INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERONAUTICAL
TELECOMMUNICATIONS

ANNEX 10
TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME III — COMMUNICATION SYSTEMS
(PART I — DIGITAL DATA COMMUNICATION SYSTEMS;
PART II — VOICE COMMUNICATION SYSTEMS)

FIRST EDITION — JULY 1995

The first edition of Annex 10, Volume III was adopted by the Council on
20 March 1995 and becomes applicable on 9 November 1995.

For information regarding the applicability of the Standards and
Recommended Practices, see Foreword.

INTERNATIONAL CIVIL AVIATION ORGANIZATION
**AMENDMENTS**

The issue of amendments is announced regularly in the *ICAO Journal* and in the monthly *Supplement to the Catalogue of ICAO Publications and Audio-visual Training Aids*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

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FOREWORD

Historical background

Standards and Recommended Practices for Aeronautical Telecommunications were first adopted by the Council on 30 May 1949 pursuant to the provisions of Article 37 of the Convention on International Civil Aviation (Chicago 1944) and designated as Annex 10 to the Convention. They became effective on 1 March 1950. The Standards and Recommended Practices were based on recommendations of the Communications Division at its Third Session in January 1949.

Up to and including the Seventh Edition, Annex 10 was published in one volume containing four Parts together with associated attachments: Part I — Equipment and Systems, Part II — Radio Frequencies, Part III — Procedures, and Part IV — Codes and Abbreviations.

By Amendment 42, Part IV was deleted from the Annex; the codes and abbreviations contained in that Part were transferred to a new document, Doc 8400.

As a result of the adoption of Amendment 44 on 31 May 1965, the Seventh Edition of Annex 10 was replaced by two volumes: Volume I (First Edition) containing Part I — Equipment and Systems, and Part II — Radio Frequencies, and Volume II (First Edition) containing Communication Procedures.

As a result of the adoption of Amendment 70 on 20 March 1995, Annex 10 was restructured to include five volumes: Volume I — Radio Navigation Aids; Volume II — Communication Procedures; Volume III — Communication Systems; Volume IV — Surveillance Radar and Collision Avoidance Systems; and Volume V — Aeronautical Radio Frequency Spectrum Utilization. By Amendment 70, Volumes III and IV were published in 1995 and Volume V was planned for publication with Amendment 71.

Table A shows the origin of Annex 10, Volume III subsequent to Amendment 70, together with a summary of the principal subjects involved and the dates on which the Annex and the amendments were adopted by Council, when they became effective and when they became applicable.

Action by Contracting States

Notification of differences. The attention of Contracting States is drawn to the obligation imposed by Article 38 of the Convention by which Contracting States are required to notify the Organization of any differences between their national regulations and practices and the International Standards contained in this Annex and any amendments thereto. Contracting States are invited to extend such notification to any differences from the Recommended Practices contained in this Annex and any amendments thereto, when the notification of such differences is important for the safety of air navigation. Further, Contracting States are invited to keep the Organization currently informed of any differences which may subsequently occur, or of the withdrawal of any differences previously notified. A specific request for notification of differences will be sent to Contracting States immediately after the adoption of each amendment to this Annex.

The attention of States is also drawn to the provisions of Annex 15 related to the publication of differences between their national regulations and practices and the related ICAO Standards and Recommended Practices through the Aeronautical Information Service, in addition to the obligation of States under Article 38 of the Convention.

Promulgation of information. The establishment and withdrawal of and changes to facilities, services and procedures affecting aircraft operations provided in accordance with the Standards, Recommended Practices and Procedures specified in Annex 10 should be notified and take effect in accordance with the provisions of Annex 15.

Use of the text of the Annex in national regulations. The Council, on 13 April 1948, adopted a resolution inviting the attention of Contracting States to the desirability of using in their own national regulations, as far as practicable, the precise language of those ICAO Standards that are of a regulatory character and also of indicating departures from the Standards, including any additional national regulations that were important for the safety or regularity of air navigation. Wherever possible, the provisions of this Annex have been deliberately written in such a way as would facilitate incorporation, without major textual changes, into national legislation.

Status of Annex components

An Annex is made up of the following component parts, not all of which, however, are necessarily found in every Annex; they have the status indicated:

1. — Material comprising the Annex proper:

a) Standards and Recommended Practices adopted by the Council under the provisions of the Convention. They are defined as follows:
Standard: Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

Recommended Practice: Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.

d) Attachments comprising material supplementary to the Standards and Recommended Practices, or included as a guide to their application.

Disclaimer regarding patents
Attention is drawn to the possibility that certain elements of Standards and Recommended Practices in this Annex may be the subject of patents or other intellectual property rights. ICAO shall not be responsible or liable for not identifying any or all such rights. ICAO takes no position regarding the existence, validity, scope or applicability of any claimed patents or other intellectual property rights, and accepts no responsibility or liability therefore or relating thereto.

Selection of language
This Annex has been adopted in four languages — English, French, Russian and Spanish. Each Contracting State is requested to select one of those texts for the purpose of national implementation and for other effects provided for in the Convention, either through direct use or through translation into its own national language, and to notify the Organization accordingly.

Editorial practices
The following practice has been adhered to in order to indicate at a glance the status of each statement: Standards have been printed in light face roman; Recommended Practices have been printed in light face italics, the status being indicated by the prefix Recommendation; Notes have been printed in light face italics, the status being indicated by the prefix Note.

The following editorial practice has been followed in the writing of specifications: for Standards the operative verb “shall” is used, and for Recommended Practices the operative verb “should” is used.

The units of measurement used in this document are in accordance with the International System of Units (SI) as specified in Annex 5 to the Convention on International Civil Aviation. Where Annex 5 permits the use of non-SI alternative units these are shown in parentheses following the basic units. Where two sets of units are quoted it must not be assumed that the pairs of values are equal and interchangeable. It may, however, be inferred that an equivalent level of safety is achieved when either set of units is used exclusively.

Any reference to a portion of this document, which is identified by a number and/or title, includes all subdivisions of that portion.
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INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

PART II — VOICE COMMUNICATION SYSTEMS

CHAPTER 1. DEFINITIONS

Note.— Material on secondary power supply and guidance material concerning reliability and availability for communication systems is contained in Annex 10, Volume I, 2.9 and Volume I, Attachment F, respectively.
CHAPTER 2. AERONAUTICAL MOBILE SERVICE

2.1 AIR-GROUND VHF COMMUNICATION SYSTEM CHARACTERISTICS

Note.—In the following text the channel spacing for 8.33 kHz channel assignments is defined as 25 kHz divided by 3 which is 8.3333... kHz.

2.1.1 The characteristics of the air-ground VHF communication system used in the International Aeronautical Mobile Service shall be in conformity with the following specifications:

2.1.1.1 Radiotelephone emissions shall be double sideband (DSB) amplitude modulated (AM) carriers. The designation of emission is A3E, as specified in the ITU Radio Regulations.

2.1.1.2 Spurious emissions shall be kept at the lowest value which the state of technique and the nature of the service permit.

Note.—Appendix S3 to the ITU Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

2.1.1.3 The radio frequencies used shall be selected from the radio frequencies in the band 117.975 – 137 MHz. The separation between assignable frequencies (channel spacing) and frequency tolerances applicable to elements of the system shall be as specified in Volume V.

Note.—The band 117.975 – 132 MHz was allocated to the Aeronautical Mobile (R) Service in the ITU Radio Regulations (1947). By subsequent revisions at ITU World Administrative Radio Conferences the bands 132 – 136 MHz and 136 – 137 MHz were added under conditions which differ for ITU Regions, or for specified countries or combinations of countries (see RR S5.203, S5.203A and S5.203B for additional allocations in the band 136 – 137 MHz, and S5.201 for the band 132 – 136 MHz).

2.1.1.4 The design polarization of emissions shall be vertical.

2.2 SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

2.2.1 Transmitting function

2.2.1.1 Frequency stability. The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency. Where 8.33 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

Note.—The above tolerances will not be suitable for offset carrier systems.

2.2.1.1.1 Offset carrier systems in 25 kHz, 50 kHz and 100 kHz channel spaced environments. The stability of individual carriers of an offset carrier system shall be such as to prevent first-order heterodyne frequencies of less than 4 kHz and, additionally, the maximum frequency excursion of the outer carrier frequencies from the assigned carrier frequency shall not exceed 8 kHz. Offset carrier systems shall not be used on 8.33 kHz spaced channels.

Note.—Examples of the required stability of the individual carriers of offset carrier systems may be found at Attachment A to Part II.

2.2.1.2 Power

Recommendation.—On a high percentage of occasions, the effective radiated power should be such as to provide a field strength of a least 75 microvolts per metre (minus 109 dBm²) within the defined operational coverage of the facility, on the basis of free space propagation.

2.2.1.3 Modulation. A peak modulation factor of at least 0.85 shall be achievable.

2.2.1.4 Recommendation.—Means should be provided to maintain the average modulation factor at the highest practicable value without overmodulation.

2.2.2 Receiving function

2.2.2.1 Frequency stability. Where 8.33 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

2.2.2.2 Sensitivity. After due allowance has been made for feeder loss and antenna polar diagram variation, the sensitivity of the receiving function shall be such as to provide on a high percentage of occasions an audio output signal with a
wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 20 microvolts per metre (minus 120 dBW/m²) or more.

2.2.2.2.3 **Effective acceptance bandwidth.** When tuned to a channel having a width of 25 kHz, 50 kHz or 100 kHz, the receiving system shall provide an adequate and intelligible audio output when the signal specified at 2.2.2.2 above has a carrier frequency within plus or minus 0.005 per cent of the assigned frequency. When tuned to a channel having a width of 8.33 kHz, the receiving system shall provide an adequate and intelligible audio output when the signal specified at 2.2.2.2 above has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency. Further information on the effective acceptance bandwidth is contained in Attachment A to Part II.

*Note.— The effective acceptance bandwidth includes Doppler shift.*

2.2.2.4 **Adjacent channel rejection.** The receiving system shall ensure an effective rejection of 60 dB or more at the next assignable channel.

*Note.— The next assignable frequency will normally be plus or minus 50 kHz. Where this channel spacing will not suffice, the next assignable frequency will be plus or minus 25 kHz, or plus or minus 8.33 kHz, implemented in accordance with the provisions of Volume V. It is recognized that in certain areas of the world receivers designed for 25 kHz, 50 kHz or 100 kHz channel spacing may continue to be used.*

### 2.3 SYSTEM CHARACTERISTICS OF THE AIRBORNE INSTALLATION

#### 2.3.1 Transmitting function

2.3.1.1 **Frequency stability.** The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.003 per cent from the assigned frequency. Where 8.33 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

2.3.1.2 **Power.** On a high percentage of occasions, the effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/m²) on the basis of free space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated.

2.3.2 **Receiving function**

2.3.2.1 **Frequency stability.** Where 8.33 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

2.3.2.2 **Sensitivity**

2.3.2.2.1 **Recommendation.**— After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 75 microvolts per metre (minus 109 dBW/m²).

*Note.— For planning extended range VHF facilities, an airborne receiving function sensitivity of 30 microvolts per metre may be assumed.*

2.3.2.3 **Effective acceptance bandwidth for 100 kHz, 50 kHz and 25 kHz channel spacing receiving installations.** When tuned to a channel designated in Volume V as having a width of 25 kHz, 50 kHz or 100 kHz, the receiving function shall ensure an effective acceptance bandwidth as follows:

a) in areas where offset carrier systems are employed, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 above has a carrier frequency within 8 kHz of the assigned frequency;
b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 above has a frequency of plus or minus 0.005 per cent of the assigned frequency.

2.3.2.4 Effective acceptance bandwidth for 8.33 kHz channel spacing receiving installations. When tuned to a channel designated in Volume V, as having a width of 8.33 kHz, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 above has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency. Further information on the effective acceptance bandwidth is contained in Attachment A to Part II.

Note.— The effective acceptance bandwidth includes Doppler shift.

2.3.2.5 Adjacent channel rejection. The receiving function shall ensure an effective adjacent channel rejection as follows:

a) 8.33 kHz channels: 60 dB or more at plus or minus 8.33 kHz with respect to the assigned frequency, and 40 dB or more at plus or minus 6.5 kHz;

Note.— The receiver local oscillator phase noise should be sufficiently low to avoid any degradation of the receiver capability to reject adjacent carrier signals. A phase noise level better than minus 99 dBc/Hz 8.33 kHz away from the carrier is necessary to comply with 45 dB adjacent channel rejection under all operating conditions.

b) 25 kHz channel spacing environment: 50 dB or more at plus or minus 25 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 17 kHz;

c) 50 kHz channel spacing environment: 50 dB or more at plus or minus 50 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 35 kHz;

d) 100 kHz channel spacing environment: 50 dB or more at plus or minus 100 kHz with respect to the assigned frequency.

2.3.2.6 Recommendation.— Whenever practicable, the receiving system should ensure an effective adjacent channel rejection characteristic of 60 dB or more at plus or minus 25 kHz, 50 kHz and 100 kHz from the assigned frequency for receiving systems intended to operate in channel spacing environments of 25 kHz, 50 kHz and 100 kHz respectively.

Note.— Frequency planning is normally based on an assumption of 60 dB effective adjacent channel rejection at plus or minus 25 kHz, 50 kHz or 100 kHz from the assigned frequency as appropriate to the channel spacing environment.

2.3.2.7 Recommendation.— In the case of receivers complying with 2.3.2.3 above used in areas where offset carrier systems are in force, the characteristics of the receiver should be such that:

a) the audio frequency response precludes harmful levels of audio heterodynes resulting from the reception of two or more offset carrier frequencies;

b) the receiver muting circuits, if provided, operate satisfactorily in the presence of audio heterodynes resulting from the reception of two or more offset carrier frequencies.

2.3.2.8 VDL — INTERFERENCE IMMUNITY PERFORMANCE

2.3.2.8.1 For equipment intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft, the receiving function shall provide an adequate and intelligible audio output with a desired signal field strength of not more than 150 microvolts per metre (minus 102 dBW/m²) and with an undesired VDL signal field strength of at least 50 dB above the desired field strength on any assignable channel 100 kHz or more away from the assigned channel of the desired signal.

Note.— This level of VDL interference immunity performance provides a receiver performance consistent with the influence of the VDL RF spectrum mask as specified in Volume III, Part I, 6.3.4 with an effective transmitter/receiver isolation of 68 dB. Better transmitter and receiver performance could result in less isolation required.

2.3.2.8.2 After 1 January 2002, the receiving function of all new installations intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft shall meet the provisions of 2.3.2.8.1.

2.3.2.8.3 After 1 January 2005, the receiving function of all installations intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft shall meet the provisions of 2.3.2.8.1, subject to the conditions of 2.3.2.8.4.

2.3.2.8.4 Requirements for mandatory compliance of the provisions of 2.3.2.8.3 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales.

2.3.2.8.4.1 The agreement indicated in 2.3.2.8.4 shall provide at least two years’ notice of mandatory compliance of airborne systems.
2.3.3 Interference immunity performance

2.3.3.1 After 1 January 1998, the VHF communications receiving system shall provide satisfactory performance in the presence of two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

2.3.3.2 After 1 January 1998, the VHF communications receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

Note.— Guidance material on immunity criteria to be used for the performance quoted in 2.3.3.1 and 2.3.3.2 above is contained in Attachment A to Part II, 1.3.

2.3.3.3 After 1 January 1995, all new installations of airborne VHF communications receiving systems shall meet the provisions of 2.3.3.1 and 2.3.3.2 above.

2.3.3.4 Recommendation.— Airborne VHF communications receiving systems meeting the immunity performance Standards of 2.3.3.1 and 2.3.3.2 above should be placed into operation at the earliest possible date.

2.4 SINGLE SIDEBAND (SSB) HF COMMUNICATION SYSTEM CHARACTERISTICS FOR USE IN THE AERONAUTICAL MOBILE SERVICE

2.4.1 The characteristics of the air-ground HF SSB system, where used in the Aeronautical Mobile Service, shall be in conformity with the following specifications.

2.4.1.1 FREQUENCY RANGE

2.4.1.1.1 HF SSB installations shall be capable of operation at any SSB carrier (reference) frequency available to the Aeronautical Mobile (R) Service in the band 2.8 MHz to 22 MHz and necessary to meet the approved assignment plan for the region(s) in which the system is intended to operate, and in compliance with the relevant provisions of the Radio Regulations.

Note 1.— See Introduction to Volume V, Chapter 3, and Figures 2-1 and 2-2.


2.4.1.1.2 The equipment shall be capable of operating on integral multiples of 1 kHz.

2.4.1.2 SIDEBAND SELECTION

2.4.1.2.1 The sideband transmitted shall be that on the higher frequency side of its carrier (reference) frequency.

2.4.1.3 CARRIER (REFERENCE) FREQUENCY

2.4.1.3.1 Channel utilization shall be in conformity with the table of carrier (reference) frequencies at 27/16 and the Allotment Plan at 27/186 to 27/207 inclusive (or frequencies established on the basis of 27/21, as may be appropriate) of Appendix S27.

Note.— It is intended that only the carrier (reference) frequency be promulgated in Regional Plans and Aeronautical Publications.

2.4.1.4 CLASSES OF EMISSION AND CARRIER SUPPRESSION

2.4.1.4.1 The system shall utilize the suppressed carrier class of emission J3E (also J7B and J9B as applicable). When SELCAL is employed as specified in Chapter 3 of Part II, the installation shall utilize class H2B emission.

2.4.1.4.2 By 1 February 1982 aeronautical stations and aircraft stations shall have introduced the appropriate class(es) of emission prescribed in 2.4.1.4.1 above. Effective this date the use of class A3E emission shall be discontinued except as provided in 2.4.1.4.4 below.

2.4.1.4.3 Until 1 February 1982 aeronautical stations and aircraft stations equipped for single sideband operations shall also be equipped to transmit class H3E emission where required to be compatible with reception by double sideband equipment. Effective this date the use of class H3E emission shall be discontinued except as provided in 2.4.1.4.4 below.

2.4.1.4.4 Recommendation.— For stations directly involved in co-ordinated search and rescue operations using the frequencies 3 023 kHz and 5 680 kHz, the class of emission J3E should be used; however, since maritime mobile and land mobile services may be involved, A3E and H3E classes of emission may be used.

2.4.1.4.5 After 1 April 1981 no new DSB equipment shall be installed.
Annex 10 — Aeronautical Telecommunications

2.4.1.4.6 Aircraft station transmitters shall be capable of at least 26 dB carrier suppression with respect to peak envelope power \( P_p \) for classes of emission J3E, J7B or J9B.

2.4.1.4.7 Aeronautical station transmitters shall be capable of 40 dB carrier suppression with respect to peak envelope power \( P_p \) for classes of emission J3E, J7B or J9B.

2.4.1.5 Audio Frequency Bandwidth

2.4.1.5.1 For radiotelephone emissions the audio frequencies shall be limited to between 300 and 2700 Hz and the occupied bandwidth of other authorized emissions shall not exceed the upper limit of J3E emissions. In specifying these limits, however, no restriction in their extension shall be implied in so far as emissions other than J3E are concerned, provided that the limits of unwanted emissions are met (see 2.4.1.7 below).

Note.—For aircraft and aeronautical station transmitter types first installed before 1 February 1983 the audio frequencies will be limited to 3000 Hz.

2.4.1.5.2 For other authorized classes of emission the modulation frequencies shall be such that the required spectrum limits of 2.4.1.7 below will be met.

2.4.1.6 Frequency Tolerance

2.4.1.6.1 The basic frequency stability of the transmitting function for classes of emission J3E, J7B or J9B shall be such that the difference between the actual carrier of the transmission and the carrier (reference) frequency shall not exceed:

- 20 Hz for airborne installations;
- 10 Hz for ground installations.

2.4.1.6.2 The basic frequency stability of the receiving function shall be such that, with the transmitting function stabilities specified in 2.4.1.6.1 above, the over-all frequency difference between ground and airborne functions achieved in service and including Doppler shift, does not exceed 45 Hz. However, a greater frequency difference shall be permitted in the case of supersonic aircraft.

2.4.1.7 Spectrum Limits

2.4.1.7.1 For aircraft station transmitter types and for aeronautical station transmitters first installed before 1 February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B the mean power of any emission on any discrete frequency shall be less than the mean power \( P_m \) of the transmitter in accordance with the following:

- on any frequency removed by 2 kHz or more up to 6 kHz from the assigned frequency: at least 25 dB;
- on any frequency removed by 6 kHz or more up to 10 kHz from the assigned frequency: at least 35 dB;
- on any frequency removed from the assigned frequency by 10 kHz or more:
  a) aircraft station transmitters: 40 dB;
  b) aeronautical station transmitters:

\[
[43 + 10 \log_{10} P_m \text{ (W)}] \text{ dB}
\]

2.4.1.7.2 For aircraft station transmitters first installed after 1 February 1983 and for aeronautical station transmitters in use as of 1 February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B, the peak envelope power \( P_p \) of any emission on any discrete frequency shall be less than the peak envelope power \( P_p \) of the transmitter in accordance with the following:

- on any frequency removed by 1.5 kHz or more up to 4.5 kHz from the assigned frequency: at least 30 dB;
- on any frequency removed by 4.5 kHz or more up to 7.5 kHz from the assigned frequency: at least 38 dB;
- on any frequency removed from the assigned frequency by 7.5 kHz or more:
  a) aircraft station transmitters: 43 dB;
  b) aeronautical station transmitters: for transmitter power up to and including 50 W:

\[
[43 + 10 \log_{10} P_p \text{ (W)}] \text{ dB}
\]

For transmitter power more than 50 W: 60 dB.

Note.—See Figures 2-1 and 2-2.

2.4.1.8 Power

2.4.1.8.1 Aeronautical station installations. Except as permitted by the relevant provisions of Appendix S27 to the ITU Radio Regulations, the peak envelope power \( P_p \) supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emissions shall not exceed a maximum value of 6 kW.

2.4.1.8.2 Aircraft station installations. The peak envelope power supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emission shall not exceed 400 W except as provided for in Appendix S27 of the ITU Radio Regulations as follows:
Annex 10 — Aeronautical Telecommunications

<table>
<thead>
<tr>
<th>Class of emission</th>
<th>Stations</th>
<th>Max. peak envelope power ($P_p$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2B, J3E, J7B, J9B, A3E*, H3E* (100% modulation)</td>
<td>Aeronautical stations, Aircraft stations</td>
<td>6 kW, 400 W</td>
</tr>
</tbody>
</table>

Other emission such as A1A, F1B                Aeronautical stations, Aircraft stations | 1.5 kW, 100 W

* A3E and H3E to be used only on 3 023 kHz and 5 680 kHz.

2.4.1.9 **Method of operation.** Single channel simplex shall be employed.
Figure 2-1. Required spectrum limits (in terms of mean power) for aircraft station transmitter types and for aeronautical station transmitters first installed before 1 February 1983.

\[
\begin{align*}
&\begin{cases}
  \text{a) aircraft station transmitters: } -40 \text{ dB} \\
  \text{b) aeronautical station transmitters: } -\left[43 + 10 \log_{10} P_m (W)\right] \text{ dB}
\end{cases}
\end{align*}
\]
Figure 2-2. Required spectrum limits (in terms of peak power) for aircraft station transmitters first installed after 1 February 1983 and aeronautical station transmitters in use after 1 February 1983

\[
\begin{align*}
\text{SSB assigned frequency} & \quad 0 \text{ dB} \\
1.4 \text{ kHz} & \quad 1.5 \text{ kHz} \quad 1.5 \text{ kHz} \\
4.5 \text{ kHz} & \quad 7.5 \text{ kHz} \quad 7.5 \text{ kHz} \\
\text{SSB carrier (reference) frequency} & \quad -30 \text{ dB} \\
& \quad -38 \text{ dB}
\end{align*}
\]

\[
\begin{align*}
\{ & \\
\text{a) aircraft station transmitters: } & -43 \text{ dB} \\
\text{b) aeronautical station transmitters:} & \\
& \text{for transmitter power up to and including 50 W:} \\
& -[43 + 10 \log_{10}P_n (W)] \text{ dB} \\
& \text{for transmitter power more than 50 W, the attenuation shall be at least 60 dB}
\end{align*}
\]
CHAPTER 3. SELCAL SYSTEM

3.1 Recommendation.— Where a SELCAL system is installed, the following system characteristics should be applied:

a) Transmitted code. Each transmitted code should be made up of two consecutive tone pulses, with each pulse containing two simultaneously transmitted tones. The pulses should be of 1.0 plus or minus 0.25 seconds duration, separated by an interval of 0.2 plus or minus 0.1 second.

b) Stability. The frequency of transmitted tones should be held to plus or minus 0.15 per cent tolerance to ensure proper operation of the airborne decoder.

c) Distortion. The over-all audio distortion present on the transmitted RF signal should not exceed 15 per cent.

d) Per cent modulation. The RF signal transmitted by the ground radio station should contain, within 3 dB, equal amounts of the two modulating tones. The combination of tones should result in a modulation envelope having a nominal modulation percentage as high as possible and in no case less than 60 per cent.

e) Transmitted tones. Tone codes should be made up of various combinations of the tones listed in the following table and designated by colour and letter as indicated:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red A</td>
<td>312.6</td>
</tr>
<tr>
<td>Red B</td>
<td>346.7</td>
</tr>
<tr>
<td>Red C</td>
<td>384.6</td>
</tr>
<tr>
<td>Red D</td>
<td>426.6</td>
</tr>
<tr>
<td>Red E</td>
<td>473.2</td>
</tr>
<tr>
<td>Red F</td>
<td>524.8</td>
</tr>
<tr>
<td>Red G</td>
<td>582.1</td>
</tr>
<tr>
<td>Red H</td>
<td>645.7</td>
</tr>
<tr>
<td>Red J</td>
<td>716.1</td>
</tr>
<tr>
<td>Red K</td>
<td>794.3</td>
</tr>
<tr>
<td>Red L</td>
<td>881.0</td>
</tr>
<tr>
<td>Red M</td>
<td>977.2</td>
</tr>
<tr>
<td>Red P</td>
<td>1 083.9</td>
</tr>
<tr>
<td>Red Q</td>
<td>1 202.3</td>
</tr>
<tr>
<td>Red R</td>
<td>1 333.5</td>
</tr>
<tr>
<td>Red S</td>
<td>1 479.1</td>
</tr>
</tbody>
</table>

Note 1.— It should be noted that the tones are spaced by \( \log 10 0.045 \) to avoid the possibility of harmonic combinations.

Note 2.— In accordance with the application principles developed by the Sixth Session of the Communications Division, the only codes at present used internationally are selected from the red group.

Note 3.— Guidance material on the use of SELCAL systems is contained in Attachment A to Part II.

Note 4.— The tones Red P, Red Q, Red R, and Red S are applicable after 1 September 1985, in accordance with 3.2 below.

3.2 As from 1 September 1985, aeronautical stations which are required to communicate with SELCAL-equipped aircraft shall have SELCAL encoders in accordance with the red group in the table of tone frequencies of 3.1 above. After 1 September 1985, SELCAL codes using the tones Red P, Red Q, Red R, and Red S may be assigned.
CHAPTER 4. AERONAUTICAL SPEECH CIRCUITS

4.1 TECHNICAL PROVISIONS RELATING TO INTERNATIONAL AERONAUTICAL SPEECH CIRCUIT SWITCHING AND SIGNALLING FOR GROUND-GROUND APPLICATIONS

Note.— Guidance material on the implementation of aeronautical speech circuit switching and signalling for ground-ground applications is contained in the Manual on Air Traffic Services (ATS) Ground-Ground Voice Switching and Signalling (Doc 9804). The material includes explanation of terms, performance parameters, guidance on basic call types and additional functions, references to appropriate ISO/IEC international standards and ITU-T recommendations, guidance on the use of signalling systems, details of the recommended numbering scheme and guidance on migration to future schemes.

4.1.1 The use of circuit switching and signalling to provide speech circuits to interconnect ATS units not interconnected by dedicated circuits shall be by agreement between the Administrations concerned.

4.1.2 The application of aeronautical speech circuit switching and signalling shall be made on the basis of regional air navigation agreements.

4.1.3 Recommendation.— The ATC communication requirements defined in Annex 11, Section 6.2 should be met by implementation of one or more of the following basic three call types:

a) instantaneous access;

b) direct access; and

c) indirect access.

4.1.4 Recommendation.— In addition to the ability to make basic telephone calls, the following functions should be provided in order to meet the requirements set out in Annex 11:

a) means of indicating the calling/called party identity;

b) means of initiating urgent/priority calls; and

c) conference capabilities.

4.1.5 Recommendation.— The characteristics of the circuits used in aeronautical speech circuit switching and signalling should conform to appropriate ISO/IEC international standards and ITU-T recommendations.

4.1.6 Recommendation.— Digital signalling systems should be used wherever their use can be justified in terms of any of the following:

a) improved quality of service;

b) improved user facilities; or

c) reduced costs where quality of service is maintained.

4.1.7 Recommendation.— The characteristics of supervisory tones to be used (such as ringing, busy, number unobtainable) should conform to appropriate ITU-T recommendations.

4.1.8 Recommendation.— To take advantage of the benefits of interconnecting regional and national aeronautical speech networks, the international aeronautical telephone network numbering scheme should be used.
CHAPTER 5. EMERGENCY LOCATOR TRANSMITTER (ELT)
FOR SEARCH AND RESCUE

5.1 GENERAL

5.1.1 Until 1 January 2005, emergency locator transmitters shall operate either on both 406 MHz and 121.5 MHz or on 121.5 MHz.

Note. — From 1 January 2000, ELTs operating on 121.5 MHz will be required to meet the improved technical characteristics contained in 5.2.1.8.

5.1.2 All installations of emergency locator transmitters operating on 406 MHz shall meet the provisions of 5.3.

5.1.3 All installations of emergency locator transmitters operating on 121.5 MHz shall meet the provisions of 5.2.

5.1.4 From 1 January 2005, emergency locator transmitters shall operate on 406 MHz and 121.5 MHz simultaneously.

5.1.5 All emergency locator transmitters installed on or after 1 January 2002 shall operate simultaneously on 406 MHz and 121.5 MHz.

5.1.6 The technical characteristics for the 406 MHz component of an integrated ELT shall be in accordance with 5.3.

5.1.7 The technical characteristics for the 121.5 MHz component of an integrated ELT shall be in accordance with 5.2.

5.1.8 States shall make arrangements for a 406 MHz ELT register. Register information regarding the ELT shall be immediately available to search and rescue authorities. States shall ensure that the register is updated whenever necessary.

5.1.9 ELT register information shall include the following:

a) transmitter identification (expressed in the form of an alphanumerical code of 15 hexadecimal characters);

b) transmitter manufacturer, model and, when available, manufacturer’s serial number;

c) COSPAS-SARSAT* type approval number;

d) name, address (postal and e-mail) and emergency telephone number of the owner and operator;

e) name, address (postal and e-mail) and telephone number of other emergency contacts (two, if possible) to whom the owner or the operator is known;

f) aircraft manufacturer and type; and

g) colour of the aircraft.

