Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

THE COMPATIBILITY & SHARING OF THE AERONAUTICAL MOBILE SATELLITE SERVICE WITH EXISTING SERVICES IN THE BAND 14.0-14.5 GHz

Molde, February 2003

Acronyms

AES	Aircraft Earth Station (operating under the AMSS)
AMSS	Aeronautical Mobile Satellite Service
BR	Radiocommunication Bureau
BRIFIC	R International Frequency Information Circular
CDMA	Coded Division Multiple Access
CEPT	European Committee for Post and Telecommunication
CPM	Conference Preparatory Meeting
DRS	Data Relay Satellite
ECA	European Common Allocation (www.ero.dk)
EIRP	Effective Isotropically Radiated Power
EN	European Norm
ECC	Electronic Communications Committee
ENG	Electronic News Gathering
ES	Earth Station
ETSI	European Telecommunication Standardization Institute
FS	Fixed Service
FSS	Fixed Satellite Service
GSO	Geostationary Satellite Orbit
ITU	International Telecommunication Union
ITU-R	Radio sector of the ITU
ITU-R DNR	Draft New Recommendation of the ITU-R
ITU-R Rec.	Recommendation of the ITU-R
ITU-R WP	Working Party of ITU-R
LES	Land Earth Station
LMSS	Land-MSS
MES	Mobile Earth Station
MMSS	Maritime-MSS
MSS	Mobile Satellite Service
NCMC	Network Control and Monitoring Center
O-QPSK	Offset-QPSK
QPSK	Quadrature Phase Shift Keying (Digital Modulation)
PFD	Power Flux Density
RAS	Radio Astronomy Service
RMS	Root-Mean-Square
RNS	Radionavigation Service
RNSS	Radionavigation Satellite Service
RR	Radio Regulation of the ITU
SRS	Space Research Service
VSAT	Very Small Aperture Terminal

WRC	World Radio Conference

EXECUTIVE SUMMARY

The requirement for Aeronautical Mobile Satellite Service (AMSS) networks is anticipated to meet a growing demand for two-way broadband communications. AMSS networks have been designed to provide in-flight data (access to Internet, e-mail, internal corporate networks on board aircraft) and entertainment content to passengers and operators of commercial and business aircraft.

This report addresses the sharing and compatibility environment within the CEPT between the secondary AMSS and existing services in the bands 14.0 – 14.5 GHz.

Currently being developed, the ITU-R Recommendation M.1643 provides guidance to system designers and licensing administrations regarding the technical and operational requirements for aircraft earth stations of AMSS networks in the 14-14.5 GHz band. Transmissions from the aircraft earth stations (AES) are under positive control of a network control facility. This control includes AES terminal entry into the network, authorisation of transmission frequencies, authorisation to change the transmit power and data rate, and control of the authorised transmit power level.

Compatibility with primary services has been addressed. This report considered the following:

- For the fixed service, a power flux density mask was developed to provide adequate protection and compatibility with fixed service networks.
- For the fixed-satellite service, AMSS networks should transmit no greater than the interference levels that have been accepted by other satellite systems.
- For the case of the mobile and radio navigation services, based on the information available, it was concluded that compatibility is feasible.

This report also considered the sharing with the following secondary services:

- For the mobile-satellite service (MSS), analysis confirmed that interference protection margins make it feasible for AMSS and MSS networks to share when they employ co-frequency transponders on adjacent satellites.
- For the Radio Astronomy service two aspects were addressed:
  - In- band sharing; AMSS stations shall not transmit within line-of-sight of radio astronomy stations operating within this band, or if an AMSS operator intends to operate, consultation with the Administrations concerned is needed, which may lead to a feasible co-ordination arrangement.
  - Adjacent band sharing; AES transmitters on channels adjacent to the Radioastronomy Service (RAS) band within line of sight of radio astronomy stations during radio astronomy observations are required to meet (with some margin) the RAS power flux-density levels in ITU-R Recommendation RA.769.
- For the radio navigation satellite or space research service, no systems were identified using, or proposing to use this secondary allocation within the CEPT. Therefore, use of the band by AMSS is considered feasible in respect of these allocations.

This report has concluded that AMSS networks can operate within the band 14.0 – 14.5 GHz provided operational constraints on the AMSS are applied and tailored to the needs of specific radio assignments and territories within the CEPT.

INDEX TABLE

1 INTRODUCTION

MSS systems have been in operation for many years offering land and maritime mobile satellite services with a proven ability to operate in co-existence with all other services having primary or secondary allocation in the same band. The requirement for the Aeronautical Mobile-Satellite Services (AMSS) networks in the band 14.0 - 14.5 GHz is anticipated to meet a growing demand for two-way broadband communications by passengers and operators of commercial aircraft.

This report addresses the sharing and compatibility environment within the CEPT between the secondary aeronautical mobile-satellite service (AMSS) and existing services in the bands 14.0 – 14.5 GHz. Studies were performed with all services including those on a secondary basis (where operating parameters were available) to assess the feasibility of compatibility with primary services and sharing with existing secondary services.

1.1 Status of the secondary aeronautical mobile-satellite service

As per Radio Regulation 5.28, stations of a secondary service:

a) shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date;

b) cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date.

C) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.

1.2 ITU Radio Regulation services allocated in the band 14.0 – 14.5 GHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>14-14.25</td><td colspan="2">FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
RADIONAVIGATION 5.504
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Space research
5.505</td></tr>
<tr><td>14.25-14.3</td><td colspan="2">FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
RADIONAVIGATION 5.504
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Space research
5.505 5.508 5.509</td></tr>
<tr><td>14.3-14.4
FIXED
FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Radionavigation-satellite</td><td>14.3-14.4
FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Radionavigation-satellite</td><td>14.3-14.4
FIXED
FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Radionavigation-satellite</td></tr>
<tr><td>14.4-14.47</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Space research (space-to-Earth)</td></tr>
<tr><td>14.47-14.5</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space) 5.484A 5.506
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) except aeronautical mobile-satellite
Radio astronomy
5.149</td></tr>
</table>

Table 1: Extract from RR Article 5 (WRC-2000)

2 AMSS OVERVIEW

AMSS networks have been designed to provide in-flight data (access to Internet, e-mail, internal corporate networks on board aircraft) and entertainment content to passengers and operators of commercial and business aircraft.

These networks are composed of four segments (see Figure 1):

- a "space segment", which consists of forward-link transponders in the 14-14.5 GHz band (Earth-space) and return-link transponders;
- an "aircraft earth station (AES) segment", which consists of AES terminals installed on multiple aircraft;
- a "land earth station (LES) segment", which consists of one or more LES providing feeder-link to the satellites;
- and a "network control and monitoring centre (NCMC) segment", which, among other functions, controls the aggregate emissions of the AMSS network in order to prevent interference to other systems. The LES segment is connected to the NCMC segment with high speed data connections.

