L	T	L	T	No
18	L	T	T	L	No
19	T	L	T	L	No

4.4.2.6.2.3.2 The relative weights of the encounter classes shall depend on layer as follows:

	for calculating risk ratio		*for ATM compatibility*	
Class	*Layers 1-3*	*Layers 4-6*	*Layers 1-3*	*Layers 4-6*
1	0.00502	0.00319	0.06789	0.07802
2	0.00030	0.00018	0.00408	0.00440
3	0.00049	0.00009	0.00664	0.00220
4	0.00355	0.0027	0.04798	0.06593
5	0.00059	0.00022	0.00791	0.00549
6	0.00074	0.00018	0.00995	0.00440
7	0.00002	0.00003	0.00026	0.00082
8	0.00006	0.00003	0.00077	0.00082
9	0.00006	0.00003	0.00077	0.00082
10	0.36846	0.10693	0.31801	0.09011
11	0.26939	0.41990	0.23252	0.35386
12	0.06476	0.02217	0.05590	0.01868
13	0.07127	0.22038	0.06151	0.18571
14	0.13219	0.08476	0.11409	0.07143
15	0.02750	0.02869	0.02374	0.02418
16	0.03578	0.06781	0.03088	0.05714
17	0.00296	0.00098	0.00255	0.00082
18	0.00503	0.00522	0.00434	0.00440
19	0.01183	0.03651	0.01021	0.03077

4.4.2.6.2.4 vmd *bins*

4.4.2.6.2.4.1 The *vmd* of each encounter shall be taken from one of ten *vmd* bins for the non-crossing encounter classes, and from one of nine or ten *vmd* bins for the crossing encounter classes. Each *vmd* bin shall have an extent of 100 ft for calculating risk ratio, or an extent of 200 ft for calculating compatibility with ATM. The maximum *vmd* shall be 1 000 ft for calculating risk ratio, and 2 000 ft otherwise.

4.4.2.6.2.4.2 For non-crossing encounter classes, the relative weights of the *vmd* bins shall be as follows:

vmd *bin*	*for calculating risk ratio*	*for ATM compatibility*
1	0.013	0.128
2	0.026	0.135
3	0.035	0.209
4	0.065	0.171
5	0.100	0.160
6	0.161	0.092
7	0.113	0.043
8	0.091	0.025
9	0.104	0.014
10	0.091	0.009

Note.— The weights for the vmd *bins do not sum to 1.0. The weights specified are based on an analysis of encounters captured in ATC ground radar data. The missing proportion reflects the fact that the encounters captured included some with* vmd *exceeding the maximum* vmd *in the model.*

4.4.2.6.2.4.3 For the crossing classes, the relative weights of the *vmd* bins shall be as follows:

vmd *bin*	*for calculating risk ratio*	*for ATM Compatibility*
1	0	0.064
2	0.026	0.144
3	0.036	0.224
4	0.066	0.183
5	0.102	0.171
6	0.164	0.098
7	0.115	0.046
8	0.093	0.027
9	0.106	0.015
10	0.093	0.010

Note.— For the crossing classes, vmd *must exceed 100 ft so that the encounter qualifies as a crossing encounter. Thus, for the calculation of risk ratio there is no* vmd *bin 1, and for calculations of the compatibility with ATM* vmd *bin 1 is limited to [100 ft, 200 ft].*

4.4.2.6.3 Characteristics of the Aircraft Trajectories in the Vertical Plane

4.4.2.6.3.1 *vmd*. The *vmd* for each encounter shall be selected randomly from a distribution that is uniform in the interval covered by the appropriate *vmd* bin

4.4.2.6.3.2 Vertical rate

4.4.2.6.3.2.1 For each aircraft in each encounter, either the vertical rate shall be constant ($\dot{z}$) or the vertical trajectory shall be constructed so that the vertical rate at *tca* – 35 s is $\dot{z}_1$ and the vertical rate at *tca* + 5 s is $\dot{z}_2$. Each vertical rate, $\dot{z}$, $\dot{z}_1$or $\dot{z}_2$, shall be determined by first selecting randomly an interval within which it lies and then selecting the precise value from a distribution that is uniform over the interval selected.

4.4.2.6.3.2.2 The intervals within which the vertical rates lie shall depend on whether the aircraft is level, i.e. marked “L” in 4.4.2.6.2.3.1, or transitioning, i.e. marked “T” in 4.4.2.6.2.3.1, and shall be as follows:

L	*T*
[240 ft/min, 400 ft/min]	[3 200 ft/min, 6 000 ft/min]
[80 ft/min, 240 ft/min]	[400 ft/min, 3 200 ft/min]
[–80 ft/min, 80 ft/min]	[–400 ft/min, 400 ft/min]
[–240 ft/min, –80 ft/min]	[–3 200 ft/min, –400 ft/min]
[–400 ft/min, –240 ft/min]	[–6 000 ft/min, –3 200 ft/min]

4.4.2.6.3.2.3 For aircraft that are level over the entire encounter window, the vertical rate $\dot{z}$ shall be constant. The probabilities for the intervals within which $\dot{z}$ lies shall be as follows:

ż (ft/min)	*prob(ż)*

[240 ft/min, 400 ft/min]	0.0382
[80 ft/min, 240 ft/min]	0.0989
[–80 ft/min, 80 ft/min]	0.7040
[–240 ft/min, –80 ft/min]	0.1198
[–400 ft/min, –240 ft/min]	0.0391

4.4.2.6.3.2.4 For aircraft that are not level over the entire encounter window, the intervals for $\dot{z}_1$ and $\dot{z}_2$ shall be determined jointly by random selection using joint probabilities that depend on altitude layer and on whether the aircraft is transitioning at the beginning of the encounter window (Rate-to-Level), at the end of the encounter window (Level-to-Rate) or at both the beginning and the end (Rate-to-Rate). The joint probabilities for the vertical rate intervals shall be as follows:

for aircraft with Rate-to-Level trajectories in layers 1 to 3,

$\dot{z}_2$ *interval*	*joint probability of* $\dot{z}_1$ *and* $\dot{z}_2$ *interval*				
[240 ft/min, 400 ft/min]	0.0019	0.0169	0.0131	0.1554	0.0000
[80 ft/min, 240 ft/min]	0.0000	0.0187	0.0019	0.1086	0.0000
[–80 ft/min, 80 ft/min]	0.0037	0.1684	0.0094	0.1124	0.0075
[–240 ft/min, –80 ft/min]	0.0037	0.1461	0.0094	0.0243	0.0037
[–400 ft/min, –240 ft/min]	0.0000	0.1742	0.0094	0.0094	0.0019
	–6 000 ft/min	–3 200 ft/min	–400 ft/min	400 ft/min	3 200 ft/min	6 000 ft/min	$\dot{z}_1$

for aircraft with Rate-to-Level trajectories in layers 4 to 6,

$\dot{z}_2$ *interval*	*joint probability of* $\dot{z}_1$ *and* $\dot{z}_2$ *interval*				
[240 ft/min, 400 ft/min]	0.0105	0.0035	0.0000	0.1010	0.0105
[80 ft/min, 240 ft/min]	0.0035	0.0418	0.0035	0.1776	0.0279
[–80 ft/min, 80 ft/min]	0.0279	0.1219	0.0000	0.2403	0.0139
[–240 ft/min, –80 ft/min]	0.0035	0.0767	0.0000	0.0488	0.0105
[–400 ft/min, –240 ft/min]	0.0105	0.0453	0.0035	0.0174	0.0000
	–6 000 ft/min	–3 200 ft/min	–400 ft/min	400 ft/min	3 200 ft/min	6 000 ft/min	$\dot{z}_1$

for aircraft with Level-to-Rate trajectories in layers 1 to 3,

$\dot{z}_2$ *interval*	*joint probability of* $\dot{z}_1$ *and* $\dot{z}_2$ *interval*				
[3 200 ft/min, 6000 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[400 ft/min, 3200 ft/min]	0.0074	0.0273	0.0645	0.0720	0.1538
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.2978	0.2084	0.1365	0.0273	0.0050
[–6 000ft/min, –3 200ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
	–400 ft/min	–240 ft/min	–80 ft/min	80 ft/min	240 ft/min	400 ft/min	$\dot{z}_1$

for aircraft with Level-to-Rate trajectories in layers 4 to 6,

$\dot{z}_2$ *interval*	*joint probability of* $\dot{z}_1$ *and* $\dot{z}_2$ *interval*				
[3 200 ft/min, 6 000 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0192
[400 ft/min, 3 200 ft/min]	0.0000	0.0000	0.0962	0.0577	0.1154
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.1346	0.2692	0.2308	0.0577	0.0192
[–6 000 ft/min, –3 200 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
	–400 ft/min	–240 ft/min	–80 ft/min	80 ft/min	240 ft/min	400 ft/min	$\dot{z}_1$

4.4.2.6.3.2.5 For a Rate-to-Rate track, if line $|\dot{z}_2 - \dot{z}_1| < 566$ ft/min then the track shall be constructed with a constant rate equal to $\dot{z}_1$.