Note 1. — Various coding protocols are available to States. Depending on the protocol adopted, States may, at their discretion, include one of the following as supplementary identification information to be registered:

a) aircraft operating agency designator and operator’s serial number; or

b) 24-bit aircraft address; or

c) aircraft nationality and registration marks.

The aircraft operating agency designator is allocated to the operator by ICAO through the State administration, and the operator’s serial number is allocated by the operator from the block 0001 to 4096.

Note 2. — At their discretion, depending on arrangements in place, States may include other relevant information to be registered such as the last date of register, battery expiry date and place of ELT in the aircraft (e.g. “primary ELT” or “life-raft No. 1”).

5.2 SPECIFICATION FOR THE 121.5 MHZ COMPONENT OF EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

Note 1. — Information on technical characteristics and operational performance of 121.5 MHz ELTs is contained in RTCA Document DO-183 and European Organization for Civil Aviation Equipment (EUROCAE) Document ED.62.

* COSPAS = Space system for search of vessels in distress; SARSAT = Search and rescue satellite-aided tracking.
Note 2.— Technical characteristics of emergency locator transmitters operating on 121.5 MHz are contained in ITU-R Recommendation M.690-1. The ITU designation for an ELT is Emergency Position — Indicating Radio Beacon (EPIRB).

5.2.1 Technical characteristics

5.2.1.1 Emergency locator transmitters (ELT) shall operate on 121.5 MHz. The frequency tolerance shall not exceed plus or minus 0.005 per cent.

5.2.1.2 The emission from an ELT under normal conditions and attitudes of the antenna shall be vertically polarized and essentially omnidirectional in the horizontal plane.

5.2.1.3 Over a period of 48 hours of continuous operation, at an operating temperature of minus 20°C, the peak effective radiated power (PERP) shall at no time be less than 50 mW.

5.2.1.4 The type of emission shall be A3X. Any other type of modulation that meets the requirements of 5.2.1.5, 5.2.1.6 and 5.2.1.7 below may be used provided that it will not prejudice precise location of the beacon by homing equipment.

Note.— Some ELTs are equipped with an optional voice capability (A3E) in addition to the A3X emission.

5.2.1.5 The carrier shall be amplitude modulated at a modulation factor of at least 0.85.

5.2.1.6 The modulation applied to the carrier shall have a minimum duty cycle of 33 per cent.

5.2.1.7 The emission shall have a distinctive audio characteristic achieved by amplitude modulating the carrier with an audio frequency sweeping downward over a range of not less than 700 Hz within the range 1 600 Hz to 300 Hz and with a sweep repetition rate of between 2 Hz and 4 Hz.

5.2.1.8 After 1 January 2000, the emission shall include a clearly defined carrier frequency distinct from the modulation sideband components; in particular, at least 30 per cent of the power shall be contained at all times within plus or minus 30 Hz of the carrier frequency on 121.5 MHz.

5.3 SPECIFICATION FOR THE 406 MHZ COMPONENT OF EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

5.3.1 Technical characteristics

Note 1.— Transmission characteristics for 406 MHz emergency locator transmitters are contained in ITU-R M.633.

Note 2.— Information on technical characteristics and operational performance of 406 MHz ELTs is contained in RTCA Document DO-204 and European Organization for Civil Aviation Equipment (EUROCAE) Document ED-62.

5.3.1.1 Emergency locator transmitters shall operate on one of the frequency channels assigned for use in the frequency band 406.0 to 406.1 MHz.

Note.— The COSPAS-SARSAT 406 MHz channel assignment plan is contained in COSPAS-SARSAT Document C/S T.012.

5.3.1.2 The period between transmissions shall be 50 seconds plus or minus 5 per cent.

5.3.1.3 Over a period of 24 hours of continuous operation at an operating temperature of –20°C, the transmitter power output shall be within the limits of 5 W plus or minus 2 dB.

5.3.1.4 The 406 MHz ELT shall be capable of transmitting a digital message.

5.3.2 Transmitter identification coding

5.3.2.1 Emergency locator transmitters operating on 406 MHz shall be assigned a unique coding for identification of the transmitter or aircraft on which it is carried.

5.3.2.2 The emergency locator transmitter shall be coded in accordance with either the aviation user protocol or one of the serialized user protocols described in Appendix 1 to this chapter, and shall be registered with the appropriate authority.
APPENDIX 1 TO CHAPTER 5. EMERGENCY LOCATOR TRANSMITTER CODING
(see Chapter 5, 5.3.2)

Note.— A detailed description of beacon coding is contained in Specification for COSPAS-SARSAT 406 MHz Distress Beacons (C/S T.001). The following technical specifications are specific to emergency locator transmitters used in aviation.

1. GENERAL

1.1 The emergency locator transmitter (ELT) operating on 406 MHz shall have the capacity to transmit a programmed digital message which contains information related to the ELT and/or the aircraft on which it is carried.

1.2 The ELT shall be uniquely coded in accordance with 1.3 below and be registered with the appropriate authority.

1.3 The ELT digital message shall contain either the transmitter serial number or one of the following information elements:
   a) aircraft operating agency designator and a serial number;
   b) 24-bit aircraft address;
   c) aircraft nationality and registration marks.

1.4 All ELTs shall be designed for operation with the COSPAS-SARSAT* system and be type approved.

Note.— Transmission characteristics of the ELT signal can be confirmed by making use of the COSPAS-SARSAT Type Approval Standard (C/S T.007).

2. ELT CODING

2.1 The ELT digital message shall contain information relating to the message format, coding protocol, country code, identification data and location data, as appropriate.

2.2 For ELTs with no navigation data provided, the short message format C/S T.001 shall be used, making use of bits 1 through 112. For ELTs with navigation data, if provided, the long message format shall be used, making use of bits 1 through 144.

2.3 Protected data field

2.3.1 The protected data field consisting of bits 25 through 85 shall be protected by an error correcting code, and shall be the portion of the message which shall be unique in every distress ELT.

2.3.2 A message format flag indicated by bit 25 shall be set to “0” to indicate the short message format or set to “1” to indicate the long format for ELTs capable of providing location data.

2.3.3 A protocol flag shall be indicated by bit 26 and shall be set to “1” for user and user location protocols, and “0” for location protocols.

2.3.4 A country code, which indicates the State where additional data are available on the aircraft on which the ELT is carried, shall be contained in bits 27 through 36 which designate a three-digit decimal country code number expressed in binary notation.

Note.— Country codes are based on the International Telecommunication Union (ITU) country codes shown in Table 4 of Part I, Volume I of the ITU List of Call Signs and Numerical Identities.

2.3.5 Bits 37 through 39 (user and serial user location protocols) or bits 37 through 40 (location protocols) shall designate one of the protocols where values “001” and “011” or “0011”, “0100”, “0101”, and “1000” are used for aviation as shown in the examples contained in this Appendix.

2.3.6 The ELT digital message shall contain either the transmitter serial number or an identification of the aircraft or operator as shown below.

2.3.7 In the serial user and serial user location protocol (designated by bit 26=1 and bits 37 through 39 being “011”), the serial identification data shall be encoded in binary notation with the least significant bit on the right. Bits 40 through 42 shall indicate type of ELT serial identification data encoded where:
   — “000” indicates ELT serial number (binary notation) is encoded in bits 44 through 63;
   — “001” indicates aircraft operator (3 letter encoded using modified Baudot code shown in Table 5-1) and a serial number (binary notation) are encoded in bits 44 through 61 and 62 through 73, respectively;

* COSPAS = Space system for search of vessels in distress;
SARSAT = Search and rescue satellite-aided tracking.
— “011” indicates the 24-bit aircraft address is encoded in bits 44 through 67 and each additional ELT number (binary notation) on the same aircraft is encoded in bits 68 through 73.

**Note.**— States will ensure that each beacon, coded with the country code of the State, is uniquely coded and registered in a data base. Unique coding of serialized coded beacons can be facilitated by including the COSPAS-SARSAT Type Approval Certificate Number which is a unique number assigned by COSPAS-SARSAT for each approved ELT model, as part of the ELT message.

2.3.8 In the aviation user or user location protocol (designated by bit 26=1 and bits 37 through 39 being “001”), the aircraft nationality and registration marking shall be encoded in bits 40 through 81, using the modified Baudot code shown in Table 5-1 to encode seven alpha-numeric characters. This data shall be right justified with the modified Baudot “space” (“100100”) being used where no character exists.

2.3.9 Bits 84 and 85 (user or user location protocol) or bit 112 (location protocols) shall indicate any homing transmitter that may be integrated in the ELT.

2.3.10 In standard and national location protocols, all identification and location data shall be encoded in binary notation with the least significant bit right justified. The aircraft operator designator (3 letter code) shall be encoded in 15 bits using a modified Baudot code (Table 5-1) using only the 5 right most bits per letter and dropping the left most bit which has a value of 1 for letters.

<table>
<thead>
<tr>
<th>Letter</th>
<th>Code (MSB LSB)</th>
<th>Figure</th>
<th>Code (MSB LSB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>111000</td>
<td>(-)*</td>
<td>011000</td>
</tr>
<tr>
<td>B</td>
<td>110011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>101110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>110010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>110000</td>
<td>3</td>
<td>010000</td>
</tr>
<tr>
<td>F</td>
<td>110110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>101011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>100101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>101100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>111010</td>
<td>8</td>
<td>001100</td>
</tr>
<tr>
<td>K</td>
<td>111110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>101001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>100111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>100110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>100011</td>
<td>9</td>
<td>000011</td>
</tr>
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<td>P</td>
<td>101101</td>
<td>0</td>
<td>001101</td>
</tr>
<tr>
<td>Q</td>
<td>111101</td>
<td>1</td>
<td>011101</td>
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<td>R</td>
<td>101010</td>
<td>4</td>
<td>001010</td>
</tr>
<tr>
<td>S</td>
<td>110100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>100001</td>
<td>5</td>
<td>000001</td>
</tr>
<tr>
<td>U</td>
<td>111100</td>
<td>7</td>
<td>011100</td>
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<tr>
<td>V</td>
<td>101111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>111001</td>
<td>2</td>
<td>011001</td>
</tr>
<tr>
<td>X</td>
<td>110111</td>
<td>/</td>
<td>010111</td>
</tr>
<tr>
<td>Y</td>
<td>110101</td>
<td>6</td>
<td>010101</td>
</tr>
<tr>
<td>Z</td>
<td>110001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( )**</td>
<td>100100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MSB =** most significant bit  
**LSB =** least significant bit  
**=** hyphen  
**=** space
### EXAMPLES OF CODING

#### ELT serial number

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>F = Format flag: 0 = Short Message</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>1 = Long Message</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>COUNTRY</td>
<td>0, 1, T</td>
</tr>
<tr>
<td>37</td>
<td>1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and 0 = otherwise</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>C = Certificate flag bit: 1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and 0 = otherwise</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
</tbody>
</table>

#### Aircraft address

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>F = Format flag: 0 = Short Message</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>1 = Long Message</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>COUNTRY</td>
<td>0, 1, T</td>
</tr>
<tr>
<td>37</td>
<td>1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and 0 = otherwise</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
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#### Aircraft operator designator and serial number

<table>
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<th>Data</th>
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<td>F = Format flag: 0 = Short Message</td>
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<tr>
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<td>1 = Long Message</td>
<td>1</td>
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<tr>
<td>36</td>
<td>COUNTRY</td>
<td>0, 1, T</td>
</tr>
<tr>
<td>37</td>
<td>1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and 0 = otherwise</td>
<td></td>
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<tr>
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<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
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<tr>
<td>44</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
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</tr>
<tr>
<td>62</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
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</table>

#### Aircraft registration marking

<table>
<thead>
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<th>Bit</th>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>F = Format flag: 0 = Short Message</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>1 = Long Message</td>
<td>1</td>
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<tr>
<td>36</td>
<td>COUNTRY</td>
<td>0, 1, T</td>
</tr>
<tr>
<td>37</td>
<td>1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and 0 = otherwise</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>T = Beacon type: TTT = 000 indicates ELT serial number is encoded; 001 indicates operating agency and serial number are encoded; 011 indicates 24-bit aircraft address is encoded.</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
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</tr>
<tr>
<td>83</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
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<tr>
<td>85</td>
<td>A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device 01 = 121.5 MHz 11 = other auxiliary radio-locating device</td>
<td></td>
</tr>
</tbody>
</table>

Note 1.— 10 bits, all 0s or National use.

Note 2.— COSPAS-SARSAT Type Approval Certificate number in binary notation with the least significant bit on the right, or National use.

Note 3.— Serial number, in binary notation with the least significant bit on the right, of additional ELTs carried in the same aircraft or default to 0s when only one ELT is carried.
### EXAMPLE OF CODING (USER LOCATION PROTOCOL)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
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<td>83→</td>
<td>106→</td>
<td>112→</td>
<td>132→</td>
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</table>

<table>
<thead>
<tr>
<th>1 1 CC</th>
<th>T</th>
<th>IDENTIFICATION DATA (AS IN ANY OF USER PROTOCOLS ABOVE)</th>
<th>A</th>
<th>21-BIT BCH ERROR CORRECTING CODE</th>
<th>E</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>12-BIT BCH ERROR CORRECTING CODE</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1 3 10</td>
<td>24</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>10</td>
<td>1</td>
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</tbody>
</table>

**Note 1:** Further details on protocol coding can be found in Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

**Note 2:** All identification and location data are to be encoded in binary notation with the least significant bit on the right except for the aircraft operator designator (3 letter code).

**Note 3:** For details on BCH error correcting code see Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

---

### EXAMPLE OF CODING (STANDARD LOCATION PROTOCOL)

<table>
<thead>
<tr>
<th>25</th>
<th>26</th>
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<th>e-37</th>
<th>e-39</th>
<th>e-40</th>
<th>85→</th>
<th>e-86</th>
<th>107</th>
<th>112</th>
<th>132→</th>
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<tbody>
<tr>
<td>36→</td>
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<td></td>
<td></td>
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<tr>
<td>1 1 10 4</td>
<td>61</td>
<td>21 6</td>
<td>20</td>
<td>12</td>
<td>26 BITS</td>
<td>26 BITS</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1 0 CC</th>
<th>PC</th>
<th>IDENTIFICATION DATA</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>SD</th>
<th>Δ LATITUDE</th>
<th>Δ LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 45</td>
<td>24</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

**CC** = Country Code;  
**PC** = Protocol Code:  
0011 indicates 24-bit aircraft address is encoded;  
0101 indicates operating agency and serial number are encoded;  
0100 indicates ELT serial number is encoded.  

**SD** = Supplementary Data bits 107 – 110 = 1101;  
bit 111 = Encoded Position Data Source (1 = internal; 0 = external)  
bit 112:  
1 = 121.5 MHz auxiliary radio locating device;  
0 = other or no auxiliary radio locating device.

---

Annex 10 — Aeronautical Telecommunications  
Volume III  

No. 80  

No. 80
### Example of Coding (National Location Protocol)

<table>
<thead>
<tr>
<th>CC</th>
<th>ID</th>
<th>SD</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>Δ LATITUDE</th>
<th>Δ LONGITUDE</th>
<th>NU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**CC** = Country Code;  
**ID** = Identification Data = 8-bit identification data consisting of a serial number assigned by the appropriate national authority;  
**SD** = Supplementary Data = bits 107 – 109 = 110;  
- bit 110 = Additional Data Flag describing the use of bits 113 to 132:  
  - 1 = Delta position; 0 = National assignment;  
- bit 111 = Encoded Position Data Source: 1 = internal, 0 = external;  
- bit 112: 1 = 121.5 MHz auxiliary radio locating device; 0 = other or no device  
**NU** = National use = 6 bits reserved for national use (additional beacon type identification or other uses).

Note 1.—Further details on protocol coding can be found in Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

Note 2.—All identification and location data are to be encoded in binary notation with the least significant bit on the right.

Note 3.—For details on BCH error correcting code see Specification for COSPAS-SARSAT 406 MHZ Distress Beacon (C/S T.001).
GUIDANCE MATERIAL FOR AERONAUTICAL MOBILE-SATELLITE SERVICE

1. INTRODUCTION

Note.— The aeronautical mobile-satellite service (AMSS) Standards and Recommended Practices (SARPs) referred to are contained in Annex 10, Volume III, Part I, Chapter 4.

1.1 Overview

1.1.1 The major elements of the aeronautical mobile-satellite service (AMSS) are the space segment (the satellites and their controlling earth stations); the ground earth stations (GESs) that provide interfaces between the satellite and fixed terrestrial voice and data networks; and the aircraft earth stations (AESs) that comprise the avionics and antenna systems on-board the aircraft.

Note.— Several operators of AMS(R)S may operate independent but compatible satellite networks. The different operators should co-operate in order for AESs to move seamlessly among the different networks.

1.1.2 The system architecture is capable of meeting a range of communication requirements which may include ATS, AOC, AAC and APC. The same system architecture is used for various service levels, from the basic low data-rate service to a multi-channel high data-rate service.

1.1.3 The level of capability of an AMSS system can be chosen to suit the performance required by the application.

Note 1.— The performance of a service will be set by the lowest level of capability available in the chain of GES, space segment and AES.

Note 2.— While a low level of capability service will have lower capital costs, it may have higher satellite user charges for the same data flow.

1.1.4 The capabilities are summarized in Table A-1* of this guidance material.

1.1.5 The examples of performance given in this section are to give a quick look at the overall system performance. If exact figures are required, the relevant paragraphs of Annex 10, Volume III, Part I, Chapter 4 should be studied.

System capabilities: Annex 10, Volume III, Part I, Chapter 4, 4.1.3

Packet data performance: Annex 10, Volume III, Part I, Chapter 4, 4.7.2

1.1.6 CIRCUIT MODE VOICE PERFORMANCE

Assuming that the AES is logged on to a GES, the AMSS will typically take the following times to set up a call:

from-aircraft:
— Use of abbreviated access request SU: 10 to 14 seconds (average)
— Use of general access request SU: less than 17 seconds (average)

to-aircraft: 9 to 11 seconds (average).

Note.— The call set-up time may be affected by the performance of the associated terrestrial network.

1.2 Levels of capability

1.2.1 The various levels of capability for the aircraft earth station (AES) and ground earth station (GES) defined in Annex 10, Volume III, Part I, Chapter 4, 4.1.3 allow various capabilities to exist which have different performance characteristics. A Level 1 capability is the minimum capability required for aeronautical mobile-satellite (route) service (AMS(R)S) providing basic packet data communications. A Level 3 is required as a minimum when, in addition to packet communications, circuit voice communications are required. All levels of capability require that the AES be under positive control either by receiving a P channel signal or through the C channel sub-band. Only one of the channel rates indicated below is required to operate at any given time.

1.2.2 The Level 1 capability provides for basic packet data communications by requiring an AES to receive and process a P channel signal operating at channel rates of 0.6 and 1.2 kbits/s. It also requires the capability for an AES to transmit on an R channel or on a T channel at these channel

* All tables are located at the end of this attachment.
Annex 10 — Aeronautical Telecommunications

rates. Both R and T channel capabilities are required. The channel rate used will depend on the link quality determined by the GES measurement of bit error rate (BER) or the estimate of that BER. Major factors that determine the channel rate are the antenna gain of the satellite and AES, and the RF power output of the satellite and AES. Level 1 requires one transmit channel (for R or T channel) and one receive channel (for P channel).

1.2.3 The Level 2 capability provides for channel rates of 0.6 and 10.5 kbit/s for the P channel; and 0.6 and 10.5 kbit/s for the R channel and the T channel. The major factor determining when to use these channel rates is the AES antenna gain, which must be at least 12 dBic when working with a “global” beam satellite. This capability provides greater data communications throughput, faster message delivery and may decrease operational cost. Level 2 requires one transmit channel and one receive channel as in Level 1.

1.2.4 The Level 3 capability adds to Level 2 packet data communications a circuit capability for voice or communications using a transmit and a receive C channel. These C channels are capable of operating at channel rates of 10.5 or 21.0 kbit/s to support 9.6 kbit/s vocoders for voice communications. The C channel can also provide circuit-mode data communications but this is not considered part of the safety services. The C channel rate used depends on the use of 1/2 rate forward error correction (FEC) coding (1/2 rate coding requires 21.0 kbit/s). Provision has been made to allow use of lower vocoder rates that could operate at channel rates of 5.25 or 6.0 kbit/s. Level 3 requires one transmit channel (R, T or C channel) and two receive channels (P channel and C channel). Simultaneous operation of two-way packet and circuit communications is not possible, but near-simultaneous operation is possible by switching between transmit channel types.

1.2.5 Level 4 capability adds to Level 3 capability additional transmit channel capability to provide simultaneous operation of two-way packet and circuit communications. Level 4 capability requires two or more transmit channels (R or T, and C channel) and two or more receive channels (P channel and C channel), power control for each channel carrier and a linear power amplifier. Channel rates are the same as Level 3. Both R and T channel capabilities are required on a transmit channel but not simultaneously.

1.2.6 The AMS(R)/S is the first aeronautical safety communications service which integrates both voice and data, as well as non-safety services. This integration of services must respect message priority. Pre-emption of one data message by another data message of higher priority is handled easily within the system without loss of information. Pre-emption of a voice call by a higher priority data call, or vice versa, will not normally be necessary in an AES which has two transmitters. However, in a Level 3 AES which has only one transmitter such a pre-emption may occasionally be necessary.

1.2.7 Although a Level 4 AES is not required to provide simultaneous packet data communications with more than one GES, such a capability is not precluded.

2. BROADBAND RF CHARACTERISTICS

2.1 Use of AMS(R)/S bands

2.1.1 Message categories. The transmission sequence at any aircraft earth station (AES) or ground earth station (GES) will be ordered in accordance with a given priority scheme. At the subnetwork interface to the AMSS, the priority scheme for packet data is as described in Annex 10. Volume III, Part I, Chapter 4, Table 4-26. Within the AMSS, this external priority scheme is augmented with internal priorities assigned to various signalling and voice-related functions. At the link layer this augmented priority scheme is referred to as the Q-precedence number and the resulting internal priority scheme is given in Table A-3 of this guidance material. This “Q-precedence” number list conforms to Annex 10 priorities, which in turn are derived from Article 544 of the ITU Radio Regulations. The single Q-precedence list includes both voice and data traffic, and also includes the signalling necessary to integrate voice and data. The Q-precedence numbers associated with the signalling were chosen to optimize the over-all system performance and integrity.

2.1.2 Receive frequency band. For historical reasons, most AESs may be capable of receiving more than the required band of 1544 to 1555 MHz but not the full band suggested by the recommendations. Typically, they cover the frequency band 1530 to 1559 MHz, and may not cover 1525 to 1530 MHz.

2.2 Frequency accuracy and compensation

2.2.1 Frequency accuracy. The Standard contained in Annex 10, Volume III, Part I, Chapter 4. 4.2.2 reflects a requirement on the signal received by the GES. There are several contributors to the frequency error observed at the GES. These include frequency errors due to the satellite oscillator, due to relative motion between the aircraft and spacecraft, due to the local oscillator of the GES (for a closed loop compensation system) and the local oscillator of the AES. Efforts are made to reduce the error caused by these two as described below. This Standard characterizes that portion of the frequency error which is due to the AES and the aircraft motion relative to the satellite. Consequently, the proper frame of reference for measuring the transmit frequency is the satellite. A practical test of this requirement would use the AES frame of reference, and the corresponding value in the satellite.
frame of reference would be calculated based on the aircraft position and velocity, and the satellite position.

2.2.2 Frequency compensation by the GES. To reduce the error due to the spacecraft oscillators, the GES should listen to an L-band pilot frequency transmitted (at C-band) by a designated GES and correct its transmission frequency to minimize the frequency error at L-band. In the from-aircraft direction a designated GES transmits an L-band pilot frequency which all GESs listen to at C-band and adjust their receiver local oscillators accordingly. This approach may not be possible in the case of satellite spot beams where the GES is not within the footprint of the spot beam of interest.

2.2.3 Doppler shift compensation by the AES. There are at least two methods of implementing Doppler-shift compensation. One approach is to use aircraft navigational aids to estimate the velocity of the aircraft in the direction of the satellite and then, estimate the Doppler shift from this. A second approach is to estimate the Doppler shift by measuring the frequency offset of the received P channel or C channel. For this latter approach, the frequency of any transmission to that ground earth station is then the basic channel frequency offset by the receive frequency, offset with opposite sign and a scaling factor of approximately 1.07. This approximately corrects the component of the frequency error due to aircraft motion (Doppler shift) but does not correct errors in the AES local oscillator.

2.2.4 Frequency error budget. The frequency error budgets used in arriving at the accuracy requirements for the GES-AES link are presented in Tables A-4 and A-5 of this guidance material. Note that in Table A-4 the Doppler shift due to aircraft motion is not included, and in Table A-5 it is assumed to be compensated for.

2.3 Aircraft earth station antenna characteristics

2.3.1 Antennas and level of capability. The Standards contained in Annex 10, Volume III, Chapter 4 specify high, intermediate and low-gain antenna systems, but one should note that these are not linked directly to a level of capability of AES. A high-gain antenna, with the supporting avionics, will mean a Level 2, 3 or 4 AES installation; and a low- or intermediate-gain antenna, with the supporting avionics will always lead to at least a Level 1 AES installation. In the future, different system characteristics may be capable of providing a Level 2 or higher service. For example, the combination of satellite spot beam antennas and a low- or intermediate-gain aircraft antenna may be capable of providing a Level 2 or higher service. The level of service provided to an aircraft will depend not only on its capabilities but those of the service providers as well.

2.3.2 Higher-gain future satellites could serve AESs with lower G/T and EIRP, but may have an effect of potentially higher service costs and reduced system capacity. AES antennas with gain less than 12 dBiC may be considered similar operationally to low-gain antennas because they have too broad a beam to discriminate against other satellite interference.

2.4 Receiver requirements

2.4.1 Gain-to-noise temperature ratio. The following factors influence the aircraft earth station receive system gain-to-noise temperature ratio (G/T):

a) climatic conditions;

b) antenna elevation angles to the satellite;

c) residual antenna pointing errors (including the effects of errors introduced by the antenna beam steering system);

d) the noise contribution of the receiver low noise amplifier at the operating temperature;

e) the transmitter power amplifier output level;

f) the attenuation and noise temperature contributions of a radome, where a radome is fitted; and

g) the RF environmental conditions in which the aircraft earth station is intended to operate.

2.4.2 Typical link carrier to noise densities. Tables A-6, A-7 and A-8 of this guidance material show typical carrier-to-noise spectral density ratios (C/No's) for the P, R, T and C channel services. In these tables modern implementation losses refer to losses in the practical implementation of a modern relative to ideal. This includes the effects due to non-ideal filtering, non-ideal synchronization in either time or frequency, non-ideal modulation, and non-linearities in the up- and down-converter chains. The analysis of the RF link is provided in the appendix to this guidance material.

2.4.3 Receiver linearity. There are multiple satellite systems being planned which have maximum L-band EIRP of 58 dBW at the centre of the antenna beam. Considering the worst case where the antenna beams of two such satellite systems overlap, the receiver must tolerate a total in-band power flux density of ~100 dBW/m². This is derived from the combined two-satellite EIRP (62 dBW), minus a spreading loss of 162 dB.

2.4.4 Receiver out-of-band performance. Potential threats to receiver performance include terrestrial mobile communications systems and high-power sources, including television transmitters with EIRP in the megawatt range and surveillance radars which are naturally located at airports and may occur along the flight route.
2.4.4.1 Under environmental conditions where high-power, out-of-band signals may be near the flight path, the receiver’s RF filter should protect against receiver saturation, which could reduce gain and degrade performance. Additionally, performance may be affected by such sources due to receiver image and spurious responses. As an example, a power flux density at the AES antenna of +3 dBW/m² could occur at a distance of a kilometre from a multi-megawatt transmitter such as permitted for television at frequencies from 470 to near 800 MHz. To protect from saturation, the RF filter would need a minimum of 75 dB rejection. Protection from degradation due to image and spurious responses is specific to the receiver design.

2.4.4.2 For a 5 000 kW peak power radar with a boresight gain of 34 dB, power levels can reach 100 dBW in the main beam. It has been calculated that, for an AES located 500 metres from an airport-located weather radar, the flux density could be as high as 30 dBW/m² below 1 459 MHz, and 38 dBW/m² from 1 675 to 18 000 MHz. It is not necessary to operate under these levels, but the equipment should survive without damage.

2.4.5 Received phase noise. The phase noise that the AES receiver must tolerate while operating within the AMSS SARPs is illustrated in Figure A-1* of this guidance material. This mask includes phase noise contributions of the transmitter and of the satellite. In practice, the receiver must be able to tolerate larger amounts of phase noise that are due to fading of the received signal.

2.5 Transmitter requirements

2.5.1 EIRP limits. An AES that is capable of an EIRP of 13.5 dBW should always be able to use the 0.6 kbit/s R and T channels when the satellite elevation angle exceeds 5 degrees. An AES that is capable of an EIRP of 25.5 dBW, and has the supporting avionics, will be capable of Level 2, 3 and 4 service grade portions of Levels 3 and 4. In practice, the transmitted power will usually be backed off from these settings, by an amount that depends on the system configuration.

2.5.1.1 The “maximum allowable operating EIRP” is based on a limit established from combined effects of HPA IM (active) and passive-component IM.

2.5.2 EIRP control. The requirement for control for the AES EIRP by the GES is for two reasons. The first reason is for dynamic power control of the C channel to optimize the system capacity. The second is to make optimal use of future spot beam satellite systems.

2.5.2.1 In initial AMSS operations using satellites with global beam coverage, an AES EIRP control range of 16 dB is required for both Class C (Levels 1-3) and Class A (Level 4 multi-channel) high-power amplifiers to cover selectable channel rates and variables in AES antenna gain. In C channel operation the AES EIRP is also frequently adjusted according to the GES-measured bit error rate. Therefore, for Level 4 AESs an additional 16 dB of control is presently required.

2.5.2.2 In future systems, AES transmission within an EIRP range satisfactory to satellite service operators may require a different control range. For example, the higher G/T of future spot beam satellites could require less AES EIRP, leading to a need for a larger control range. The range cannot be closely predetermined because spot beam size that affects satellite G/T is a future operator design choice.

2.5.3 Out-of-band EIRP spectral density. The out-of-band EIRP including discrete spurious, harmonics, intermodulation products and noise radiated by the AES should not cause harmful interference to other radio services. In particular, they should not interfere with other aeronautical communications/navigation radio services such as global positioning system (GPS) operating in the band 1 559 to 1 585 MHz, global orbiting navigation satellite system (GLONASS) operating in the band 1 598 to 1 610 MHz (1 597 to 1 605 MHz after the year 2005), the AMSS receive band 1 525 to 1 559 MHz, and the VHF band 108 to 137 MHz. Intermodulation product levels in the 1 598 to 1 610 MHz band should be checked when satellite navigation receiver operation in this band is planned on the same aircraft. Frequency management, additional filtering or increased antenna separation (for greater than 40 dB isolation) may be required aboard the same aircraft if interference potential to navigation equipment exists.