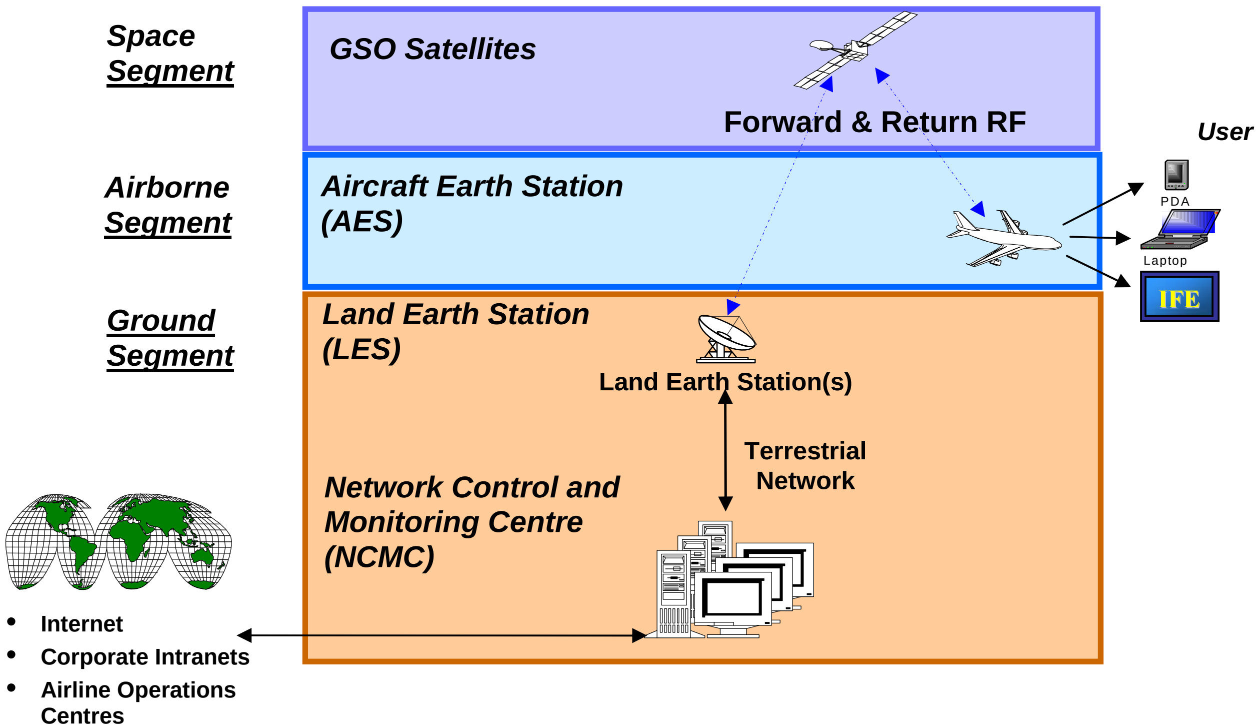

Figure 1: AMSS network architecture

The communication service to the aircraft in the satellite network consists of two parts (see Figure 1), a forward link and a return link.

- Each forward link carries data from the NCMC to the AES, via the LES and the satellite link. Multiple AES terminals share the same forward link transponder signal.

- The return link carries data from multiple AES terminals to the NCMC using code division multiple access (CDMA), via the satellite and the LES link, and uses transponders that are separate from the forward link. Each AES may transmit at variable data rates.

Transmissions from the AES are under positive control of the NCMC. This control includes AES terminal entry into the network, authorization of transmission frequencies, authorization to change the transmit power and data rate, and control of the authorized transmit power level.

Positive control of AES terminals is essential to maintaining control of aggregate off-axis emissions towards other satellite networks. Features are included in the system design to ensure that no transmissions take place from an AES unless it is under positive control. In addition, the system will include methods to identify and shut down malfunctioning terminals.

The NCMC ensures that the aggregate off-axis emissions from a group of co-frequency AES terminals are no greater than the interference levels that have been accepted by other satellite systems.

The AES high gain antennas are mounted on top of the aircraft and they point to a single orbital position.

AMSS networks will protect terrestrial services by limiting emissions towards the ground in locations and frequency bands where terrestrial services are operating. The NCMC is aware of the location of AES terminals within its AMSS network and can enforce operational limits based on the location of AES terminals. In order to protect Fixed Service (FS) links, AMSS networks can restrict AES power flux density (pfd) at the Earth surface when AES terminals are visible to territories where FS is operating. In order to protect the Radio Astronomy Service (RAS) and Space Research Service (SRS), AMSS networks can restrict AES terminal operating frequencies and power when AES terminals are visible to specific RAS and SRS sites. Operational limits may be tailored to the needs of specific sites and territories.

2.1 Service Up-Link Frequencies

The AMSS-AES systems are intended to operate their service uplink in the band 14.0-14.5 GHz. TABLE 2, provides the operational transmit AES frequencies, the employed operational bandwidths and transponder size of typical AMSS systems.

Parameter	Unit	Value
Transmit Band:	GHz	14.0 to 14.5
Transponder Bandwidth:	MHz	27.0 to 36.0
Antenna type		Phased Array or Reflector
Transmit Carrier Bandwidth:	MHz	24.0 to 33.0

Table 2: Typical AMSS system parameters

2.2 Antenna characteristics

The tables 3 and 4 below show the AES antenna characterisitcs for the two antenna types. The antenna gain is very similar, except that the phased array antenna will have a antenna gain that reduces with the higher scan angle by a factor equal to cos(scan_angle).

Antenna characteristics		Phased Array	Reflector (Steerable)
Antenna Aperture:	cm	38 (diameter)	20 (vertical) x 90 (horizontal)
Antenna Maximum Scan Angle:	degrees	70	80
Ant. Gain (pointed @ zenith)	dBi	34.0	33.0
Ant. Gain (at max. scan angle)	dBi	29.3	33.0
Beam Pointing Errors (r.m.s.):	degrees	0.15	0.3
Antenna Polarization:		Linear	Linear or Circular

Table 3: AES Transmit Antenna Characteristics

Antenna Characteristics		Phased array	Reflector (Steerable)
Antenna Aperture:	cm	43 x 61	20 (vertical) x 90 (horizontal)
Antenna Maximum Scan Angle:	degrees	70	80
Ant. Gain (pointed @ zenith)	dBi	35.3	-
Ant. Gain (at max. scan angle)	dBi	30.6	-
Beam Pointing Errors (r.m.s.):	degrees	0.15	-
Antenna Polarization:		Linear	Linear or Circular

Table 4: AES Receive Antenna Characteristics

2.3 AES Emission Characteristics

Table 5 below shows the typical AMSS system emission characteristics.

