

## RECOMMENDATION ITU-R M.1643\*

**Technical and operational requirements for aircraft earth stations  
of aeronautical mobile-satellite service including those  
using fixed-satellite service network transponders in  
the band 14-14.5 GHz (Earth-to-space)**

(2003)

**Summary**

This Recommendation provides the technical and operational requirements for aircraft earth stations (AES) of aeronautical mobile-satellite service (AMSS), including those using FSS network transponders operating in the band 14-14.5 GHz (Earth-to-space), that should be used by administrations as a technical guideline for establishing conformance requirements for AES and facilitating their licensing, for worldwide use.

The ITU Radiocommunication Assembly,

*considering*

- a) that various technically and operationally different aeronautical mobile-satellite service (AMSS) networks have been designed to commence operation in the near future;
- b) that these planned AMSS networks may provide access to a variety of broadband communication applications (Internet, email, internal corporate networks) to and from aircraft on a global basis;
- c) that the aircraft earth station (AES) will operate on national and international airlines around the world;
- d) that circulation of AES is usually a subject of a number of national and international rules and regulations including satisfactory conformance to a mutually agreed technical standard and operational requirements;
- e) that there is a need for identifying the technical and operational requirements for the conformance testing of AES;

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\* NOTE – The Arab Group represented at RA-03 reserves its position on this Recommendation and is not ready to accept any repercussions with respect to WRC-03 Agenda item 1.11.

f) that the identification of technical and operational requirements for AES would provide a common technical basis for facilitating conformance testing of AES by various national and international authorities and the development of mutual recognition arrangements for conformance of AES;

g) that the technical and operational requirements need to achieve an acceptable balance between radio equipment complexity and the need for effective use of the radio-frequency spectrum,

*considering also*

a) that in the frequency band 14-14.5 GHz there are allocations to the FSS (Earth-to-space), radionavigation, fixed and mobile (except aeronautical mobile) services on a primary basis; that secondary services allocated in the band 14-14.5 GHz or in parts of the band include mobile-satellite (except aeronautical mobile-satellite) service (Earth-to-space), space research service (SRS), radio astronomy service (RAS), and radionavigation-satellite service;

b) that there is a requirement to fully protect all primary services and pre-existing systems of secondary services in the band 14-14.5 GHz;

c) that results of the studies conducted in accordance with Resolution 216 (Rev.WRC-2000) showed the feasibility of using the band 14-14.5 GHz by AMSS (Earth-to-space) on a secondary basis under certain conditions and arrangements<sup>1</sup>;

d) that the identification by ITU-R of technical and operational requirements for AES operating in the band 14-14.5 GHz could assist administrations to prevent harmful and/or unacceptable interference to other services;

e) that technical and operational characteristics should be continuously and accurately measurable and controllable,

*recommends*

**1** that the technical and operational requirements<sup>1</sup> for aircraft earth stations of AMSS networks operating in the band 14-14.5 GHz given in Annexes 1 and 2 be used by administrations as a guideline for:

- establishing conformance requirements for AES;
- facilitating AES operations.

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<sup>1</sup> The characteristics of the typical aircraft earth stations need to fulfil the requirements described in this Recommendation and, further, need to be within the envelope of those initially published in the International Frequency Information Circular (BR IFIC) relating to the corresponding FSS network. In the case that the characteristics are outside of the envelope of those in the initial publication, the required coordination of such an aircraft earth station needs to be effected in accordance with the current provisions of the Radio Regulations (RR) and a modified Rule of Procedure as contained in § 2 of the Rules of Procedure relating to RR No. 11.32, as appropriate.