2.5.3.1 Table 4-3 contained in Annex 10, Volume III, Part I, Chapter 4, provides for a maximum EIRP density of –155 dBc/1 MHz in the 1 559 to 1 585 MHz band, which protects GPS receiver operation on the same aircraft as AMSS, and also GPS operation on nearby aircraft.

2.5.3.2 Table 4-3 contained in Annex 10, Volume III, Part I, Chapter 4, also indicates that the maximum EIRP spectral density shall be –143 dBc/1 MHz in the 1 585 to 1 605 MHz band and –117 dBc/1 MHz in the 1 605 to 1 610 MHz band. These limits will provide protection for GLONASS receiver operation on the same aircraft as AMSS assuming a minimum 40 dB antenna isolation and on nearby aircraft. The 40 dB isolation is measured from the AMSS antenna port to the GLONASS antenna port at the GLONASS frequencies, with the AMSS antenna steered for maximum coupling with the GLONASS antenna. This also holds for the GPS antenna.

2.5.4 Intermodulation (IM) products. Control of unwanted emissions from the AES is important to system operations in order to avoid blocking channels and reducing needed spectrum. Intermodulation occurs during multicharacter (Level 4) operation on predictable frequencies related to wanted signals due to component non-linearities. Potential sources are many, but can be controlled. Minimizing IM effects is accomplished both in AES design for linearity meeting the standards and in operation.

* All figures are located at the end of this attachment.
2.5.4.1 Intermodulation products (IM) that may be emitted by a Level 4 AES in multicharrier operation arise both from the high-power amplifier (HPA) and from other passive components that are subject to high AES RF power levels. Passive components causing IM may include connectors, particularly if they are subject to corrosion or looseness; and the diodes used in phased-array antennas. Depending on the choice of frequencies and levels in the GES, such IM can appear at frequencies and levels in the AES receiver that will degrade BER, disable reception, or affect reception of signals by other aircraft equipment.

2.5.4.2 AES-transmitted IM can block GES receivers. The HPA is a primary IM source because its linearity is limited by technology and heat dissipation.

2.5.4.3 Intersystem effects may arise from Level 4 AESs that may radiate IM. An AES operating with a global beam satellite must transmit higher EIRP than an AES operating with a more sensitive spot beam satellite. Therefore, this higher level of IM would be more readily received by the spot beam satellite for relay to its GES, where it could impair reception of that channel. Even if the two satellites are using separated portions of the frequency band and therefore cannot reuse the same assigned channel frequencies, the global beam AES transmitter’s IM that is out of assigned channels could fall into the spot beam satellite’s band. All GES frequency and EIRP level assignments should account for this possibility.

2.5.4.4 Frequency management techniques are used to eliminate 3rd and 5th order products below 1610 MHz as described in 4.2.3.5.7. If GLONASS is to be installed on the same aircraft as AMSS, it may be necessary to employ frequency management techniques or other methods to ensure that AMSS 7th and higher order intermodulation products will not cause harmful interference to GLONASS operations.

2.5.5 Frequency management. Careful frequency management is needed because:

a) AMSS includes safety services;

b) there is concern about the availability of adequate AMSS spectrum, and adequate capacity for AMSS safety services; and

c) the difficulty in co-ordinating mobile satellite networks due to the poor discrimination characteristics of mobile station antennas.

Guidelines that should be considered when co-ordinating frequency plans to minimize intra and interservice interference include:

a) compliance with the relevant ITU Radio Regulations;

b) each provider should provide monitoring facilities to identify the actual usage of AMS(R)S and non-AMS(R)S communications;

c) in those AMSS systems with global and spot beams, operational measures to minimize the amount of global bandwidth used and to maximize the use of spot beams;

d) using the ITU-R Recommendations M.1089 and M.1233 technical co-ordination method, wherever possible;

e) efficient spectrum use including the following:

1) using other system providers’ satellite transponder guard bands;

2) using frequency assignment by aircraft location;

3) taking advantage of improvements in aircraft earth station antenna sidelobe discrimination;

4) using offset and interleaved carriers;

5) using satellite spot/shaped beams;

6) reducing spacecraft antenna sidelobe levels;

7) increasing the resistance of systems to interference;

8) using earth station power control;

9) using satellite transponder adjustable gain setting;

10) using knowledge of operational schedules to take advantage of the difference in time zones;

11) appropriately grouping carriers;

12) repositioning satellites; and

13) taking advantage of high-gain AES antennas and the resulting ability to use lower carrier powers.

2.5.6 Transmitted phase noise. The phase noise mask that the AES transmitter must meet is illustrated in Figure A-2 of this guidance material. The purpose of this mask is to minimize the contribution of the AES transmitter phase noise to the degradation of GES performance.

2.6 Interference

2.6.1 Intrasystem interference. Intrasystem interference refers to interference among AMS(R)S services. Some examples would be co-channel, adjacent channel interference and intermodulation noise. Due to disparate satellite system designs, there is no single specification for intrasystem interference. Each satellite system operator must be able to show that intrasystem interference to AMS(R)S services, when combined with other noise sources in the link, does not degrade the achieved link C/N0 below the required C/N0 for a given performance.
2.6.2 Intersystem interference. Intersystem interference refers to interference to an AMS(R)/S service from any other system, whether it is providing AMS(R)/S services or otherwise. Required performance should be maintained at whatever level of interference is adopted as operable through co-ordination among the particular satellite system operators. As a minimum, the AMSS satellite system should provide adequate performance in the presence of single-entry interference resulting in a $\Delta T/T$ of 6 per cent, as adopted by WARC-ORB-88 as the threshold requiring co-ordination between satellite systems. A suggested criterion for aggregate interference due to all sources, including intrasystem interference, is a $\Delta T/T$ of 20 per cent.

3. RF CHANNEL

CHARACTERISTICS

3.1 Modulation characteristics

3.1.1 Modulation types. Two modulation types are used in aeronautical mobile-satellite service (AMSS), each providing a system advantage. A form of binary phase shift keying (BPSK) is used for channel rates up to 2.4 kbits/s, providing more robustness against phase noise generated in frequency conversion processes in the aircraft earth station (AES), satellite, and ground earth station (GES). Above 2.4 kbits/s, phase noise effects on the demodulation process are diminished, and conservation of bandwidth at these higher channel rates becomes important. Therefore, a more bandwidth-efficient modulation type, quaternary phase shift keying (QPSK), is used.

3.1.2 Aviation BPSK. Aviation BPSK is a form of phase shift keying modulation with shaped filters especially adapted to perform in an RF environment subject to fading. It has four possible phase states of which only two are permissible during any symbol period. The modulation technique maps binary "0"s into a phase shift of $-90^\circ$ and binary "1"s into $+90^\circ$. This results in differential encoding of the transmitted data, and implies that during any symbol period two decisions separated by $180^\circ$ are possible, and that these two decisions are rotated by $90^\circ$ from the possible decisions in the previous symbol period. This modulation strategy is illustrated conceptually in Figures A-3 and A-4 of this guidance material. Consequently, A-BPSK is almost identical to minimum shift keying (MSK), except that the pulse shaping has a 40 per cent root raised cosine spectral shape, as opposed to sinuosoidal weighting. The amplitude and phase masks which this pulse-shaping filter must satisfy are illustrated in Figures A-5 and A-7 of this guidance material. These correspond to the transmit filter requirements given in the definition of A-BPSK. Those requirements apply to the transmitted signal before it undergoes any non-linear amplification; their purpose is to limit and control the distortion and corresponding degradation in performance caused by nonlinear amplification. A-BPSK is a linear modulation with nearly constant envelope. Consequently, it may be transmitted through a "Class C" amplifier with little spectral spreading and performance degradation.

3.1.3 Aviation QPSK. Aviation QPSK is a form of offset QPSK modulation that is used for data rates above 2.4 kbits/s and is illustrated conceptually in Figures A-3 and A-4 of this guidance material. The A-QPSK data encoder is driven by a binary data sequence (at) at the bit rate 2/T. The "even" bits are switched onto the I line and the "odd" bits onto the Q line, generating two data streams at rate 1/T. The synchronous samplers S operated at rate 1/T and generate ideal positive and negative impulses depending on whether the data bits are "1" or "0". The pulse shaping filters in each channel have a 100 per cent root raised cosine spectral shape, except for the 8400 bits/s C channel, which has a 60 per cent root raised cosine spectral shape. The outputs of the I and Q pulse shaping filters modulate the same carrier in quadrature and are combined linearly. The amplitude and phase masks that the 100 per cent root raised cosine pulse shaping filter must satisfy are shown in Figures A-6 and A-7 of this guidance material, while those of the 60 per cent root raised cosine filter are shown in Figures A-23 and A-24. These correspond to the transmit filter requirements given in the definition of A-QPSK. Those requirements apply to the transmitted signal before it undergoes any non-linear amplification; their purpose is to limit and control the distortion and corresponding degradation in performance caused by non-linear amplification. There is no requirement for actual modulators to be implemented in this way, as long as the modulated RF signal is indistinguishable from one that was generated by an ideal modulator.

3.2 Bounds on radiated power

spectral density

3.2.1 Spectrum masks. These spectrum masks allow for degradation from the ideal Nyquist model that could occur due to non-ideal system characteristics, e.g. saturation in the amplifier chain.

3.2.2 From-aircraft. The spectral mask that must be satisfied by any A-BPSK signal transmitted in the from-aircraft direction is shown in Figure A-8 of this guidance material. This mask is applicable for 100 per cent root raised cosine filtering. This was derived assuming a non-linear amplifier (Class C) is used on board the AES, but it is applicable to Class A linear amplifiers as well. The same spectral mask (Figure A-8) applies to A-QPSK. The spectral mask (Figure A-22) applies to A-QPSK with a 60 per cent root raised cosine filter.

3.2.3 To-aircraft. The spectral mask that must be met in the to-aircraft direction with A-BPSK is shown in Figure A-9 of this guidance material. This was derived assuming that all amplifiers in the to-aircraft transmission path are operating linearly. The corresponding spectral mask for A-QPSK is shown in Figure A-10 of this guidance material.
3.3 Demodulator performance

3.3.1 The performance specified in the Standards can be attained using coherent detection and a Viterbi decoder with 3-bit soft decisions. The R and T channel demodulators are allowed more $E_b/N_0$ to achieve the bit error rate of $10^{-3}$ because of the short bursty nature of communications over these channels. The theoretical performance of A-QPSK in additive white Gaussian noise is better than that of A-BPSK because the bits are not differentially encoded. However, for A-QPSK modulation, more margin is included (relative to theoretical) because of its poorer performance over fading channels.

3.3.2 The relative motion of the aircraft and the satellite means that any signal reflections from aircraft wings or tail, or the sea or ground below can result in time-varying multipath. This is in part due to the rather broad beamwidth of the AES antenna. The characteristics of this multipath depend on a number of characteristics including the aircraft velocity, the look-angle of the satellite with respect to the aircraft and the slope of the reflecting surface. The rate of these variations (Doppler bandwidth) increases with aircraft velocity and elevation angle to the satellite. However, the multipath intensity is inversely proportional to the aircraft velocity and the satellite elevation angle. Consequently, it is primarily below elevation angles of 20 degrees that multipath is a significant problem. At elevation angles of 5 to 20 degrees the Doppler bandwidth can vary from 20 to 100 Hz or more and the multipath power can be as much as −7 dB relative to the direct path signal.

3.4 Acquisition delay

This delay requirement is a high-level specification composed of a number of components due to various sub-systems including satellite acquisition, frequency and bit acquisition, and frame synchronization. The total delay of 16 seconds is the worst-case delay allowed. This is the time from when one first commands the AES to find the satellite until the time at which the AES can attempt to log-on. Once logged on, typical times for setting up a voice call or transmitting a packet data message will be much less than this.

4. CHANNEL FORMAT TYPES AND DATA RATES

4.1 General

4.1.1 System timing. All timing of the different transmission channels is derived from the P channel. If required, synchronization of the P channels of each ground earth station (GES) to universal co-ordinated time (UTC) is one way of ensuring a world-wide timing reference for all aircraft using aeronautical mobile-satellite service (AMSS). The synchronization of all P channels to UTC is currently not required because there has not been an application identified which would benefit significantly enough to warrant the increased cost.

4.1.2 Channel spacings. The channel spacings in Table A-9 of this guidance material make adequate provision for separation to reduce adjacent channel interference and to ensure correct channel tuning in the presence of Doppler shifts due to all causes. In the case of the channels at the lowest bit rate, the possible spacings for the to-aircraft direction (P channels) and from-aircraft directions (R and T channels) are different. This is due to the uncorrected Doppler shift on to-aircraft channels, and the use of automatic frequency control (AFC) to minimize Doppler shift in the from-aircraft direction. Note that the requirement on the aircraft earth station (AES) to be capable of tuning in steps of 2.5 kHz accommodates all the potential channel spacings listed below and allows the interleaving of channels between adjacent satellite spot beams.

4.1.3 P channel synchronization/loss/degradation. Actions by the AES management depend upon indications of the signal quality of the received P channel. These include an indicator of when the AES is synchronized to the P channel, and when it is degraded and/or lost. The AES must synchronize to a P channel before it can receive P channel signal units, or transmit over the R or T channel. A degraded/lost P channel indicates reduced operational performance and is usually an indication that a switching operation, for example, a satellite or spot beam handover, should be performed.

4.1.3.1 These indicators of signal quality generally are based on physical measurements exceeding a threshold. However, the measurements used and the threshold settings depend upon the AES implementation. P channel synchronization is declared whenever the P channel unique word is detected reliably. Synchronization is lost whenever the unique word is not detected reliably.

4.1.3.2 Either of two conditions will cause a declaration of degradation/loss of the P channel. The first condition corresponds to a “degraded” P channel and has two cases: 1) if the bit error rate rises above $10^{-4}$ in a three-minute averaging period; and 2) if synchronization is lost ten or more times during a three-minute period. This three-minute averaging period provides confidence that the degradation is not temporary, due, for example, to an aircraft manoeuvre. The second condition corresponds to a “lost” P channel, which is declared if synchronization is lost continuously for ten seconds. There is a single indicator for either of these conditions and, consequently, the action by the AES management for either event is the same.
4.2 P channel

4.2.1 General. At least one P channel is transmitted continuously by each GES that forms part of the AMSS service. Each AES must continuously monitor the P channel transmitted by the GES to which it is logged on. The P channel implements a time division multiplexing strategy to send small packets of information to the AESs that are monitoring it. The functional blocks at the GES end of each P channel are as follows:

a) data scrambler;

b) forward error correction (FEC) encoder;

c) interleaver;

d) timing mark inserter (unique word); and

e) modulator.

The functional blocks at the receive end of each P channel are complementary to those at the transmit end. The complete series of functional blocks from transmit end to receive end is shown in Figure A-11 of this guidance material.

4.2.2 FUNCTIONAL BLOCKS

4.2.2.1 Data scrambler. A data scrambler is a logical device which multiplies the data sequence by a known pseudo-random sequence. The data is unscrambled at the receiver by multiplying by the same sequence of random bits. This has no direct effect on the bit error rate performance on the link. However, it prevents the possibility of transmitting long sequences of 1’s or 0’s over the link. The latter could be detrimental to the performance of acquisition and tracking circuitry.

4.2.2.2 Forward error correction coding. Satellite communications are, in general, power-limited due to the limited resources at the satellite. One can reduce the amount of power required for communications by introducing forward error correction coding, which adds redundancy to the transmitted signal at the expense of requiring more bandwidth. At the receiver, a decoder uses the redundancy to correct those errors which normally occur when transmitting at a lower power.

4.2.2.3 Interleaving. Mobile communications are generally subject to fading due to reflections from nearby objects. The fading is correlated with time and when it occurs, can cause a sequence of correlated errors in the data detected at the receiver. These errors can be corrected by the forward error correction coding. However, most decoders work best with uncorrelated errors. The purpose of the (transmit) interleaver and its inverse, the (receive) de-interleaver, is to randomize the order of bits presented to the channel compared to those presented to the decoder, thus reducing any correlation between the errors which may be caused by the channel.

4.2.2.4 Timing mark. A unique word is inserted in each data stream, at periodic intervals, to provide timing information to the receiver. This timing information is needed in order to properly synchronize the de-scrambler, the decoder, and the de-interleaver with their counterparts on the transmit side. It also allows recovery of this synchronization if the signal happens to be lost momentarily.

4.2.3 P channel frame duration. The frame duration is either 500 milliseconds (channel rates of 2.4 kbits/s and higher) or a multiple of 500 milliseconds to provide simple derivation of a superframe used for R channel slotting and the reservation TDMA T channel. Scrambling and FEC coding of rate 1/2 is used on all P channels. The FEC encoder is used to correct the errors caused by the channel. The duration of the interleaver is 500 milliseconds. For the 0.6 kbits/s, the interleaver is 384 bits corresponding to 2/3 second.

4.2.4 P channel frame format. All P channel frame formats include a 16-bit field (encoded) as a format identifier and for derivation of the superframe that has a duration of 8 seconds. The format identifier is a 4-bit field and is always set to the value 0001 when the channel is a P channel. The remaining 12 bits of this field are used as a superframe counter. To achieve this, the field is subdivided into three 4-bit fields, of which the first is used to indicate the start of a new superframe, while the remaining two are used to indicate the frame number. It is advisable for AES implementations to make use of all 12 bits to achieve reliable superframe synchronization in the presence of bit errors.

4.2.5 For P channels of 4.8 and 10.5 kbits/s, a small number of “dummy” bits are included in the frame just after the framing bits. This matches the number of bits of the interleaver to the number of bits required to be transmitted on the channel.

4.2.6 To facilitate the re-synchronization of an AES transferring from one P channel to another on the same GES, all P channels transmitted by the same GES are synchronized.

4.3 R channel

4.3.1 General. All AESs will log on to AMSS using an R channel that has been designated for that purpose in the particular service area of the AES. For the duration of its log-on period an AES will be assigned one or more R channels (at the appropriate channel rates). These R channels, the AES can transmit signalling, short data packets, and requests for additional capacity on the T channel. The burst mode data channel characteristics for the R channel have been specified in the AMSS SARPs as has been the slot structure used for its
4.4.2 T channel format. The T channel burst length can vary from 2 to 31 signal units. The number of columns used in the interleaver varies with the transmission bit rate and the burst length according to the AMSS SARP. Each burst includes a special short signal unit, the burst identifier, which ensures that the originating AES and destination GES are always known. If a GES receives a burst in which the burst identifier is lost, absent or indicates a different GES, the GES would discard the burst.

4.4.3 T channel transmit timing. The T channel is also synchronized to the P channel superframe, but in this case the superframe is subdivided into 1 024 slots of approximately 7.8 milliseconds. The shortest guard time between the burst of two different AESs is under control of the receiving GES and is set to approximately 39 milliseconds (5 slots).

4.5 C channel

4.5.1 General. The C channel is a circuit-mode channel used for digital voice or data communications. A C channel can be requested by an AES over the R channel, and assigned by the GES over the P channel. The functional blocks at the transmit end of each C channel are as follows:

a) interfaces for primary (e.g. voice) and sub-band channel;

b) primary channel/sub-band channel data multiplexor;

c) data scrambler;

d) FEC encoder (unless it is not used);

e) interleaver (unless FEC is not used);

f) preamble and unique word generator; and

g) modulator.

The functional blocks at the receive end of each C channel are complementary to those at the transmit end. The complete series of functional blocks form transmit end to receive end is shown in Figure A-13 of this guidance material.

4.5.1.1 The C channel has been specified at a number of different channel rates: 5.25, 6.0, 8.4, 10.5 and 21.0 kbits/s. The underlying motivation is to allow the evolution of the system to lower channel rates as voice processing technology improves. Two of these channel rates, 5.25 and 10.5 kbits/s, do not include coding. Potential applications of these uncoded channels include transmitting 4.8 and 9.6 kbits/s vocoded speech in satellite systems that have limited spectrum, but are not power limited. Alternative applications could include the use of vocoders that include their own coding, protecting the important bits more than the others; this could eliminate the need for coding in the channel modem.
4.5.2 \textit{C channel frame.} The frame duration at all channel rates is 500 milliseconds. Carrier activation (burst mode) based on speech activity is used in the to-aircraft direction. At each activation, a preamble and unique word are transmitted to commence the burst, and from then on further unique words occur every 500 milliseconds. Thus the phasing of the unique word depends on the instant when activation commences. A postamble is sent when there is no voice content in the interleaver block.

4.5.3 \textit{Voice activation.} In the to-aircraft direction, carrier activation is controlled by an electrical signal at the C channel interface. When the C channel is used for voice, this signal is controlled by the voice encoder. The voice encoder turns the signal on as soon as it detects voice, but applies a hangover time before turning the signal off to avoid excessive turn-offs between syllables. In addition, the forward carrier is activated by sub-band channel signalling as required.

4.5.3.1 The channel unit starts a new burst immediately after the “active” state is signalled. When the “not active” state is signalled, the channel unit continues transmission for a period and then drops the carrier. In the case of channels with FEC and an interleaver, the channel unit completes transmission of the current interleaver block, plus another complete interleaver block, which ends with a postamble to terminate the C channel carrier burst. In the case of channels with no FEC or interleaver, the channel unit continues transmission for 20 milliseconds. For both cases, during this period the required bits are taken from the primary channel interface as usual.

4.5.3.2 The same timing rules apply to the corresponding control signal from the sub-band signalling channel equipment.

4.5.3.3 In the from-aircraft direction, the carrier is transmitted continuously during the call regardless of speech activity. The start of the transmission is the same as for the forward direction, with a preamble and unique word transmitted at the beginning, followed by further unique words at 500 millisecond intervals.

4.5.4 \textit{Data activation.} The capability to use the C channel for data other than vocoded speech is not required for safety applications. However, the C channel may be used for the transmission of data by non-safety services and some details of its operation are included here. In the to-aircraft direction the forward carrier is operated in burst mode for circuit-mode data transfer. Circuit 109 (CF) as defined in CCITT Recommendation V.24 (termed DCD in EIA RS-232C), from the GES voice band modem controls the activation interface of the C channel. The interface is initially activated when the call enters data mode, which is indicated by the circuit 109 transition to ON state. The interface normally remains activated until deactivation of data mode by the AES. If the circuit 109 changes to the OFF state indicating loss of received carrier from the far-end modem, the transmit circuit-mode interface unit finishes sending the contents of the plesiochronous buffer and then changes to “not active”. The C channel activation interface is reactivated again when (if) the circuit 109 changes to the ON state.

4.5.5 \textit{Interleaver size.} In any data transmission system where interleaving is required to randomize the errors, the interleaver size is always a trade-off between the delay incurred and its effectiveness at randomizing the errors. The interleaver blocksize for the 21 kbit/s C channel is 384 bits, which corresponds to 192 information bits. This 192 bits is the frame size (20 milliseconds) of most 9.6 kbits/s vocoders. This direct mapping between vocoder frames and interleaver buffers minimizes the delay caused by interleaving and its effect on voice communications. The resulting over-all transmission delay is around 30 milliseconds (rising to 50 milliseconds at the lowest channel rate). To match the number of interleaver bits to the required number of channel bits, a small number of “dummy” bits are included in the frame just after the framing bits.

4.5.5.1 The delay at the transmitter arising from the interleaver depends on the relationship between the voice frame and the interleaver size. The full de-interleaver delay of around 20 milliseconds will be experienced at the receiving end.

4.5.6 \textit{Voice channel delay.} To maintain voice circuit quality, the CCITT recommends that the end-to-end delay should be limited to 440 milliseconds or less. Given that the nominal satellite delay is 270 milliseconds, the voice processing system delay should not exceed 65 milliseconds. This assumes that the terrestrial network is allotted 40 milliseconds of delay, and the modem and RF sub-systems are allotted 65 milliseconds of delay. It is to be noted that with current voice processing algorithms, the processing delay tends to increase as the vocoder rate decreases. Consequently, this end-to-end delay objective may be difficult to meet with low-rate vocoders, e.g. 2.4 and 4.8 kbit/s.

4.5.7 \textit{Sub-band C channel.} The data transferred by the sub-band C channel includes control and signalling for the call set-up of the C channel, continuity checks, and power control. In each frame, the first 24 half-octets of the sub-band C channel are combined to form a standard length 96-bit signal unit. Successive groups of 24 half-octets are combined in the same way, if available. The 25th data field of the last voice/data block in the frame is discarded. When the C channel is activated, and there are no other signal units to be sent, fill-in signal units are sent.

5. \textbf{LINK LAYER P CHANNEL AND R CHANNEL PROTOCOLS}

5.1 \textbf{General}

The P and R channels are used for signalling and data communications in the to-aircraft and from-aircraft directions,
respectively. Data transmission on the R channel is restricted to short messages (less than 33 octet link service data units (LSDUs)). This section of the guidance material describes issues related to the R and the P channel link layer protocols.

5.2 SU set generation

5.2.1 In both the aircraft earth station (AES) and the ground earth station (GES) link layers, an SU set cannot be generated from a received LIDU as described in Annex 10, Volume III, Part I, Chapter 4, 4.5.3.2.3 until a reference number is assigned to it, except for system table broadcast LIDUs and LIDUs received from the circuit-mode service entities to be transmitted, either on the R channel at the AES, or the P channel at the GES. System table broadcast LIDUs do not require reference numbers. Circuit-mode services LIDUs are assigned application reference numbers by the circuit-mode service entities at the AES and the GES, thus an SU set is generated upon receipt of the LIDU. For all LIDUs exchanged between the link layer, at the AES or the GES, and any of its service users, no formats have been specified in the SARPs. Such formats are implementation dependent.

5.2.2 When an LIDU received from the subnetwork layer is assigned a reference number, the LSDU of the LIDU is encoded in the data field of the ISU/SSU(s) of a P channel SU set or in the data field of the SU(s) of an R channel SU set. The number of SU(s) needed in the SU set depends on the LSDU length. Each SU, except the last one, will contain the maximum permitted number of user data octets. The number of user data octets in the last SU which belong to the set may have less than the maximum length. In a P channel SU set, the number of octets in the final SU (ISU or SSU) is encoded in the "No. of octets in the final SSU" field of the ISU. On the R channel, the number of octets in the last SU is encoded in the SU's "SU type" field (Annex 10, Volume III, Part I, Appendix 3 to Chapter 4, Item 67).

5.3 SUs transmission according to precedence

At the AES and the GES, in order to meet the SUs transmission requirements of Annex 10, Volume III, Part I, Chapter 4, 4.5.8.2.3, the R and P channel protocols may employ several first-in-first-out (FIFO) queues, one queue per valid Q number, to store the SUs prior to transmission. For the R channel, the SUs of an SU set would be queued according to the ascending order of their sequence indicators (Annex 10, Volume III, Part I, Appendix 3 to Chapter 4, Item 58). For the P channel, the SUs of an SU set would be queued with the ISU, or RTX SU for a retransmission set, first followed by the SSUs according to the descending order of the SSUs sequence numbers. At the instance of transmission, an SU would be selected from the highest priority queue with one or more SUs in it.

5.4 P channel protocol

5.4.1 The P channel link layer protocol is used in the to-aircraft direction for processing the transmission of: 1) the LIDUs received from the GES management, 2) the LIDUs received from the circuit-mode services with routing parameters indicating transmission on the P channel, and 3) all LIDUs received from the subnetwork layer. The P channel protocol reliable link service (RLS) is used for processing the transmission of the LIDUs received from the subnetwork layer only. The transmission of all other LIDUs is processed according to the P channel protocol direct link service (DLS). The P channel is also used for the transmission of the following link layer signalling SUs:

- a) T channel reservation (RES) and reservation forthcoming (RFC) SU set associated with the T channel reservation protocol (Annex 10, Volume III, Part I, Chapter 4, 4.6);
- b) T channel acknowledgement (TACK) SU; and
- c) R channel acknowledgement (RACK) SU.

The above SUs are transmitted in accordance with the P channel protocol DLS service.

5.4.2 At a given time, the P channel protocol may be processing the transmission of several LSDUs (a reference number has been assigned and an SU set has been generated from each LIDU to transmit the LSDU). However, for RLS, at each Q number only one LSDU of the LSDUs destined to the same AES is permitted to be in process for transmission at one time. The other RLS LSDUs with the same Q number and destined to the same AES will be stored until the transmission of the current LSDU at that Q number is over, either successfully or unsuccessfully. Thus, at the AES, only one RLS SU set per Q number could be in the reassembly process at a given time and the AES will discard an incomplete RLS SU set if it starts receiving another RLS SU set with the same Q number and a different reference number. After either a successful or an unsuccessful transmission of an SU set, the GES link layer releases all link layer resources associated with that SU set, i.e. the assigned reference number, activated timers, memory allocation, etc.

5.4.3 For RLS, the P channel protocol implements a selective-repeat-ARQ scheme for error control. Accordingly, upon transmitting an SU set the GES expects to receive a P channel acknowledgement (PACK) SU from the AES. The PACK SU may indicate either complete or incomplete reception of the SU set using its acknowledgement control field. In the latter case, this field also indicates whether a complete or a partial retransmission of the SU set is required. For a partial retransmission request, this field, which is present in every PACK SU, further indicates the number of PACK SUs identifying the remainder of the missing SSUs of the SU set to follow; each PACK SU can identify, at most, three missing SSUs. A partial retransmission from the GES is assembled by
the AES as any other SU set; however, a retransmission SU set is
headed by an RTX SU rather than an ISU and the
retransmitted SSUs' Sequence Numbers are as prescribed in
Annex 10, Volume III, Part I, Appendix 3 to Chapter 4, Item
59. Failure to receive an acknowledgement from the AES
would cause the GES to solicit such acknowledgement by
sending a request for acknowledgement (RQA) SU to that
AES. The AES keeps track of the status of the RLS SU set that
the AES is currently processing at a given Q number in order to
correctly respond to an RQA.

5.4.4 In an SU set, original or retransmitted, only the ISU,
or the RTX SU, identifies the destination AES ID. In order to
avoid erroneous processing due to the broadcast nature of the
P channel, the AES discards an SSU if received without
previously receiving the corresponding (same reference
number and Q-number) ISU or RTX SU.

5.5 R channel protocol

5.5.1 The R channel link layer protocol is used in the
from-aircraft direction for processing the transmission of: 1)
the LIDUs received from the AES management, 2) the LIDUs
received from the circuit-mode services with routing parameter
indicating transmission on the R channel, and 3) some of the
LIDUs carrying LSDUs of 33 or less octets received from the
subnet layer. The R channel protocol reliable link service
(RLS) is used for processing the transmission of the LIDUs
received from the subnet layer only. The transmission of
all other LIDUs is processed according to the R channel
protocol direct link service (DLS).

5.5.2 The R channel is also used for the transmission of the
following link layer signalling SUs:

a) P channel acknowledgements (PACKs);

b) T channel request for acknowledgement (RQA); and

c) T channel request for reservation (REQ).

The above SUs are transmitted in accordance with the R
channel protocol DLS service.