Parameter	Unit	Typical system Characterisitics		
Carrier EIRP (min/avg/max):	dBW	29	38	49
Carrier Data Rates (min/avg/max):	kbit/s	16	128	1024
Carrier Bandwidth	MHz	24.0 to 33MHz		
Aggregate AES EIRP per transponder	dBW	49		
Off-axis EIRP:		Recommendation ITU-R S.728-1		
Transmit Modulation:		O-QPSK or QPSK		
Satellite Access Scheme		CDMA		
G/T Satellite:	dB/K	1		
Number of Carriers per Transponder:		64	8	1
Carrier Data Rates	kbit/s	<16	128	1024

Table 5: Typical AES Emission Characteristics

2.4 Typical forward and return link budget of the AMSS system

The link performance and the offered data rates depend on the specific satellite EIRP and G/T which will change from region to region due to beam shape. Table 6: Forward Link Budget and Table 7: Return Link Budget; they identify typical parameters of the code division multiple access AMSS network.

Forward Downlink Budget Summary

Receiver Location		Brussels
Rain Region		E
Satellite		
Satellite Longitude	degrees	12.5 West
Transponder Center Frequency	GHz	12.625
Spread Bandwidth	MHz	32.4
Transponder EIRP	dBW	44.0
Clear Sky Path Loss	dB	206.2
Atmospheric Attenuation[1]	dB	0.10
Rain Attenuation[2]	dB	0.50
Polarization Tracking Loss	dB	0.32
Pointing Loss	dB	0.50
Aircraft Receive Antenna Gain	dBi	31.6
Receive Power at Aircraft	dBW	-132.0
Information Rate	Mbps dB Hz	3.00 64.8
Eb	dB (W/Hz)	-196.8
Aircraft Receive Noise Temperature	K dBK	270 24.3
No	dB (W/Hz)	-204.3
Co-Polarization Interference	dBW	-143.4
Cross-Polarization Interference	dBW	-146.4
Total Receive Interference Power	dBW	-141.7
Io Adjacent Satellite	dB (W/Hz)	-216.8
No + Io	dB (W/Hz)	-204.0
Eb/(No+Io) Downlink	dB	7.3

End-to-End Summary

Eb/No Uplink	dB	40.3
Eb/(No+Io) Downlink	dB	7.3
Eb/(No+Io) End-to-End	dB	7.3
Eb/No Required	dB	3.3
Eb/No Turbo Code	dB	3.0
Other Margin	dB	0.3
Margin	dB	4.0

Table 6: Forward Link Budget

1 Atmospheric attenuation is given by ITU-R Recommendation P.676-3, corrected for altitudes above sea level. A sea level water vapor density of 20 g/m3 and a water vapor scale height of 2.1 km based on a rain condition are assumed.

2 Rain attenuation is given by the greater of the ITU-R Recommendation P.618-6 rain model or 0.5 dB. Rain attenuation is calculated for 99.9% rain availability at the service altitude of 3 km (10,000 feet). Below 3km height, the availability of the service would be diminished. At northern latitudes in North America and Europe, the 0º isotherm may be near or below 3km resulting in negligible or zero rain attenuation. In order to maintain a minimum level of rain attenuation at northern latitudes, a 0.5 dB rain attenuation ‘floor’ is used.

Return Uplink Budget Summary

Receiver Location		Brussels
ITU Rain Region		E
Satellite Longitude	degrees	12.5 West
Transponder Frequency	GHz	14.125
Spread Bandwidth	MHz	32.4
Available Transmit EIRP[1]	dBW	45.3
Output Back off[2]	dB	3.9
Transmit EIRP	dBW	41.5
Path Loss	dB	207.2
Atmospheric Attenuation[3]	dB	0.11
Rain Attenuation[4]	dB	0.50
Polarization Tracking Loss	dB	0.32
Pointing Loss	dB	0.21
Satellite Gain	dB	33.0
Receive Power	dBW	-133.9
Data Rate	kbps dB Hz	256.0 54.1
Eb	dB(W/Hz)	-187.9
Receive System Temperature	K dB K	794 29.0
No	dB Hz	-199.6
Io Adjacent Satellite Uplink	dB(W/Hz)	-198.3
Io Spread Spectrum	dB(W/Hz)	-194.6
No + Io	dB(W/Hz)	-192.2
Eb/(No+Io)	dB	4.3
End-to-End Summary		
Eb/(No + Io) Uplink	dB	4.3
Eb/No Downlink	dB	26.2
Eb/(No+Io) End-to-End	dB	4.2
Eb/No Required	dB	4.2
Eb/No Turbo Code	dB	3.0
Power Control Margin	dB	0.9
Other Margin	dB	0.3

Table 7: Return Link Budget

1 The peak e.i.r.p. for a phased array is scan angle dependent.
2 The airborne terminal transmits with the minimum e.i.r.p. needed to achieve the threshold Eb/No.
3 Atmospheric attenuation is given by ITU-R Recommendation P.676-3, corrected for altitudes above sea level. A sea level water vapor density of 20 g/m3 and a water vapor scale height of 2.1 km based on a rain condition are assumed.
4 Rain attenuation is given by the greater of the ITU-R Recommendation P.618-6 rain model or 0.5 dB. Rain attenuation is calculated for 99.9% rain availability at the service altitude of 10,000 feet. Below 10,000 feet, the availability of the service may be diminished. At northern latitudes in the United States, the 0º isotherm may be near or below 10,000 feet resulting in negligible or zero rain attenuation. In order to maintain a minimum level of worst case rain attenuation at northern latitudes, a 0.5 dB rain attenuation 'floor' is used.

2.5 Deployment forecast

Table 8 indicates the projected number of aircraft for the period that are considered to be within the addressable market for wide band AMSS systems operating in Ku-band.

		2004	2005	2006	2007	2008	2009	2010	2011
Total addressable aircraft market[1]	number of aircraft	18500	19000	19500	20000	21000	21500	22250	25000
Market penetration	number of aircraft	200	600	2000	4200	6200	8500	10000	12000
Estimated number of Satellite Transponders for European coverage	in units of 36 MHz	2	2	3	4	7	10	13	14
Estimated number of Satellite Transponders for Global coverage	in units of 36 MHz	12	20	53	89	167	223	250	278

Table 8: Projected Ku-band AMSS market penetration

The market penetration represents the estimated number of aircraft that will be equipped with broadband aircraft earth stations operating over the period to 2011. It is assumed that there will be up to three competing systems. The bandwidth requirements can not be precisely calculated due to the lack of information about the transponder reuse factor. In most cases the required bandwidth will be provided through more than one satellite serving a particular region.