4.4.2.6.3.3 Vertical acceleration

4.4.2.6.3.3.1 Subject to 4.4.2.6.3.2.5, for aircraft that are not level over the entire encounter window, the rate shall be constant and equal to $\dot{z}_1$ over at least the interval [*tca* – 40 s, *tca* – 35 s] at the beginning of the encounter window, and shall be constant and equal to $\dot{z}_2$ over at least the interval [*tca* + 5 s, *tca* + 10 s] at the end of the encounter window. The vertical acceleration shall be constant in the intervening period.

4.4.2.6.3.3.2 The vertical acceleration (z) shall be modelled as follows:

$$z = (A\dot{z}_2 - \dot{z}_1) +$$

where the parameter A is case-dependent as follows:

	$A(s^{-1})$	
Case	*Layers 1-3*	*Layers 4-6*

Rate-to-Level	0.071	0.059
Level-to-Rate	0.089	0.075
Rate-to-Rate	0.083	0.072

and the error is selected randomly using the following probability density:

$$p(\varepsilon) = \frac{1}{2\mu}\exp\left(-\frac{|\varepsilon|}{\mu}\right)$$

where $\mu = 0.3$ ft s^{-2}.

Note.— The sign of the acceleration z is determined by $\dot{z}_1$ and $\dot{z}_2$. An error ε that reverses this sign must be rejected and the error reselected.

4.4.2.6.3.4 Acceleration start time. The acceleration start time shall be distributed uniformly in the time interval [tca – 35 s, tca – 5 s] and shall be such that $\dot{z}_2$ is achieved no later than tca + 5 s.

4.4.2.6.4 Characteristics of the Aircraft trajectories in the Horizontal Plane

4.4.2.6.4.1 Horizontal miss distance

4.4.2.6.4.1.1 For calculations of the effect of ACAS on the risk of collision (4.4.3), *hmd* shall be uniformly distributed in the range [0, 500 ft].

4.4.2.6.4.1.2 For calculations concerning the compatibility of ACAS with ATM (4.4.4), *hmd* shall be distributed so that the values of *hmd* have the following cumulative probabilities:

	cumulative probability			*cumulative probability*	
hmd *(ft)*	*Layers 1-3*	*Layers 4-6*	hmd *(ft)*	*Layers 1-3*	*Layers 4-6*
0	0.000	0.000	17 013	0.999	0.868
1 215	0.152	0.125	18 228	1.000	0.897
2 430	0.306	0.195	19 443		0.916
3 646	0.482	0.260	20 659		0.927
4 860	0.631	0.322	21 874		0.939
6 076	0.754	0.398	23 089		0.946
7 921	0.859	0.469	24 304		0.952
8 506	0.919	0.558	25 520		0.965
9 722	0.954	0.624	26 735		0.983
10 937	0.972	0.692	27 950		0.993

	cumulative probability			*cumulative probability*	
hmd *(ft)*	*Layers 1-3*	*Layers 4-6*	hmd *(ft)*	*Layers 1-3*	*Layers 4-6*

12 152	0.982	0.753	29 165	0.996
13 367	0.993	0.801	30 381	0.999
14 582	0.998	0.821	31 596	1.000
15 798	0.999	0.848		

4.4.2.6.4.2 *Approach angle.* The cumulative distribution for the horizontal approach angle shall be as follows:

approach angle (deg.)	*cumulative probability Layers 1-3*	*Layers 4-6*	*approach angle (deg.)*	*cumulative probability Layers 1-3*	*Layers 4-6*
0	0.00	0.00	100	0.38	0.28
10	0.14	0.05	110	0.43	0.31
20	0.17	0.06	120	0.49	0.35
30	0.18	0.08	130	0.55	0.43
40	0.19	0.08	140	0.62	0.50
50	0.21	0.10	150	0.71	0.59
60	0.23	0.13	160	0.79	0.66
70	0.25	0.14	170	0.88	0.79
80	0.28	0.19	180	1.00	1.00
90	0.32	0.22			

4.4.2.6.4.3 Aircraft speed. The cumulative distribution for each aircraft's horizontal ground speed at closest approach shall be as follows*:*

Ground speed (kt)	*cumulative probability Layers 1-3*	*Layers 4-6*	*ground speed (kt)*	*cumulative probability Layers 1-3*	*Layers 4-6*
45	0.000		325	0.977	0.528
50	0.005		350	0.988	0.602
75	0.024	0.000	375	0.997	0.692
100	0.139	0.005	400	0.998	0.813
125	0.314	0.034	425	0.999	0.883
150	0.486	0.064	450	1.000	0.940
175	0.616	0.116	475		0.972
200	0.700	0.171	500		0.987
225	0.758	0.211	525		0.993
250	0.821	0.294	550		0.998
275	0.895	0.361	575		0.999
300	0.949	0.427	600		1.000

4.4.2.6.4.4 Horizontal manoeuvre probabilities. For each aircraft in each encounter, the probability of a turn, the probability of a speed change given a turn, and the probability of a speed change given no turn shall be as follows:

Prob(speed change) *Prob(speed change)*

Layer	*Prob(turn)*	*given a turn*	*given no turn*
1	0.31	0.20	0.5
2	0.29	0.20	0.25
3	0.22	0.10	0.15
4, 5, 6	0.16	0.05	0.10

4.4.2.6.4.4.1 Given a speed change, the probability of a speed increase shall be 0.5 and the probability of a speed decrease shall be 0.5.

4.4.2.6.4.5 Turn extent. The cumulative distribution for the extent of any turn shall be as follows:

	cumulative probability	
Turn extent (deg.)	*Layers 1-3*	*Layers 4-6*
15	0.00	0.00
30	0.43	0.58
60	0.75	0.90
90	0.88	0.97
120	0.95	0.99
150	0.98	1.00
180	0.99	
210	1.00	

4.4.2.6.4.5.1 The direction of the turn shall be random, with the probability of a left turn being 0.5 and the probability of a right turn being 0.5.

4.4.2.6.4.6 Bank angle. An aircraft's bank angle during a turn shall not be less than 15 degrees. The probability that it equals 15 degrees shall be 0.79 in layers 1-3 and 0.54 in layers 4-5. The cumulative distribution for larger bank angles shall be as follows:

	cumulative probability	
Bank angle (deg.)	*Layers 1-3*	*Layers 4-6*
15	0.79	0.54
25	0.96	0.82
35	0.99	0.98
50	1.00	1.00

4.4.2.6.4.7 Turn end time. The cumulative distribution for each aircraft's turn end time shall be as follows:

Turn end time	*cumulative probability*	
(seconds before tca*)*	*Layers 1-3*	*Layers 4-6*
0	0.42	0.28
5	0.64	0.65
10	0.77	0.76

15	0.86	0.85
20	0.92	0.94
25	0.98	0.99
30	1.00	1.00

4.4.2.6.4.8 Speed change. A constant acceleration or deceleration shall be randomly selected for each aircraft performing a speed change in a given encounter, and shall be applied for the duration of the encounter. Accelerations shall be uniformly distributed between 2 kt/s and 6 kt/s. Decelerations shall be uniformly distributed between 1 kt/s and 3 kt/s.