5.5.3 At a given time, the R channel protocol at the AES
may be processing the transmission of several LSDUs
(reference number is assigned and an SU set is generated from
each LIDU to transmit the LSDU). However, for RLS, at each
Q number only one LSDU is permitted to be in process for
transmission to the GES at one time. Other RLS LSDUs with
the same Q number will be stored in the AES until the
transmission of the current RLS LSDU at that Q number is
over, either successfully or unsuccessfully. Thus, at the GES,
only one RLS SU set per Q number per AES could be in the
reassemble process at a given time and the GES will discard
an incomplete RLS SU set if it starts receiving another RLS
SU set with the same Q number from the same AES. After
either a successful or an unsuccessful transmission of an SU
set, the AES link layer releases all link layer resources
associated with that SU set, i.e. the assigned reference number,
activated timers, memory allocation, etc.

5.5.4 For RLS, the R channel protocol implements a
selective-repeat-ARQ scheme for error control. Accordingly,
upon transmitting an SU set, the AES expects to receive an R
channel acknowledgement (RACK) SU from the GES. The
RACK SU may indicate either complete or incomplete
reception using its acknowledgement control field. In the latter
case, the RACK SU also indicates the missing SUs of the SU
set by identifying their sequence indicators. The AES transmits
the indicated missing SUs without any alterations to their
contents. The largest SU set on the R channel contains three
SUs, thus, the GES may identify at the most two missing SUs
in a RACK SU, one SU of the set must be correctly received
at the GES in order to detect an attempt of an SU set
transmission.

5.5.5 The R channel is a multiple access channel,
therefore, the GES concurrently receives SUs from all AES
assigned to one set of R channel frequencies. Each received
SU contains the source AES ID. Thus, the received SUs are
first sorted out according to their AES IDs and then
independently processed. Annex 10, Volume III, Part I, 4.5.8.3
contains the R channel protocol requirements corresponding to
the processing of SUs from a given AES.

6. LINK LAYER T CHANNEL AND
SUB-BAND C CHANNEL PROTOCOLS

6.1 General
The link layer T channel protocols specified in Annex 10,
Volume III, Part I, Chapter 4, 4.6 applies to link service data
units (LSDUs) in the from-aircraft direction which cannot be
transmitted via the R channel (e.g. because its length exceeds
33 octets). There are two T channel protocols: one for
requesting the T channel capacity and the other for the
transmission of SUs in assigned capacity. The link layer sub-
band C channel protocol specified in Annex 10, Volume III,
Part I, Chapter 4, 4.6 applies to the transmission of signalling
SUs corresponding to the circuit-mode services in the to-
aircraft and from-aircraft directions.

6.2 SU set generation
An SU set cannot be generated from the received LIDU as
described in Annex 10, Volume III, Part I, Chapter 4, 4.6.4.2.1
until a reference number is assigned to it by the T channel
reservation protocol. The LSDU (used data) is encoded in the
user data field of the ISU/SSU of a T channel SU set. The
number of SUs needed in the SU set depends on the LSDU
length. Each SU, except the last one, will contain a maximum permitted number of user data octets. The number of user data octets of the last SU which belongs to the set may have less than the maximum length; unused octets are then padded with dummy bits. The number of octets in the final SU is encoded in the "No. of octets in the final SSU" field of the ISU.

6.3 T channel transmission protocol

6.3.1 General

6.3.1.1 The T channel transmission protocol is used when there are LSDUs present for transmission on the T channel and the AES has received a requested T channel burst reservation. The T channel transmission protocol specifies reliable link service (RLS) for data transfer.

6.3.2 Aircraft Earth Station (AES)

6.3.2.1 The aircraft earth station (AES) is the transmitting end of the T channel transmission protocol. The oldest SU of the SUs with the highest Q number is transmitted first. If an SU set is waiting for transmission in an allocated burst reservation and a higher precedence SU set is submitted for transmission then the higher precedence SUs will displace the lower precedence SUs. Thus, a burst reservation may carry SUs corresponding to an LSDU other than the one which initiated the original request for reservation.

6.3.2.2 The AES, after transmitting the SU set to the ground earth station (GES), waits for T channel acknowledgement (TACK) SU(s) from the GES. The TACK SUs are received at the AES by the receiving end of the P channel protocol, which then passes them to the T channel transmission protocol. The AES may receive more than one TACK SU indicating the missing SUs of an SU set at the GES. Each TACK SU can identify up to three missing SUs. The receipt of a TACK SU of the TACK SU set identifying the missing SUs, initiates a timer tA5 in the AES and indicates the number of additional TACK SUs that are expected. If the timer tA5 expires before another TACK SU of the TACK SU set is received, the AES transmits the missing SUs identified in the so far received TACK SUs. If TACK SU(s) are received after the corresponding timer tA5 has expired and the AES has not yet transmitted the retransmission SU set identified in the received TACK SU(s), the AES discards the received TACK SU(s).

6.3.2.3 The AES computes the length of the expected reservation for retransmission based upon the number of missing SUs indicated in the received TACK SUs of the TACK SU set. This length is associated with the timer tA8 initiated by the T channel reservation protocol to supervise the receipt of reservation for retransmission. This length may be less than the length of the reservation actually assigned for retransmission by the GES if, for example, some TACK SUs of the TACK SU set are not received by the AES.

6.3.2.4 The AES saves a copy of an SU set for retransmission purposes. After passing the transmission status indication LIDU to the subnetwork layer indicating success or failure, the AES destroys the saved copy.

6.3.2.5 If after several retries, an expected reservation from the GES is not received, the AES discards at least the number of SUs for which the reservation was requested. The SUs discarded may not be those which initiated the original request for reservation because of the fact that the transmission of SUs is based upon the precedence described in Annex 10, Volume III, Part I, Chapter 4, 4.6.4.2.2, but will be of equal or lower precedence. If an ISU is among the SUs discarded at the AES, the complete SU set headed by the discarded ISU is discarded. This may result in discarding more SUs than required. If the SU discarded is a REQ SU, then the AES retransmits the REQ SU on either the T or R channel. If the SU discarded is a last SU of an SU set, then the AES starts a timer for the supervision of TACK SU(s) for that SU set.

6.3.3 Ground Earth Station (GES)

6.3.3.1 This is the receiving end of the T channel transmission protocol. The GES, upon receipt of an SU set, reassembles it into an LSDU. Before reassembling the SU set, the GES checks whether or not all the SUs of the SU set have been received. If the SU set is not complete after no more SUs of the SU set are expected (determined by the criterion specified in the AMSS SARPs), the GES requests for the retransmission of the missing SUs by transmitting appropriate number of TACK SUs, indicating error, on the P channel to the AES.

6.3.3.2 If while waiting for retransmissions from the AES, the GES receives an ISU with the same AES ID and Q number as the SU set awaiting completion and with a reference number belonging to a pair whose other member is the reference number of the SU set awaiting completion, the GES discards the SU set awaiting completion and proceeds with the new SU set. The receipt of the ISU with the parameters described above indicates that the AES has given up on the transmission of the previous SU set and has released the reference number, thus making available the other member of the pair for assignment.

6.3.3.3 The GES may receive an RQA SU from the AES in the following circumstances:

a) initial SU set loss (i.e. loss of at least the ISU): the RQA SU does not refer to an SU set which has been processed just before;
b) negative acknowledgement loss or retransmission loss: the RQA SU refers to an SU set under correction; and

c) positive acknowledgement loss: the RQA SU refers to an SU set which has been processed just before.

When the initial SU set has been lost, the GES determines the initial SU set length from the message length parameter in the RQA SU in order to reserve and send the correct T channel capacity along with the request for complete retransmission.

6.4 T channel reservation protocol

6.4.1 GENERAL

The T channel reservation protocol is used to request reservations for the transmission of data on the T channel.

6.4.2 AIRCRAFT EARTH STATION (AES)

6.4.2.1 The T channel reservation protocol in the AES assigns reference numbers to the LIDUs received from the subnetwork layer for transmission on the T channel. The reference numbers are assigned in such a way that no two consecutive LIDUs with the same Q number transmitted from an AES to a GES have the same reference number. The reference number assigned to an LSDU is used by the T channel reservation protocol in the request for reservation (REQ) SU and by all the associated signalling and by the T channel transmission protocol in the data SUs and by the associated acknowledgements and request for acknowledgement SUs.

6.4.2.2 The REQ SU is transmitted to the GES on the T channel or on the R channel. Every time the REQ SU is transmitted on the T channel, the requested length in the REQ SU is incremented by one in order to account for the T channel capacity used to transmit the REQ SU.

6.4.2.3 The timer tA8 in the AES is used to supervise the receipt of expected T channel reservation (RES) SUs associated with either previously received reservation forthcoming (RFC) SUs or received TACK SUs. Due to the priority scheme for the transmission of SU sets, resulting in higher priority SU sets potentially occupying reservation assignments for lower priority SU sets, there will be instances of time where multiple tA8 timers associated with the same SU set might have been initiated at the AES. Upon receipt of an awaited RES SU for that SU set, the AES must stop the corresponding tA8 timer (Annex 10, Volume III, Part I, Chapter 4, 4.6.5.2.6 and 4.6.5.2.7). However, since a one-to-one correspondence between a tA8 timer and a received RES SU is not guaranteed, a selection of a most suitable tA8 timer must be made. Such selection is implementation dependent.

For instance, the selection could be made dependent on the time-out values of all outstanding tA8 timers, such that the tA8 timer with the shortest remaining time to time-out is selected regardless of the size of reservation in the received RES SU. In this case, care must be taken in the implementation to request reservations for any resulting deficit in the total size of outstanding reservations associated with an SU set at the AES when all tA8 timers have been stopped. Other criteria for the selection may be used; however, the constraint that at least the total size of all outstanding reservations associated with any given SU set must be received prior to releasing the reference number assigned to that SU set must always be observed.

6.4.2.4 Reservations may not be received in chronological order. The minimum inter-reservation gap between two reservations on two different T channels is made adequate to allow for frequency (T channel) switching at the AES. A reservation (RES) SU defines one or more burst allocations on one T channel. The starting frame number of the initial burst is encoded within the RES SU and is known as belonging to one of the sixteen frames following the reception of the RES SU (the time window). Thereafter, further reservations (if any) occur every 2BI frames until the number of reserved bursts is reached. BI is the encoding of the burst interval information element within the RES SU. The AES computes the starting frame for each reserved burst using both the starting frame number of the initial burst and the burst interval information. Once a reserved burst has elapsed, the AES deletes its time plan.

6.4.3 GROUND EARTH STATION (GES)

6.4.3.1 The GES assigns reservations in response to requests for reservations from its logged-on AESs. The GES also assigns reservations for retransmissions of missing SUs of an SU set transmitted by the AES. So, whenever the T channel transmission protocol at the GES transmits a TACK SU set comprised of one or more TACK SUs indicating errors, the T channel reservation protocol at the GES makes reservations for the retransmissions.

6.4.3.2 The GES assigns reservations to an AES for any one of the four T channels that may have been assigned to the AES at the time of log-on. The GES indicates the T channel on which the reservation has been made to the AES in the RES SU. A procedure to select a T channel, out of the possible four assigned to the AES at the time of log-on, is implementation dependent. The following methods may be utilized for selecting the T channel:

a) all T channels available to a particular AES are polled. Reservations are assigned to any T channel on which the minimum allowable reservation delay is achievable, or to the channel offering the shortest reservation delay if no T channel offers the minimum allowable reservation delay;
b) each T channel assigned to a particular AES is associated with one or more message precedence. A T channel is selected according to the precedence of the message identified in the REQ SU; and

c) reservations for all non-safety messages are made on a single T channel; reservations for all safety messages are made on a T channel which offers a shortest reservation delay.

6.4.3.3 The GES transmits the RES SU to the AES whenever the start of the reservation is within eight seconds of the current time. This is done to avoid any misinterpretation of the reservation start time at the AES. The reservation start time in the RES SU is specified in terms of start frame number within a superframe. The superframe number is not specified. So, if the RES SU is not received by the AES within the superframe which actually includes the start frame number, the AES will apply the information incorrectly to the superframe within which the RES SU is received by the AES. If the frames in this superframe have been assigned to another AES, then there could be a collision of the T channel transmissions from the two AESs. Because of the fact that the RES SU should be received by the AES within the correct superframe, the precedence of the RES SU is set to 15 in order to minimize the P channel queuing delays that otherwise can be experienced by the RES SU.

6.4.3.4 If the start of the burst reservation is outside the eight second time window from the time the reservation was made, the GES transmits a reservation forthcoming (RFC) SU to the AES in order to prevent a timeout resulting in another request for reservation. The RFC SU gives an upper limit for the delay to the start of burst reservation in entire number of super frames (8 seconds). The time-plan in the GES is limited in length. Whenever the GES is not capable to assign a reservation within its current time-plan, it sends an RFC SU with the delay to RES set equal to its maximum time-plan length and saves the request for later assignment. Subsequently, when the GES is capable of serving the request, the GES sends a further RFC SU giving the delay to reservation which is now known. The size of the GES time-plan is implementation dependent and has not been specified in the AMSS SARPs.

6.4.3.5 The TACK SU's transmission must always precede the associated T channel reservation. As the precedence level of an RES SU is higher than the one of the TACK SU, the GES must wait until all TACK SU's have been effectively transmitted before allocating a reservation for retransmission. The TACK SU's transmitted to the AES by the T channel transmission protocol in the GES includes an estimation for the delay before the RES SU will be sent to the AES by the GES; this estimation is a function of the T channel(s) loading. Subsequently, if the reservation cannot be assigned within the estimated delay specified in the TACK SU, the GES transmits an RFC SU with the actual delay or with the maximum delay value corresponding to its time-plan length if it has not been able to assign a reservation within its current time-plan. In the latter case, the GES will delay T channel burst assignment until capacity is available. The length of the reservation for retransmission is the number of missing SU's identified by the TACK SU set indicating missing SU's at the GES plus one.

6.4.3.6 The GES assigns reservations such that no two AESs use the same T channel for transmission at the same time. The length of a reservation is such that the AES is always capable to send at least one REQ SU in addition to the SUs for which the reservation is made. This prevents delaying either the transmission of an REQ SU when its precedence level is lower than the precedence level of the SUs awaiting transmission, or the transmission of the complete SU set when interrupted by a single REQ SU. Long LSDUs are assigned burst reservation in multiple bursts of equal length, each burst being separated from the precedent one by a fixed burst interval. The intervals between bursts can be assigned to AESs for transmission or retransmissions. The burst interval between two bursts and the burst length of each burst corresponding to the same LSDU are made such that the transfer delay for the entire LSDU meets the performance requirements specified in Annex 10, Volume III, Part I, Chapter 4, 4.7. Since the transmitter in the AES could be shared between the R and T channels and the T channel mode of the transmitter has higher priority than its R channel mode, the assignment of reservations on the T channel will affect the R channel transmissions. The reservations are assigned on the T channel in such a way that most of the time there is at least one R channel burst every eight seconds from each AES logged on to the GES assigning reservations. The burst length and burst interval are not specified in the AMSS SARPs; they are implementation dependent.

6.4.3.7 Typical values for the length of an individual burst are as follows:

a) 18 SUs for a T channel operating at 600 bits/s;
b) 17 SUs for a T channel operating at 1 200 bits/s;
c) 31 SUs for a T channel operating at 2 400 bits/s; and
d) 31 SUs for a T channel operating at 10 500 bits/s.

Typical values for the burst interval are as follows:

a) 16 frames for a T channel operating at 600 bits/s;
b) 8 frames for a T channel operating at 1 200 bits/s;
c) 4 frames for a T channel operating at 2 400 bits/s; and
d) 1 frame for a T channel operating at 10 500 bits/s.

6.4.3.8 The earliest starting time that a reservation can be made by the GES must be such that the AES can receive the reservation in time to transmit at the start of the assigned reservation. This time takes into account the processing time at both the GES and the AES as well as coding and decoding.
delays. The value for the earliest starting time is implementation dependent and is computed according to the formula given below:

Minimum delay to start of reservation = P channel unit delay + GES processing delay + P channel queuing delay + R-slot duration + 0.2 sec(*) + propagation delay + AES processing delay.

* 0.2 seconds is the R/T channel switching time.

A system implementor has obtained the typical values shown in Table A-10 for some of the components. A typical value for GES processing delay is in the order of 200 msec.

6.4.3.9 The GES, upon receipt of either a log-on to another GES or log-off information about an AES which was logged on to it, may discard the reservations assigned to the AES, making the slots available for assignment to its other logged on AESs.

6.5 Sub-band C channel
to-aircraft and
from-aircraft protocol

6.5.1 GENERAL

The sub-band C channel protocol defined in AMSS SARPs contained in Annex 10, Volume III, Part I, Chapter 4, 4.6 specifies direct link service (DLS) for signalling SUs. The sub-band C channel carries signalling for circuit-mode services to set-up, maintain or release the C channel.

7. SATELLITE SUBNETWORK LAYER

7.1 General provisions

7.1.1 ARCHITECTURE

To facilitate the development of interoperability specifications, the subnetwork layer has been divided into functional areas. This functional division is not intended to preclude implementations that aggregate functions in other ways, so long as the airborne and ground implementations of the subnetwork layer each behaves (to an external observer) as if it conformed with the provisions of this section.

7.1.1.1 SSND function

Each SSNDPX function contains one or more SSNDPX entities. Each entity communicates with the peer SSNDPX entity using the SSNDP.

7.1.1.2 SNAc function

Each SNAc function contains one or more ISO 8208 DCE entities. Each ISO 8208 DCE entity communicates with the peer ISO 8208 data terminal equipment (DTE) entity in the attached aeronautical telecommunication network (ATN) router using the ISO 8208 protocol.

7.1.1.3 (Reserved)

7.1.1.4 IW function

Each IW function contains one IW entity. The IW function performs the necessary harmonization between the SSND and the SNAc functions. It forwards ISO 8208 packets between the ISO 8208 DCE and SSNDPX entities.

7.1.2 BACKGROUND FOR THE USE OF ISO 8208 AND THE ASSOCIATED SUBNETWORK DEPENDENT PROTOCOL

In the satellite subnetwork, data may be received out-of-sequence or duplicated. The subnetwork dependent convergence function (SNDCF) in the ATN router which uses the services provided by the satellite subnetwork assumes an underlying connection-mode service which provides sequenced delivery of data. The SNDCF does not perform any error recovery function to handle data duplication and data received out-of-sequence. Therefore, it requires a reliable connection-mode service which is provided by the ISO 8208 and SSND protocols. Furthermore, for the satellite subnetwork, it is more efficient to use these connection-mode protocols. Finally, ISO 8208 is the most mature connection-mode protocol available.

7.1.3 SERVICES

7.1.3.1 The packet data interface allows AMSS to function as the satellite subnetwork of the ATN. The satellite subnetwork transfers data packets from air to ground and from ground to air. Packet data transfers are provided in the form of connection-mode service, using ISO 8208 as a subnetwork access protocol (see Figure A-14 of this guidance material).

7.1.3.2 The subnetwork user must initiate the set-up of each connection by sending an ISO 8208 CALL REQUEST packet. In normal operation, this action results in the establishment of a switched virtual circuit (SVC) between the calling subnetwork user and the called subnetwork user. SVCs can be released by either subnetwork user (when the connection is no longer needed) or by the subnetwork (when the connection is no longer supportable).

7.1.3.3 One or more subnetwork users on an aircraft may be connected to one or more subnetwork users on the ground,
but all ground users will normally interface via a single ground earth station (GES) at any given time. Handovers from one GES to another may result in the temporary interruption of service.

7.1.3.4 The originator of a CALL REQUEST packet will normally identify both the called and calling subnetwork user. The originator may also identify quality of service requirements by invoking the appropriate ISO 8208 facilities.

7.1.3.5 Implementations of a satellite subnetwork will normally contain elements that are not standardized by ICAO. One of these elements is a packet switch that interprets DTE addresses and delivers packets to the appropriate DTE. The AMSS SARPs permit (but do not require) the connection of multiple DTEs with an aircraft earth station (AES) or with a GES, or with both. AMSS SARPs also permit the use of any DTE address format subject to the limitations of ISO 8208. Subnetwork users are responsible for co-ordinating the DTE address formats (and address compression schemes, if employed) between the air and the ground.

7.1.3.6 The satellite subnetwork provides connectivity notification event messages to the attached ATN routers. Since CN event messages are not transferred across the subnetwork, the standardization of formats and media for these messages are considered to be local matters.

7.1.4 ERROR HANDLING FOR COMMUNICATION FAILURES

If communication between an AES and a GES is abruptly terminated (e.g. due to a loss of physical connectivity), it is possible for the subnetwork layer to remain in its last state until connections are cleared by the user. The GES subnetwork layer is particularly susceptible, since it may not immediately be aware of the loss of communication. Users and/or implementors may use supplemental means to detect and correct such conditions.

7.2 Packet data performance

7.2.1 GENERAL

7.2.1.1 The need for ICAO performance specifications

7.2.1.1.1 AMSS minimum system performance standards apply over a geographic coverage area to be identified by each AMSS service provider. In general, the minimum system performance should be continuously available to each AES within the identified coverage area. However, AES antennas are not required to provide full coverage in all directions; multiple antennas and/or multiple satellites may be needed in order to achieve the minimum system performance.

7.2.1.2 Physical layer

The basic performance standard for the physical layer is the maximum bit error rate, which is specified as $10^{-3}$ for digital voice and $10^{-5}$ for packet data and associated signalling. These system specifications avert the need to specify detailed satellite link budgets, thus allowing the flexibility to implement a variety of satellite and GES architectures.

7.2.1.3 Packet data subnetwork layer

7.2.1.3.1 The specification of subnetwork service performance will allow flexibility in the design and operation of GESs while assuring a uniform minimum level of performance for the packet data user. In general, the subnetwork performance parameters are based on the definitions given in Section 10 of ISO 8348, "Information processing systems — Data communications — Network service definition" (1987), which are incorporated into the AMSS SARPs by reference. The mapping between packets and subnetwork service primitives is defined in ISO 8878, "Information processing systems — Data communications — Use of X.25 to provide the OSI connection mode network service".

7.2.1.3.2 The term "subnetwork service" in the context of packet data performance refers to the service provided by the subnetwork to the higher layer user. The term "service provider" in this same context refers to the protocols within the satellite subnetwork and to the net effect of their operation. These terms should not be confused with the services of the satellite communication provider or GES operator. Packet data service depends on all elements of the system: AES, satellite, GES, and the physical paths between them.

7.2.1.3.3 The values of the performance parameters in the AMSS SARPs are intended to permit economical and spectrum-efficient operation. They are calculated under nominal worst case conditions, including maximum physical bit error rate and peak busy hour traffic loading. Improved speed of service performance (relative to the specified values) may be achieved by increasing the number of physical channels used to serve a given traffic load, thus decreasing the traffic load per channel. Using this technique, cost of service may be expected to increase (and spectrum efficiency may be expected to decrease) as the speed of service is improved.
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7.2.1.3.4 AMSS subnetwork performance does not include the effects of other links in the end-to-end data path. Subnetwork performance includes the effects of all operations beginning with the ISO 8208 DCE protocol at the sending end of the satellite subnetwork and terminating with the ISO 8208 DCE operations at the receiving end of the satellite subnetwork, including:

a) the satellite subnetwork interworking functions;

b) the satellite subnetwork dependent protocols;

c) the satellite data link layers; and

d) the satellite physical layers.

ISO 8208 operations associated with the DTE are not part of the satellite subnetwork, and are excluded from AMSS packet data performance specifications, as are data link layer and physical layer operations between the DCE and the DTE.

7.2.2 SPEED OF SERVICE

7.2.2.1 Speed of service is determined by a number of factors, including:

a) the system architecture;

b) the channel rate(s) in use;

c) the priority of the traffic for which speed of service is being measured;

d) the length of the messages for which speed of service is being measured, the traffic loading on the system; and

e) data processing delays.

Finally, the actual speed of service in the from-aircraft direction depends on the amount and type of traffic being transmitted from each aircraft, to the extent that packets may be delayed on the aircraft while other packets are being transmitted to the GES.

7.2.2.2 In accordance with current industry practice, speed of service is specified in terms of packets containing 128 octets of subnetwork user data.

7.2.2.3 There is no specification for the maximum amount of traffic to be handled on P or T channels. However, the speed of service performance standards are based on a maximum utilization of approximately 70 per cent (of theoretical capacity) for these channel types. Higher utilizations are permitted, provided that all of the applicable performance standards are met. For example, a GES that operates multiple T channels in an appropriate multiserver configuration may be able to achieve T channel utilization factors of 80 per cent or more within the constraints imposed by the speed of service requirements. P channels may be operated at utilization factors higher than 70 per cent if the total P channel utilization by traffic at and above the lowest priority associated with safety and regularity of flight does not exceed 70 per cent.

7.2.2.4 A GES that is intended to serve as a backup to another GES should be appropriately sized to provide the required performance in the event of the failure of the primary GES.

7.2.2.5 The term "highest priority service" denotes priority 14 service, which is reserved for distress, urgency and certain infrequent network/system management messages. The term "lowest priority service" denotes the lowest priority used for safety and regularity of flight, under peak-hour traffic loading. Performance for priority levels not used for safety or regularity of flight is not specified.

7.2.2.6 Transit delay and 95 per cent data transfer delay

7.2.2.6.1 Transit delay is a standard speed of service performance measure for single DATA packets; transit delay is defined as an average value. Because the civil aviation community typically does not rely on average values for the most critical performance measures, the 95 per cent data transfer delay is also specified. Under actual operational conditions, the relationship between the average and 95 per cent delay values is not fixed, but may depend on the distribution of traffic. A typical statistical distribution of to-aircraft delays, under projected peak traffic loading and at the lowest P channel rate, is illustrated in Figure A-15 of this guidance material for the highest and lowest priority of data. A typical statistical distribution of from-aircraft delays under similar conditions is shown in Figure A-16 of this guidance material. From-aircraft delays are independent of priority unless two or more from-aircraft packets contend for resources within a particular AES. The extent to which such internal contention may occur within a particular AES will depend on the avionics architecture of the aircraft in which the AES is installed.

7.2.2.6.2 Transit delay and 95 per cent data transfer delay are specified on the basis of a standard reference DATA packet containing 128 octets of subnetwork user data. Actual delays for shorter packets may be reduced, but not necessarily in proportion to the packet length. The delay parameters associated with DATA packets shorter than 128 octets (of subnetwork user data) should not exceed the corresponding parameters for 128 octet DATA packets.

7.2.2.7 Throughput

Throughput is the standard speed of service performance parameter for the transfer of multiple DATA packets. In accordance with current industry practices, throughput is computed on the basis of standard reference DATA packets
containing 128 octets of subnetwork user data. Throughput is computed for the transfer of multiple independent packets. Throughput performance for the transfer of M-bit sequences may be substantially higher. The subnetwork is expected to support the minimum throughput values shown in Table A-11.

7.2.2.8 Connection establishment delay, connection release delay

7.2.2.8.1 Connection establishment delay. The maximum connection establishment delay is based on a connection request of the lowest priority, containing a total of 15 octets of DTE address information and 42 octets of facility fields and optional data. The specified value for each channel rate applies to an equal mix of GES-originated requests and AES-originated requests. The maximum connection establishment delay is the standard speed of service specification for the connection establishment phase; it is not intended to limit in any way the future use of optional facilities, user data fields, or address fields.

7.2.2.8.2 Connection release delay. The maximum connection release delay is based on a disconnect request at the lowest priority, containing no user data, invoking no optional facilities and carrying no address information. The specified value for each channel rate applies to an equal mix of GES-originated requests and AES-originated requests, when the connection release is not delayed by the presence of packets in transit on the connection. The maximum connection release delay is the standard speed of service specification for the connection release phase; it is not intended to limit in any way the future use of optional facilities, user data fields, or address fields.

7.2.3 RELIABILITY OF SERVICE

7.2.3.1 Reliability of service is determined by the system architecture, by the physical layer bit error rate, and by the average rate of "collisions" on R channels. There is no specification on the rate of R channel collisions. However, the system performance specifications for both speed of service and reliability of service are based on an average R channel occupancy factor (i.e. the ratio of occupied R channel slots to the total number of R channel slots during a given interval) of approximately 0.15. Higher R channel occupancies are permitted, provided that all of the applicable performance standards are met.

7.2.3.2 The standard reliability of service parameter for the transfer of a single DATA packet is residual error probability, which is the probability that an attempt to transfer a single DATA packet is not entirely successful. It is based on a standard reference DATA packet containing 128 octets of subnetwork user data. The undetected error probability for AMSS packet data service is expected to be less than $3 \times 10^{-7}$ for standard reference DATA packets containing 128 octets of subnetwork user data. The undetected error probability for shorter packets is reduced approximately in proportion to the packet length.

7.2.3.3 Other reliability of service parameters are resilience of the virtual circuit or logical channel with respect to reset and release, i.e. the probability that the subnetwork service provider invokes a reset or release over some period of time. Reset and release operations may result in the loss of user data, whether invoked by the subnetwork user or by the subnetwork service provider.

7.3 Satellite subnetwork dependent protocol services and operations

7.3.1 LOGICAL CHANNELS

The requirements for selecting logical channel numbers are intended to prevent call collisions.

7.3.2 CONNECTION ESTABLISHMENT

7.3.2.1 The following describes a normal connection establishment between two SNS users.

7.3.2.2 When a subnetwork connection is initiated by one of the SNS users, an ISO 8208 DCE entity in the satellite subnetwork receives an ISO 8208 CALL REQUEST packet from the ISO 8208 DTE. This packet is forwarded to the IWF. The IWF forwards this packet to the appropriate SSNDPX entity. This SSNDPX entity forwards this packet as a CONNECTION REQUEST SNPDU to the remote SSNDPX. When the remote SSNDPX receives this SNPDU, it forwards this to the IWF as an ISO 8208 INCOMING CALL packet. The IWF forwards this packet to the appropriate ISO 8208 DCE entity. The ISO 8208 DCE entity forwards this packet to the peer ISO 8208 DTE entity. The ISO 8208 DTE forwards this connection request to the receiving SNS user. After the receiving SNS user has accepted this connection request, the ISO 8208 DTE entity forwards an ISO 8208 CALL ACCEPTED packet to the peer ISO 8208 DCE entity. The ISO 8208 DCE entity forwards this packet to the IWF. The IWF forwards this packet to the appropriate SSNDPX entity. This SSNDPX entity forwards this packet as a CONNECTION CONFIRM SNPDU to the peer SSNDPX entity. When the remote SSNDPX entity receives this SNPDU, it forwards this as an ISO 8208 CALL CONNECTED packet to the IWF. The IWF forwards this packet to the appropriate ISO 8208 DCE entity. This ISO 8208 DCE entity forwards this packet to the peer ISO 8208 DTE entity. When the ISO 8208 DTE entity receives this packet, it informs the originating SNS user about the establishment of a connection to the remote SNS user.

7.3.2.3 A connection between two SNS users consists of a series of logical channels. Each logical channel is selected
based on the established rule by the receiving entity. Therefore, these logical channels may not have the same number. Figure A-17 of this guidance material shows an example of connection establishment between three pairs of SNS users.