3 USE OF THE RADIO SPECTRUM AND ASSOCIATED PROTECTION REQUIREMENTS

3.1 European Common Allocation (as of January 2003)

Within the CEPT the band 14.0 – 14.5 GHz is allocated to the following services (from the European Common Allocation www.ero.dk):

14 – 14.25 GHz FIXED SATELLITE (Earth-to-space)
Mobile Satellite except aeronautical mobile satellite
Space Research

14.25 – 14.3 GHz FIXED SATELLITE (Earth-to-space)
Mobile Satellite except aeronautical mobile satellite
Space Research
5.508

14.3 – 14.47 GHz FIXED SATELLITE (Earth-to-space)
Mobile Satellite except aeronautical mobile satellite

14.47 – 14.5 GHz FIXED SATELLITE (Earth-to-space)
Mobile Satellite except aeronautical mobile satellite
Radio Astronomy

[1] Boeing Commercial Airlines Group: http://www.boeing.com/commercial/cmo/7_1_namerica.html

RR 5.508 Additional allocation: In Germany, Bosnia and Herzegovina, France, Greece, Ireland, Iceland, Italy, The Former Yugoslav Republic of Macedonia, Lybia, Liechtenstein, Portugal, the United Kingdom, Slovenia, Switzerland and Yugoslavia, the band 14.25-14.3 GHz is also allocated to the fixed service on a primary basis.

ECA Note: in the band 14.25.14.5 GHz, "Fixed links to be coordinated with fixed satellite service on a national basis."

3.2 Fixed Service

Current CEPT policy for this band (e.g. ERC/REC 13-03) discourages development of FS in those countries, where it was not up to now used for FS. This measure is seen as necessary to create most favourable conditions for development of VSAT and SNG services, by eliminating the need to co-ordinate with FS as much as possible. Regarding compatibility with the aircraft earth stations of the AMSS and the fixed service, no co-ordination is deemed possible. In accordance with this policy, there was no CEPT channel arrangement developed for FS in this band.

Current analysis confirms that the above policy reached its objectives. Today only 3 countries still use the band 14.25-14.5 GHz for FS and a limited number of transportable links is also in operation in one another country. No other country intends to introduce FS applications in this band, which is in line with ERC/REC 13-03.

In those countries using the band for FS, the total number of links had been almost stable over the past four years. The channel bandwidth range from 1.75 MHz to 28 MHz, the minimum hop length (based on data from one country only) is 6 km.

3.2.1 FS systems in UK

The 14.25-14.5 GHz band is used in the UK for medium to high capacity point-to-point (P-P) fixed links. There are currently around 900 links in the 14.25-14.5 GHz band.

FS systems in the 14 GHz bands are most likely to be a mixture of analogue television and low or medium capacity digital systems conforming to the channel plan contained in ITU-R Recommendation F.746-3 (Annex 5). The deployment of these links as well as their general characteristics are given in appendix A 1

3.2.2 FS systems in France

The 14.25-14.5 GHz band is used in France for medium capacity point-to-point (P-P) fixed links. There are currently around 600 links in the 14.25-14.5 GHz band.
The deployment of these links as well as their general characteristics are given in appendix

A 2.

3.2.3 FS use in Italy

In Italy the frequency band 14.25 –14.50 GHz is allocated on a primary basis to FSS (uplink) and FS. Fixed Service has priority over FSS Satellite News Gathering.

This frequency band is used by broadcasters users, for point to point analogue fixed links, for the transportation of video-signals from studios to broadcasting transmitters.
This frequency band is of great importance in Italy for fixed service due to the extensive usage all over the country. Currently more than 1000 video links are operating and this number will increase when other video links, now operating in other bands will be moved to this band.

3.2.4 General characteristics

ITU-R Recommendations

ITU-R F.758-1 includes FS receiver system characteristics to be taken into account while performing interference analysis such as those proposed in Table 8. In addition, ITU-R F.1245 provides a reference radiation pattern to be used for the FS stations in sharing studies with multiple sources of interference.

Channel bandwidth (MHz)	1.75	3.5	7	14	28	28	
Bit rate (Mbit/s)	2	2 × 2	8	2 × 8/17	34	140/155	Video
Assumed modulation	4PSK	4PSK	4PSK	4PSK	4PSK	(Note 2)	FM Video
Thermal noise KT (dBW/MHz)	–144	–144	–144	–144	–144	–144	–144
RX bandwidth B (dB/MHz)	2.4	5.4	8.5	11.5	14.5	14.5	12.5
Noise figure (dB)	9	9	9	9	9	6	3
Receiver noise KTBF (dBW)	–132.6	–129.6	–126.5	–123.5	–120.9	–123.6	–128.5
C/N for BER 10^{-6} (dB)	13.5	13.5	13.5	13.5	13.5	-	
S/N for BER = 10^{-6} without coding gain			-	-	-	25	
S/N for BER = 10^{-6} with coding gain			-	-	-	23.8	
Fixed system losses (dB) (Note 1)	5	5	5	5	5	4	
Reference sensitivity for BER 10^{-6} (dBW) (Note 3)	–113	–111	–108	–106	–103	–96	
Sensitivity for BER 10^{-3} (dBW)	–116	–114	–111	–109	–106	–99	
Nominal long-term interference (dBW)	–152.6	–149.6	–146.5	–143.5	–140.9	–143.6	–135.0
Spectral density (dBW/MHz)	–155	–155	–155	–155	–155.4	–158.1	–147.6
Antenna gain (dBi)	45	45	45	45	45	49	35
NOTE 1 – Includes modulation/demodulation losses, other implementation factors and branching network losses. NOTE 2 – 140/155 Mbit/s calculation based on 64 QAM, higher order schemes may be used as appropriate. NOTE 3 – Sensitivity for 140/155 Mbit/s rounded to nearest whole number.							

Table 8: Parameters for fixed service systems

FS Antenna Gain	43 dBi
FS Elevation Angle	0°->5°
FS System losses	3 dB
FS Noise Figure	9 dB
FS Receiver Noise	-120.5 dBW
FS Bandwidth	28 MHz

Table 9: FS characteristics used in FDP simulations

3.2.5 Protection criteria

As part of the studies pertaining to the definition of pfd mask to protect FS from AMSS, the FS protection criteria have been defined within the ITU-R when developing compatibility between AMSS and FS.

3.2.5.1 Long-Term Criteria

As far as a secondary allocation is concerned, based on a 1% performance degradation, the following long-term levels should apply:

- I/N = -20 dB, not to be exceeded for no more than 20% of the time, as defined in ITU-R Recommendation SF.1006;

  or

- FDP criteria not to exceed 1%.

Note: the FDP is a statistical calculation of the simultaneous occurrence of a fading event and a varying interference which jointly give rise to a performance degradation and is detailed in ITU-R Recommendation F.1108-2.

3.2.5.2 Short-Term Criteria

With regards to the short-term criteria and on the general principle that fade margins (typical fade margin of 24 dB has been used) can be given to the single-entry interference, an I/N = 16 dB not to be exceeded, would be adequate to protect the FS, in association with the above mentioned long-term levels.

It has to be noted that the interference level derived from the application of this I/N level on a receiver with a 4.5 dB noise figure (-123.5 dB(W/MHz) is consistent with the required protection level of existing links presenting 18 dB fade margin with a noise figure of 9 dB (-125 dB(W/MHz).

3.2.5.2.1 Derivation of the Short Term Interference value

The interference level at the receiver front-end, required to protect existing FS links with a typical net fade margin FM = 18 dB and a noise figure of 9 dB.