## Annex 1

### Technical and operational requirements for AES of AMSS networks in the band 14-14.5 GHz (Earth-to-space)

#### Part A

#### Essential requirements related to the protection of FSS networks

- 1** AMSS networks should be coordinated and operated in such a manner that the aggregate off-axis e.i.r.p. levels produced by all co-frequency AES within AMSS networks are no greater than the interference levels that have been published and coordinated for the specific and/or typical earth station(s) pertaining to FSS networks where FSS transponders are used.
- 2** The design, coordination and operation of an AES should, at least, account for the following factors which could vary the aggregate off-axis e.i.r.p. levels generated by the AES:

  - 2.1** mispointing of AES antennas. Where applicable, this includes, at least, effects caused by bias and latency of their pointing systems, tracking error of closed loop tracking systems, misalignment between transmit and receive apertures for systems that use separate apertures, and misalignment between transmit and receive feeds for systems that use combined apertures;
  - 2.2** variations in the antenna pattern of AES. Where applicable, this includes, at least, effects caused by manufacturing tolerances, ageing of the antenna and environmental effects. AMSS networks using certain types of AES antennas, such as phased arrays, should account for variation in antenna pattern with scan angles (elevation and azimuth). Networks using phased arrays should also account for element phase error, amplitude error and failure rate;
  - 2.3** variations in the transmit e.i.r.p. from AES. Where applicable, this includes, at least, effects caused by measurement error, control error and latency for closed loop power control systems. Network control and monitoring centres (NCMCs) that calculate the e.i.r.p. of AES based on the received signal need to take into account error sources and latency in this calculation. NCMCs that calculate the e.i.r.p. of AES based on input power must account for measurement error and reporting latency.
- 3** AES that use closed loop tracking of the satellite signal need to employ an algorithm that is resistant to capturing and tracking adjacent satellite signals. AES must immediately inhibit transmission when they detect that unintended satellite tracking has happened or is about to happen.
- 4** AES should be subject to the monitoring and control by an NCMC or equivalent facility. AES must be able to receive at least “enable transmission” and “disable transmission” commands from the NCMC. AES must automatically cease transmissions immediately on receiving any

“parameter change” command, which may cause harmful interference during the change, until it receives an “enable transmission” command from its NCMC. In addition, it should be possible for the NCMC to monitor the operation of an AES to determine if it is malfunctioning.

5 AES need also to be self-monitoring and, should a fault which can cause harmful interference to FSS networks be detected, the AES must automatically mute its transmissions.

## Part B

### Essential requirements related to the protection of the fixed service

In the 14-14.5 GHz frequency band as used by fixed service networks, within line-of-sight of the territory of an administration where fixed service networks are operating in this band, the maximum pfd produced at the surface of the Earth by emissions from a single AES, of an AMSS network should not exceed:

$$\begin{array}{lll} -132 + 0.5 \cdot \theta & \text{dB(W/(m}^2 \cdot \text{MHz))} & \text{for } \theta \leq 40^\circ \\ -112 & \text{dB(W/(m}^2 \cdot \text{MHz))} & \text{for } 40 < \theta \leq 90^\circ \end{array}$$

where  $\theta$  is the angle of arrival of the radio-frequency wave (degrees above the horizontal).

NOTE 1 – The aforementioned limits relate to the pfd and angles of arrival that would be obtained under free-space propagation conditions.

NOTE 2 – An e.i.r.p. mask can be derived from the aforementioned pfd mask by applying the method given in Annex 2 of this Recommendation. Simplification of the resulting e.i.r.p. mask could also be considered.

## Part C

### Essential requirements related to sharing with the RAS

In order to protect the radio astronomy in the band 14.47-14.5 GHz, AMSS earth stations should comply with both following measures:

#### *AMSS channels in the 14.47-14.5 GHz band*

- AMSS stations do not transmit in the 14.47-14.5 GHz band within line-of-sight of radio astronomy stations operating within this band;
- or,
- if an AMSS operator intends to operate co-frequency within the visibility of the radio astronomy station, a specific agreement with the radio astronomy station will be needed to ensure that AMSS AES will meet the requirements of Recommendations ITU-R RA.769 and ITU-R RA.1513 within the 14.47-14.5 GHz band during observations. Where practicable, this may include advance information to AMSS operators regarding observation schedules.