4.4.2.7 ACAS Equipage of The Intruder

The performance requirements specified in 4.4.3 and 4.4.4 each apply to three distinct situations in which the following conditions concerning the intruder's ACAS and trajectory shall apply:

a) where the intruder involved in each encounter is not equipped (4.4.2.1 j) 1)), it follows a trajectory identical to that which it follows when own aircraft is not equipped;

b) where the intruder is ACAS-equipped but follows a trajectory identical to that in the unequipped encounter

(4.4.2.1 j) 2)):

1) it follows the identical trajectory regardless of whether or not there is an RA;

2) the intruder ACAS generates an RA and transmits an RAC that is received immediately after any RA is first announced to the pilot of own aircraft;

3) the sense of the RAC generated by the intruder ACAS and transmitted to own aircraft is opposite to the sense of the first RAC selected and transmitted to the intruder by own aircraft (4.3.6.1.3);

4) the RAC transmitted by the intruder is received by own aircraft; and

5) the requirements apply both when own aircraft has the lower aircraft address and when the intruder aircraft has the lower aircraft address; and

c) where the intruder is equipped with an ACAS having a collision avoidance logic identical to that of own ACAS
(4.4.2.1 j) 3)):

1) the conditions relating to the performance of own aircraft, ACAS and pilot apply equally to the intruder aircraft, ACAS and pilot;

2) RACs transmitted by one aircraft are received by the other; and

3) the requirements apply both when own aircraft has the lower aircraft address and when the intruder aircraft has the lower aircraft address.

4.4.2.8 Compatibility between Different Collusion Avoidance Logic Designs

When considering alternative collision avoidance logic designs, certification authorities should verify that:

a) the performances of the alternative design are acceptable in encounters involving ACAS units that use existing designs; and

b) the performances of the existing designs are not degraded by the use of the alternative design.

Note.— To address the compatibility between different collision avoidance logic designs, the conditions described in 4.4.2.7 b) are the most severe that can be anticipated in this respect.

4.4.3 Reduction in the risk of collision

Under the conditions of 4.4.2, the collision avoidance logic shall be such that the expected number of collisions is reduced to the following proportions of the number expected in the absence of ACAS:

a) when the intruder is not ACAS equipped 0.18;

b) when the intruder is equipped but does not respond 0.32; and

c) when the intruder is equipped and responds 0.04.

4.4.4 Compatibility with air traffic management (ATM)

4.4.4.1 Nuisance Alert Rate

4.4.4.1.1 Under the conditions of 4.4.2, the collision avoidance logic shall be such that the proportion of RAs which are a “nuisance” (4.4.4.1.2) shall not exceed:

.06 when own aircraft’s vertical rate at the time the RA is first issued is less than 400 ft/min; or

.08 when own aircraft’s vertical rate at the time the RA is first issued exceeds 400 ft/min.

Note.— This requirement is not qualified by the ACAS equipage of the intruder (4.4.2.7) since it has negligible effect on the occurrence and frequency of nuisance RAs.

4.4.4.1.2 An RA shall be considered a “nuisance” for the purposes of 4.4.4.1.1 unless, at some point in the encounter in the absence of ACAS, the horizontal separation and the vertical separation are simultaneously less than the following values:

horizontal *vertical*

	separation	*separation*
above FL100	2.0 NM	750 ft
below FL100	1.2 NM	750 ft

4.4.4.2 Compatible sense selection

Under the conditions of 4.4.2, the collision avoidance logic shall be such that the proportion of encounters in which following the RA results in an altitude separation at closest approach with the opposite sign to that occurring in the absence of ACAS shall not exceed the following values:

a) when the intruder is not ACAS equipped 0.08;

b) when the intruder is equipped but does not respond 0.08; and

c) when the intruder is equipped and responds 0.12.

4.4.4.3 Deviations caused by ACAS

4.4.4.3.1 Under the conditions of 4.4.2, the collision avoidance logic shall be such that the number of RAs resulting in "deviations" (4.4.4.3.2) greater than the values indicated shall not exceed the following proportions of the total number of RAs:

	when own aircraft's vertical rate at the time the RA is first issued	
	is less than 400ft/min	*exceeds 400ft/min*
when the intruder is not ACAS equipped,		
for deviations ≥300 ft	0.15	0.23
for deviations ≥600 ft	0.04	0.13
for deviations ≥1 000 ft	0.01	0.07
when the intruder is equipped but does not respond,		
for deviations ≥300 ft	0.23	0.35
for deviations ≥600 ft	0.06	0.16
for deviations ≥1 000 ft	0.02	0.07
when the intruder is equipped and responds,		
for deviations ≥300 ft	0.11	0.23
for deviations ≥600 ft	0.02	0.12
for deviations ≥1 000 ft	0.01	0.06

4.4.4.3.2 For the purposes of 4.4.4.3.1, the "deviation" of the equipped aircraft from the original trajectory shall be measured in the interval from the time at which the RA is first issued until the time at which, following cancellation of the RA, the equipped aircraft has recovered its original altitude rate. The deviation shall be calculated as the largest altitude difference at any time in this interval between the trajectory followed by the equipped aircraft when responding to its RA and its original trajectory.

4.4.5 Relative value of conflicting objectives

The collision avoidance logic should be such as to reduce as much as practicable the risk of collision (measured as defined in 4.4.3) and limit as much as practicable the disruption to ATM (measured as defined in 4.4.4).

4.5 ACAS Use Of Extended Squitter

4.5.1 ACAS hybrid surveillance using extended squitter position data

Note: Surveillance protocols defined in this section are for ACAS hybrid surveillance, and surveillance protocols for ACAS not equipped for hybrid surveillance are defined in 4.3.7.1.

4.5.1.1 Definitions

Active surveillance. The process of tracking an intruder by using the information gained from the replies to own ACAS interrogations.

Extended hybrid surveillance. The process of using qualified ADS-B airborne position messages via 1 090 MHz extended squitter without validating 1 090 extended squitter data for the track by ACAS active interrogations.

Hybrid surveillance. The process of using a combination of active surveillance and passive surveillance with validated data to update an ACAS track in order to preserve ACAS independence.

Passive surveillance. The process of tracking another aircraft without interrogating it, by using the other aircraft's extended squitters. ACAS uses the information obtained via 1 090 MHz extended squitter to monitor the need for active surveillance, but not for any other purpose. Passive surveillance applies to both hybrid and extended hybrid surveillance.

Validation. The process of verifying the relative position of an intruder using passive information via 1 090 MHz extended squitter by comparing it to the relative position obtained by ACAS active interrogation.

4.5.1.2 An ACAS equipped to receive extended squitter airborne position messages for passive surveillance of non-threatening intruders shall utilize this passive position information in the following manner.

4.5.1.3 Passive Surveillance

4.5.1.3.1 *EXTENDED HYBRID SURVEILLANCE*

4.5.1.3.1.1 Systems using extended hybrid surveillance mode shall establish a track in such a way that no interrogations are performed, i.e. acquiring the track through exclusive use of ADS-B extended squitter, when the following conditions are met:

1) Own aircraft position data meets the following minimum level of quality:

   a) own aircraft horizontal position uncertainty (95 per cent) is < 0.1 NM; and

   b) own aircraft horizontal position integrity shall be such that the probability of an undetected position error, which is greater than 0.6 NM radius, is less than 1 x 10-7.

2) The received signal strength is equal or less than -68 dBm +/-2 dB (extended hybrid surveillance minimum triggering level), or own aircraft is operating on the surface; and

3) The intruder data quality meets the following minimum requirements:

a. the ADS-B version number ≥ 2;
b. the reported NIC ≥ 6 (< 0.6 NM);
c. the reported NACp ≥ 7 (< 0.1 NM);
d. the reported SIL = 3;
e. the reported SDA = 2 or 3; and
f. the barometric altitude is valid.

4.5.1.3.1.2 The system shall not use ADS-rebroadcast (ADS-R) and TIS-B data to passively acquire an aircraft.

Note 1.— ADS-R is described in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Note 2.— The signal level strength cannot be applied to ADS-R and TIS-B data.

4.5.1.3.1.3 A track maintained under extended hybrid surveillance mode shall transition to a track maintained under active surveillance mode if range and altitude of hybrid threat criteria are met.

Note.— Information concerning range and altitude hybrid threat criteria can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

4.5.1.3.1.4 A track under extended hybrid surveillance mode shall transition to a track under hybrid surveillance mode if:

1) The signal indicates a high probability to be in close proximity, i.e. signal > Extended Hybrid Surveillance MTL, except when operating on the airport surface; or

2) Intruder data or own data quality does not meet minimum requirements.