(i.e. $I/N = FM - (\Delta+\delta) = 18 - (5+3) = 10$ dB; where $\Delta=5$ dB is in line with the requirement for the Error Second performance in ITU-R F.1495 and $\delta=3$ dB is an extra cushion).

$$I/N = FM - (\Delta - \delta) = 18 - (5+3) = 10 \text{ dB}$$
$$\text{Bandwidth} = 1 \text{ MHz}$$

$$I = I/N + k + 10\log(T) + 10\log(\text{Bandwidth}) + \text{Noise Figure}$$

$$I = 10 \text{ dB} + (-228.6) \text{ dBJ/K} + 10\log(290 \text{ K}) + 10\log(10^6 \text{ Hz}) + 9 \text{ dB}$$

$$I = -125 \text{ dBW/MHz}$$

The time percentages corresponding to the above Interference level should be calculated from ITU-R Recommendation F.1241, which requires a transmission rate and a link hop length as input parameters.

Therefore, as far as a secondary service is concerned, a provisional permissible level of interference of -125 dB(W/MHz) has been agreed as a short-term interference level not to be exceeded to protect the fixed service.

3.3 Fixed-Satellite Service (Earth-to-space)

3.3.1 General characteristics

The FSS has a primary allocation status in both the ECA and ITU RR Article 5 in the band 14.0-14.5 GHz.

The AMSS networks will employ leased capacity in the 14 GHz (Earth-to-space, return-link) and 10-12 GHz (space-to-Earth, forward-link) bands from existing GSO satellite networks that provide Fixed-Satellite-Service (FSS) applications. In this respect, the satellites that provide support for the AMSS are the same as those of the FSS.

The link characteristics of the AMSS systems are likely to be similar to those of VSAT (Very Small Aperture Terminal) FSS systems. Thus, the interference potential from AMSS systems to any other FSS systems will be comparable to that of existing FSS systems. References to ETSI standard and ECC decision with respect to VSATs are given hereafter :

a) EN301 428 provides the emission levels of VSAT equipment;

b) ECC/DEC/(00)05 provides the basis for exemption from individual licensing of VSATs.

3.3.2 Protection requirement of FSS networks from the AMSS

ITU-R has considered two ways a secondary AMSS service could operate under the conditions above:

a) the most direct way is for the interference emission levels of a secondary service to be below the interference noise level permitted from other primary applications. This approach is referred to as an independent AMSS system approach for the remainder of this section;

b) another approach is for the interference emission levels of the secondary service to fall within the envelope of coordination agreements reached by particular primary FSS satellites and the service is implemented in lieu of the coordinated FSS assignment. This approach is referred to as an FSS dependent approach for the remainder of the section.

3.3.2.1 Independent AMSS system approach

It has been suggested that an acceptable situation would be for the level of interference from the secondary service to be no more than 10% of the level which would be acceptable from another primary service in the same bands. Based on this, interference from an individual system in a service having a secondary allocation should be less than 0.6% of the total system noise budget at the input to the demodulator of the FSS earth station. Based on studies, it has been concluded that such stringent criteria might make it difficult for the AMSS system designer to implement, and that, if these levels were exceeded, the FSS would be at risk of harmful interference. Therefore, this approach has been disregarded.

3.3.2.2 FSS dependent system approach

Under this approach, depending on the actual interference levels that have been coordinated, facilities of an FSS network could be used for AMSS transmissions operating on a secondary basis. If the aggregate transmissions due to this AMSS service are in place of FSS transmissions for specific facilities, the adjacent satellites are not expected to receive harmful interference if the operations are within the coordinated EIRP envelope.

The characteristic of a system that has the potential to cause interference to GSO FSS satellites is its aggregate off-axis EIRP density along the GSO arc. From the perspective of interference to a GSO FSS space station, the important criterion is the amount of unwanted energy that is being directed towards it. The use of an aggregate parameter properly accounts for spread spectrum multiple access systems, which may have more than one terminal operating simultaneously at the same frequency. An aggregate may need to include any other signals sharing the facilities on a co-frequency basis. The use of a spectral density parameter as an operational control criterion, accounts for the difference in signal power, bandwidth, and modulation of the co-frequency AMSS carriers. The calculation of an aggregate EIRP density also must account for the uncertainties in transmitter antenna pointing, ageing, environmental conditions, and power control.

Although different than AMSS systems, LMSS and MMSS systems operating in the 14 -14.5 GHz band using GSO FSS network facilities have been licensed on a case by case basis by a number of nations and have been operating on a secondary basis for many years.

Specific regulatory limits do not exist for Earth-to-space transmissions of LMSS and MMSS systems in the 14 - 14.5 GHz band because they are secondary services. Authorizations for MSS operation in this frequency band are on a secondary basis and shall not cause harmful interference to the primary service. If there is harmful interference, the secondary service must correct the situation. However, at least one administration has accepted, on a domestic basis, operating limits for these type of services.

In addition, the European Telecommunications Standard Institute (ETSI) has issued a performance standard for land mobile earth stations in the 14 - 14.25 GHz band (ETS 300 255)[2]. This standard specifies that the emissions from a single land-mobile earth station along the GSO arc shall not exceed:

Angle off-axis	Maximum EIRP (dBW in any 40 kHz band)
$2.5° \leq \varphi + \delta\varphi \leq 7°$	$33 - 25 \log(\varphi + \delta\varphi) - 10 \log K$
$7° < \varphi + \delta\varphi \leq 9.2°$	$12 - 10 \log K$
$9.2° < \varphi + \delta\varphi \leq 48°$	$36 - 25 \log(\varphi + \delta\varphi) - 10 \log K$
$48° < \varphi + \delta\varphi \leq 180°$	$-6 - 10 \log K$

[2] Now superseded by EN 301 427. The EIRP emission mask of the EN 301 427 (Euteltracs / Omnitracs) is identical to that of EN301 428 (VSAT).

where:

φ is the topocentric off-axis angle at the transmitting antenna;

$\delta\varphi$ is a pointing error term equal to the greater of the RMS antenna tracking error or twice the static RMS antenna pointing error;

K is the power density ratio between a fully loaded CDMA system and a single land-mobile earth station.

Note 1: The 10 log K terms relate the emissions of a single terminal to the aggregate level for the system. Removing this term gives the aggregate level for the system.

Note 2: The off-axis EIRP criteria could be used to assist administrations in introducing AMSS in the 14 GHz band.

3.4 Mobile Service (except aeronautical mobile)

The Mobile Service is not listed in the ECA table but it has a primary status in the ITU RR Article 5 in the band 14.3 - 14.5 GHz.

In addition, there are no records in the ITU Master Register indicating any use of the mobile service (MS) allocation in the band. No additional information was obtained on mobile service use of the band as a result of inquiries within the ITU-R, nor as a result of the BR Administrative Circular (CA/91).

However, based on information received in the course of conducting studies with the FS, it was learned that the band is used by some administrations for Electronic News Gathering (the service is termed temporary-fixed by some Administrations).