#### *AMSS channels in the 14-14.47 GHz band*

All AES transmitters on channels in the 14-14.47 GHz band within line-of-sight of radio astronomy stations during radio astronomy observations have emissions in the band 14.47-14.5 GHz such that they meet the levels and percentage of data loss given in

Recommendations ITU-R RA.769 and ITU-R RA.1513. Results from studies show that the following AES pfd levels (dB(W/(m<sup>2</sup> · 150 kHz))) in the band 14.47-14.5 GHz are sufficient, with some margin, to meet the radio astronomy pfd levels in Recommendation ITU-R RA.769 and the percentage of data loss given in Recommendation ITU-R RA.1513, i.e.:

$$\begin{array}{lll} -190 + 0.5 \cdot \theta & \text{dB(W/(m}^2 \cdot 150 \text{ kHz))} & \text{for } \theta \leq 10^\circ \\ -185 & \text{dB(W/(m}^2 \cdot 150 \text{ kHz))} & \text{for } 10^\circ < \theta \leq 90^\circ \end{array}$$

where  $\theta$  is the angle of arrival of the radio-frequency wave (degrees above the horizontal).

Such AES pfd levels in the band 14.47-14.5 GHz may be achieved by the AMSS operators through a combination of reduced AES signal power, sharp filtering, maintaining adequate frequency separation, or better AES antenna performance.

## Part D

### Essential requirements related to sharing with the space research service

Coordination agreements should be developed between AMSS and space research systems based on controlling the emissions levels of the AES in the frequency band used by the SRS systems, and, in severe cases, may require cessation of AES emissions on frequencies used by the SRS system when operating in the vicinity of the space research earth station. Specifics of the agreements will vary based on the characteristics of the individual SRS sites and the AMSS networks.

## Annex 2

### Derivation of a lower hemisphere e.i.r.p. mask from a pfd mask

In testing AMSS equipment to determine if it meets a given pfd mask, such as the one in Annex 1, Part B, it may be useful to determine an equivalent e.i.r.p. mask that can be used for testing purposes.

The pfd mask,  $\text{pfd}(\theta)$  where  $\theta$  is the angle of arrival (elevation angle) at the Earth's surface, can be used to mathematically determine an e.i.r.p. mask,  $\text{e.i.r.p.}(\gamma, H)$  where  $\gamma$  is the angle below the local horizontal plane and  $H$  is the altitude of the aircraft. This conversion proceeds in two steps. First,  $\gamma$  is converted to an equivalent angle of arrival,  $\theta$ . Then the length of the propagation path for angle of arrival  $\theta$  is determined and used to calculate the spreading loss for the path and the resulting e.i.r.p.

*Step 1:* Calculation of an angle of arrival in degrees,  $\theta$ , from  $\gamma$  and  $H$ :

$$\theta = \arccos((R_e + H) \cos(\gamma)/R_e)$$

where:

- $\theta$ : angle of arrival
- $R_e$ : earth radius (6378 km)
- $H$ : altitude of the aircraft (km)
- $\gamma$ : angle below horizontal.

NOTE 1 – If the argument of the arccos function is greater than 1, the propagation path in the direction of the angle  $\gamma$  does not intersect the Earth. In this case, which occurs for values of  $\gamma$  of about  $3.5^\circ$  or less, a value for  $\theta$  does not exist and so there is no defined value for the pfd mask.

Step 2: Calculation of the e.i.r.p. value from the defined pfd( $\theta$ ):

$$d = (R_e^2 + (R_e + H)^2 - 2 R_e (R_e + H) \cos(\gamma - \theta))^{1/2}$$

$$\text{e.i.r.p.}(\gamma, H) = \text{pfd}(\theta) + 10 \log_{10}(4 \pi d^2) + 60$$

where:

- $d$ : distance between the AES and the considered point on the Earth's surface (km)
- pfd( $\theta$ ): (dB(W/(m<sup>2</sup> · MHz)))
- e.i.r.p.: (dB(W/MHz)).

The graph in Fig. 1 shows this function for various aircraft altitudes based on the pfd mask provided in Annex 1, Part B of this Recommendation.