7.3.2.4 Throughput negotiation

Since the GES has the knowledge of available throughput based on the throughputs that have been assigned to the existing subnetwork connections (SNCs), it should assign the throughput classes for each direction of data transmission. The recommended actions by the GES are given in 7.3.6.1 and 7.3.7.1 of this guidance material.

7.3 CONNECTION RELEASE

7.3.3.1 SSNDPX

To avoid unnecessary releases at the SSNDPG caused by residual DATA/INTERRUPT SNPDUs from the SSNDPA, the SSNDPA waits until all DATA/INTERRUPT SNPDUs in transmission and pertaining to that connection have been transmitted before forwarding a CONNECTION RELEASED or a CONNECTION RELEASE COMPLETE SNPDU to the SSNDPG. The SSNDPA need not correlate the transmission status of each DATA/INTERRUPT SNPDU with transmission status indications from the data link layer. However, the SSNDPA waits until all outstanding DATA/INTERRUPT SNPDUs have been acknowledged by the link layer (success/fail LIDU) before sending a CONNECTION RELEASED or CONNECTION RELEASE COMPLETE SNPDU. Since to-aircraft SNPDUs are always delivered in proper sequence by the link layer, the SSNDPG may send a CONNECTION RELEASED or CONNECTION RELEASE COMPLETE SNPDU without waiting for acknowledgement of previously sent DATA/INTERRUPT SNPDUs.

7.3.4 DATA TRANSFER

7.3.4.1 IWF

The IWF should forward the DATA packets between the appropriate SSNDPX and ISO 8208 DCE entities and supply these entities with sufficient information to identify the appropriate logical channel.

7.3.4.2 SSNDPG

Since the DATA SNPDUs from the AES are sent through either the R or T channel, they may be received out-of-sequence at the GES. Therefore, the SSNDPG should have sufficient storage to reorder the out-of-sequence DATA SNPDUs before forwarding the data in these SNPDUs to the IWF.

7.3.4.3 Flow control procedure

7.3.4.3.1 Memory management mechanisms are implementation dependent. In order to minimize the possibility of memory overflow and the consequent loss of data, the satellite subnetwork layer provides flow control, which may be invoked by the AES, the GES, or the subnetwork user. The SSNDPX uses start-stop flow control, while the DCE uses ISO 8208 window flow control. ISO 8208 RECEIVE READY and RECEIVE NOT READY packets are produced locally; they are never transferred across the subnetwork. If the SSNDPX remains in the "flow control not ready" state for 60 seconds, the subnetwork initiates a reset of the connection, regardless of whether flow control was suspended by the subnetwork or by the subnetwork user. The timer (tN7) is associated with the receiving SSNDPX, i.e., the SSNDPX that originated the FLOW CONTROL SUSPEND SNPDU.

7.3.4.3.2 System designs should minimize the possibility that flow control will be invoked on priority 14 connections, e.g., by dynamic memory allocation or by providing additional fixed memory allocation for priority 14 connections. Dynamic memory allocation procedures, if used, should take connection priority into consideration.

7.3.4.3.3 SSNDPX

7.3.4.3.3.1 When the SSNDPX surpasses a storage threshold or receives a FLOW CONTROL (suspend) SNPDU from the remote SSNDPX, it should notify the IWF of this condition.

7.3.4.3.3.2 If the SSNDPX falls below a storage threshold or receives a FLOW CONTROL (resume) SNPDU from the remote SSNDPX after it has informed the IWF of the flow control suspend condition, it should notify the IWF of this condition.

7.3.4.3.3.3 When the SSNDPX surpasses a storage threshold or receives flow control suspend information from the IWF, it should forward a FLOW CONTROL (suspend) SNPDU to the remote SSNDPX when the next DATA SNPDU is received on that VC, providing the situation has not cleared by then.

7.3.4.3.3.4 If the SSNDPX falls below a storage threshold or receives flow control resume information from the IWF after forwarding a FLOW CONTROL (suspend) SNPDU to the remote SSNDPX, it should forward a FLOW CONTROL (resume) SNPDU to the remote SSNDPX.

7.3.4.3.4 ISO 8208 DCE

7.3.4.3.4.1 When the ISO 8208 DCE surpasses a storage threshold or receives flow control suspend information from the IWF, it should suspend the updating of the lower window edge of the local DTE or forward a RECEIVE NOT READY packet to the local DTE.
7.3.4.3.4.2 If the ISO 8208 DCE falls below a storage threshold or receives a flow control resume information from the IWF after it has suspended the updating of the lower window edge of the local DTE or forwarded a RECEIVE NOT READY packet to the local DTE, it should resume updating the lower window edge of the local DTE or forward a RECEIVE READY packet to the local DTE.

7.3.4.3.4.3 When the ISO 8208 DCE surpasses a storage threshold or receives a RECEIVE NOT READY packet from the local DTE, it should notify the IWF of this condition.

7.3.4.3.4.4 If the ISO 8208 DCE falls below a storage threshold or receives a RECEIVE READY packet from the local DTE after it has informed the IWF of the flow control suspend condition, it should notify the IWF of this condition.

7.3.4.4 Data loss

7.3.4.4.1 In a connection release or connection reset, DATA SNPDUs and ISO 8208 DATA packets on that connection may be lost. To guarantee end-to-end delivery of end-user data, a confirmed service such as the one provided by a transport protocol may be used.

7.3.4.4.2 System designs should minimize the possibility that flow control will be invoked on priority 14 connections, e.g. by dynamic memory allocation or by providing additional fixed memory allocation for priority 14 connections. Dynamic memory allocation procedures, if used, should take connection priority into consideration.

7.3.4.5 Expedited data transfer

7.3.4.5.1 It is expected that the ATN will not require expedited data transfer service. However, expedited data transfer service is supported in accordance with ISO 8208.

7.3.4.5.2 For each logical channel, the expedited data transfer allows an interrupt SNPU packet to be sent in a given direction while data transfer in that direction is suspended. This is accomplished by sending the interrupt SNPU or interrupt packet ahead of data SNPDUs or data packets that have been suspended.

7.3.4.6 Connection reset

7.3.4.6.1 SSNDPX. To avoid resets at the SSNDPG caused by residual DATA/INTERRUPT SNPDUs from the SSNDPA, the SSNDPA waits until all DATA/INTERRUPT SNPDUs in transmission and pertaining to that connection have been transmitted before forwarding RESET or RESET CONFIRM SNPDUs to the SSNDPG. The SSNDPA need not correlate the transmission status of each DATA/INTERRUPT SNPU with transmission status indications from the data link layer. However, the SSNDPA waits until all outstanding DATA/INTERRUPT SNPDUs have been acknowledged by the link layer (success/fail LIDU) before sending a RESET SNPU. Since to-aircraft SNPDUs are always delivered in proper sequence by the link layer, the SSNDPG may send a RESET SNPU without waiting for acknowledgement of previously sent DATA/INTERRUPT SNPDUs.

7.3.5 SNPU formats

7.3.5.1 Fast select facility

The fast select facility with parameter set to “use not permitted” may be included in the CONNECTION REQUEST SNPU to explicitly indicate that no user data may be transferred in the CONNECTION CONFIRM and CONNECTION RELEASED SNPDUs. This facility is not included in the CONNECTION REQUEST SNPU, then up to 128 octets of user data may be transferred in the CONNECTION CONFIRM and CONNECTION RELEASED SNPDUs.

7.3.6 Packet to SNPU Mapping Rules

7.3.6.1 GES Actions

7.3.6.1.1 The selected throughput class in the CALL ACCEPTED packet should be transferred to the TCN value in the CONNECTION CONFIRM SNPU.

7.3.6.1.2 If the throughput class in the CALL REQUEST packet is less than or equal to the calculated available value, then the throughput class should be transferred to the TCN value in the CONNECTION REQUEST SNPU; otherwise, the calculated available throughput, rounded down to the nearest standard value, should be transferred to the TCN value.

7.3.7 SNPU to Packet Mapping Rules

7.3.7.1 GES Actions

7.3.7.1.1 If the throughput class negotiation (TCN) value in the CONNECTION REQUEST SNPU is less than or equal to the calculated available throughput value, the throughput class in the INCOMING CALL packet should be set equal to the TCN value; otherwise, the throughput class in the INCOMING CALL packet should be set equal to the calculated available throughput, rounded down to the nearest standard value.

7.3.7.1.2 The selected throughput class in the CALL CONNECTED packet should be transferred from the TCN value in the CONNECTION CONFIRM SNPU.
7.4 ISO 8208 DCE protocol operations

7.4.1 CONFORMANCE REQUIREMENTS

The capabilities which the ISO 8208 DCE is not required to support include the following:

a) modulo 128 packet sequencing;

b) default window size of more than 2; and

c) either the use of the D-bit or the optional mechanism for negotiating use or non-use of the D-bit since these capabilities are not required by the subnetwork users.

Note.—The use of D-bit or the optional mechanism for negotiating use or non-use of the D-bit is strongly discouraged.

7.5 Management interface

7.5.1 AES MANAGEMENT INTERFACE

When an AES logs off or otherwise terminates communication with a GES, the SSNL clears all connections and SVCs associated with that GES. This may be done by sending CLEAR INDICATION packets to each ISO 8208 DCE logical channel associated with these connections and releasing the resources for the logical channels in the associated SSNDPA entity.

7.5.1.1 (Reserved)

7.5.2 GES MANAGEMENT INTERFACE

When an AES logs-off from a GES, the SSNL should clear the connections between the SNS user(s) and the logged-off AES. This may be done by sending CLEAR INDICATION packets to each ISO 8208 DCE logical channel associated with these connections and releasing resources for the logical channels in the associated SSNDPG entity.

8. CIRCUIT-MODE SERVICES

8.1 Circuit-mode voice signalling protocols

8.1.1 General. The circuit-mode logic processes defined in Annex 10, Volume III, Part I, Chapter 4, 4.8 represent the minimum set of protocol interactions necessary to ensure interoperability of aircraft earth stations (AESs) and ground earth stations (GESs) operating in the safety service. The protocol interactions necessary to support air and ground-originated calls arriving at the AES or GES are defined via separate signalling procedures in each.

8.1.2 Logic for air-origination. The AES and GES air-origination signalling procedures for the prevalent aeronautical mobile-satellite service (AMSS) and for the aeronautical mobile satellite (route) service (AMS(R)S) are the same. Provisions are made for an abbreviated call establishment procedure, specifically voice calls at the safety priorities (i.e. distress/urgency, flight safety and regularity/meteorological).

8.1.3 Link layer services. Circuit-mode services use the R, P, and C channel sub-band link layer protocols defined in Annex 10, Volume III, Part I, Chapter 4, 4.5 and 4.6 for all call signalling information exchanged between the AES and GES. This information is exchanged with the link layer via circuit-mode link interface data units (CM-LIDUs). Link layer services perform conversions between CM-LIDUs and the respective AMS(R)S circuit-mode signalling units (SUs). In all cases, only the direct link service (DLS) is used since circuit-mode services are responsible for recovering from missing SUs.

8.1.4 AIR-ORIGINATION PROCEDURES

8.1.4.1 Aircraft earth station (AES) procedure

8.1.4.1.1 Call origination

8.1.4.1.1.1 General call establishment. The AES commences an air-origination by transmitting to the GES an “access request” CM-LIDU. The AES then awaits receipt from the GES of a C channel assignment CM-LIDU for a period of tA50 seconds. This sequence is repeated four times before aborting the call attempt. Calls aborted by the AES in this manner must be re-attempted by the user.

8.1.4.1.1.2 Abbreviated call establishment. The AES commences an air-origination by transmitting to the GES a series of four, three, or two contiguous “access request” CM-LIDUs. The series length is determined by whether the call priority is distress/urgency, flight safety or regularity/meteorological, respectively. The purpose of the multiple transmissions is to mitigate the effects of an SU lost due to R channel collisions. The AES then awaits receipt from the GES of a C channel assignment CM-LIDU for a period of tA50 seconds. This sequence will be repeated four times before aborting the call attempt. Calls aborted by the AES in this manner must be re-attempted by the user.

8.1.4.1.2 At the instant at which the call origination begins, if sufficient AES resources for the call are not available due to blockage attributable to a lower priority call at the AES, the AES will defer pre-emption of these resources and proceed as per 8.1.4.1.1 until a C channel assignment is received from the GES. This will allow the AES to make a proper
pre-emption decision based on the exact EIRP assignment from the GES. Upon receipt of the C channel assignment, all required AES C channel resources (i.e., channel unit and AES EIRP) are pre-empted from a lower priority call (if necessary) and allocated to the call. This is followed immediately by further signalling and continuity checks on the C channel sub-band while the GES is engaged in completing the call to the ground destination.

Note.— As a secondary benefit, by requiring that the AES defer pre-emption until a C channel assignment is received, the future development of an alternative procedure incorporating reuse of an existing C channel is facilitated.

8.1.4.1.3 Address digits

8.1.4.1.3.1 General call establishment. The “access request” CM-LIDU contains the first two digits of the AMS(RS) ground address. The remaining digits are provided on the C channel sub-band as “call information — service address” CM-LIDUs which serve as a basis for the C channel continuity check procedure.

8.1.4.1.3.2 Abbreviated call establishment. The “access request” CM-LIDU contains all digits of the fixed-length 10-digit AMS(RS) ground address. Providing this information concurrent with the access request allows the GES to begin forward completion of the call across the ground network while it proceeds simultaneously with C channel establishment. These address digits are repeated on the C channel sub-band as “call information — service address” CM-LIDUs which serve as a basis for the C channel continuity check procedure. However, their presence in these CM-LIDUs serves no purpose for the AMS(RS) air-origination procedure other than to allow the AES to interwork with a GES which supports prevalent non-safety AMSS circuit-mode procedures rather than the SARPs-specific air-origination procedure.

8.1.4.2 Ground earth station (GES) procedure

8.1.4.2.1 Processing of call initiation

8.1.4.2.1.1 General call establishment. Upon receipt of an “access request” CM-LIDU from an AES, the GES immediately allocates C channel resources and responds with a “C channel assignment” CM-LIDU. Simultaneously, the GES analyses the network-ID contained in the access request and awaits the completion of the receipt of the service address. Forward call set-up across the ground network is then completed.

8.1.4.2.1.2 Abbreviated call establishment. Upon receipt of an “access request” CM-LIDU from an AES, the GES immediately allocates C channel resources and responds with a “C channel assignment” CM-LIDU. Simultaneously, the GES analyses the network-ID contained in the access request and begins forward call completion across the selected ground network.

8.1.4.2.2 The GES circuit-mode procedure monitors the status of the from-aircraft C channel carrier throughout the call. Loss of carrier for more than tG13 seconds will result in termination of the call by the GES. When this happens, the GES will send six “call progress — channel release” CM-LIDUs during this phase so as to ensure that the AES’s call state is cleared. If the AES carrier were to reappear (possibly indicative of anomalous propagation conditions non-conducive to call continuance) the GES will attempt to again clear the AES call by sending six additional “call progress — channel release” CM-LIDUs on the C channel sub-band and one on the P channel.

8.1.4.2.3 When the GES passes the forward call origination to the selected ground network, it must also convey the call priority and the AES and terminal IDs of the originator. This will ensure that the ground network can be sensitive to the call’s priority during routing; and that the ground user is always advised of the identity of the originator so as to facilitate return calls to aircraft that a controller may not otherwise be aware of. In those cases where a call is blocked due to an engaged (busy) condition at the ground destination, the GES may, as an option: (1) interpret a specific backward signal from the ground network which indicates that the call attempt has been recorded at the ground destination, and then (2) forward a corresponding CM-LIDU to the AES. This is accomplished by a specific combination of cause codes in the “call progress — channel release” CM-LIDU and the BITE 16 telephony event at the interworking interfaces with the external aircraft and terrestrial networks. This will serve to alert an aircrew that a ground user has been alerted to the existence of the unsuccessful call attempt and has been provided the information necessary to initiate a return call at a later time.

8.1.5 Ground-origination procedures

8.1.5.1 Ground earth station (GES) procedure

8.1.5.1.1 Upon receipt of a call origination from a ground network, the GES commences a ground-origination by allocating AES resources to the call and then sending to the AES via the P channel a “call announcement” CM-LID followed by a “C channel assignment” CM-LID. The GES will then await receipt of the from-aircraft C channel carrier prior to conducting a continuity check on the C channel sub-band. The AES will initiate the continuity check by sending a “call progress — test” CM-LIDU to which the GES will respond with a “call progress — test” CM-LIDU every tG35 seconds until the call is either completed to the aircraft destination or terminated unsuccessfully (e.g., destination busy, call clearing, etc.). The AES will acknowledge receipt of a “call progress — test” CM-LIDU, thereby completing the continuity check, by sending either a positive “telephony acknowledge” CM-LIDU or a “call progress — connect” CM-LIDU. (The latter will have been sent in lieu of the former if the aircraft user answered the call immediately after the continuity check procedure.) The GES will react to either CM-LIDU by

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forwarding an "address complete" BITE to the ground network and, in the case of the latter CM-LIDU, an "answer" BITE as well. At this point the talk phase of the call may proceed.

8.1.5.1.2 The GES will monitor the status of the C channel for the duration of the call. If a "call progress — connect" CM-LIDU is received during this phase and subsequent to the completion of the continuity check phase, the GES will forward an "answer" BITE to the ground network and maintain the C channel. The GES monitors the status of the from-aircraft C channel carrier throughout the call. Loss of carrier for more than tG19 seconds will result in termination of the call by the GES. When this happens, the GES will send six "call progress — channel release" CM-LIDUs during this phase so as to ensure that the AES's call state is cleared. If the AES carrier were to reappear (possibly indicative of anomalous propagation conditions non-conducive to a usable call) the GES will attempt to again clear the AES call by sending twelve additional "call progress — channel release" CM-LIDUs on the C channel sub-band and one on the P channel.

8.1.5.1.3 If the GES receives a "call progress — channel release" CM-LIDU (indicating that the aircraft user has terminated the call) the GES will forward a "clear back" BITE to the ground network and terminate the call. Similarly, if the GES receives a "clear forward" FITE from the ground network (indicating that the ground user has terminated the call) the GES will send six "call progress — channel release" CM-LIDUs over the C channel sub-band and then monitor the AES to ensure that it has terminated its from-aircraft C channel carrier.

8.1.5.1.4 Events such as unsuccessful continuity checks and call clearing will result in the eventual termination of C channel transmissions from the AES. While these various termination events are progressing, the GES will monitor the from-aircraft carrier to ensure that the AES is performing similar call termination activities. If the from-aircraft carrier has not terminated within tG17 seconds after the transmission of an initial series of "call progress — channel release" CM-LIDUs, the GES will send twelve additional of these CM-LIDUs via the C channel sub-band and a thirteenth via the P channel. If these transmissions are not successful in causing the AES to terminate its C channel transmission within tG18 seconds after the last transmission, the GES will terminate all call activities unilaterally.

8.1.5.2 Aircraft earth station (AES) procedure

8.1.5.2.1 An incoming call to an AES is announced by the receipt of "call announcement" and "C channel assignment" CM-LIDUs. Since these are sent on the direct link service, circuit-mode services implements an error recovery procedure whereby the AES can infer that one of these CM-LIDUs is missing (e.g. due to bit errors on the P channel) and request that it be repeated by the GES. The AES initiates the request by transmitting an appropriately encoded "telephony acknowledge" CM-LIDU via the R channel. When an AES has received a "call announcement" CM-LIDU and its associated "C channel assignment" CM-LIDU it will initially verify that the called terminal is available and that adequate C channel resources (i.e. channel unit and AES EIRP) are either available or pre-emptable. If the foregoing requirements are not all met the AES will send an appropriately encoded "call progress — call attempt result" CM-LIDU via the R channel and then terminate all activities for the call. Otherwise, it will activate a C channel unit on the assigned C channel frequency pair and begin the C channel continuity check procedure by sending a "call progress — test" CM-LIDU via the C channel sub-band.

8.1.5.2.2 The AES will send an additional "call progress — test" CM-LIDU every tA26 seconds for tA41 seconds until an identical CM-LIDU is received from the GES. This constitutes a successful continuity check and will immediately cause the AES to: (1) enable the voice circuit between the aircraft voice channel and the C channel unit, (2) forward a "call origination" FITE to the aircraft destination, and (3) send a "telephony acknowledge" CM-LIDU via the C channel sub-band to the GES. The AES will then await tA42 seconds for the aircraft destination to answer the call. If the call is not answered within this time period the AES will clear the call toward the aircraft destination, send six "call progress — channel release" CM-LIDUs to the GES, and then terminate the call. Otherwise, if the aircraft destination answers within this time limit the AES will send a "call progress — connect" CM-LIDU to the GES and maintain the C channel during the talk phase of the call.

8.1.5.2.3 When the "call progress — connect" CM-LIDU is sent, the AES will initiate an error recovery procedure to ensure its receipt at the GES. (The talk phase progresses in the interim.) Timer tA26 is used to implement a transmission repeat cycle for this CM-LIDU which must result in receipt at the AES of a "telephony acknowledge" CM-LIDU within tA30 seconds of the original transmission. Failure to receive the acknowledgement within tA30 seconds will cause the AES to terminate the call.

8.2 Interworking of circuit-mode services with other voice networks

8.2.1 AMS(R/S) circuit-mode procedures. A standardized set of circuit-mode procedures within the AES and GES implement the AMS(R/S) circuit-mode protocols and provide specific interfaces with non-AMS(R/S) telephony interworking procedures. The AMS(R/S) circuit-mode procedures correspond to specific AES and GES circuit-mode processes and represent the highest level of functionality contained in the AMSS SARPs. The interworking procedures, although physically contained within the AES and GES equipment, represent the initial "layer" of functionality immediately adjacent to and external from the AMS(R/S) circuit-mode procedures. The interworking procedures represent the
functional area where specific conversions between the AMS(RS) circuit-mode procedures and user or service provider-specific signalling implementations are effected. The interworking protocol between the AMS(RS) circuit-mode procedures and the interworking procedures is defined using a standard set of interworking telephony events.

8.2.2 Interworking with external telephony systems. Interworking is the controlled transfer of signalling information across the interface between different signalling systems where the significance of the information is identical or where the significance is translated in a defined manner.

8.2.2.1 Interworking protocol basis. The interworking protocol is defined through the use of a set of forward and backward interworking telephone events (FITEs and BITEs). The interworking telephone events that are used herein to define the interworking protocol are a subset derived from the standardized definitions contained in CCITT Recommendation Q.606. Defining the interworking protocols on the basis of FITEs and BITEs is in conformance with standard telephony system practice. It should be noted that the use of FITEs and BITEs is merely a convenient nomenclature and in no way places dependencies on specific equipment implementations.

8.2.2.1.1 FITE. A FITE is an event where telephony signalling information is transferred in the forward direction from an incoming signalling system to an outgoing signalling system. The "forward" direction of a FITE is referenced to the fact that a FITE propagates in a direction that is away from the originating end of a call. Certain FITEs may also carry mandatory and optional information elements pertinent to the event (e.g. address digits).

8.2.2.1.2 BITE. A BITE is an event where telephony signalling information is transferred in the reverse direction from an outgoing signalling system to an incoming signalling system. The "backward" direction of a BITE is referenced to the fact that a BITE propagates in a direction that is toward the originating end of a call. Certain BITEs may also carry mandatory and optional information elements pertinent to the event (e.g. call attempt result information).

8.2.3 AES TELEPHONY INTERWORKING

8.2.3.1 Relationship of AES signalling systems. Figure A-18 of this guidance material depicts the relationship between the AES circuit-mode procedures, their respective interworking procedures, and aircraft-specific telephony signalling implementations. In particular, the referenced figure defines both the usage of "incoming" and "outgoing" procedures from the viewpoint of the originating call party and the external interface of the AES circuit-mode procedures.

8.2.3.2 AES interworking telephony event definition. The AES circuit-mode procedures interwork with aircraft telephony signalling systems via the forward and backward interworking telephony events defined in the Standards. The AES circuit-mode procedures must map specific interworking telephony events to specific protocol interactions in the AES circuit-mode logic procedures where interactions with an aircraft signalling system are required. This mapping must also include parameter mapping where indicated in the Standards.

8.2.3.3 Aircraft telephony interworking. An on-aircraft telephony network is not to be required to implement any type or manner of physical network implementation. Any particular implementation is at the option of the aircraft operator as long as that implementation is made to interwork with the AES circuit-mode procedure's interworking protocol.

Note 1.— An aircraft operator might choose to not implement a discrete aircraft telephony signalling network external to the AES equipments. At their option, a "call control agent" function could be integrated within the AES equipments in such a manner as to eliminate the need for a discrete aircraft signalling network.

Note 2.— In those cases where an AES is configured to sustain more than one simultaneous ATS call, the aircraft's called terminal addresses should be configured into one or more appropriate "hunt groups". This will reduce the incidence of ground-originated calls to a specific called terminal being blocked by an engaged condition when an equally appropriate called terminal is available.

8.2.4 GES TELEPHONY INTERWORKING

8.2.4.1 Relationship of GES signalling systems. Figure A-19 of this guidance material depicts the relationship between the GES circuit-mode procedures, their respective interworking procedures, and ground-specific telephony signalling implementations. In particular, the referenced figure defines both the usage of "incoming" and "outgoing" procedures from the viewpoint of the originating call party and the interworking interface of the GES circuit-mode procedures.

8.2.4.2 GES interworking telephony event definition. The GES circuit-mode procedures interwork with terrestrial network telephony signalling systems via the forward and backward interworking telephony events defined in the Standards. The GES circuit-mode procedures must map specific interworking telephony events to specific protocol interactions in the GES circuit-mode logic procedures where interactions with a terrestrial network signalling system are required. This mapping must also include parameter mapping where indicated in the Standards.

8.3 Implementing satellite voice in the ATS environment

8.3.1 Overview. The AMS(RS) voice service has basic operational attributes which fundamentally differ with
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prevalent very high frequency (VHF) and high frequency (HF) voice operations. This will require close attention to how satellite voice is implemented in a data link-oriented ATS environment. These differences include a statistical delay in speech channel establishment, a perceptible delay in speech propagation, circuit-switched operation, full-duplex operation, and the inability for aircraft to monitor communications between the ground and other aircraft. Additionally, the AMS(R)S voice service places functional requirements on terrestrial facilities which are external to the GES (e.g. terrestrial networks and ACF automation equipment) in order to maximize its utility.

8.3.2 Channel establishment delay. Upon call origination, each user must provide to its respective AES or GES the telephone number of the desired destination and then wait for the system to establish a speech channel. This is in sharp contrast with conventional radio operations where typically each user maintains a continuous listening watch on a radio channel. In addition, the channel establishment delay is statistical in nature and is dependent upon the over-all traffic load on the AMSS system.

8.3.3 Call annunciation. It is anticipated that aircraft operators will integrate the satellite voice equipment with other aircraft systems in a manner very similar to current VHF and HF radio equipment. This may lead to minor inconsistencies in how voice calls are managed on different aircraft. For instance, interwiring satellite voice equipment with existing aircraft audio control panels may lead to inherently half-duplex operation on certain aircraft even though all of the intervening speech channels are full-duplex. Incoming air-originated calls will, in many cases, be annunciated to the aircrew via a SELCAL chime or other audible indication, and will require a crew action to answer the call. This means that a ground user must await a positive answer indication (e.g. crew voice response) before speech can begin. Otherwise, there would be no assurance to the ground user that the call is audible to the crew. This particular aspect is quite important given the expectation that:

a) satellite voice calls will be very infrequent in a data link oriented environment; and

b) the inability of an aircrew to monitor satellite voice communications by other aircraft precludes positive, routine assurance that the proper aircraft audio panel selections have been made.

8.3.4 Aircraft call management. Aircraft flight management computer systems can be useful in managing routine aspects of voice call management for the aircrew. For instance, ground number directories and selection menus can be provided by these systems so that the need for an aircrew to enter discrete telephone numbers on a control/display device can be minimized. These systems could also correlate with directory information the associated data link end-system address information or the aircraft’s position in order to recommend an appropriate ground address for use in an ATC call. However, it should be noted that the crew must be able to select or otherwise imply the appropriate priority of a call attempt prior to origination.

8.3.5 Air-originated call information. When the GES forwards an air-originated call to the terrestrial network, the call indication will include, in addition to the desired ground address, the call’s priority, and the AES-ID and calling terminal-ID associated with the call. (Annex 10, Volume III, Part 1, Appendix 5 to Chapter 4, Figure A5-28 refers). The call priority can be used by the terrestrial network to facilitate a potential pre-emption action within that network and to notify the ground destination of the call’s priority in cases where the ground user might be servicing other calls. The AES and terminal ID information is provided so as to facilitate correlated routing (8.3.6) of the call (by an ACF or other facility) to the proper destination within that facility as determined by the facility’s information concerning the aircraft.

8.3.6 Correlated routing. Call routing functions within a facility should be able to determine the proper internal destination to which a call should be routed based on the facility’s current data pertaining to the aircraft. This requires that the facility correlate the originating aircraft’s AES-ID (see 8.3.5) with information that it may have concerning the aircraft and then route the call to the relevant ground user. Consideration should be given to the establishment of a universal default agent code in the AMS(R)S ground numbering plan (e.g. “000”) which would be known to all facilities to be an implied request by the aircrew to provide the correlation function. The remaining 999 code values in the agent code field would remain available for discrete ground user addresses within a facility.

8.3.7 Facility incoming call management. The ground user should have several options available for those instances when an air-originated call arrives while they are conducting a pre-existing call with another aircraft. A ground user should be able to combine any reasonable number of satellite voice calls in a conference so that the communications service can be managed in a manner similar to a VHF radio channel if the ground user so chooses. This can be implemented with a conventional telephony conference bridge situated between the ground user and the terrestrial voice network. In addition, the ground user should receive an immediate presentation of the call information listed in 8.3.5 for all arriving calls so as to facilitate a proper call handling decision. Examples of two possible operational modes are as follows:

a) Barge-in. All arriving calls for an individual destination are automatically answered by an automation function on behalf of the ground user, and are placed in a multi-way conference consisting of the ground user and any existing calls. This is intrinsically the simplest mode of operation in that it allows all users to immediately contend for the ground user’s attention by listening for any active conversation just as in VHF radio. Barging in
to an active conversation, however, would require that the caller tie up a C channel resource while waiting for the previous conversation to end.

b) Serial access with priority override. An arriving call for an individual destination is automatically answered by an automation function on behalf of the ground user. Any additional calls arriving at a priority equal to or lower than an existing call receive a “busy” indication and are cleared automatically. Any additional calls arriving at a priority higher than an existing call are answered automatically and conferenced with any call(s) that the ground user is currently conducting. This allows only higher priority calls to “barge-in” on existing calls. It also allows a calling aircrew (at the higher priority) to gain the ground user’s attention verbally without needlessly terminating an existing lower priority call.