4.5.1.3.2 Validation. To validate the position of an intruder reported by extended squitter and not meeting the criteria for extended hybrid surveillance mode, ACAS shall determine the relative range and relative bearing as computed from the position and geographical heading of own aircraft and the intruder's position as reported in the extended squitter. This derived range and relative bearing and the altitude reported in the squitter shall be compared to the range, relative bearing and altitude determined by active ACAS interrogation requiring a short reply from the aircraft. Differences between the derived and measured range and relative bearing and the squitter and reply altitude shall be computed and used in tests to determine whether the extended squitter data is valid. If these tests are satisfied the passive position shall be considered to be validated and the track shall be maintained on passive data unless it is a near threat as described in 4.5.1.4. If any of these validation tests fail, active surveillance shall be used to track the intruder.

Note.— Suitable tests for validating extended squitter data information for the purposes of ACAS hybrid surveillance can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

4.5.1.3.3 Supplementary active interrogations. In order to ensure that an intruder's track is updated at least as frequently as required in the absence of extended squitter data (4.3.7.1.2.2), each time a track is updated using squitter information the time at which an active interrogation would next be required shall be calculated. An active interrogation shall be made at that time if a further squitter has not been received before the interrogation is due.

4.5.1.4 Near threat. An intruder shall be tracked under active surveillance if it is a near threat, as determined by separate tests on the range and altitude of the aircraft. These tests shall be such that an intruder is considered a near threat before it becomes a potential threat, and thus triggers a traffic advisory as described in 4.3.3. These tests shall be performed once per second. All near threats, potential threats and threats shall be tracked using active surveillance.

Note.— Suitable tests for determining that an intruder is a near threat can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

4.5.1.5 Revalidation and monitoring. If an aircraft is being tracked using passive surveillance and if criteria for extended hybrid surveillance mode are not met, periodic active interrogations shall be performed to validate and monitor the extended squitter data as required in 4.5.1.3.1. The default rates of revalidation shall be once per minute for a non-threat and once per 10 seconds for a near threat. The tests required in 4.5.1.3.1 shall be performed for each interrogation, and active surveillance shall be used to track the intruder if these revalidation tests fail.

Note.— More information about criteria of revalidation rate can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

4.5.1.6 Full active surveillance. If the following condition is met for a track being updated via passive surveillance data:

a) $|a| \leq 10\ 000$ ft and both;

b) $|a| \leq 3\ 000$ ft or $|a - 3\ 000 \text{ ft}| / |a| \leq 60$ s; and

c) $r \leq 3$ NM or $(r - 3 \text{ NM}) / |r| \leq 60$ s;

where: a = intruder altitude separation in ft
a = altitude rate estimate in ft/s
r = intruder slant range in NM r = range rate estimate in NM/s

the aircraft shall be declared an active track and shall be updated on active range measurements once per second for as long as the above condition is met.

4.5.1.6.1 All near threats, potential threats and threats shall be tracked using active surveillance.

4.5.1.6.2 A track under active surveillance shall transition to passive surveillance if it is neither a near, potential threat nor a threat. The tests used to determine it is no longer a near threat shall be similar to those used in 4.5.1.4 but with larger thresholds in order to have hysteresis which prevents the possibility of frequent transitions between active and passive surveillance.

Note.— Suitable tests for determining that an intruder is no longer a near threat can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance..

4.5.2 ACAS operation with an improved receiver MTL

Note.— Applications of extended squitter that are independent of ACAS might be implemented (for convenience) using the ACAS receiver. The use of an improved receiver minimum triggering level (MTL) will make it possible to receive extended squitters from ranges of up to 60 NM and beyond in support of such applications.

4.5.2.1 An ACAS operating with a receiver having a MTL more sensitive than –74 dBm shall implement the capabilities specified in the following paragraphs.

4.5.2.2 Dual minimum triggering levels. The ACAS receiver shall be capable of setting an indication for each squitter reception as to whether the reply would have been detected by an ACAS operating with a conventional MTL (–74 dBm). Squitter receptions received at the conventional MTL shall be passed to the ACAS surveillance function for further processing. Squitter receptions that do not meet this condition shall not be passed to the ACAS surveillance function.

Note 1.— Extended squitters containing position report information will be disseminated for display in connection with an extended squitter application.

Note 2.— Use of the conventional MTL for the ACAS surveillance function preserves the current operation of ACAS surveillance when operating with a receiver with an improved MTL.

4.5.2.3 Dual or re-triggerable reply processor. The ACAS Mode S reply processing function shall:

a) use separate reply processors for Mode S reply formats received at or above the conventional MTL and a separate reply processor for Mode S reply formats received below the conventional MTL; or,

b) use a Mode S reply processor that will re-trigger if it detects a Mode S preamble that is 2 to 3 dB stronger than the reply that is currently being processed.

Note.— Care must be taken to ensure that low-level squitters (i.e. those below the conventional MTL) do not interfere with the processing of acquisition squitters for ACAS. This could happen if the low-level squitter is allowed to capture the reply processor. This can be prevented by using a separate reply processor for each function, or by requiring the reply processor to be re-triggered by a higher level squitter.

CHAPTER 5. MODE S EXTENDED SQUITTER

Note 1.— A functional model of Mode S extended squitter systems supporting ADS-B and/or TIS-B is depicted in Figure 5-1.

Note 2.— Airborne systems transmit ADS-B messages (ADS-B OUT) and may also receive ADS-B and TIS-B messages (ADS-B IN and TIS-B IN). Ground systems (i.e. ground stations) transmit TIS-B (as an option) and receive ADS-B messages.

Note 3.— Although not explicitly depicted in the functional model presented in Figure 5-1, extended squitter systems installed on aerodrome surface vehicles or fixed obstacles may transmit ADS-B messages (ADS-B OUT).

5.1 Mode S Extended Squitter Transmitting System Characteristics

Note.— Many of the requirements associated with the transmission of Mode S extended squitter are included in Chapter 2 and Chapter 3 for Mode S transponder and non-transponder devices using the message formats defined in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871). The provisions presented within the following subsections are focused on requirements applicable to specific classes of airborne and ground transmitting systems that are supporting the applications of ADS-B and TIS-B.*

5.1.1 ADS-B out requirements

5.1.1.1 Aircraft, surface vehicles and fixed obstacles supporting an ADS-B capability shall incorporate the ADS-B message generation function and the ADS-B message exchange function (transmit) as depicted in Figure 5-1.

5.1.1.1.1 ADS-B transmissions from aircraft shall include position, aircraft identification and type, airborne velocity, periodic status and event driven messages including emergency/priority information.

5.1.1.1.2 Extended squitter transmitting equipment should use formats and protocols of the latest version available.

Note 1.— The data formats and protocols for messages transferred via extended squitter are specified in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871).*

Note 2.— Some States and/or regions require extended squitter version 2 to be transmitted by specific dates.

5.1.1.2 Extended squitter ADS-B transmission requirements. Mode S extended squitter transmitting equipment shall be classified according to the unit's range capability and the set of parameters that it is capable of transmitting consistent with the following definition of general equipment classes and the specific equipment classes defined in Tables 5-1 and 5-2:

a) Class A extended squitter airborne systems support an interactive capability incorporating both an extended squitter transmission capability (i.e. ADS-B OUT) with a complementary extended squitter reception capability (i.e. ADS-B IN) in support of onboard ADS-B applications;

b) Class B extended squitter systems provide a transmission only (i.e. ADS-B OUT without an extended squitter reception capability) for use on aircraft, surface vehicles, or fixed obstructions; and

c) Class C extended squitter systems have only a reception capability and thus have no transmission requirements.

5.1.1.3 Class A extended squitter system requirements. Class A extended squitter airborne systems shall have transmitting and receiving subsystem characteristics of the same class (i.e. A0, A1, A2, or A3) as specified in 5.1.1.1 and 5.2.1.2.