3.5 Mobile-Satellite Service (except aeronautical mobile-satellite)

3.5.1 General characteristics

The MSS except aeronautical satellite service is listed in the ECA and ITU RR Article 5 for the band 14.0 - 14.5 GHz.

In respect to Euteltracs MSS:

a) EN 301 427 provides the emission levels of Euteltracs equipment;

b) ECC Decision (98)15 provides the basis of exemption from individual license of Omintracs/Euteltracs equipment.

Mobile-satellite service (MSS) (except AMSS) systems, in the 14.0 - 14.5 GHz band, are operational in all three ITU Regions.

3.5.2 Protection Criteria

Through the data reported in response to BR Administrative Circular CA/91, it was learned that MSS use of the 14.0 - 14.5 GHz band requires that the MSS systems operate such that the aggregate, off-axis EIRP of all co-frequency transmissions is within the limits set by the administrations wherein these systems are employed. These limits have been based on the principles of, and closely related to, the limits developed during the adoption of ITU-R Recommendation S.728-1, as is appropriate for the satellite spacing environment. Since these existing MSS networks have a secondary status, they must accept interference from primary users of the band, but can claim protection against harmful interference from users of new secondary allocations, such as the AMSS.

3.6 Radio Astronomy Service

3.6.1 General characteristics

The RAS is a service with a secondary status in the band 14.47 - 14.5 GHz, both in the ECA table and ITU RR Article 5. Footnote 5.149, which applies to this frequency band, states “administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see RR Nos. 4.5 and 4.6 and Article 29)”.

During an observation, a radio astronomy telescope points towards a celestial radio source at a specific right ascension and declination corresponding with a specific azimuth and elevation at a given moment in time. During an observation the pointing direction of the telescope is continuously adjusted to compensate for the rotation of the Earth. For compatibility studies, it must be assumed that a radio telescope can point to all directions in the sky, i.e. its azimuth can vary between 0º and 360º and its elevation can vary between 0º and 90º. For terrestrial interferers, the interference scenario must assume an elevation of 0º. For interference from space, the worst interference case occurs when the telescope points towards the interfering source.

Depending on the relative location of the interferer and the telescope, the interference occurs in the near field or the far field of the telescope. The far field area, or Fraunhofer area, lies beyond a distance of $2D^2/\lambda$, where D is the diameter of the telescope and λ the wavelength. For the frequency range of 14.0 - 14.5 GHz, this distance is about 250 km for a radio telescope of 50 meter diameter. A diameter of 50 meter can be considered as representative for radio telescopes in Europe operating at ~14 GHz; the largest has a diameter of 100 meter.

3.6.2 Protection criteria

The protection criteria given in ITU-R Recommendation RA.769 assume that the interferer is in the far field of a radio telescope. This implies that a compatibility study using the criteria from ITU-R Recommendation RA.769 should be done with appropriate care for smaller distances. ITU-R Recommendation RA.769 assumes also that the interference is received in a sidelobe of the antenna pattern, i.e. at a level of 0 dBi at >19º from boresight (see also ITU-R Recommendation SA.509). It should be noted that a radio telescope is an antenna with a very high gain, typically of the order of 77 dB for a telescope with diameter of 50 meter. If interference is received via the main lobe of the antenna pattern, this high gain should also be taken into account. However, ITU-R Recommendation RA.769 assumes that the probability that the interference is received by the main lobe of the antenna is low, and therefore uses the level of 0 dBi in the calculation of the levels of detrimental interference given in this Recommendation. However, considering that the aggregated interference of AMSS devices must be taken into account in the interference scenario, it is not a priori certain that the 0 dBi assumption of this Recommendation is valid in practice. In the case that the interferers are distributed randomly (which must be verified for this case), the equivalent power flux density (epfd) concept should be applied, in which the entire antenna pattern, including the full main beam, is taken into account in the calculations. For such calculations also ITU-R Recommendation RA.1513 applies, which assumes that for a single system, the Radio Astronomy Service accepts a maximum data loss of 2%.

Radio astronomy observing programs are a mixture of spectral line and continuum observations. Therefore, radio astronomy always needs to be protected according to the most stringent protection levels as specified for the radio astronomy service in the frequency bands under consideration.

3.7 Radionavigation Service

RNS is not listed in the ECA table. In the ITU RR Article 5 it is allocated on a primary basis in the band 14.0 - 14.3 GHz.

There are no records in the ITU Master Register indicating use of the radionavigation allocation in the 14.0 - 14.3 GHz band by any administration. No additional information was obtained on radionavigation use of the band as a result of inquiries within the ITU-R and the BR Administrative Circular (CA/91). Consideration of compatibility matters has not revealed a problem in the use of this band by AMSS with respect to RNS.

3.8 Radionavigation-Satellite Service

RNSS is not listed in the ECA table and in ITU RR Article 5 is listed in the band 14.3 - 14.4 GHz.

There are no records in the ITU Master Register indicating any use of the radionavigation-satellite service (RNSS) allocation in the 14.3 - 14.4 GHz band. Nor is there any record in any BR list of a prior Advance Publication Information (per RR No. 9.1) by an administration for use of the band by RNSS. Nor was any information on proposed RNSS use of the band provided by Administrations in response to the BR Administrative Circular (CA/91). Consideration of sharing matters has not revealed a problem on the use of this band by AMSS with respect to the RNSS.

3.9 Space Research Service

SRS is in the ECA table and in RR Article 5 allocated on a secondary basis in the band 14.0 - 14.3 GHz. Data relay satellite (DRS) networks use earth stations in the SRS at a very few sites in the world. Within CEPT there is no known use of SRS.

4 SHARING/COMPATIBILITY STUDIES

4.1 Fixed Service (Primary Service)

The general approach was to develop I/N criteria for short and long-term protection of the fixed service from services sharing on a secondary basis, and compute statistics of I/N based on the information obtained from the AMSS system characteristics.

4.1.1 Pfd mask analysis

The pfd mask based on the results of ITU-R studies (Document ITU-R 8/78) was based on two different types of analysis:

- short-term analysis, based a single entry interference calculation, which led, for 5°elevation to a pfd limit of –129.5 dB(W/m^2 per MHz) for sensitive FS links.
- long-term analysis, based on aggregation of interference from multiple AES based on traffic simulations, using a 1% criteria for the average FDP.

4.1.2 Pfd mask models

The three different pfd masks considered in the studies are presented in Appendix A3.2.