8.3.8 Aircraft microphone push-to-talk operation. The AMSS voice channel provides a bi-directional audio path which is inherently full-duplex. However, it is strongly recommended that conventional (i.e. VHF-like) half-duplex push-to-talk (PTT) operation be maintained in all aircraft installations — but only to the extent that the flight crew must actuate a PTT key in order to be heard by the ground user. In other words, to-aircraft audio should always be audible in headphones without muting when the PTT key is actuated. (Designers should still pay due attention to cockpit speaker muting when a microphone is keyed.) This will allow the crew to manage the satellite voice conversation in consideration of other concurrent flight deck activities. In addition, enforced PTT operation will help ensure that the potential future use of audio conferencing at a ground user workstation is not impaired by uncontrolled cockpit ambient noise (i.e. from “hot” microphones) in those instances where a controller has several satellite voice calls operating simultaneously.

8.3.8.1 Flight crews should be able to override enforced half-duplex operation so they can take advantage of the full-duplex voice channel when the operational situation warrants (e.g. in-flight medical emergencies).

8.4 Terrestrial voice network considerations

8.4.1 Overview. The AMSS SARPs provide for the implementation of a shared, common-user terrestrial voice switching network that interconnects each GES with one or more ground facilities expressly for aeronautical safety communications. This network can be composed of one or more subnetworks operating in tandem to provide the appearance of a single cohesive network service between GESs and external ground facilities (e.g. ACF, aircraft dispatch, etc.) This network should be separate and distinct from other networks which may be attached to a GES for non-safety purposes (e.g. the public switched telephone network).

8.4.2 Access control. For air-originated calls, access to the terrestrial safety network is achieved by the AES encoding the access request signalling with a network-ID value of “10”. This value will indicate to the GES that the call shall be routed to the terrestrial safety network and that all specific signalling information must be included with the call indication. AES implementations should be subject to certification provisions that ensure that it will not be possible for non-safety users on an aircraft to gain access to the terrestrial safety network.

8.4.3 Routing analysis. For air-originated calls, the GES will not analyze the ground address information contained within an access request other than to interpret the network-ID value for selection of the proper terrestrial network (i.e. “10”). Upon receipt of the call indication from the GES, the terrestrial safety network must interpret the country and facility code fields contained in the call information and route the call to the proper facility as required. For ground-originated calls, the originating facility must provide the terrestrial safety network with the ID of the desired GES along with the other call information (i.e. AES-ID, terminal-ID, and call priority) when the call indication is conveyed to the network.

8.4.4 Call routing functions. Call routing functions external to the GES can be categorized as being either high-level routing between GESs and ground facilities, and low-level routing carried out within a facility.

8.4.4.1 High-level routing. For air-originated calls, high-level routing consists of the terrestrial safety network interpreting the country and facility codes which are contained in the ground address and routing the call to the network's terminus with the proper facility. For ground-originated calls, high-level routing consists of the terrestrial safety network interpreting the AES-ID which was received in the call information from the originating facility and routing the call to the network’s terminus with the proper GES.

8.4.4.2 Low-level routing. When an air-originated call reaches the desired facility over the terrestrial safety network, a low-level routing function within the facility must interpret the agent code contained within the call information and then route the call to the indicated ground user. It should be noted that, if the agent code value indicates that the call must be correlated with other aircraft information at the facility, the low-level routing function must also interpret the AES-ID contained within the call information and then route the call within the facility based on the correlation results.

8.4.5 Terrestrial network implementation alternative. Particular switching network architectures are not mandated for the terrestrial safety network. For instance, individual agreements between AMSS service providers and either administrations or aircraft operators may provide for the integration into the GES equipments of some or all of the high-level routing functions. This would then require that the GES perform the routing tasks described in 8.4.4.1 and route calls to individual facilities via dedicated GES-to-facility trunk groups.
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8.4.6 Pre-emption. The terrestrial safety network, and/or its individual tandem subnetworks are required to pre-empt and reallocate any resource assigned to an existing call when that call is blocking the completion of a higher-priority call attempt. The incidence of pre-empted calls can be minimized by reserving one or more channels within all voice trunk group for high priority calls (e.g. distress/urgency).

8.5 Implementing the group call/broadcast functions

8.5.1 Overview. Under certain conditions a ground user may desire to establish a ground-originated conference call (a group call) with several aircraft at once. Similarly, there may be occasions where there is a need to establish a one-way broadcast to a group of aircraft (a group broadcast). Although the group call and group broadcast functions are not explicitly provided for in the AMS(R/S) system protocols, equivalent functions can be readily catered for by implementing several basic call origination functions in the facility automation system.

8.5.2 Group call. The group call function can be effected by requiring that the ground user (or an associated automation service) place independent calls to each aircraft designated by the user to be in the group call or “conference”. Separate, parallel calls through the terrestrial network and AMSS satellite service would then be established for each aircraft in the conference. The use of individual voice calls for each aircraft in the group can be easily implemented and it also facilitates the centralized management of aircraft entry-to and exit-from the conference by the user. Except for the facility automation functions and the low-level voice switching equipment serving the ground user, no other intervening tandem network (terrestrial or AMSS) need do any specialized call processing in order to establish a group call.

8.5.2.1 The terrestrial network equipment immediately adjacent to the ground user should provide an audio conference function on behalf of the user whereby all aircraft in the conference can hear speech audio generated by other aircraft as well as the ground user. This will provide a passive means to serialize access to the ground user that is identical to that of VHF radio except for the satellite delay effects. Additionally, the facility automation function should also manage the “list” of aircraft in the group so that the ground user can be constantly aware of the presence — or absence — of each aircraft in the group call.

8.5.2.2 During group call origination, the individual aircraft speech channels in a group call cannot be expected to begin operation simultaneously. This is because: (1) the call announcement signalling arriving over the P channel will not reach all aircraft in the group call simultaneously, (2) C channel establishment delay after receipt of this signalling will vary, and (3) all aircrew in the group may not be able to answer the incoming call simultaneously due to primary attention to flight deck duties. This latter human factors issue has the potential to cause considerable confusion as various aircrew answer the call and enter the group conference, especially if the aircrew are not aware that an incoming call is a group call. The risk of this confusion can be mitigated if the aircrew can be advised that an incoming call is actually a group call so that they can remain quiet on the circuit until the ground user begins speaking. One way to accomplish this is for the facility automation function to transmit a repetitive audio alert tone sequence or recorded verbal advisory until all aircraft have answered the call and are ready to participate in the conference.

8.5.3 Group broadcast. The procedures for group broadcast can be identical to those of group call except that the conference function provided by the facility should not convey or relay any air-to-ground audio that might inadvertently arrive from aircraft in the broadcast group. As in the case of group call, human factors considerations may require that there be some way to indicate the arrival of a one-way group broadcast to the aircrew.

8.6 Implementing the call registration function

8.6.1 General. Under normal circumstances, an ATS specialist who has available an AMS(R/S) voice communications service should be able to receive and maintain concurrent air-originated calls from a reasonable number of aircraft. (Paragraph 8.3 provides further guidance on how this may be implemented.) However, there may be operational situations where the ATS specialist wishes either to bar incoming calls or to service arriving calls one at a time — in other words return a “busy” indication to calling aircraft. In these instances, good operational practice should include both making an automatic record of the call attempt for the ATS specialist (call “registration”) and advising the aircrew that their failed call attempt has been registered. This notification to the aircrew would carry an implied intent on the part of the ATS specialist to originate a subsequent reciprocal call to the originating aircraft at the first opportunity.

Note.— Paragraph 8.3.5 describes the air-originated call information elements that can be used by the terrestrial facilities to accomplish call registration. The GES and terrestrial network facilities are required to convey this information to the ground user facility.

8.6.2 Signalling of the call registration event. The AMSS SARPs require that a call attempt to a busy destination be deemed unsuccessful and that a “call unsuccessful — called party busy” event (BITE 16) then be generated by the end-user’s network facilities. (Intervening telephony signalling systems, including those of the AMS(R/S) subnetwork, convey this event to the aircrew.) The call registration event is considered a variation of the BITE 16 event and it is carried
over the AMS(R)S subnetwork by a unique code value in the cause value parameter of the AMS(R)S “call progress — channel release” LIDU (Annex 10, Volume III, Part I, Appendix 5 to Chapter 4, Figures A5-7 and A5-34 refer). Both terrestrial network facilities and network-specific telephony interworking logic within the GES must support the conveyance of this backward signal to the GES’s air-originating logic procedure if the recommended call registration facility is implemented.

8.7 Notes on the abbreviated air-originating procedures

8.7.1 General. The procedures defined in the AMSS SARPs for use in air-originated calls provide for a general call set-up and an abbreviated call set-up. The abbreviated procedures provide comparatively shorter and more consistent access delay performance.

8.7.2 ACCESS REQUEST PHASE

8.7.2.1 Abbreviated access request SU. An “abbreviated access request” SU is used in the AMS(R)S procedures as a means to deliver all call information (i.e. ground address and calling terminal-ID) to the GES concurrent with the R channel access request. This eliminates the need for the GES to await receipt of this information on the C channel sub-band as is the case for the general access request procedure.

8.7.2.2 Series transmission of redundant access requests. In order to mitigate the effects of R channel collisions on circuit-mode access delay performance, the AES will send a short series of identical abbreviated access request SUs upon both the initial access attempt and each of the four subsequent attempts (which are initiated by expiry of timer tA50) for a total of five attempts. The quantity of identical SUs in the series increases with increasing call priority. The probability of receiving at least one abbreviated access request SU at the GES upon each of the five attempts over an R channel loaded to 15 per cent is depicted in Table A-12 of this guidance material. (The table brackets the expected performance by depicting two cases where all conflicting R channel traffic from other AESs comprises either 1-SU bursts or 3-SU bursts.)

8.7.3 Simultaneous set-up of circuit segments by the GES. In addition to the enhanced delivery reliability for the abbreviated access request SU as described in 8.7.2.2, end-to-end access delay performance is further aided by the GES beginning forward completion of the call across the terrestrial network at the same instant at which the GES allocates C channel resources and begins C channel establishment in the backward direction. Immediate initiation of forward call completion is possible because the abbreviated access request SU contains all necessary call information as described in 8.7.2.1. By establishing both the satellite and terrestrial segments of the end-to-end call concurrently, the limiting factor in end-to-end access delay (after receipt of the abbreviated access request SU) is the longer of either the terrestrial network call completion delay or the C channel establishment delay — but not the sum total of both delays as would be typical of the general call origination procedure.

8.7.4 AES interworking with non-compliant GES. There may be certain AMS(R)S service areas where one or more GESs are not equipped to support the abbreviated air-originating procedure (e.g. prior to a mandatory ICAO implementation date). The abbreviated procedure as defined for the AES accommodates this by being inherently compatible with both equipped and non-equipped GESs (mode switching or crew intervention are not necessary). Specific attributes of the abbreviated air-originating procedure that allow an equipped AES to interwork with both types of GESs are as follows:

a) the format of the abbreviated access request SU is identical to that of the equivalent general access request SU except that the digit No. 2-9 and terminal ID fields are designated as reserved in the latter SU. This allows a non-equipped GES to interpret the call attempt as it would for a general call (i.e. the call information extracted from the SU is identical to that for a general call);

b) equipped and non-equipped GESs will discard any redundant copies of an access request SU. Therefore, receipt by the GES of multiple copies of the abbreviated access request SU will not result in call processing logic errors (multiple receipt may occur in the absence of R channel collisions or if timer tA50 has expired before the AES has received a C channel assignment SU); and

c) the C channel sub-band signalling and continuity test logic for equipped and non-equipped AESs and GESs is identical. Of particular note is the fact that an equipped AES will repeat the digit No. 2-9 and terminal ID fields (from the abbreviated access request SU) on the C channel sub-band in a manner identical to that of a non-equipped AES. This particular aspect of the AMS(R)S procedure is key to the ability for an equipped AES to interwork with any GES.

Note.— The end-to-end access delay performance through a non-equipped GES will not correspond to that realized when an equipped GES is in use.

8.8 Circuit-mode access delay performance

Note.— Except where noted, projections of end-to-end circuit-mode access delay performance are based on R and P channels operating at channel rates of 10 500 bits/s.
8.8.1 Air-originated calls. Paragraphs 8.7.2 and 8.7.3 describe the special attributes of the abbreviated air-origination procedure that result in enhanced access delay performance for the safety versus non-safety user. With respect to the concurrent set-up of both C channel and terrestrial network resources (8.7.3), the benefits of this improved procedure are most apparent when the access delay component that is incurred within the terrestrial network facilities is no greater than that which is incurred by C channel establishment. As a point of reference it should be noted that the GES will require a minimum of six seconds (latency) to establish a C channel — measured from the time at which the C channel assignment SU is enqueued for P channel service. This implies that to derive maximum benefit from the enhanced air-origination procedure, the terrestrial network facilities should impart no more than an equivalent delay component to the end-to-end access delay performance — including the time for the answer indication to flow in the backward direction.

8.8.1.1 GES C channel demodulator acquisition delay. Annex 10, Volume III, Part I, Chapter 4, 4.3.4.4 allows three seconds (99 per cent) for the GES C channel demodulator to recover the received carrier and achieve frame lock (this is included in the aforementioned six-second minimum for the GES to establish a C channel after it has received a request). The AMSS SARPs further recommends that implementors achieve shorter acquisition times. This delay has a direct effect on the minimum achievable end-to-end delay in those cases where the terrestrial network is able to provide an access delay component of less than six seconds (8.8.1).

8.8.1.2 End-to-end access delay for air-originations. If one can assume that the delay component which is attributable to the terrestrial network facilities can be constrained to be no greater than the component attributable to C channel establishment, then end-to-end access delay in the absence of any significant contending P channel traffic can be as short as eight seconds (95 per cent) for air-originations. If a GES is provisioned with C channel demodulators which exhibit acquisition performance akin to that of the AES's burst mode of operation, then a five second (95 per cent) end-to-end access delay figure is possible provided that the terrestrial network facilities can provide an equivalent improvement in performance.

8.8.2 Ground-originated calls. The AES and GES logic procedures for ground-originated AMS(R)S calls are essentially identical to those of the prevalent non-safety AMSS procedures. The expected access delay component that is attributable to the AMS(R)S subnetwork in the absence of any significant contending P channel traffic is projected to be six seconds (95 per cent). (Inclusive of three seconds for GES C channel demodulator acquisition overhead). A terrestrial network facility delay component of four to six seconds will result in an expected end-to-end access delay of 10 to 12 seconds (95 per cent). Improvements in either terrestrial network or GES demodulator overhead will yield an equivalent improvement in the end-to-end delay performance.

8.8.3 Projections of AMS(R)S subnetwork call set-up delay. The call processing delays in Annex 10, Volume III, Part I, Chapter 4, 4.8.4.1 specify only the components of AMS(R)S call set-up delay attributable to the performance of AES and GES equipment. These performance parameters, while not entirely deterministic in nature, are not likely to exhibit a significant statistical variance. This is because the parameters are specified as maximum internal processing delays exclusive of any transmission delays or queuing delays for link layer service such as that which might be experienced by a telephony signalling CM-LIDU awaiting P channel transmission. However, the over-all AMS(R)S subnetwork delay to establish an air or ground-originated call, which will be subject to the statistical performance of the link layer, is likely to be of interest to system planners. Based on simulation studies using a traffic model identical to that used to determine the packet-mode performance requirements in Annex 10, Volume III, Chapter 4, 4.7. AMS(R)S subnetwork call set-up delay performance for abbreviated air and ground-originated calls is projected to be as depicted in Table A-13 of this guidance material.

Note.— Each performance parameter is applicable to all AMS(R)S priorities except for those parameters expressed as a range of values for highest to lowest priority.

8.8.4 PSTN end-to-end call set-up delay. End-to-end call set-up delay may be excessive when the AMS(R)S subnetwork is interconnected with the PSTN unless a specific performance is specified for the PSTN.

8.9 Subjective voice quality evaluation

8.9.1 BT LABORATORIES 9.6 kBITS/S
LPC CODEC

8.9.1.1 Vocoders employing the algorithm described in Appendix 7, among others, were evaluated by BT Research Laboratories (BTRL) and the U.K. CAA. The results of these evaluations were used in the selection of this algorithm from the three finalist contenders.

8.9.1.2 Intelligibility. The BTRL evaluation used the mean opinion score (MOS) assessment methodology. In the BTRL evaluation, an MOS of about 3.1 was obtained under conditions of optimized input and listen levels, no channel noise and no ambient aircraft noise. When a channel bit error rate (BER) of 0.001 or greater was introduced and aircraft ambient noise was added, the MOS ranking decreased.

8.9.1.3 The U.K. CAA evaluations used a specially constructed test environment in which the test subject, a controller, was placed in a simulated work situation. A "pseudo-pilot" read typical ATC messages to the controller and responded to the controller's queries and instructions. Varying levels of channel bit error rates were introduced. The
qualitative conclusion was that the vocoder was acceptable for ATC purposes in low-density airspace, such as oceanic.

8.9.2 DVS1 4.8 Kbits/s AMBE CODEC

8.9.2.1 The acceptability of the DVS1 codec as a suitable alternative was assessed based on comparative tests against the BTRL 9.6 kbits/s LPC codec. These comparative tests were carried out by Comsat Laboratories based on test requirements agreed at RTCA Special Committee 165 and had the objective of determining whether this codec had an equivalent or better performance than the BTRL codec. Diagnostic rhyme test (DRT) and MOS were used in this assessment.

8.9.2.2 The results of the comparative tests led to the conclusion that the DVS1 codec was statistically equivalent to the BTRL codec under most conditions and that it was suitable for operations in the same environment, e.g. oceanic airspace.

Note — Test results have also shown that the use of noise reduction or cancelling techniques for operation under high propeller background noise is recommended.

9. AIRCRAFT EARTH STATION (AES) MANAGEMENT

9.1 General

Annex 10, Volume III, Part I, Chapter 4, 4.9 defines the minimum set of requirements that the AES management must meet in order to ensure interoperability. This chapter of the guidance material describes issues related to the AES management SARPs.

9.2 AES management interfaces

The AES management is described in the AMSS SARPs as an entity which interfaces to other AES entities, such as the link and subnetwork layers. The interfaces are defined in terms of the information exchanged between the AES management and these other entities and are shown in Figure A-20 of this guidance material. No formats of the exchanged information are specified in the AMSS SARPs. Such formats are considered to be implementation dependent.

9.3 AES management functions

9.3.1 AES TABLE MANAGEMENT

9.3.1.1 Two sets of information are required to be maintained by the AES. These sets of information are given in the AMSS SARPs in the form of tables, namely the system table and the log-on confirm table. The specifics of storing this information in the AES are not regulated by the AMSS SARPs, they are implementation dependent.

9.3.1.2 The information listed under “system table” is provided by the GES. This information contains the necessary search frequencies to enable the AES to select a satellite, a beam, and a GES in order to carry out the log-on procedure. Thus, it is mandatory that this information be current in the AES prior to logging on. The currency of the system table information is maintained at the AES by monitoring the system table broadcast sequences transmitted by the GES as stated in Annex 10, Volume III, Part I, Chapter 4, 4.9.3.2.3.1.

9.3.2 AES LOG STATUS MANAGEMENT

9.3.2.1 Satellite, beam and GES selections

9.3.2.1.1 Depending on the geographical location of the aircraft, the AES may have more than one option for the selection of a satellite, beam, and GES combination. The AMSS SARPs provide the flexibility of allowing the AES management to select the most desirable combination at a given time. The only requirement imposed on the selection is the AES capability of receiving an adequate signal on the selected GES $P_{smc}$ channel.

9.3.2.1.2 The information used by the AES management in making its selection is contained in the AES system table. A GES is uniquely identified by the frequency of its $P_{smc}$ channel transmitted within a specific beam in the service area of a given satellite. A satellite is uniquely identified by one or more sets of satellite/beam-identifying $P_{smc}$ channel frequencies. Each set contains at least two frequencies and is associated with the ID of the beam within which the associated P channels are transmitted. If the satellite identification is made via the global beam (beam ID=0), the AES management may further attempt to select a spot beam, if any exist. For a satellite service area with spot beam only, the satellite identification will be made via a spot beam, thus the satellite and the spot beam selections are made concurrently.

9.3.2.1.3 AESs commonly have a programmable owner preference table by which there may be preferential selection of certain systems, satellites, and/or GESs and communication requirements. There are several criteria by which preferential selection for log on can be made; e.g. service provider identity, cost, service options. If this capability were misused (e.g. to exclude particular systems, satellites or GESs), safety could be derogated due to restricted availability of alternate/diverse communication paths. If exclusion is permitted in an AES owner preference table, it should be verified that the safety communication availability requirements for that aircraft’s installation are met.

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9.3.2.2 Log-on procedure

9.3.2.2.1 Log-on initiation. As prescribed by the AES management AMSS SARPs, the log-on procedure could be initiated by the receipt of a log-on command. The log-on command could specify the GES and/or the satellite to be selected to log on. These AMSS SARPs specify neither the source nor the format of such command. The source could be external to the AES relaying the command to the AES management on a specific interface. The format is implementation dependent.

9.3.2.2.2 Log-on rejection. Several reasons have been identified for the GES rejection of an AES log-on request. A list of these reasons is given in Annex 10, Volume III, Appendix 3 to Chapter 4. No specific AES responses corresponding to the specified rejection reasons have been given in the AMSS SARPs. Such responses are implementation dependent. However, the AMSS SARPs further classify the rejection reasons into three categories: permanent unavailability, temporary unavailability, and invalid parameters. The response of the AES management to a rejection reason could be defined in accordance with the category of the rejection reason in the following manner:

permanent unavailability: cease further log-on attempts to the same GES;
temporary unavailability: reattempt log on to the same GES only after a suitable period of time, or after attempting to log on to other suitable GES;
invalid parameters: reattempt log on to the same GES, only with different parameters.

9.3.2.3 Universal time broadcast

Some applications on the aircraft may need to be synchronized with the counterpart applications on the ground. The AMSS SARPs contain recommendations for support of a time synchronization facility at the AES and the GES. Thus, for interoperability consideration, a universal time signal unit (Annex 10, Volume III, Part I, Appendix 2 to Chapter 4, Figure A2-35) containing the current time to the nearest second, synchronized to the UTC standard has been defined in the AMSS SARPs. Upon receipt of a universal time SU from the GES, the AES may provide the received time information to the appropriate applications on the aircraft. The method selected by the AES to provide this time information to an application is implementation dependent.

9.3.2.4 User commands

9.3.2.4.1 The AMSS SARPs specify the AES responses to a minimum set of commands intended to influence some of the AES operations. Such commands may be initiated either prior to (Annex 10, Volume III, Part I, Chapter 4, 4.9.3.3.3.1) or after (Annex 10, Volume III, Part I, Chapter 4, 4.9.3.3.4.2) the AES log-on. Neither the sources nor the formats of such commands are specified in the AMSS SARPs. Such sources may be internal or external to the AES and operating in accordance with some stimulus criteria to satisfy a particular user requirement, such as continuity of service. For example, a stimulus criterion to invoke a beam-to-beam handover could be based on the knowledge of the beam pattern of a given satellite and the position and heading of the aircraft. The formats of the handover commands are implementation dependent.

9.3.2.4.2 Handover commands. The handover commands specified in the AMSS SARPs are intended to enable the AES user to alter the AES log-on conditions in various ways, as deemed suitable by the user.

9.3.2.4.2.1 A GES-to-GES handover command could be issued by the AES user in order to:

a) renew the log-on to the same GES but through a different spot beam;
b) to switch the log-on to a different GES in the same satellite service area, either through the same or a different spot beam.

Such command may have to specify the GES ID and spot beam ID when those IDs are different than the current values. Circuit-mode calls in a Level-4 AES (multiple transmit and receive channel units) are not effected by the execution of this command. Level-3 AES operation is as specified in Annex 10, Volume III, Part I, Chapter 4, 4.9.3.4.2 b).

9.3.2.4.2.2 A satellite-to-satellite handover command could be issued by the AES user in order to switch the AES log-on to a new GES within the service area of another satellite. Any circuit-mode call established through the current satellite will have to be forcibly terminated after a fixed period of time prior to switching to the new satellite. In the AMSS SARPs, this period of time is set to 3 minutes. If the AES was unable to tune to any of the listed satellite/beam-identifying P_{nmc} channels of the new satellite, the AES may revert back to the previous satellite or any other satellite in view.

9.3.2.5 P channel loss/degradation

9.3.2.5.1 P channel loss/degradation declaration is conveyed to the AES management in the form of an indication from the AES physical layer (P channel receiver). The criteria on which such declaration is based are given in 4.1.3 of Attachment A. If the P channel loss or degradation is caused by the aircraft flying out of the selected beam coverage, the P channel loss/degradation declaration will cause the AES management to search for a new GES, within the same or a different satellite service area, and log-on to it. However, the loss/degradation of the P channel would cause an undesirable discontinuity of both data and voice services. Therefore, the use of such practice is not advisable as a means to invoke an
AES handover. The handover commands described in Annex 10, Volume III, Part I, Chapter 4, 4.9.3.3.4.2 b) and c) provide a more controlled means to invoke AES handovers.

9.3.2.5.2 Because all R and T channel transmissions are synchronized to the framing format of the P channel, and in order to ensure positive control of the AES from the GES, such transmissions must cease with the loss of the P channel.

9.3.3 AES CHANNEL MANAGEMENT

9.3.3.1 Voice-voice pre-emption

9.3.3.1.1 Several circuit-mode calls could be contending for the limited resources in the AES. In such cases, the establishment and continuation of a circuit-mode call is regulated by the priority and pre-emption requirement of Annex 10, Volume III, Part I, Chapter 4, 4.8.3.2 according to the precedence of the Q number assigned to the C channels carrying the calls. The C channels Q number assignment for the various categories of voice transactions is given in Annex 10, Volume III, Part I, Chapter 4, Table 4-43.

9.3.3.1.2 Various requirements are included in the AMSS SARPs in order to enforce the priority and pre-emption statement of Annex 10, Volume III, Part I, Chapter 4, 4.8.3.2 in the AES. In this regard, the circuit-mode services will only request the assignment of a transmit/receive channel unit pair from the AES management if, and only if, there are either sufficient resources available or at least one of the circuit-mode calls in progress has at a Q number strictly lower than the Q number of the call being established. In the latter case, the AES management will make available the channel units being used by the call in progress to support the call being established.

9.3.3.2 Level 3 AES voice/data arbitration

In a Level 3 AES, a single transmit channel unit is shared among the R, T and C channels. The arbitration between the R channel and the T channel is resolved in the AMSS SARPs by considering that the T channel signal unit (SU) transmissions, regardless of the Q number of the SU, have precedence over the SU's transmission on the R channel. However, a minimum number of “gaps” in the T channel slot reservations to a particular aircraft are required to ensure that the R channel transmission are not totally blocked (Annex 10, Volume III, Part I, Chapter 4, 4.6.5.3.3). Arbitration between the C channel and the R or T channels is accomplished according to the priorities of the transactions on these channels. The specific requirements for such arbitration are given in Annex 10, Volume III, Part I, Chapter 4, 4.9.3.3.4.1.4. It should be noted that the AMSS SARPs do not require that an established voice call be terminated if the transmission of a higher precedence data message is required; rather, such action is optional. An alternative scheme allowed by the AMSS SARPs would be to cease transmission on the C channel long enough to transmit any higher precedence signal units in the AES link layer and then reassign the transmit channel unit to the C channel.

10. GROUND EARTH STATION (GES) MANAGEMENT

10.1 General

10.1.1 Ground earth station (GES) management functions specified in Annex 10, Volume III, Part I, Chapter 4, 4.10 are mandatory for each GES implementation. The GES management includes functions to manage the AES log-on to a GES, to control the assignment of P, R and T channels for data and signalling transfer, to reassign new channels on detection of an excess loading on a channel, to assign C channel frequencies on-demand, to control the power of the assigned C channels, to update the system table and time information in the AES and to verify the operational status of its logged-on AESs.

10.2 GES management architecture

10.2.1 SATellite SERVICE AREA

A service area of a satellite is defined as the satellite coverage area within which a satellite provider provides services. Different satellites can have overlapping satellite service areas.

10.2.2 SATellite SYSTEM CONFIGURATIONS

The following are the three satellite system configurations:

a) Satellite with global beam only. In this configuration, there is only one beam per satellite. This beam is referred to as a global beam. In this configuration, two GESs may be required per satellite in a satellite service area to account for two satellite-identifying $P_{smc}$ channels for satellite identification.

b) Satellite with global beam and spot beams. In this configuration, a satellite supports multiple beams with some beams enclosed within another beam. The beams enclosed within a beam are called spot beams and the enclosing beam is referred to as a global beam. In this configuration, two GESs may be required per satellite in a satellite service area to account for two satellite-identifying $P_{smc}$ channels for satellite identification. The satellite-identifying $P_{smc}$ channels for satellite identification in this configuration are transmitted in the global beam.
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10.2.3 GES CAPABILITY

At a minimum, the GES should be capable of operating through a space segment with a Level 4 AES. This implies that the GES should support voice channels for ATC and AOC services and interface with public switched telephone network or leased circuits at the option of the GES operator. The GES should also have provision for the highest specified rate data channels and interface with private or public switched networks at the option of the GES operator. The number of AESs that a GES can support depends upon the channel loading and the channel frequencies allocated to a GES. The loading on the channel should be such that the packet-mode data transfer meets the performance requirements specified in Annex 10, Volume III, Part I, Chapter 4, 4.7.

10.2.4 GES-TO-GES COMMUNICATION

GES-to-GES communication link is used to transfer information regarding the status of logged-on AESs to other GESs within the same satellite service area. It is also to be used to transfer the C channel access requests and C channel call announcements/C channel assignments between the log-on GES and the GES handling the particular call.

10.3 GES management interfaces

10.3.1 GES management interfaces to other GES entities are defined in Annex 10, Volume III, Part I, Chapter 4, 4.10 in terms of the information exchanged over these interfaces. The format of the information exchanged is not specified; it is implementation dependent.

10.3.2 The GES management interfaces with the link layer to use its services to transfer the management LIDUs to its peer in the AES. The GES management interfaces with the subnetwork layer to inform the subnetwork layer about the AES connectivity. The GES management interfaces with the circuit-mode services to pass the C channel frequencies and channel units assigned to a circuit-mode call. The GES management interfaces with the physical layer to control the frequency and power of the transmitted and received channels and to pre-empt the channel units for higher precedence voice or data calls.

10.4 GES management functions

10.4.1 GES TABLE MANAGEMENT

10.4.1.1 The term “table” refers to the system information stored at a GES. The information stored at the log-on GES includes the status of logged-on AESs and the status of AESs logged on to other GESs within the same satellite service area. It also includes information about the satellite — its identifying frequencies, its location, the beams supported by the satellite, the GESs within the satellite service area and the frequencies and bit rates of the P^smc/R^smc channels supported by each GES within the satellite service area. The format and the storage capacity for the information is not specified in the AMSS SARPs; it is implementation dependent.