Note.— Class A transmitting and receiving subsystems of the same specific class (e.g. Class A2) are designed to complement each other with their functional and performance capabilities. The minimum air-to-air range that extended squitter transmitting and receiving systems of the same class are designed to support are:

a) A0-to-A0 nominal air-to-air range is 10 NM;

b) A1-to-A1 nominal air-to-air range is 20 NM;

c) A2-to-A2 nominal air-to-air range is 40 NM; and

d) A3-to-A3 nominal air-to-air range is 90 NM.

The above ranges are design objectives and the actual effective air-to-air range of the Class A extended squitter systems may be larger in some cases (e.g. in environments with low levels of 1 090 MHz fruit) and shorter in other cases (e.g. in environments with very high levels of 1 090 MHz fruit).

5.1.1.4 Control of ADS-B out Operation

5.1.1.4.1 Protection against reception of corrupted data from the source providing the position should be satisfied by error detection on the data inputs and the appropriate maintenance of the installation.

5.1.1.4.2 If an independent control of the ADS-B OUT function is provided, then the operational state of the ADS-B OUT function shall be indicated to the flight crew, at all times.

Note.— There is no requirement for an independent control for the ADS-B OUT function.

5.1.2 TIS-B out requirements

5.1.2.1 Ground stations supporting a TIS-B capability shall incorporate the TIS-B message generation function and the TIS-B message exchange function (transmit).

5.1.2.2 The extended squitter messages for TIS-B shall be transmitted by an extended squitter ground station when connected to an appropriate source of surveillance data.

Note 1.— Extended squitter messages for TIS-B are specified in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871).*

Note 2.— Ground stations supporting TIS-B use an extended squitter transmission capability. The characteristics of such ground stations, in terms of transmitter power, antenna gain, transmission rates, etc., are to be tailored to the desired TIS-B service volume of the specific ground station assuming airborne users are equipped with (at least) Class A1 receiving systems.

5.1.2.3 The maximum transmission rates and effective radiated power of the transmissions should be controlled to avoid unacceptable levels of RF interference to other 1 090 MHz systems (i.e. SSR and ACAS).

5.1.3 ADS-B OUT requirements for surface vehicles

5.1.3.1 All surface vehicles supporting any versions of extended squitter ADS-B capability shall transmit extended squitter messages as per 5.1.1.2.

5.1.3.2 Extended squitter version 2 required system performance. The position source and equipment installed in surface vehicles to transmit extended squitter version 2 messages shall support the following performance characteristics:

5.1.3.2.1 The NACP for the navigation position data shall be greater than or equal to 9, a 95 per cent accuracy bound on horizontal position less than 30 metres.

Note.— NACP is calculated based on satellite performance.

5.1.3.2.2 The NACV for the navigation velocity data shall be greater than or equal to 2, a velocity error less than 3 metres per second.

5.1.3.2.3 The NACP and NACV minimum values shall be met at a minimum availability of 95 per cent.

5.1.3.2.4 The system design assurance parameter shall be equal to 1 or more, which defines the probability of a failure resulting in transmission of false or misleading information to be less than or equal to 1x10-3.

Note 1.— These minimum performance requirements for extended squitter version 2 transmitted position data from surface vehicles are necessary to support aircraft-based alerting applications.

Note 2.— Guidance material for implementation of surface vehicle ADS-B systems is contained in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

5.2 Mode S Extended Squitter Receiving System Characteristics (ADS-B IN AND TIS-B IN)

Note 1.— The paragraphs herein describe the required capabilities for 1 090 MHz receivers used for the reception of Mode S extended squitter transmissions that convey ADS-B and/or TIS-B messages. Airborne

receiving systems support ADS-B and TIS-B reception while ground receiving systems support only ADS-B reception.

Note 2.— Detailed technical provisions for Mode S extended squitter receivers can be found within RTCA DO-260B/EUROCAE ED-102A, "Minimum Operational Performance Standards for 1 090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS B)."

5.2.1 Mode S extended squitter receiving system functional requirements

5.2.1.1 Mode S extended squitter receiving systems shall perform the message exchange function (receive) and the report assembler function.

Note.— The extended squitter receiving system receives ADS-B Mode S extended squitter messages and outputs ADS-B reports to client applications. Airborne receiving systems also receive TIS-B extended squitter messages and output TIS-B reports to client applications. This functional model (shown in Figure 5-1) depicts both airborne and ground 1 090 MHz ADS-B receiving systems.

5.2.1.2 *Mode S extended squitter receiver classes*. The required functionality and performance characteristics for the Mode S extended squitter receiving system will vary depending on the ADS-B and TIS-B client applications to be supported and the operational use of the system. Airborne Mode S extended squitter receivers shall be consistent with the definition of receiving system classes shown in Table 5-3.

Note.— Different equipment classes of Mode S extended squitter installations are possible. The characteristics of the receiver associated with a given equipment class are intended to be appropriate to support the required level of operational capability. Equipment classes A0 through A3 are applicable to those Mode S extended airborne installations that include a Mode S extended squitter transmission (ADS OUT) and reception (ADS-B IN) capability. Equipment classes B0 through B3 are applicable to Mode S extended installations with only a transmission (ADS-B OUT) capability and includes equipment classes applicable to airborne, surface vehicles and fixed obstructions. Equipment classes C1 through C3 are applicable to Mode S extended squitter ground receiving systems.

5.2.2 Message exchange function

5.2.2.1 The message exchange function shall include the 1 090 MHz receiving antenna and the radio equipment (receiver/demodulator/decoder/data buffer) sub-functions.

5.2.2.2 Message exchange functional characteristics. The airborne Mode S extended squitter receiving system shall support the reception and decoding of all extended squitter messages as listed in Table 5-3. The ground ADS-B extended squitter receiving system shall, as a minimum, support the reception and decoding of all of the extended squitter message types that convey information needed to support the generation of the ADS-B reports of the types required by the client ATM ground applications.

5.2.2.3 Required message reception performance. The airborne Mode S extended squitter receiver/demodulation/ decoder shall employ the reception techniques and have a receiver minimum trigger threshold level (MTL) as listed in Table 5-3 as a function of the airborne receiver class. The reception technique and MTL for extended squitter ground receiver shall be selected to provide the reception performance (i.e. range and update rates) as required by the client ATM ground applications.

5.2.2.4 Enhanced reception techniques. Class A1, A2 and A3 airborne receiving systems shall include the following features to provide improved probability of Mode S extended squitter reception in the presence of multiple overlapping Mode A/C fruit and/or in the presence of an overlapping stronger Mode S fruit, as compared to the performance of the standard reception technique required for Class A0 airborne receiving systems:

a) Improved Mode S extended squitter preamble detection.

b) Enhanced error detection and correction.

c) Enhanced bit and confidence declaration techniques applied to the airborne receiver classes as shown below:

   1) Class A1 — Performance equivalent to or better than the use of the “Centre Amplitude” technique.

   2) Class A2 — Performance equivalent to or better than the use of the “Multiple Amplitude Samples” baseline technique, where at least 8 samples are taken for each Mode S bit position and are used in the decision process.

   3) Class A3 — Performance equivalent to or better than the use of the “Multiple Amplitude Samples” baseline technique, where at least 10 samples are taken for each Mode S bit position and are used in the decision process.

Note 1.— The above enhanced reception techniques are as defined in RTCA DO-260B/EUROCAE ED-102A, Appendix I.

Note 2.— The performance provided for each of the above enhanced reception techniques when used in a high fruit environment (i.e. with multiple overlapping Mode A/C fruit) is expected to be at least equivalent to that provided by the use of the techniques described in RTCA DO-260B/EUROCAE ED-102A, Appendix I.

Note 3.— It is considered appropriate for ground extended squitter receiving systems to employ the enhanced reception techniques equivalent to those specified for airborne Class A2 or A3 receiving systems.

5.2.3 Report assembler function

5.2.3.1 The report assembler function shall include the message decoding, report assembly, and output interface sub-functions.

5.2.3.2 When an extended squitter message is received, the message shall be decoded and the applicable ADS-B report(s) of the types defined in 5.2.3.3 shall be generated within 0.5 seconds.