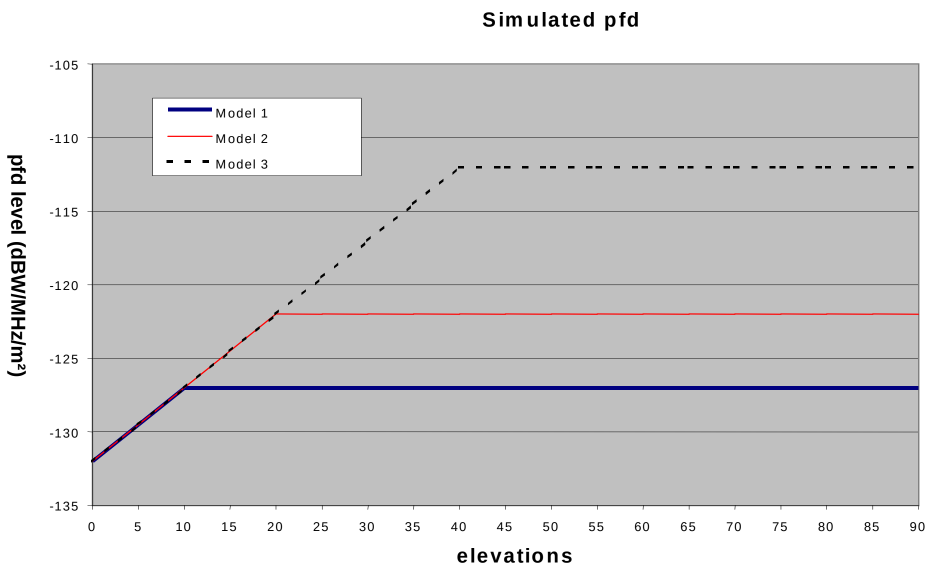

Figure 2: Pfd mask models used in simulations

Model 1:

$-132 + 0.5*\theta$	for $\theta \leq 10°$
-127	for $10° < \theta \leq 90°$

Model 2:

$-132 + 0.5*\theta$	for $\theta \leq 20°$
-122	for $20° < \theta \leq 90°$

Model 3:

$-132 + 0.5*\theta$	for $\theta \leq 40°$
-112	for $40° < \theta \leq 90°$

where:

θ is the angle of arrival of the radio-frequency wave at the fixed receiver at the earths service (degrees above the horizontal).

Note: the shape of the three masks modelled is the same between 0 and 10° since they all meet the short-term criteria at the 5 degree arrival angle and cases where the AES are potentially seen in the main beam of the FS link.

From the studies referenced in appendix A 3, it was concluded that the model 3 pfd mask will ensure the FS protection on a short and long term basis.

4.1.3 Derivation of Short Term PFD point

The proposed pfd mask for the AMSS AES is:

$-132 + 0.5\,\theta$	$dBW/m^2/MHz$	for $\theta \leq 40^\circ$
-112	$dBW/m^2/MHz$	for $40^\circ < \theta \leq 90^\circ$

This mask is based on the receive antenna gain of 49 dBi, feeder loss of 0 dB, elevation angle of 5 degrees and maximum allowed interference level of -125 dBW/MHz. Assuming that the operating frequency is 14.25 GHz, a pfd level at a reference point (assumed to be 5 degrees elevation angle) is calculated as follows:

$$\textbf{pfd = Interference Power – Receiver Gain + 10 log } (4\pi/\lambda^2) \textbf{ + Feeder Loss}$$

$$\textbf{pfd = -125 dBW/1MHz/m}^2 \textbf{ - 49 dBi + 10 log } (4\pi/(0.021)^2) \textbf{ dB + 0 dB}$$

$$\textbf{pfd = -129.5 dBW/MHz}$$

It is worth noting that the above pfd point assumes no losses between the antenna and the receiver front end.

The pfd values between 0 and 40 degrees are extrapolated using the formula $-132 + 0.5\,\theta$. For the elevation angles greater than 40 degrees, the pfd mask is assumed to be constant at the pfd value calculated at 40 degrees.

4.2 Fixed Satellite Service (Primary Service)

A compatibility study with the FSS was based on a Monte Carlo simulation of a planned AMSS network, including the ability to evaluate the impact of transmissions from adding AES, and sources of random errors and inherent latencies for each co-frequency AES in the system. Running over 100 000 trials, the simulation determined that the NCMC could control the aggregate off-axis EIRP levels to those of ITU-R Recommendation S.728-1 (Maximum permissible level of off-axis e.i.r.p. density from VSATs) for both 2º and 3º GSO satellite spacing to a 99.99% confidence level. This analysis verified that it was feasible to control the aggregate off-axis EIRP density levels from an AMSS network to be no greater than that of coordinated VSATs, as characterized in ITU-R Recommendation S.728-1.

The studies show that an AMSS system operating on a secondary basis is compatible to operate with the FSS in the 14.0 - 14.5 GHz frequency band, applying equally to GSO and non-GSO FSS. Compatibility is ensured provided that aggregate co-frequency AES emissions in the direction of adjacent satellites are limited to levels that are equal to or less than the levels that have been accepted by other satellite networks.

In addition, newly developed ITU-R Recommendation 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 14.0 - 14.5 GHz (Earth-to-space) provides guidance to system designers and licensing administrations regarding the technical and operational requirements for aircraft earth stations of AMSS networks in the 14.0 - 14.5 GHz band needed to permit operation of AMSS networks with the FSS.

4.3 Mobile Service (Primary Service)

Since Electronic News Gathering (ENG) is considered by some administrations as a mobile service, and the system aspects of ENG are similar to those of the FS, the methodology recommended for AMSS studies with the FS was employed for such MS studies using ENG network characteristics.

These studies showed that the use of AMSS in this band is feasible, based on the information available.

4.4 Protect Mobile Satellite Service (Secondary Service)

A study was conducted to determine the ability of a planned AMSS network to share the band 14.0 - 14.5 GHz with an operational MSS network. The study concluded that sharing is feasible.

Analyses confirmed that interference protection margins make it feasible for AMSS and MSS networks to share the band 14.0 - 14.5 GHz, both on a secondary basis, when they employ co-frequency transponders on adjacent satellites.

4.5 Radio Astronomy Service (Secondary Service)

Sharing studies were performed using two alternative methodologies to determine if sharing between the RA service and the AMSS networks would be feasible in the 14.0 - 14.5 GHz band.

a. One study applied the ITU-R Recommendation RA.769 power flux-density level of –221 dB(W/(m2·Hz)) to the AES emissions and derived the required AES power flux-density values to protect the RAS receiver;

b. The second study used the simulation methodology developed for sharing studies between non-GSO satellite systems and the RAS. This methodology, identified in ITU-R Recommendation M.1583. Interference calculations between non-geostationary mobile-satellite service or radionavigation-satellite service systems and radio astronomy telescope sites, consists in a division of the sky into cells of approximately equal solid angles and in calculation of the epfd generated by all aircraft for each cell, averaged over time slots of 2 000 seconds. This methodology also assumes worst-case assumptions for the AMSS interference environment. Temporal statistics are obtained by performing a sufficient number of trials, randomly changing the RA station antenna pointing direction within a cell and the position of aircraft from one trial to another. The study showed that, above a 5° elevation angle, the epfd limit of –303 dB(W/(m2·Hz)) (derived from ITU-R Recommendation RA.769 and the RAS antenna peak gain for a radio telescope with 100m diameter) was exceeded for less than 2% of the time (this criterion comes from ITU-R Recommendation RA.1513).