10.4.1.2 The AES system table specified in Annex 10, Volume III, Part I, Chapter 4, 4.10 can be used for any satellite configuration. The initial search data for a satellite service area served by a satellite with spot beams may include two or more satellite-identifying P^smc channel frequencies per satellite plus a spot beam map, indicating the geographical coverage of the spot beams of that satellite. The regional data of the AES system table for a satellite service area served by a satellite with a global beam will include the GES ID for each GES within the satellite service area and the P^smc and R^smc channel frequencies supported by each GES in the global beam as well as the services each GES supports in the global and spot beams.

10.4.1.3 AES log-on status table

The AES log-on status table maintained by a GES other than the log-on GES contains information about each AES logged-on to any GES within the same satellite service area. This information can be used by a GES for call routing purposes such as to reject a ground-initiated call request destined for an AES not logged-on to any GES in the satellite service area or to forward the call request to the GES to which the destined AES is logged-on.

10.4.1.4 Each GES also maintains an authorization table. This table contains the list of all aircraft addresses for those AESs whose operators have successfully completed the administrative requirements necessary to enable the AES to operate within an AMS(R)S system. These administrative steps include, but are not limited to: confirmation that the aircraft address is correct and issued by an appropriate body; AES equipment has successfully passed unit testing; and contact and billing details for the AES operator are correct.

10.4.2 GES LOG-ON STATUS MANAGEMENT

10.4.2.1 GES handover functions

10.4.2.1.1 A log-on GES, upon receipt of an AES log-on information from another GES in the satellite service area
served by the same satellite as the one serving the log-on GES, suspends any data transaction in progress with the AES if this AES was previously logged on to it. The voice calls in progress via the previous log-on GES does not have to be cleared since the AES can establish calls via a GES other than its log-on GES. The previous log-on GES does not indicate the AES in its AES log-on status table as being its logged on AES; however, it still retains the required information about the AES.

10.4.2.1.2 If the log-on information about an AES is received from a GES in a different satellite service area, then the received GES suspends the data transaction and clears voice calls in progress with the AES if this AES was previously logged-on to it and then deletes the AES from its AES log-on status table completely. The old log-on GES then transmits log-off information to other GESSs in its satellite service area.

10.4.2.2 Log-on verification

10.4.2.2.1 The AMSS SARPs on GES management specify two methods of verifying the operational status of an AES. The direct verification method is utilized by the GES if the log-on verification (LOV) bit in the log-on request LIDU is set to zero by the AES; otherwise, indirect verification method is used.

10.4.2.2.2 The purpose of log-on verification is to optimize the use of resources among AESs. If an AES is not active for a period of time specified in the AMSS SARPs (i.e. it is not transmitting data or does not have a voice call set up to the log-on GES or to any other GES in the same satellite service area), the log-on GES logs-off the AES if the AES does not respond to log-on interrogation (for direct log-on verification) or remains inactive for 12 hours (for indirect verification). The resources released can thus be made available to other AESs that are trying to log on but cannot succeed due to insufficient resources at the GES.

10.4.2.2.3 The reason for an AES logged on to a GES to be inactive is that the AES has either landed without logging off or has switched satellites. Under such conditions, it is appropriate for the log-on GES to log off the AES.

10.4.2.3 Log-on prompt

The log-on prompt facility at a GES is used to prompt an AES to log on when the GES link layer receives a signal unit (SU) from an AES on an Rₚ channel and the AES is not in its AES log-on status table. This situation can occur if the GES has not updated its AES log-on status table after the initial log-on. The GES transmits the log-on prompt LIDU to the AES on all P channel frequencies.

10.4.2.4 Assignment of data channels

The GES management assigns data channels (P, R, and T channels) at the highest bit rate, which is provided at both the GES and the AES and is supported by the combination of a satellite in use and the level of the AES. The decision as to which channels and with what EIRP to assign, can be made by the GES management from the following information:

a) the satellite in use (its return link sensitivity); and

b) the level of AES.

The GES management can assign up to eight R channels and up to four T channels at the time of log-on.

10.4.3 GES CHANNEL MANAGEMENT

10.4.3.1 C channel frequency management

On the basis of known/planned/predicted traffic capacity requirements, the GES can be pre-assigned a number of SCPC frequencies for use as a forward and return C channels. The total number of frequencies assigned to GESSs within the same satellite service area is normally less than the total capacity available for the satellite in operation. On demand, each GES assigns the frequencies for a circuit-mode call from its own pool. However, lack of channel frequency for a call at the GES results in the initiation of a channel frequency reassignment request to a central authority which initially made the pre-assignment. The central authority can then make an assignment of frequency to the GES utilizing the frequencies held in a common pool.

10.4.3.2 C channel power management

10.4.3.2.1 The GES calculates the initial EIRP of the C channel according to the value derived from the worst case link budget.

10.4.3.2.2 The GESSs can be assigned power budgets consistent with performance requirements of the channels operating to the satellite. Once this power budget is fully utilized, the GES management rejects further channels/call requests until sufficient power has been released to be assigned to the new requests or until the log-on request LIDU indicates AES in distress. The C channel power can be controlled for example in accordance with the following power control decision table:

for the 21 000 bits/s, rate 1/2 FEC channel, if the average number of errors per 2 560 channel bits (before decoding) is:

greater than 172: increase EIRP by 2 dB
between 119 and 172: increase EIRP by 1 dB
between 76 and 119: leave EIRP unchanged
between 44 and 76: decrease EIRP by 1 dB
less than 44: decrease EIRP by 2 dB.
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Note.—These values correspond to the input bit error rates to a rate 1/2 Viterbi decoder as specified for the C channel that provide an output bit error rate of $10^{-3}$ (nominal) to $10^{-4}$ (1 dB above nominal), with a margin of 1.5 dB.

10.4.4 GES PRE-EMPTION MANAGEMENT

10.4.4.1 Voice versus voice pre-emption

The purpose of this capability at the GES is to make resources available for a higher precedence voice call if there are no additional resources available at the GES and lower precedence voice calls are being serviced. The GES management, upon receipt of a request from circuit-mode services for a channel unit for a voice call, checks if the precedence of the new request for voice call set-up is higher than any call already in progress. If the precedence of new call request is higher than any one call-in-progress, the GES management then ruthlessly pre-empts the lowest precedence call in progress to make resources available for the higher precedence call. If there are more than one call at the lowest precedence in progress at a given time then it is at the discretion of the GES operator to pre-empt a call. One option could be to pre-empt the call which has been in progress for the longest time.

10.4.4.2 Data versus voice pre-emption

The purpose of this capability at the GES is to make resources available to set up an additional P channel for higher precedence data traffic when there are no additional resources available at the GES to set up an additional P channel, and lower precedence voice calls are being serviced and transmission of additional data traffic on the already operational P channels would violate the data transfer delay requirements specified in Annex 10, Volume III, Part I, Chapter 4, 4.7. However, a higher precedence voice call does not pre-empt an operational P channel to make resources available for setting up a higher precedence voice call because doing so will be detrimental to data transmissions from the AES.

10.4.5 GES SYSTEM BROADCAST

10.4.5.1 System table broadcast

10.4.5.1.1 This facility at the GES allows the GES to update the system table information and spot beam map information stored in an AES. The system table and spot beam map updates are transmitted to AESs as complete or partial sequences.

10.4.5.1.2 The initial search data in the system table contains satellite-identifying $P_{smt}$ channel frequencies for all satellites. Any changes to the system table are made centrally by the satellite system provider and are disseminated to all GESs within all the satellite service areas provided by the satellite system provider, as required. The revision number for a system table and spot beam map are unique to each satellite service area.

10.4.5.1.3 The complete sequence is transmitted by the designated GES on the satellite-identifying $P_{smt}$ channel and it comprises all broadcast LIDUs headed by a broadcast index LIDU. The partial sequence comprises one or more broadcast LIDUs headed by a broadcast index LIDU. The partial sequence contains the most recent updates only. The broadcast index LIDU identifies the presence of individual LIDU series within both the complete and partial sequences. Each GES broadcasts a partial sequence on all its operational P channels. Each satellite service area has its own system table and spot beam map broadcast information.

10.4.5.1.4 The system table complete and partial sequence broadcast rates may be reduced due to high P channel loading. This may delay the initiation of the log-on procedure at the AES. It is recommended that the GES management monitor such broadcast rates and provide further P channel capacity to maintain these rates at acceptable levels.

10.4.5.1.5 The system table consists of:

a) system table broadcast index SU (Figure A2-30, Chapter 4, Annex 10, Volume III);

b) system table broadcast satellite/beam ID channel advice SU (Figure A2-32, Chapter 4, Annex 10, Volume III);

c) system table broadcast GES P/R channel advice SU (Figure A2-31, Chapter 4, Annex 10, Volume III);

d) system table broadcast GES beam support advice SU (Figures A2-34 and A2-61, Chapter 4, Annex 10, Volume III); and

e) system table broadcast data channel EIRP SU (Figure A2-62, Chapter 4, Annex 10, Volume III).

The system table broadcast data channel EIRP SU is used by the AES in accordance with 4.10.4.4.3.1.1 of Annex 10, Volume III.

10.4.5.1.6 Where a satellite supports spot beam service, a GES transmits the spot beam map series consisting of SUs as shown in Figure A-21 of this guidance material. This sequence is independent to the system table broadcast series and contains the definition of the spot beam coverage areas and the GES services supported in the spot beams. The AES, upon receiving the complete series, will then know what spot beam(s) it is currently in and the services that are available to it. The AES may use this information to determine which GES to log on to. The message types for the spot beam map series are:
18 spot beam map broadcast — complete sequence — initial SU
19 spot beam map broadcast — complete sequence — SSU
26 spot beam map broadcast partial sequence — initial SU
27 spot beam map broadcast partial sequence — SSU

10.5 Considerations for GES services

10.5.1 The AMSS system, which forms part of the ICAO communications, navigation, and surveillance/air traffic management (CNS/ATM) systems concept, provides communication services on a global basis. The AMSS system architecture consists of a number of satellites and a limited number of GESs. All States/administrations can have full access to the AMSS, but most of them will not need to have their own GES; rather they will connect to the network through service providers.

10.5.2 Although a small number of GESs are sufficient for AMSS in a given geographical area, some States or administrations may feel it is necessary to install and operate their own GES for reasons such as:

a) redundancy — reducing the impact of GES failure;

b) less dependency on other States (who operate GESs) and service providers; and

c) exerting authority and control in their airspace.

10.5.3 However, the proliferation of GESs can lead to problems such as:

a) increased demand for spectrum because of the inefficiencies introduced by dividing the available spectrum into small pieces;

b) degraded packet data performance as AESs are subjected to more log-on/log-off cycles as they transit between various flight information regions (FIRs) which operate their own GESs;

c) increased workload for the flight crew (or cost and complexity of the AES) as they transit between various FIRs which operate their own GESs.

10.5.4 Additional factors which affect the number of GESs are the following:

a) available satellite power will limit the number of 600 bit/s P-channels, i.e. GESs, which can be supported per satellite; and

b) the cost of installing and operating a GES will not be economical for most administrations.

Given this, some States may be concerned about their dependency on other States or service providers, for GES services. This concern can be alleviated by several considerations:

a) For packet services, the ATN will allow States without GESs to choose between a number of different States or service providers to obtain GES services.

b) In States where the ATN is less developed, fixed satellite links between a GES and the air traffic control centre could provide an alternative to terrestrial links. This approach could be a source of both cost-competitiveness and redundancy. If designed properly, the extra delay introduced by a second satellite link will have a negligible effect on the packet data performance. A second satellite link may not be adequate for voice communications, at least not in a normal conversation mode. However, its effect on verbal exchanges typical of ATC applications has not been studied.

c) States should have adequate institutional arrangements with service providers based on ICAO guidelines for AMSS.
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### TABLES FOR ATTACHMENT A

#### Table A-1. Typical implementation versus levels of capability

<table>
<thead>
<tr>
<th>Levels of capability</th>
<th>Packet data service (kbits/s)</th>
<th>Circuit mode service (kbits/s)</th>
<th>Number of channels</th>
<th>AES antenna gain</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6 1.2</td>
<td>Not available</td>
<td>1 transmit 1 receive</td>
<td>0 dB</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.6 4.8 10.5</td>
<td>Not available</td>
<td>1 transmit 1 receive</td>
<td>12 dB or 6 dB (6 dB does not support 10.5 kbits/s data channels)</td>
<td>Higher speed for packet data</td>
</tr>
<tr>
<td>3</td>
<td>0.6 4.8 10.5</td>
<td>Voice 21.0 and/or 8.4</td>
<td>1 transmit 2 receive</td>
<td>12 dB or 6 dB (6 dB does not support 21.0 kbits/s voice or 10.5 kbits/s data channels)</td>
<td>Provides digitized voice and packet data, but not simultaneously</td>
</tr>
<tr>
<td>4</td>
<td>0.6 4.8 10.5</td>
<td>Voice 21.0 and/or 8.4</td>
<td>2 or more transmit 2 or more receive</td>
<td>12 dB or 6 dB (6 dB does not support 21.0 kbits/s voice or 10.5 kbits/s data channels)</td>
<td>Simultaneous two-way packet and voice. Needs linear amplifier and power control for each carrier</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Circuit mode data services may be supported by some implementation, but these are not defined in the AMSS SARPs.
2. The 4.8 kbits/s channel applies only to the P channel.

#### Table A-2. Worst case data performance versus channel rate

<table>
<thead>
<tr>
<th>Minimum channel rate in use by AES (bit/s)</th>
<th>Maximum connection establishment delay (95th percentile) (seconds)</th>
<th>Transit delay (average) (seconds)</th>
<th>Data transfer delay (95th percentile) (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>To-aircraft</td>
<td>Data transfer delay (95th percentile) (seconds)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Highest priority Lowest priority</td>
<td>Highest priority Lowest priority Highest priority</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 40</td>
<td>40 15 110 80</td>
</tr>
<tr>
<td>600</td>
<td>70</td>
<td>45 8 25</td>
<td>30 9 60 65</td>
</tr>
<tr>
<td>1 200</td>
<td>45</td>
<td>25 5 12</td>
<td>15 6 30 35</td>
</tr>
<tr>
<td>2 400</td>
<td>25</td>
<td>25 4 7</td>
<td>13 5 20 30</td>
</tr>
<tr>
<td>4 800</td>
<td>25</td>
<td>25 4 5</td>
<td>13 4 10 30</td>
</tr>
<tr>
<td>10 500</td>
<td>25</td>
<td>40 12 15</td>
<td>80 30 30 30</td>
</tr>
</tbody>
</table>

Residual error rate:
- from-aircraft direction: $10^{-4}$ per SNSDU (maximum)
- to-aircraft direction: $10^{-6}$ per SNSDU (maximum)

**NOTES:**
1. In any particular AES, lower priority from aircraft traffic may be subject to additional delay, depending on the amount and rate of from-aircraft traffic loading.
2. The values of the transfer delays are based on packet sizes of 128 octets.
### Table A-3. Q-precedence structure for AMSS transmissions

<table>
<thead>
<tr>
<th>AMSS Q-number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Distress/urgency voice; signalling</td>
</tr>
<tr>
<td>14</td>
<td>Distress/urgency data messages</td>
</tr>
<tr>
<td>13</td>
<td>Reserved for signalling</td>
</tr>
<tr>
<td>12</td>
<td>Flight safety voice; signalling</td>
</tr>
<tr>
<td>11</td>
<td>Flight safety data messages; communications related to direction finding</td>
</tr>
<tr>
<td>10</td>
<td>Meteorological and flight regularity voice; signalling</td>
</tr>
<tr>
<td>9</td>
<td>Reserved for signalling</td>
</tr>
<tr>
<td>8</td>
<td>Meteorological data messages</td>
</tr>
<tr>
<td>7</td>
<td>Flight regularity data messages</td>
</tr>
<tr>
<td>6</td>
<td>Aeronautical Information Service Messages</td>
</tr>
<tr>
<td>5</td>
<td>Aeronautical administrative data messages, network/systems administrative data messages</td>
</tr>
<tr>
<td>4</td>
<td>Routine cockpit and cabin voice; signalling</td>
</tr>
<tr>
<td>3-0</td>
<td>Various AAC and APC categories; other</td>
</tr>
</tbody>
</table>

### Table A-4. Frequency error budget for receiving the P channel

<table>
<thead>
<tr>
<th></th>
<th>Specification</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GES transmit reference error</td>
<td>±100 Hz</td>
<td>57.7 Hz</td>
</tr>
<tr>
<td>AFC pilot transmit error</td>
<td>±100 Hz</td>
<td>57.7 Hz</td>
</tr>
<tr>
<td>GES AFC error</td>
<td>±100 Hz</td>
<td>57.7 Hz</td>
</tr>
<tr>
<td>AES receive reference error</td>
<td>±155 Hz</td>
<td>89.5 Hz</td>
</tr>
</tbody>
</table>

**Oscillator related errors at AES**
- standard deviation: 134.2 Hz
- 99 per cent contour: ±345.6 Hz

**NOTES:**

1. It is assumed that oscillator specifications define a uniform error distribution.
2. The contribution of a number of oscillators to the overall error is estimated using a root-sum-square calculation.
### Table A-5. AES-to-GES frequency error budget with a P channel reference

<table>
<thead>
<tr>
<th>Specification (Hz)</th>
<th>Standard deviation (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES receive reference error × 1.07¹</td>
<td>107</td>
</tr>
<tr>
<td>AES transmit/receive reference error (165 + 155) = 320</td>
<td>184.8</td>
</tr>
<tr>
<td>AES AFC error</td>
<td>57.5</td>
</tr>
<tr>
<td>AFC pilot transmit frequency error²</td>
<td>43.3</td>
</tr>
<tr>
<td>GES AFC error²</td>
<td>57.7</td>
</tr>
<tr>
<td>Frequency error at GES demodulator — standard deviation</td>
<td>232.6</td>
</tr>
<tr>
<td>— 99 per cent contour³</td>
<td>±600</td>
</tr>
</tbody>
</table>

1. This is the total of the first three contributors to frequency error for the P channel. The factor of 1.07 is the approximate ratio of the transmit and receive frequencies.
2. The combination of the GES AFC error and the AFC pilot transmit error produce the frequency error of the satellite translation oscillators on the return link.
3. This is the GES demodulator specification.

### Table A-6. Typical C channel carrier-to-noise densities required

<table>
<thead>
<tr>
<th>Elevation angle to the satellite (degrees)</th>
<th>To-aircraft link C channels (voice)</th>
<th>From-aircraft link C channels (voice)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Objective FEC decoder output BER</td>
<td>10⁻³</td>
<td>10⁻³</td>
</tr>
<tr>
<td>AES minimum antenna gain (dB)</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Carrier/multipath ratio (dB)</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Multipath fading bandwidth (Hz)</td>
<td>20 to 100</td>
<td>20 to 100</td>
</tr>
<tr>
<td>FEC coding rate</td>
<td>½</td>
<td>½</td>
</tr>
<tr>
<td>Modulation method</td>
<td>A-QPSK</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>Theoretical required $E_b/N_0$ (dB)</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Modem implementation loss (dB)</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Imperfect interleaving loss (dB)</td>
<td>3.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Adjacent channel interference loss (dB)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Modem $E_b/N_0$ (dB) required</td>
<td>5.4</td>
<td>2.8</td>
</tr>
<tr>
<td>REQUIRED $C/N_0$ (dBHz)</td>
<td>21.0 kbits/s</td>
<td>48.6</td>
</tr>
</tbody>
</table>
### Table A-7. Typical P channel carrier-to-noise densities required

<table>
<thead>
<tr>
<th></th>
<th>To-aircraft link P channels (low rate data)</th>
<th>To-aircraft link P channel (high rate data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation angle to the satellite (degrees)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Objective FEC decoder output BER</td>
<td>$10^{-5}$</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>AES minimum antenna gain (dB)</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Carrier/multipath ratio (dB)</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Multipath fading bandwidth (Hz)</td>
<td>20 to 100</td>
<td>20 to 100</td>
</tr>
<tr>
<td>FEC coding rate</td>
<td>$\frac{1}{2}$</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>Modulation method</td>
<td>A-BPSK</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>Theoretical required $E_b/N_0$ (dB)</td>
<td>5.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Modem implementation loss (dB)</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Imperfect interleaving loss (dB)</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Adjacent channel interference loss (dB)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Modem $E_b/N_0$ (dB) required</td>
<td>7.3</td>
<td>5.4</td>
</tr>
</tbody>
</table>

**REQUIRED C/N<sub>0</sub> (dBHz)**

<table>
<thead>
<tr>
<th>Data rate (kbits/s)</th>
<th>REQUIRED C/N&lt;sub&gt;0&lt;/sub&gt; (dBHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>35.0</td>
</tr>
<tr>
<td>1.2</td>
<td>38.1</td>
</tr>
<tr>
<td>2.4</td>
<td>41.1</td>
</tr>
<tr>
<td>4.8</td>
<td>42.2</td>
</tr>
<tr>
<td>10.5</td>
<td>45.6</td>
</tr>
</tbody>
</table>

### NOTES:

1. The adjacent channel interference loss is a function of channel spacing. The example losses are for channel rates of 2.4 and 10.5 kbits/s, for A-BPSK and A-QPSK, respectively. The losses should be no greater for the other channel rates because the channel spacing, relative to the channel rate, will be larger.

2. The low data rates (A-BPSK) can also be used with high gain antennas with potentially less C/N<sub>0</sub> required.
### Table A-8. Typical R/T channel carrier to noise densities required

<table>
<thead>
<tr>
<th></th>
<th>From-aircraft link R/T channels (low rate data)</th>
<th>From-aircraft link R/T channel (high rate data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation angle to the satellite (degrees)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Objective FEC decoder output BER</td>
<td>$10^{-5}$</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>AES minimum antenna gain (dB)</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Carrier/multipath ratio (dB)</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Multipath fading bandwidth (Hz)</td>
<td>20 to 100</td>
<td>20 to 100</td>
</tr>
<tr>
<td>FEC coding rate</td>
<td>$\frac{1}{2}$</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>Modulation method</td>
<td>A-BPSK</td>
<td>A-BPSK</td>
</tr>
<tr>
<td>Theoretical required $E_b/N_0$ (dB)</td>
<td>5.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Modem implementation loss (dB)</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Imperfect interleaving loss (dB)$^1$</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Adjacent channel interference loss (dB)$^2$</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Modem $E_b/N_0$ (dB) required</td>
<td>7.5</td>
<td>5.3</td>
</tr>
</tbody>
</table>

**REQUIRED $C/N_0$ (dBHz)**

<table>
<thead>
<tr>
<th>Rate (kbits/s)</th>
<th>$C/N_0$ (dBHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>35.0</td>
</tr>
<tr>
<td>1.2</td>
<td>38.1</td>
</tr>
<tr>
<td>2.4</td>
<td>41.3</td>
</tr>
<tr>
<td>4.8</td>
<td>42.5</td>
</tr>
<tr>
<td>10.5</td>
<td>45.9</td>
</tr>
</tbody>
</table>

**NOTES:**

1. The interleaver loss is a function of channel rate, the example losses correspond to channel rates of 2.4 and 10.5 kbits/s for A-BPSK and A-QPSK, respectively.

2. The adjacent channel interference loss is a function of channel spacing, the example losses correspond to channel rates of 2.4 and 10.5 kbits/s for A-BPSK and A-QPSK, respectively. The losses should be no greater for the other channel rates because the channel spacing, relative to the channel rate, will be larger.

3. The low data rates (A-BPSK) can also be used with high gain antennas with potentially less $C/N_0$ required.
### Table A-9. Channel spacings

<table>
<thead>
<tr>
<th>Channel rate (kbits/s)</th>
<th>Channel spacing (kHz)</th>
<th>Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.0</td>
<td>17.5</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>10.5</td>
<td>10.0/7.5(^1)</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>8.4</td>
<td>7.5</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>6.0</td>
<td>5.0</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>5.25</td>
<td>5.0</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>4.8</td>
<td>5.0</td>
<td>A-QPSK</td>
</tr>
<tr>
<td>2.4</td>
<td>5.0</td>
<td>A-BPSK</td>
</tr>
<tr>
<td>1.2</td>
<td>5.0/2.5(^2)</td>
<td>A-BPSK</td>
</tr>
<tr>
<td>0.6</td>
<td>5.0/2.5(^2)</td>
<td>A-BPSK</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Channel spacing for 10.5 kbits/s channels may be 10.0 or 7.5 kHz, according to the relative availability of power and bandwidth in the operating satellite.
2. Channel spacing of 5.0 kHz applies to the P channel and 2.5 kHz applies to the R and T channel.

### Table A-10. Typical values for computing earliest starting time

<table>
<thead>
<tr>
<th>P Channel bit rate bits/s</th>
<th>P Channel unit delay(s)</th>
<th>Queuing delay(s)</th>
<th>AES processing delay(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>3.0</td>
<td>0.7</td>
<td>1.8</td>
</tr>
<tr>
<td>1200</td>
<td>2.0</td>
<td>0.5</td>
<td>1.2</td>
</tr>
<tr>
<td>≥1200</td>
<td>1.5</td>
<td>0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Table A-11. Minimum throughput values

(minimum achievable throughput on a subnetwork connection, bits/s, with 128-octet packets)

<table>
<thead>
<tr>
<th>Minimum channel rate in use by AES (bits/s)</th>
<th>To-aircraft</th>
<th>From-aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest priority service</td>
<td>Lowest priority service</td>
</tr>
<tr>
<td>600</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>1200</td>
<td>130</td>
<td>70</td>
</tr>
<tr>
<td>2400</td>
<td>150</td>
<td>90</td>
</tr>
<tr>
<td>4800</td>
<td>160</td>
<td>110</td>
</tr>
<tr>
<td>10500</td>
<td>165</td>
<td>115</td>
</tr>
</tbody>
</table>
### Table A-12. Probability of delivering at least one abbreviated access request SU (per cent)

<table>
<thead>
<tr>
<th>Call priority (series length)</th>
<th>Conflicting traffic comprising 1-SU bursts</th>
<th>Conflicting traffic comprising 3-SU bursts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distress/urgency (4)</td>
<td>99.99</td>
<td>97.9</td>
</tr>
<tr>
<td>Flight safety (3)</td>
<td>99.7</td>
<td>93.7</td>
</tr>
<tr>
<td>Regularity/meteorological (2)</td>
<td>97.5</td>
<td>89.2</td>
</tr>
</tbody>
</table>

### Table A-13. Projected AMS(R)S subnetwork abbreviated call set-up delay performance, (seconds) (R and P channels operating at 600 and 10 500 bits/s)

<table>
<thead>
<tr>
<th>AMS(R)S subnetwork signalling transit delay</th>
<th>Average</th>
<th>95 percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Difference between the time at which an air-originated call request (incoming FITE 18) is received at the AES interworking interface and the time at which the GES forwards the resultant call indication (outgoing FITE 18) to the terrestrial network.)</td>
<td>4 [＠600 bits/s]</td>
<td>6 to 11 [＠600 bits/s]</td>
</tr>
<tr>
<td></td>
<td>3 [＠10 500 bits/s]</td>
<td>3 to 7 [＠10 500 bits/s]</td>
</tr>
</tbody>
</table>

**AIR-ORIGINATIONS**

<table>
<thead>
<tr>
<th>Call set-up delay</th>
<th>Average</th>
<th>95 percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Difference between the time at which an air-originated call request (incoming FITE 18) is received at the AES interworking interface and the time at which the C channel is ready for speech).</td>
<td>12 to 14 [＠600 bits/s]</td>
<td>14 to 23 [＠600 bits/s]</td>
</tr>
<tr>
<td></td>
<td>10 to 11 [＠10 500 bits/s]</td>
<td>11 to 14 [＠10 500 bits/s]</td>
</tr>
</tbody>
</table>

**GROUND-ORIGINATIONS**

<table>
<thead>
<tr>
<th>Call set-up delay</th>
<th>Average</th>
<th>95 percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Difference between the time at which a ground-originated call request (incoming FITE 18) is received at the GES interworking interface and the time at which the C channel is ready for speech and the AES forwards the resultant call indication (outgoing FITE 18) to the AES interworking interface.)</td>
<td>9 to 11 [＠600 bits/s]</td>
<td>10 to 17 [＠600 bits/s]</td>
</tr>
<tr>
<td></td>
<td>9 [＠10 500 bits/s]</td>
<td>10 [＠10 500 bits/s]</td>
</tr>
</tbody>
</table>
Figure A-1. Phase noise of L-band signals received by AES

Figure A-2. AES transmit phase noise mask
A-BPSK (Differential encoding)

Source of alternating 1s and 0s synchronous with \( \{a_i\} \)

\[ \text{ENCODING RULES} \]

\[ I_i = Q_i \oplus a_i \]

\[ Q_i = I_i \oplus s_i \]

A-QPSK (Absolute encoding)

\[ \text{Rate } 2/T \]

(Demultiplexer) \[ \text{Rate } 1/T \]

Figure A-3. Data encoders for modulator model
(a) is input data sequence. Channel rate is
1/T for A-BPSK
2/T for A-QPSK

(a) is mapped into two bit streams on the I and Q lines,
each with bit rate 1/T

S
is an ideal sampling process:
input = "1", output = $\delta(t)$
input = "0", output = $-\delta(t)$

D1
is a delay of: 0 for A-BPSK
T/2 for A-QPSK

PSF
are Pulse Shaping Filters

represents an ideal linear modulator

Σ
represents an ideal combiner

Figure A-4. Ideal modulator (A-BPSK and A-QPSK)
Figure A-5. AES A-BPSK transmit filter response mask

Figure A-6. AES A-QPSK transmit filter response mask for 100 per cent roll-off
Figure A-7. Phase deviation tolerance for A-BPSK and A-QPSK transmit filter response mask for 100 per cent roll-off
Figure A-8. Required spectral limits for AES transmissions for 100 per cent roll-off.
Figure A-9. Spectral mask of A-BPSK received by AES

Figure A-10. Spectral mask of A-QPSK received by AES
Figure A-11. P channel functional blocks
Figure A-12. R and T channel functional blocks
Figure A-13. C channel functional blocks
Figure A-14. Satellite subnetwork connection-oriented packet data service
Figure A-15. Typical to-aircraft delay distributions
Figure A-16. Typical from-aircraft delay distribution

600 bits/s, 128 octet SNSDU
Nominal Worst Case Traffic Loading
Highest Priority Service
Figure A-17. Satellite subnetwork protocol entities and virtual circuit establishment
Figure A-18. AES telephony interworking block diagram
GES TELEPHONY INTERWORKING
FUNCTIONAL BLOCK DIAGRAM

AIR ORIGINATED CALL

TERRESTRIAL
TELEPHONY
SIGNALLING
SYSTEM
(e.g. SSB, R2, other)

CIT'T 0.600 series
Recommendations

BITEs

TERRESTRIAL
NETWORK-
SPECIFIC
OUTGOING
SIGNALLING
LOGIC
PROCEDURES

BITEs

IMPLEMENTATION-
SPECIFIC
INTERWORKING
LOGIC
PROCEDURES

GES TELEPHONY
PROCEDURES

CM-LIDUs

CM-LIDus

GES "EXTERNAL" INTERFACE

GROUND ORIGINATED CALL

TERRESTRIAL
TELEPHONY
SIGNALLING
SYSTEM
(e.g. SSB, R2, other)

CIT'T 0.600 series
Recommendations

BITEs

TERRESTRIAL,
NETWORK-
SPECIFIC
INCOMING
SIGNALLING
LOGIC
PROCEDURES

BITEs

IMPLEMENTATION-
SPECIFIC
INTERWORKING
LOGIC
PROCEDURES

GES TELEPHONY
PROCEDURES

CM-LIDus

CM-LIDus

GES "EXTERNAL" INTERFACE

Figure A-19. GES telephony interworking block diagram
Figure A-20. AES management and interfaces
Figure A-21. Spot beam map broadcast
Figure A-22. Required spectral limits for AES transmissions for 60 per cent roll off

Figure A-23. Phase deviation tolerance for A-QPSK transmit filter response mask for 60 per cent roll off
Figure A-24. AES A-QPSK transmit filter response mask for 60 per cent roll-off
Appendix to Attachment A
PERFORMANCE ANALYSIS

A1. RF link analysis

The typical performance measure for an RF link is the average bit error rate (BER). The satellite subnetwork end-to-end performance is related to the RF link performance by a required average BER. The relationship between a channel BER and the achieved carrier-to-noise density performance depends upon the modulation technique and the channel conditions. For the case of ideal linear modulation techniques and an additive white Gaussian noise channel, this relationship can be derived analytically. For the case of a random fading channel this relationship can be derived through simulation, or using a worst case assumption that all multipath energy is equivalent to noise.