Note 1.— Two configurations of extended squitter airborne receiving systems, which include the reception portion of the ADS-B message exchange function and the ADS-B/TIS-B report assembly function, are allowed:

a) Type I extended squitter receiving systems receive ADS-B and TIS-B messages and produce application-specific subsets of ADS-B and TIS-B reports. Type I extended squitter receiving systems are customized to the particular client applications using ADS-B and TIS-B reports. Type I extended squitter receiving systems may additionally be controlled by an external entity to produce installation-defined subsets of the reports that those systems are capable of producing.

b) Type II extended squitter receiving systems receive ADS-B and TIS-B messages and are capable of producing complete ADS-B and TIS-B reports in accordance with the equipment class. Type II extended squitter receiving systems may be controlled by an external entity to produce installation-defined subsets of the reports that those systems are capable of producing.

Note 2.— Extended squitter ground receiving systems receive ADS-B messages and produce either application-specific subsets or complete ADS-B reports based on the needs of the ground service provider, including the client applications to be supported.

Note 3.— The extended squitter message reception function may be physically partitioned into hardware separate from those that implement the report assembly function.

5.2.3.3 ADS-B Report Types

Note 1.— The ADS-B report refers to the restructuring of ADS-B message data received from Mode S extended squitter broadcasts into various reports that can be used directly by a set of client applications. Five ADS-B report types are defined by the following subparagraphs for output to client applications. Additional information on the ADS-B report contents and the applicable mapping from extended squitter messages to ADS-B reports can be found in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871) and RTCA DO-260B / EUROCAE ED-102A.*

Note 2.— The use of precision (e.g. GNSS UTC measured time) versus non-precision (e.g. internal receiving system clock) time sources as the basis for the reported time of applicability is described in 5.2.3.5.

5.2.3.3.1 State vector report. The state vector report shall contain time of applicability, information about an airborne or vehicle's current kinematic state (e.g. position, velocity), as well as a measure of the integrity of the navigation data, based on information received in airborne or ground position, airborne velocity, identification and category, aircraft operational status and target state and status extended squitter messages. Since separate messages are used for position and velocity, the time of applicability shall be reported individually for the position related report parameters and the velocity related report parameters. Also, the state vector report shall include a time of applicability for the estimated position

and/or estimated velocity information (i.e. not based on a message with updated position or velocity information) when such estimated position and/or velocity information is included in the state vector report.

Note.— Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne). The state vector data is the most dynamic of the four ADS-B reports; hence, the applications require frequent updates of the state vector to meet the required accuracy for the operational dynamics of the typical airborne or ground operations of airborne and surface vehicles.

5.2.3.3.2 Mode status report. The mode status report shall contain time of applicability and current operational information about the transmitting participant, including airborne/vehicle address, call sign, ADS-B version number, airborne/vehicle length and width information, state vector quality information, and other information based on information received in aircraft operational status, target state and status, aircraft identification and category, airborne velocity and aircraft status extended squitter messages. Each time that a mode status report is generated, the report assembler function shall update the report time of applicability. Parameters for which valid data is not available shall either be indicated as invalid or omitted from the mode status report.

Note 1.— Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).

Note 2.— The age of the information being reported within the various data elements of a mode status report may vary as a result of the information having been received within different extended squitter messages at different times.

5.2.3.3.3 Air referenced velocity report. Air referenced velocity reports shall be generated when air referenced velocity information is received in airborne velocity extended squitter messages. The air referenced velocity report shall contain time of applicability, airspeed and heading information. Only certain classes of extended squitter receiving systems, as defined in 5.2.3.5, are required to generate air referenced velocity reports. Each time that an individual mode status report is generated, the report assembly function shall update the report time of applicability.

Note 1.— The air referenced velocity report contains velocity information that is received in airborne velocity messages along with additional information received in airborne identification and category extended squitter messages. Air referenced velocity reports are not generated when ground referenced velocity information is being received in the airborne velocity extended squitter messages.

Note 2.— Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).

5.2.3.3.4 Resolution advisory (RA) report. The RA report shall contain time of applicability and the contents of an active ACAS resolution advisory (RA) as received in a Type=28 and Subtype=2 extended squitter message.

Note.— The RA report is only intended to be generated by ground receiving subsystems when supporting a ground ADS-B client application(s) requiring active RA information. An RA report will nominally be generated each time a Type=28, Subtype=2 extended squitter message is received.

5.2.3.3.5 Target State Report

Note.— The target state report will be generated when information is received in target state and status messages, along with additional information received in airborne identification and category extended squitter messages. The target state and status message is defined in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871). Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).*

5.2.3.4 TIS-B Report Types

5.2.3.4.1 As TIS- B messages are received by airborne receiving systems, the information shall be reported to client applications. Each time that an individual TIS-B report is generated, the report assembly function shall update the report time of applicability to the current time.

Note 1.— The TIS-B message format0s are defined in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871).*

Note 2.— The TIS-B report refers to the restructuring of TIS-B message data received from ground Mode S extended squitter broadcasts into reports that can be used by a set of client applications. Two ADS-B report types are defined by the following subparagraphs for output to client applications. Additional information on the TIS-B report contents and the applicable mapping from extended squitter messages to ADS-B reports can be found in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871).*

Note 3.— The use of precision (e.g. GNSS UTC measured time) versus non-precision (e.g. internal receiving system clock) time sources as the basis for the reported time of applicability is described in 5.2.3.5.

5.2.3.4.2 *TIS-B target report.* All received information elements, other than position, shall be reported directly, including all reserved fields for the TIS-B fine format messages and the entire message content of any received TIS-B management message. The reporting format is not specified in detail, except that the information content reported shall be the same as the information content received.

5.2.3.4.3 When a TIS-B position message is received, it is compared with tracks to determine whether it can be decoded into target position (i.e. correlated to an existing track). If the message is decoded into target position, a report shall be generated within 0.5 seconds. The report shall contain the received position information with a time of applicability, the most recently received velocity measurement with a time of applicability, the estimated position and velocity applicable to a common time of applicability, airborne/vehicle address, and all other information in the received message. The estimated values shall be based on the received position information and the track history of the target.

5.2.3.4.4 When a TIS-B velocity message is received, if it is correlated to a complete track, a report shall be generated, within 0.5 seconds of the message reception. The report shall contain the received velocity information with a time of applicability, the estimated position and velocity applicable to a common time of applicability, airborne/vehicle address, and all other information in the received message. The estimated values shall be based on the received ground reference velocity information and the track history of the target.

5.2.3.4.5 TIS- B management report. The entire message content of any received TIS-B management message shall be reported directly to the client applications. The information content reported shall be the same as the information content received.

5.2.3.4.5.1 The contents of any received TIS-B management message shall be reported bit-for-bit to the client applications.

5.2.3.5 Report Time of Applicability

The receiving system shall use a local source of reference time as the basis for reporting the time of applicability, as defined for each specific ADS-B and TIS-B report type (see 5.2.3.3 and 5.2.3.4).

5.2.3.5.1 Precision time reference. Receiving systems intended to generate ADS-B and/or TIS-B reports based on the reception of surface position messages, airborne position messages, and/or TIS-B messages shall use GNSS UTC measured time for the purpose of generating the report time applicability for the following cases of received messages:

a) version zero (0) ADS-B messages, as defined in 3.1.2.8.6.2, when the navigation uncertainty category (NUC) is 8 or 9; or

b) version one (1) or version two (2) ADS-B or TIS-B messages, as defined in 3.1.2.8.6.2 and 3.1.2.8.7 respectively, when the navigation integrity category (NIC) is 10 or 11;

UTC measured time data shall have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) seconds.

5.2.3.5.2 Non-Precision Local Time Reference

5.2.3.5.2.1 For receiving systems not intended to generate ADS-B and/or TIS-B reports based on reception of ADS-B or TIS-B messages meeting the NUC or NIC criteria as indicated in 5.2.3.5.1, a non-precision time source shall be allowed. In such cases, where there is no appropriate precision time source available, the receiving system shall establish an appropriate internal clock or counter having a maximum clock cycle or count time of 20 milliseconds. The established cycle or clock count shall have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) seconds.

Note.— The use of a non-precision time reference as described above is intended to allow the report time of applicability to accurately reflect the time intervals applicable to reports within a sequence. For example the applicable time interval between state vector reports could be accurately determined by a client application, even though the absolute time (e.g. UTC measured time) would not be indicated by the report.

5.2.3.6 Reporting Requirements

5.2.3.6.1 Reporting requirements for Type I Mode S extended squitter airborne receiving systems. As a minimum, the report assembler function associated with Type I Mode S extended squitter receiving systems, as defined in 5.2.3, shall support that subset of ADS-B and TIS-B reports and report parameters, that are required by the specific client applications being served by that receiving system.

5.2.3.6.2 Reporting requirements for Type II Mode S extended squitter airborne receiving systems. The report assembler function associated with Type II receiving systems, as defined in 5.2.3, shall generate ADS-B and TIS-B reports according to the class of the receiving system as shown in Table 5-4 when the prerequisite ADS-B and/or TIS-B messages are being received.

5.2.3.6.3 Reporting requirements for Mode S extended squitter ground receiving systems. As a minimum, the report assembler function associated with Mode S extended squitter ground receiving systems, as defined in 5.2.3, shall support that subset of ADS-B reports and report parameters, that are required by the specific client applications being served by that receiving system.

5.2.4 Interoperability

The Mode S extended squitter receiving system shall provide interoperability between the different versions of extended squitter ADS-B message formats.

Note 1.— All defined ADS-B versions and their corresponding message formats are contained in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871) and are identified by a version number.*

Note 2.— ADS-B message formats are defined with backward compatibility with previous versions. An extended squitter receiver can recognize and decode signals of its own version, as well as the message formats from lower versions. The receiver, however, can decode the portion of messages received from a higher version transponder according to its own capability.

5.2.4.1 Initial Message Decoding

The Mode S extended squitter receiving system shall, upon acquiring a new ADS-B target, initially apply the decoding provisions applicable to version 0 (zero) ADS B messages until or unless an aircraft operational status message is received indicating that a higher version message format is in use.

5.2.4.2 Applying Version Number

The Mode S extended squitter receiving system shall decode the version number information conveyed in the aircraft operational status message and shall apply the corresponding decoding rules for the reported version, up to the highest version supported by the receiving system, for the decoding of the subsequent extended squitter ADS-B messages from that specific aircraft or vehicle.

5.2.4.3 Handling of Reserved Message Subfields

The Mode S extended squitter receiving system shall ignore the contents of any message subfield defined as reserved.

Note.— This provision supports interoperability between message versions by allowing the definition of additional parameters that will be ignored by earlier receiver versions and correctly decoded by newer receiver versions.

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TABLES FOR CHAPTER 5

Table 5-1. ADS-B Class A equipment characteristics

Equipment class	*Minimum transmit power (at antenna terminal)*	*Maximum Transmit Power (at antenna terminal)*	*Airborne or surface*	*Minimum extended squitter message capability required (see* Note 2*)*
A0 (Minimum)	18.5 dBW (see *Note 1*)	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
A1 (Basic)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
A2 (Enhanced)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status Target state and status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
A3 (Extended)	23 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status Target state and status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status

Note 1.— See Chapter 3, 3.1.2.10.2 for restrictions on the use of this category of Mode S transponder.

Note 2.— The extended squitter messages applicable to Class A equipment are defined in the Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871).*

Table 5-2. ADS-B Class B equipment characteristics

Equipment class	*Minimum transmit power (at antenna terminal)*	*Maximum transmit power (at antenna terminal)*	*Airborne or surface*	*Minimum extended squitter message capability required*
B0 (Airborne)	18.5 dBW (see *Note 1*)	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
B1 (Airborne)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
B2 Low (Ground Vehicle)	8.5 dBW	< 18.5 dBW (see *Note 2*)	Surface	Surface position Aircraft identification and category Aircraft operational status
B2 (Ground Vehicle)	18.5 dBW	27 dBW (see *Note 2*)	Surface	Surface position Aircraft identification and category Aircraft operational status
B3 (Fixed Obstacle)	18.5 dBW	27 dBW (see *Note 2*)	Airborne (see *Note 3*)	Airborne position Aircraft identification and category Aircraft operational status

Note 1.— See Chapter 3, 3.1.2.10.2 for restrictions on the use of this category of Mode S transponder.

Note 2.— The appropriate ATS authority is expected to get the maximum power level permitted.

Note 3.— Fixed obstacles use the airborne ADS-B message formats since knowledge of their location is of primary interest to airborne aircraft.

Table 5-3. Reception performance for airborne receiving systems

Receiver class	*Intended air-to-air operational Range*	*Receiver minimum trigger threshold level (MTL) (see* Note 1*)*	*Reception Technique (see* Note 2*)*	*Required extended squitter ADS-B message support*	*Required extended squitter TIS-B message support*
A0 (Basic VFR)	10 NM	–72 dBm	Standard	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management
A1 (Basic IFR)	20 NM	–79 dBm	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management
A2 (Enhanced IFR)	40 NM	–79 dBm	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status Target state and status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management
A3 (Extended capability)	90 NM	–84 dBm (and –87 dBm at 15% probability of reception)	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status Target state and status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management

Note 1.— Specific MTL is referenced to the signal level at the output terminal of the antenna, assuming a passive antenna. If electronic amplification is integrated into the antenna assembly, then the MTL is referenced at the input to the amplifier. For Class A3 receivers, a second performance level is defined at a received signal level of –87 dBm where 15 per cent of the messages are to be successfully received. MTL values refer to reception under non-interference conditions.

Note 2.— The extended squitter receiver reception techniques are defined in 5.2.2.4. "Standard" reception techniques refer to the baseline techniques, as required for ACAS 1 090 MHz receivers, that are intended to handle single overlapping Mode A/C fruit. "Enhanced" reception techniques refer to techniques intended to provide improved reception performance in the presence of multiple overlapping Mode A/C fruit and improved decoder re-triggering in the presence of overlapping stronger Mode S fruit. The requirements for the enhanced reception techniques that are applicable to the specific airborne receiver classes are defined in 5.2.2.4.

Table 5-4. Mode S extended squitter airborne receiving system reporting requirements

Receiver class	*Minimum ADS-B reporting requirements*	*Minimum TIS-B reporting Requirements*
A0 (Basic VFR)	ADS-B state vector report (per 5.2.3.3.1) And ADS-B mode status report (per 5.2.3.3.2)	TIS-B state report And TIS-B management report
A1 (Basic IFR)	ADS-B state vector report (per 5.2.3.3.1) And ADS-B mode status report (per 5.2.3.3.2) And ADS-B air referenced velocity report (ARV) (per 5.2.3.3.3)	TIS-B state report And TIS-B management report
A2 (Enhanced IFR)	ADS-B state vector report (per 5.2.3.3.1) And ADS-B mode status report (per 5.2.3.3.2) And ADS-B ARV report (per 5.2.3.3.3) And ADS-B target state report (per 5.2.3.3.5)	TIS-B state report And TIS-B management report
A3 (Extended capability)	ADS-B state vector report (per 5.2.3.3.1) And ADS-B mode status report (per 5.2.3.3.2) And ADS-B ARV report (per 5.2.3.3.3) And ADS-B target state report (per 5.2.3.3.5)	TIS-B state report And TIS-B management report