The digital RF communications link can be assured of satisfactory average BER performance if the achieved carrier-to-noise power density ratio is greater than or equal to the carrier-to-noise power density ratio required for communication at the desired average BER:

\[
\left( \frac{C}{N_0} \right)_{\text{ACHIEVED}} \geq \left( \frac{C}{N_0} \right)_{\text{REQ}}
\]  

[A.1]

where:

\[
\left( \frac{C}{N_0} \right)_{\text{REQ}}
\]

is the minimum required carrier-to-noise density ratio for communication at the desired average BER.

\[
\left( \frac{C}{N_0} \right)_{\text{ACHIEVED}}
\]

is the carrier-to-noise density ratio achieved by the end-to-end link.

The required carrier-to-noise density ratio is determined by the particular signaling wave-form used and by the noise and propagation characteristics of the channel. Statistical methods can be used to determine the minimum required carrier-to-noise ratio needed to assure operation at an average BER. Statistical methods can also be used to include the effects of propagation environment and other random losses in the form of a required margin.

Hence, for operation at a desired average BER the following relationship must hold:

\[
M_p \times \left( \frac{C}{N_0} \right)_{\text{REQ}} \leq \left( \frac{C}{N_0} \right)_{\text{ACHIEVED}}
\]

[A.2]

where: \( M_p \) is the link margin required for the propagation environment and various random RF parameter variations.

The carrier-to-noise performance measures must be allocated to various portions of the RF link, which are discussed below.

---

A1.1 To-aircraft link analysis

The achieved carrier-to-noise density ratio on the forward link is determined by a number of noise sources in the RF link. With simple, frequency translating transponders, the achieved signal (carrier)-to-noise power ratio can be computed from the expression:

\[
\left( \frac{C}{N_0} \right)_{\text{ACHIEVED}} = \left( \frac{C}{N_0} \right)_{\text{UPR}} \times \left( \frac{C}{N_0} \right)_{\text{FD}} \times \left( \frac{C}{N_0} \right)_{\text{IN}} \times \left( \frac{C}{N_0} \right)_{\text{I10G}} \times \left( \frac{C}{N_0} \right)_{\text{I20G}}
\]

[A.3]

where:

\[ N_{UP} \] = the thermal noise power density of the uplink feeder link.

\[ N_D \] = the thermal noise power density of the L-band downlink.

\[ I_M \] = the intermodulation power density on the L-band downlink due to the satellite transponder.

\[ I_{IS} \] = the intrasystem interference power density.

\[ I_{OD} \] = the downlink L-band intersystem interference power density at the receiver.

\[ I_{OUF} \] = the intersystem interference power density on the feeder link uplink.

An important assumption is inherent in equation [A.3]. It is assumed that in an individual channel bandwidth all the noise sources can be considered to be “white Gaussian” in nature.

A1.2 From-aircraft link analysis

In the same manner as the forward link, the achieved carrier-to-noise density ratio is determined by a number of noise sources in the return link. The achieved carrier-to-noise power density ratio can be obtained from the expression:

\[
\left( \frac{C}{N_0} \right)_{\text{ACHIEVED}} = \left( \frac{C}{N_0} \right)_{\text{FD}} \times \left( \frac{C}{N_0} \right)_{\text{IN}} \times \left( \frac{C}{N_0} \right)_{\text{I10G}} \times \left( \frac{C}{N_0} \right)_{\text{I20G}}
\]

[A.4]
Annex 10 — Aeronautical Telecommunications

where:

\[ N_{DF} = \text{the thermal noise power density of the downlink feeder link.} \]

\[ N_U = \text{the thermal noise power density of the L-band uplink.} \]

\[ I_{M AES} = \text{the minimum operable intermodulation power density expected on the L-band uplink from the multi-carrier operation of the AES high power amplifiers.} \]

\[ I_{ISR} = \text{the intrasystem interference power density.} \]

\[ I_{ODU} = \text{the intersystem interference power density at L-band expected on the uplink.} \]

\[ I_{ODF} = \text{the intersystem interference power density on the feeder link downlink.} \]

A1.3 Propagation anomalies and required margins

An idealized RF link can be adversely affected by a number of factors which can be divided into two basic classes: deterministic and nondeterministic. Deterministic factors influencing RF link margin requirements depend on the propagation path established by the relative locations of the aircraft, satellite and earth in a particular situation. Other deterministic factors are fixed by the system design, such as, information bit rates, modulation type, interleaver depths, coding schemes, etc.

The nondeterministic factors that influence the RF link requirements are system design and operational elements specified by the service provider, degradation due to interference and other propagation-related random losses.

Many factors that influence the RF link requirements may be viewed as losses that reduce the available carrier power and degrade link performance. Detailed discussions of several of these factors are included in the following sections.

A1.3.1 Multipath fading

The term "multipath" refers to a condition in which energy reaches the receiver of a telecommunications system by more than one path. Multipath propagation may result from reflection from land and water surfaces and man-made structures. Multipath operation is generally undesirable, because signals arriving over the different paths arrive with variable relative phase, with the result that they alternatively add constructively or destructively in space. Hence, the total received signal will be characterized by fading, involving repeated minima which may fall below the signal level required for acceptable communications performance. Fading is also significantly higher over water as opposed to land. Furthermore, the signals arriving over the different paths also have different time delays, and in digital systems intersymbol interference can result.

A number of investigators have researched the effects of multipath fading on aeronautical satellite communications. The statistical nature of multipath fading for aeronautical channels is therefore well understood. The amplitude of fading is known to have a Rician distribution. Furthermore, the carrier-to-multipath ratio is known to be a function of the elevation angle to the satellite, and can be expected to be less than 10 dB for elevation angles below 10 degrees.

The carrier-to-noise ratio for a channel is affected by multipath and the particular form of modulation and coding. It is appropriate to include the effects of multipath in setting the carrier-to-noise requirement rather than including it in a separate margin: a conservative approach is to treat the multipath energy as equivalent to additive Gaussian noise, and then, in a coded system, to add additional margin for imperfect interleaving.

A1.3.2 Scintillation

Ionospheric scintillation is a phenomenon involving the effects of the sun and the earth’s magnetic field that produces random variations in electromagnetic waves traversing the ionosphere. The phenomenon is manifested in satellite-earth station RF links as “scintillation fading”; positive and negative (loss) changes in the amplitude of the received signal that can be significant at the L-band frequencies used for the satellite-to-AES link. Values as high as 27 dB have been observed for short periods of time during severe scintillation events; however, the expected value is substantially lower. Phase shifting is also associated with scintillation fading, the effects of which can further degrade RF link performance.

As satellite RF link power margins are normally small for economic reasons, a loss value due to scintillation fading as low as 0.3 dB could be significant. Scintillation loss is highly correlated with the position and local time of the aircraft, thus is of major concern to certain routes and times of flight. Scintillation events also exhibit a seasonal influence, peaking during the vernal and autumnal equinoxes. Significant scintillation loss can be expected for aircraft located near the geomagnetic equator (between 15 degrees latitude North and South) at aircraft local time between 2130 and 0230 hours, and for aircraft located in polar regions (latitudes greater than ±65 degrees although coverage by geosynchronous satellites is effectively limited of latitudes to 80 degrees or less) at any time of day. Available data indicate that scintillation fading is about twice as intense in the equatorial region as compared with the polar regions. For a stationary earth station, about 1 per cent of equatorial region fades exceed 20 dB, and stay above 15 dB for several seconds. Eastward motions of the
Ionosphere at rates of 50 to 200 metres/second are typically seen, implying correlation distances of 10 to 100 metres. It would be possible for an eastbound aircraft's velocity to become "synchronized", resulting in substantially longer fading periods.

Fading in the polar regions is less intense, (about 10 dB for a stationary earth station) as compared with the equatorial region. Also, the velocity of the polar ionosphere is typically higher and more variable, in the range of 100 to 1 000 metres/second.

Data regarding the scintillation effects on earth stations in motion — in particular, on the signal-in-space used by AMSS — is currently limited. Further, the probability of an aircraft experiencing significant effects of scintillation is highly sensitive to its route and timing of its flight. Consequently, the effects of scintillation fading have not been accounted for herein.

A1.3.3 Polarization Loss

The transmission loss between two antennas due to imperfect circular polarization can be calculated by:

\[
L_{pol} = 10 \log \frac{(R_i^2+1)(R_j^2+1)}{(R_i R_j+1)^2 \cos^2(\theta) + (R_i+R_j)^2 \sin^2(\theta)} \quad [A.5]
\]

where it is assumed that the antennas have the same sense (e.g. righthand circular) and where:

- \( R_i \) = the voltage axial ratio (AR) of the ith antenna.
- \( \theta \) = the angle between the major axes of the two elliptically polarized waves that would be radiated, one from each antenna.

The polarization loss is determined completely by the axial ratios and relative orientation of their major axes. The worst case situation is when the major axes are orthogonal, i.e. \( \theta = 90^\circ \). Various forms of equation [A.5] are possible, depending upon the assumptions about the reference antenna. For link budget calculations, one typically might consider the worst case satellite antenna orientation, and a statistical estimate of the effects of AES antenna orientation.

A1.3.4 Path Loss

The path loss due to space is a function only of the frequency and range. The path loss is easily calculated by:

\[
L = \left( \frac{4\pi R^2}{\lambda} \right) \quad [A.6]
\]

where:

\( r \) = the range from the AES to the satellite in metres.

\( \lambda \) = the wavelength in metres.

In general, the range to the satellite, \( r \), is a function of the geographical position of the AES. Conveniently, the range to the satellite is simply a function of the observed elevation to the satellite and is given by:

\[
r = \sqrt{R^2 + (R+h)^2 - 2R(R+h)\cos(\beta)} \quad [A.7]
\]

where:

- \( R \) = the Earth’s mean radius \( \equiv 6378 \) km
- \( h \) = the geosynchronous altitude = 35 786 km (from earth surface at the subsatellite point).
- \( \beta \) = \[ \cos^{-1} \left( \frac{R \cos(\theta)}{R+h} \right) - \theta \]

where:

\( \theta \) = the elevation angle of the satellite relative to level flight.

With the satellite directly overhead, the path loss at 1.545 MHz is 187.3 dB. At 5° elevation, the path loss is 188.5 dB. Therefore, the path loss for aircraft operating with a 5° elevation angle to the satellite is 1.2 dB greater than an aircraft with the satellite directly overhead. In practice, the path loss is calculated for a specific elevation angle to the satellite.

A1.3.5 Precipitation Loss

Raindrops cause attenuation to radio waves by both absorption and scatter. The magnitude of attenuation is a function of frequency, average droplet size, aircraft altitude, elevation angle and rainfall rate. The relationships among these factors are well established through years of research and experimental measurement, making it possible to predict performance with confidence.

In general, attenuation due to rainfall is not significant at the L-band frequencies used for the AMSS service links. However, the feeder links for the AMSS services will be at much higher frequencies where the rain attenuation could be very significant. Feeder link design must take into account the expected rainfall for the location of the ground earth station, particularly as regards link availability.

The effect of rain attenuation on the feeder link in the forward direction can be compensated for by GES power control. The GES power is increased such that the signal maintains the
required level when received at the satellite. One consequence of this increase in power can be to increase the intermodulation products originating at the GES. The link must be designed so that this additional interference will not degrade the over-all achieved carrier-to-noise performance below the required level.

In the return direction, rain attenuation will lower the carrier power to thermal noise ratio for the feeder link. Again, this additional interference must not degrade the over-all achieved carrier-to-noise performance below the required level.

There is no specific allotment in the required margin to account for the effects of rain fading. It is the responsibility of the satellite system designer to ensure that the satellite and GES design is such that the over-all link carrier-to-noise ratio can be maintained under the expected rain conditions in the stated coverage areas.
ATTACHMENT B TO PART I. GUIDANCE MATERIAL FOR THE VHF DIGITAL LINK (VDL)

1. GUIDANCE MATERIAL FOR THE VHF DIGITAL LINK (VDL)

   Note.— The Standards and Recommended Practices (SARPs) referred to are contained in Annex 10, Volume III, Part 1, Chapter 6.

2. SYSTEM DESCRIPTION

2.1 The VDL system provides an air-ground data communications link within the aeronautical telecommunications network (ATN). The VDL will operate in parallel with the other ATN air-ground subnetworks.

2.2 VDL ground stations consist of a VHF radio and a computer capable of handling the VDL protocol throughout the coverage area. The VDL stations offer connectivity via a ground-based telecommunications network (e.g. X.25 based) to ATN intermediate systems which will provide access to ground-based ATN end systems.

2.3 In order to communicate with the VDL ground stations, aircraft are required to be equipped with VDL avionics which will include a VHF radio and a computer capable of handling the VDL protocol. The air-ground communication will utilize 25 kHz channels in the VHF aeronautical mobile (route) service band.

3. VDL PRINCIPLES

3.1 Communications transfer principles

3.1.1 Connectivity between applications running in ATN end systems (ES) using the ATN and its subnetworks, including the VDL, for air-ground communication is provided by the transport layer entities in these end systems. Transport connections between airborne and ground end systems shall be maintained through controlled changes of the precise ATN intermediate systems (IS) and VDL network elements that provide this connectivity.

3.1.2 Transport connections between ATN ES are not linked to a particular subnetwork and ISO 8473 network protocol data units transmitted by an ES can pass via any air-ground ATN compatible subnetwork (such as aeronautical mobile-satellite service (AMSS) data link, SSR Mode S data link or VDL) that meets the quality of service (QOS) requirements. A transport connection between an aircraft ES and a ground ES shall be maintained as long as there is at least one air-ground subnetwork connection between the aircraft IS and a ground IS which has connectivity to the ground ES. In order to maximize subnetwork connectivity, aircraft are expected to maintain air-ground subnetwork connections via any subnetwork (AMSS, Mode S or VDL) with which link layer connectivity can be established.

3.1.3 The VDL subnetwork provides connectivity in the form of switched virtual circuits between ISO 8208 data terminal equipment (DTE) entities of aircraft and ground-based ATN intermediate systems. Due to the fact that VHF signals have only line-of-sight propagation, it is necessary for aircraft in flight to regularly establish link connections with new VDL ground stations in order to maintain VHF coverage. An established VDL virtual circuit between an aircraft DTE and a ground DTE is maintained through a controlled change to a ground station through which the ground DTE can be accessed.

3.1.4 VDL virtual circuits may be cleared when the aircraft or ground IS identifies a policy situation where the virtual circuit to the ground DTE is no longer necessary but this shall only happen if another VDL virtual circuit remains established. A policy situation is a situation where considerations other than coverage influence the decision to establish or maintain a connection. This could be, for example, a situation where an aircraft is within the designated operational coverage area of ground stations operated by different operators and a decision must be made with which operator to establish a connection. The case where an aircraft crosses a border between two States needs special attention. An aircraft has to establish a virtual circuit to the DTE in the IS of the State entered before clearing the virtual circuit with the DTE in the IS of the State left.

3.1.5 The scenarios for subnetwork connection maintenance are shown in Figure B-1. If the ground stations on each side of a State border do not offer ISO 8208 connectivity to

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1. All figures are located at the end of this attachment.

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the DTEs of the IS in both States, aircraft crossing the border
will have to set up a link connection to a ground station in the
State entered before being able to establish a virtual circuit to
the IS of that State. Only after establishment of the new link
connection and virtual circuit, the aircraft will clear the virtual
circuit with the DTE of the IS of the country left over the link
which gave access to that IS. If the VDL aeronautical stations
on both sides of the State border offer connectivity to the IS
in both States, the changeover of the virtual circuits has to
take place over the same link connection.

3.2 VDL quality of service for ATN routing

3.2.1 The use of the VDL system for air-ground
communications will depend on the routing decisions of
aircraft and ground-based ATN intermediate systems (IS).
These ISs will decide on the path to be used for air-ground
communications based on quality of service values requested
by transmitting end systems (ESs).

3.2.2 The IS at each end of the air-ground connections
must interpret the requested QOS value and decide which of
the available connections can best be met. It is important that
the level of QOS which a VDL connection is perceived as
providing is set at a level which corresponds to its true
performance.

3.2.3 In cases where the VDL is the only data link with
which an aircraft has been equipped, all communications must
be routed via a VDL connection and the value set for QOS to
be provided by the connection must not block the
communication.

3.2.4 In other cases where aircraft are equipped with
other air-ground data links (such as AMSS and SSR Mode S)
there may be simultaneous parallel connections over multiple
subnetworks. In these cases, the values for QOS provided by
each subnetwork must be set so as to ensure that the VDL
connection will be used where appropriate.

3.2.5 It is necessary that co-ordination take place
between aircraft operators, ground station operators and ground
system operators to ensure that the right balance is achieved
between different subnetworks.

4. VDL GROUND STATION
NETWORK CONCEPT

4.1 Access

4.1.1 A VDL ground station will provide access for
aircraft to the ground ATN IS using the VDL protocol over a
VHF channel.

4.2 Institutional issues concerning VDL
ground station network operators

4.2.1 An ATS provider wishing to use VDL for air
traffic service (ATS) communications needs to ensure that the
VDL service is available. The ATS provider can either operate
the VDL ground station network itself or arrange for the
operation of the VDL stations (or VDL network) by a tele-
communications service provider. It seems likely that
individual States will make different arrangements for the
provision of VDL service to aircraft. Operation and imple-
mentation of VDL need to be co-ordinated at a regional level
in order to ensure acceptable service on international routes.

4.2.2 The use of a VDL ground station network by enti-
ties external to the ATS provider will be subject to service
agreements between the ATS provider and the telecommuni-
cations service provider. These agreements set out the obliga-
tions of the two parties and need, in particular, to be specific
on the quality of service provided as well as the characteristics
of the user interface.

4.2.3 It seems likely that some VDL ground station
network operators will levy user charges. These are expected
to be levied either on the aircraft operators and/or on the ATS
providers. It is necessary to ensure that the use of VDL is
feasible for those aircraft operators intended to use VDL for
ATS/AOC communications.

4.3 VDL ground
station equipment

4.3.1 A VDL ground station will consist of a VHF radio
and a computer which may be separate or integrated with the
radio. The VDL functionality of the VHF radio equipment will
be similar to that installed in aircraft.

4.3.2 The provision of network status monitoring is an
important element in the maintenance of the highest avail-
ability possible.

4.4 Ground station siting

4.4.1 The line of sight limitations of VHF propagation
is an important factor in the siting of ground stations. It is
necessary to ensure that the ground stations are installed in a
manner which provides coverage throughout the designated
operational coverage area (DOC).

4.4.2 The coverage requirements for VDL depend on the
applications that are intended to operate over the VDL. These
applications may function, for example, when an aircraft is at
en-route altitude, in a terminal area or on the ground at an
airport.
4.4.3 En-route coverage can be provided using a small number of ground stations with a large DOC (for example, the range of a VHF signal from a station at sea level and an aircraft at 37,000 ft is approximately 200 NM). Hence, it is in fact desirable that the smallest number of ground stations possible be used to provide en-route coverage in order to minimize the possibility of simultaneous uplink transmissions from ground stations which may cause message collisions on the VHF channel. The factors limiting en-route coverage will be availability of landmass and the availability of a communications link from a ground station to other ground systems.

4.4.4 Terminal area coverage requires, in general, the installation of ground stations at all airports where VDL operation is required in order to ensure coverage throughout the terminal area.

4.4.5 Aerodrome surface communication coverage must be provided by a ground station at the airport but, due to the physical structure of the airport, it may not be possible to guarantee coverage in all areas with a single station.

4.5 Ground station frequency engineering

4.5.1 The choice of the VHF channel on which a ground station will operate depends on the coverage that the ground station will be required to provide. Coverage on a particular channel is provided by a collection of ground stations operating on that channel and the communications on that channel will occupy the channel for all the ground stations in a coverage area.

4.5.2 As with VHF voice communications, VDL communications cannot be limited to propagating only within States and frequency co-ordination between States will be required in the allocation of VDL frequencies. The nature of the protocol does, however, allow for frequency re-use by several ground stations within the same coverage area and hence the rules for the assignment of frequencies are not the same as for voice communications.

4.5.3 The carrier sense multiple access (CSMA) media access control protocol (MAC) layer used in VDL cannot exclude message collisions if some stations using a frequency channel cannot receive the transmissions of other stations, a situation known as a hidden transmitter situation. Hidden transmitters lead to simultaneous transmissions which can cause the intended receiver of one or both transmissions to be unable to decode the received signal.

4.5.4 A frequency will be assigned to providing en-route coverage and all the en-route stations will be set to operate on this frequency. In order to minimize the probability of simultaneous transmissions on the channel by hidden transmitters in a CSMA environment, this channel may not be used for terminal area or aerodrome surface communications except in areas of very low channel loading.

4.5.5 The VDL SARPs call for the provision of a common signalling channel (CSC) on which access to VDL service will be guaranteed in all areas where VDL Mode 2 service is available. This is especially important at airports and on the edge of VDL en-route coverage zones where aircraft are likely to establish initial VDL connectivity. Since the characteristics of Mode 1 and Mode 2 radio frequency transmissions are not compatible, the CSC cannot be used for Mode 1 communications. There is no requirement for a CSC for VDL Mode 1.

4.6 Ground station connection to intermediate systems

4.6.1 In order to provide access to the ground systems which are connected to the aeronautical telecommunications network, a VDL ground station needs to be connected to one or more ATN IS. The purpose of a VDL ground station is to interconnect aircraft with the ground-based ATN via which communications with terrestrial ATN ES can take place.

4.6.2 The ground-based ATN IS can be co-hosted in the VDL ground station computer in which case the VDL subnetwork virtual circuit will end in that computer. This architecture will have an impact on the exchanges required when an aircraft establishes a VDL link with a new ground station. The exact exchange will depend on whether the ground stations contain separate IS or elements of the same distributed intermediate system.

4.6.3 If the IS is not contained in the VDL ground station, it will be connected to the ground station by one of the following means:

a) wide area network (WAN);

b) local area network (LAN); and

c) dedicated communications line.

4.6.4 In all cases, in order to be in accordance with the Manual of the Aeronautical Telecommunication Network (ATN) (Doc 9578) for providing an open systems interconnection (OSI) compatible connection-oriented subnetwork service between the aircraft IS and the ground-based IS, the VDL ground station computer will be required to extend the VDL virtual circuit across the terrestrial network or link.

4.6.5 In order to provide simultaneous virtual circuits to several terrestrial ISs, the VDL ground station computer needs to contain a VDL subnetwork entity capable of converting addresses in VDL subnetwork call requests into addresses in the ground-based network.
5. VDL AIRBORNE
OPERATING CONCEPT

5.1 Avionics

5.1.1 **VDL avionics.** In order to operate in a VDL network, aircraft need to be equipped with an avionics system providing the VDL subnetwork user (ISO 8208 DTE) function. The system providing this function will also provide the subnetwork user functions for the other air-ground ATN-compatible subnetworks and the aircraft ATN intermediate system function and, hence, its development is necessary in order to provide ATN communications to multiple end-systems or over multiple air-ground subnetworks.

5.2 VDL avionics certification

5.2.1 The VHF digital radio may also provide for double-side band amplitude modulation (DSB-AM) voice capability for emergency back-up to VHF radios used for voice communications. It would be necessary in this case to demonstrate that the VDL functionality of the VDR does not interfere with the DSB-AM voice functionality.

5.2.2 The VDL function in the VHF digital radio provides an air-ground data link service to the VDL subnetwork user entity of the aircraft ATN intermediate system.

If the provision of a VHF subnetwork service to an ATN intermediate system were considered an essential service for a particular installation, the VDL functionality of the VDR would need to be certified as an essential function. The use of VDL for ATS communications is not, however, intended to require two aircraft radios to operate simultaneously in VDL mode.

5.3 Registration of aircraft with VDL network operators

5.3.1 For normal communications service, it is to be expected that aircraft operators will be required to register their aircraft with the network operators. In emergency or back-up situations, it must be possible for any VDL-equipped aircraft to establish connectivity over any VDL ground station network.

5.3.2 Registration of aircraft VDL stations with VDL network operators is desirable for network management since, for example, a network operator may identify a temporary fault in the VDL communications from an aircraft and would wish to contact the operator of the aircraft in order to have the fault resolved. Registration of aircraft is also useful in planning the required ground station network capacity. Registration with a VDL ground station network operator does not necessarily imply that the aircraft operator will be charged for use of the VDL ground station network.
FIGURE FOR ATTACHMENT B

Scenario where boundary ground stations provide access to a single IS

Scenario where boundary ground stations provide access to IS in two routing domains

Figure B-1
ATTACHMENT A TO PART II. GUIDANCE MATERIAL FOR COMMUNICATION SYSTEMS

1. VHF COMMUNICATIONS

1.1 Audio characteristics of VHF communication equipment

1.1.1 The aeronautical radiotelephony services represent a special case of the application of radiotelephony, in that the requirement is for the transmission of messages in such a way that fidelity of wave form is of secondary importance, emphasis being upon fidelity of basic intelligence. This means that it is not necessary to transmit those parts of the wave form which are solely concerned with individuality, accent and emphasis.

1.1.2 The effective acceptance bandwidth for 8.33 kHz equipment is required to be at least plus and minus 3 462 Hz. This value considers the general case, i.e. air-to-ground transmissions and consists of 2 500 Hz audio bandwidth, 685 Hz for an aircraft transmitter instability of 5 ppm, 137 Hz for a ground receiver instability of 1 ppm and 140 Hz due to Doppler shift (2.2.2.4 and 2.3.2.6 of Part II refer).

1.2 Off-set carrier system

The following are examples of offset carrier systems which meet the requirements of Part II, 2.2.1.1.1.

a) 2-carrier system. Carriers should be spaced at plus and minus 5 kHz. This requires a frequency stability of plus or minus 2 kHz (15.3 parts per million at 130 MHz).

b) 3-carrier system. Carriers should be spaced at zero and plus and minus 7.3 kHz. This requires a frequency stability of plus or minus 0.65 kHz (5 parts per million at 130 MHz).

The following are examples of 4- and 5-carrier systems which meet the requirements of Part II, 2.2.1.1.1.

c) 4-carrier system. Carriers should be spaced at plus and minus 2.5 kHz and plus and minus 7.5 kHz. This requires a frequency stability of plus or minus 0.5 kHz (3.8 parts per million at 130 MHz).

d) 5-carrier system. Carriers should be spaced at zero, plus and minus 4 kHz and plus and minus 8 kHz. A frequency stability in the order of plus or minus 40 Hz (0.3 parts per million at 130 MHz) is an achievable and practicable interpretation of the requirement in this case.

Note 1.— The carrier frequency spacings referred to above are with respect to the assigned channel frequency.

Note 2.— In aircraft receivers which employ a measurement of the received carrier-to-noise ratio to operate the mute, the audio heterodynes caused by the reception of two or more off-set carriers can be interpreted as noise and cause the audio output to be muted even when an adequate wanted signal is present. In order that the airborne receiving system can conform with the sensitivity recommendations contained in Part II, 2.3.2.2, the design of the receivers may need to ensure that their sensitivity is maintained at a high level when receiving off-set carrier transmissions. The use of a carrier level override is an unsatisfactory solution to this requirement, but where it is employed, setting the override level as low as possible can ameliorate the problem.

1.3 Immunity performance of COM receiving systems in the presence of VHF FM broadcast interference

1.3.1 With reference to the Note of 2.3.3.2 of Part II, the immunity performance defined there must be measured against an agreed measure of derogation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the checking of receiving station equipment on bench test can be performed to a repeatable set of conditions, and results, and to facilitate their subsequent approval. An adequate measure of immunity performance may be obtained by the use of wanted signal of minus 87 dBm into the receiving equipment and the signal modulated with a 1 kHz tone at 30 percent modulation depth. The signal-to-noise ratio should not fall below 6 dB when the interfering signals specified at Part II, 2.3.3.1 and 2.3.3.2 are applied. The broadcast signals should be selected from frequencies in the range between 87.5 and 107.9 MHz and should be modulated with a representative broadcast type signal.

Note 1.— The signal level of minus 87 dBm assumes a combined antenna and feeder gain of 0 dB.

Note 2.— The reduction in the signal-to-noise ratio quoted above is for the purpose of standardization when checking that receiving station equipment on bench measurements meet the required immunity. In the planning of frequencies and in the assessment of protection from FM broadcast interference, a value not less than this, and in many cases higher, depending on the operational circumstances in individual cases, should be chosen as the basis of the interference assessment.
2. SELCAL SYSTEM

2.1 This material is intended to provide information and guidance relating to the operation of the SELCAL system. It is associated with the Recommended Practices contained in Part II, Chapter 3.

1) **Function.** The purpose of the SELCAL system is to permit the selective calling of individual aircraft over radiotelephone channels linking the ground station with the aircraft, and is intended to operate on en-route frequencies with existing HF and VHF ground-to-air communications transmitters and receivers with a minimum of electrical and mechanical modification. The normal functioning of the ground-to-air communications link should be unaffected, except at such time as the selective calling function is being formed.

2) **Principles of operation.** Selective calling is accomplished by the coder of the ground transmitter sending a single group of coded tone pulses to the aircraft receiver and decoder. The airborne receiver and decoder equipment is capable of receiving and interpreting, by means of an indicator, the correct code and rejecting all other codes in the presence of random noise and interference. The ground portion of the coding device (ground selective calling unit) supplies coded information to the ground-to-air transmitter. The airborne selective calling unit is the special airborne equipment which operates with existing communications receivers on the aircraft to permit decoding of the ground-to-air signals for display on the signal indicator. The type of signal indicator can be chosen to suit operational requirements of the user and may consist of a lamp, a bell, a chime or any combination of such indicating devices.

--- END ---