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FIGURE FOR CHAPTER 5

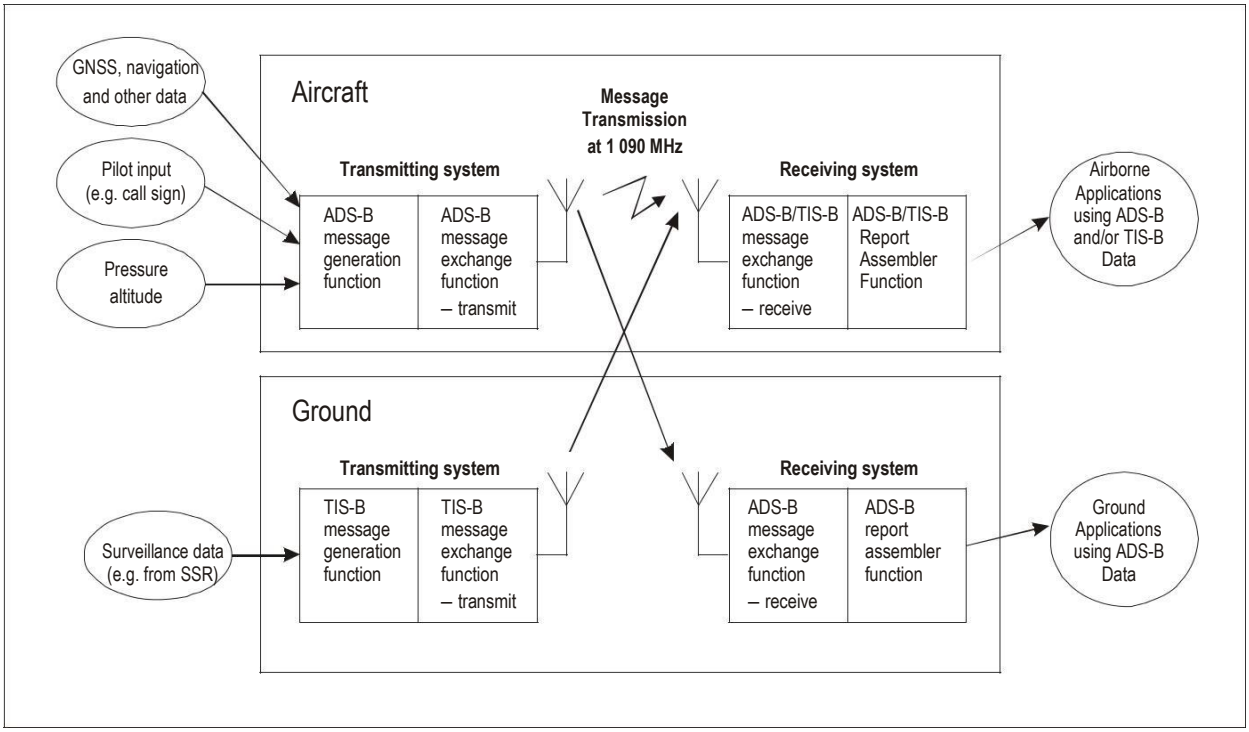

Figure 5-1. ADS-B/TIS-B system functional model

CHAPTER 6. MULTILATERATION SYSTEMS

Note 1.— Multilateration (MLAT) systems use the time difference of arrival (TDOA) of the transmissions of an SSR transponder (or the extended squitter transmissions of a non-transponder device) between several ground receivers to determine the position of the aircraft (or ground vehicle). A multilateration system can be:

a) passive, using transponder replies to other interrogations or spontaneous squitter transmissions;

b) active, in which case the system itself interrogates aircraft in the coverage area; or

c) a combination of a) and b).

Note 2.— Detailed technical guidance for MLAT and WAM can be found in the Aeronautical Surveillance Manual (Doc 9924), Appendix L. Material contained in EUROCAE ED-117A – MOPS for Mode S Multilateration Systems for Use in A-SMGCS and ED-142 – Technical Specifications for Wide Area Multilateration System (WAM) provides information for planning, implementation and satisfactory operation of MLAT systems for most applications.

6.1 Definitions

Multilateration (MLAT) System. A group of equipment configured to provide position derived from the secondary surveillance radar (SSR) transponder signals (replies or squitters) primarily using time difference of arrival (TDOA) techniques. Additional information, including identification, can be extracted from the received signals.

Time Difference of Arrival (TDOA). The difference in relative time that a transponder signal from the same aircraft (or ground vehicle) is received at different receivers.

Wide area multilateration (WAM) system. A multilateration system deployed to support en-route surveillance, terminal area surveillance and other applications such as height monitoring and precision runway monitoring (PRM).

6.2 Functional Requirements

6.2.1 Radio frequency characteristics, structure and data contents of signals used in 1 090 MHz MLAT systems shall conform to the provisions of Chapter 3.

6.2.2 An MLAT system used for air traffic surveillance shall be capable of determining aircraft position and identity.

Note 1.— Depending on the application, either two- or three-dimensional position of the aircraft may be required. Note 2.— Aircraft identity may be determined from:

a) Mode A code contained in Mode A or Mode S replies; or

b) *Aircraft identification contained in Mode S replies or extended squitter identity and category message.*

Note 3.— Other aircraft information can be obtained by analysing transmissions of opportunity (i.e. squitters or replies to other ground interrogations) or by direct interrogation by the MLAT system.

6.2.3 Where an MLAT system is equipped to decode additional position information contained in transmissions, it shall report such information separately from the aircraft position calculated based on TDOA.

6.3 Protection of the Radio frequency Environment

Note.— This section only applies to active MLAT systems.

6.3.1 In order to minimize system interferences the effective radiated power of active interrogators shall be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.

Note.— Guidance material on power consideration is contained in the Aeronautical Surveillance Manual *(ICAO Doc 9924).*

6.3.2 An active MLAT system shall not use active interrogations to obtain information that can be obtained by passive reception within each required update period.

Note.— Transponder occupancy will be increased by the use of omnidirectional antennas. It is particularly significant for Mode S selective interrogations because of their higher transmission rate. All Mode S transponders will be occupied decoding each selective interrogation not just the addressed transponder.

6.3.3 An active MLAT system consisting of a set of transmitters shall be considered as a single Mode S interrogator.

6.3.4 The set of transmitters used by all active MLAT systems in any part of the airspace shall not cause any transponder to be impacted such that its occupancy, because of the aggregate of all MLAT 1 030 MHz interrogations, is greater than 2 per cent at any time.

Note 1.— This represents a minimum requirement. Some regions may impose stricter requirements.

Note 2.— For an MLAT system using only Mode S interrogations, 2 per cent is equivalent to no more than 400 Mode S interrogations per second received by any aircraft from all systems using MLAT technology.

6.3.5 Active MLAT systems shall not use Mode S All-Call interrogations.

Note.— Mode S aircraft can be acquired by the reception of acquisition squitter or extended squitter even in airspace where there are no active interrogators.

6.4 Performance Requirements

6.4.1 The performance characteristics of the MLAT system used for air traffic surveillance shall be such that the intended operational service(s) can be satisfactorily supported.

CHAPTER 7. TECHNICAL REQUIREMENTS FOR AIRBORNE SURVEILLANCE APPLICATIONS

Note 1.— Airborne surveillance applications are based on aircraft receiving and using ADS-B message information transmitted by other aircraft/vehicles or ground stations. The capability of an aircraft to receive and use ADS-B/TIS-B message information is referred to as ADS-B/TIS-B IN.

Note 2.— Initial airborne surveillance applications use ADS-B messages on 1 090 MHz extended squitter to provide airborne traffic situational awareness (ATSA) and are expected to include "In-trail procedures" and "Enhanced visual separation on approach".

Note 3.— Detailed description of aforementioned applications can be found in RTCA/DO-289 and DO-312.

7.1 General Requirements

7.1.1 Traffic data functions

Note.— The aircraft transmitting ADS-B messages used by other aircraft for airborne surveillance applications is referred to as the reference aircraft.

7.1.1.1 Identifying The Reference Aircraft

7.1.1.1.1 The system shall support a function to identify unambiguously each reference aircraft relevant to the application.

7.1.1.2 Tracking The Reference Aircraft

7.1.1.2.1 The system shall support a function to monitor the movements and behavior of each reference aircraft relevant to the application.

7.1.1.3 Trajectory Of The Reference Aircraft

7.1.1.3.1 The system should support a computational function to predict the future position of a reference aircraft beyond simple extrapolation.

Note.— It is anticipated that this function will be required for future applications.

7.1.2 Displaying traffic

Note.— Provisions contained in this section apply to cases wherein tracks generated by ACAS and by reception of ADS-B/TIS-B IN messages are shown on a single display.

7.1.2.1 The system shall display only one track for each distinct aircraft on a given display.

Note.— This is to ensure that tracks established by ACAS and ADS-B/TIS-B IN are properly correlated and mutually validated before being displayed.

7.1.2.2 Where a track generated by ADS-B/TIS-B IN and a track generated by ACAS have been determined to belong to the same aircraft, the track generated by ADS-B/TIS-B IN shall be displayed.

Note.— At close distances, it is possible that the track generated by ACAS provides better accuracy than the track generated by ADS-B/TIS-B IN. The requirement above ensures the continuity of the display.

7.1.2.3 The display of the tracks shall comply with the requirements of ACAS traffic display.

Note.— Section 4.3 addresses color coding and readability of the display.

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