4.6 Radio Navigation Service (Primary Service)

Based on the information available, AMSS use of this band does not present any difficulty.

4.7 Radio Navigation Satellite Service (Secondary Service)

Since there are no radionavigation-satellite service systems using, or proposing to use this secondary allocation, use of the band by AMSS is feasible.

4.8 Space Research Service (Secondary Service)

Sharing studies were performed to determine if it is feasible for AES in the AMSS to share the 14.0 - 14.3 GHz and 14.4 - 14.47 GHz bands with the space research service (SRS) on a secondary basis. Data relay satellite (DRS) networks use earth stations in the SRS at a very few sites in the world. These studies showed that the use of AMSS in this band is feasible.

5 CONCLUSIONS OF STUDIES

ITU-R Recommendation 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 14.0 - 14.5 GHz (Earth-to-space) provides guidance to system designers and licensing administrations regarding technical and operational requirements of AMSS networks in the 14.0 - 14.5 GHz band, which takes into consideration the protection of existing and planned services to permit the operation of AMSS networks.

5.1 Conclusions of compatibility with the Fixed Service (Primary Service)

As detailed in section 4.1, AMSS networks, within line-of-sight of the territory of an administration where fixed service networks are operating in the band 14.25 - 14.5 GHz, the maximum power flux-density produced at the surface of the Earth by emissions from a single AES, of an AMSS network should not exceed:

$-132 + 0.5 \cdot \theta$	$dB(W/m^2)$ in 1 MHz	for	$\theta \leq 40°$
-112	$dB(W/m^2)$ in 1 MHz	for	$40° < \theta \leq 90°$

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

NOTE 1 – The aforementioned limits relate to the power flux-density 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 appendix A 4.

5.2 Conclusions of compatibility with the Fixed Satellite Service (Primary Service)

AMSS networks should be designed, 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 accepted by other satellite systems.

5.3 Conclusions of compatibility with the Mobile Service (Primary Service)

Since there are no known mobile service systems using this allocation, a sharing analysis was accomplished employing characteristics of ENG systems that do use the allocation. These studies showed that the use of AMSS in this band is feasible, based on the information available.

5.4 Conclusions of sharing with the Mobile Satellite Service (Secondary Service)

Analysis confirmed that interference protection margins make it feasible for AMSS and MSS networks to share the band 14.0 - 14.5 GHz, both on a secondary basis, when they employ co-frequency transponders on adjacent satellites.

5.5 Conclusions of sharing with the Radio Astronomy Service (Secondary Service)

5.5.1 AMSS Channels in the 14.47 - 14.5 GHz band (In-band sharing)

a) AMSS stations shall not transmit in the 14.47 - 14.5 GHz band within line-of-sight of radio astronomy stations operating within this band, or

b) If an AMSS operator intends to operate co-frequency within the visibility of the RA station, consultation with the Administrations concerned is needed, which may lead to a feasible co-ordination arrangement.

5.5.2 AMSS channels in the 14.0 - 14.47 GHz band (Adjacent-band sharing)

All AES transmitters on channels in the 14.0 - 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 given in ITU-R Recommendation RA.769. Results from studies show that the following AES power flux-density levels in the band 14.47 - 14.5 GHz are sufficient, with some margin, to meet the RAS power flux-density levels in ITU-R Recommendation RA.769, i.e.:

pfd = $-190 + 0.5*\theta$ dB(W/m2) in 150 kHz for $\theta \leq 10°$
pfd = -185 dB(W/m2) in 150 kHz for $10° < \theta \leq 90°$

where θ is the angle of arrival, measured in degrees.

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 enhanced AES antenna performance.

5.6 Conclusions of compatibility with the Radionavigation Service (Primary Service)

Based on the information available, AMSS use of this band does not present any difficulty.

5.7 Conclusions of sharing with the Radionavigation Satellite Service (Secondary Service)

Since there are no radionavigation-satellite service systems using, or proposing to use this secondary allocation, use of the band by AMSS is feasible.

5.8 Conclusions of sharing with the Space Research Service (Secondary Service)

Based on the studies, it was concluded that it is feasible for the AMSS to share with the space research service (SRS) in the 14.0 - 14.3 GHz and 14.4 - 14.47 GHz bands, and that sharing can be accomplished through coordination as per Article 9 of the Radio Regulations.

It should be noted that there are no known earth stations operating within the SRS allocation within the CEPT.

6 REFERENCES

6.1 ITU-R Recommendations

Rec. F.1245: FS antenna pattern

Rec. F.758: Tables of FS parameters

Rec. PN.530: Propagation in FS links

Rec. RA.769: Radio Astronomy protections requirements

Rec. RA.1513: Radio Astronomy protection requirements

ITU-R Recommendation 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 14.0 - 14.5 GHz (Earth-to-space)

ITU-R Recommendation M.1583 Interference calculations between non-geostationary mobile-satellite service or radionavigation-satellite service systems and radio astronomy telescope sites

Rec. S.728: VSAT emissions limits

6.2 Relevant European standards

EN 301 427: Euteltracs 14.0 - 14.25 GHz
EN 301 428: VSAT 14.0 - 14.25 GHz
ES 300 255: LMSS 14.0 - 14.25 GHz
Draft EN 302 186: Ku-band AMSS 14.0 - 14.25 GHz

6.3 Relevant ECC Decisions

Dec. (00) 05: VSAT license exemption
Dec. (98) 15: Omnitracs/Euteltracs license exemption

APPENDICES

A 1 Fixed Service characteristics in the United Kingdom

A 1. 1 FS systems in UK

The 14.25 - 14.5 GHz band is used in the UK for medium to high capacity point-to-point (P-P) fixed links. There are currently around 900 links in the 14.25 - 14.5 GHz band.

FS systems in the 14 GHz bands are most likely to be a mixture of analogue television and low or medium capacity digital systems conforming to the channel plan contained in ITU-R Recommendation 746-3 (Annex 5).

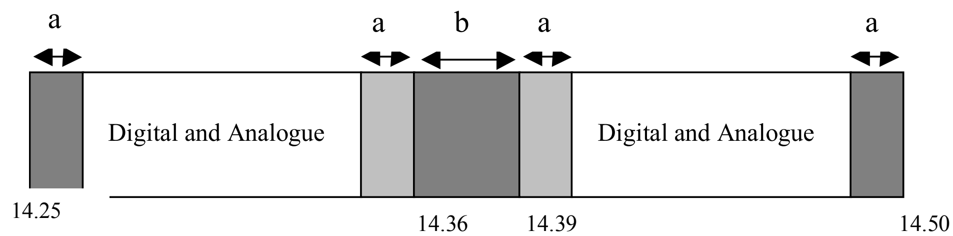

Figure A 1

Channel Spacing	A	b
1.75	0.75	30
3.5	2.5	30
7	6	30
14	13	30
28	27	30
28	-1	30

Table A 1: ITU-R Recommendation F.746 Channel Plan

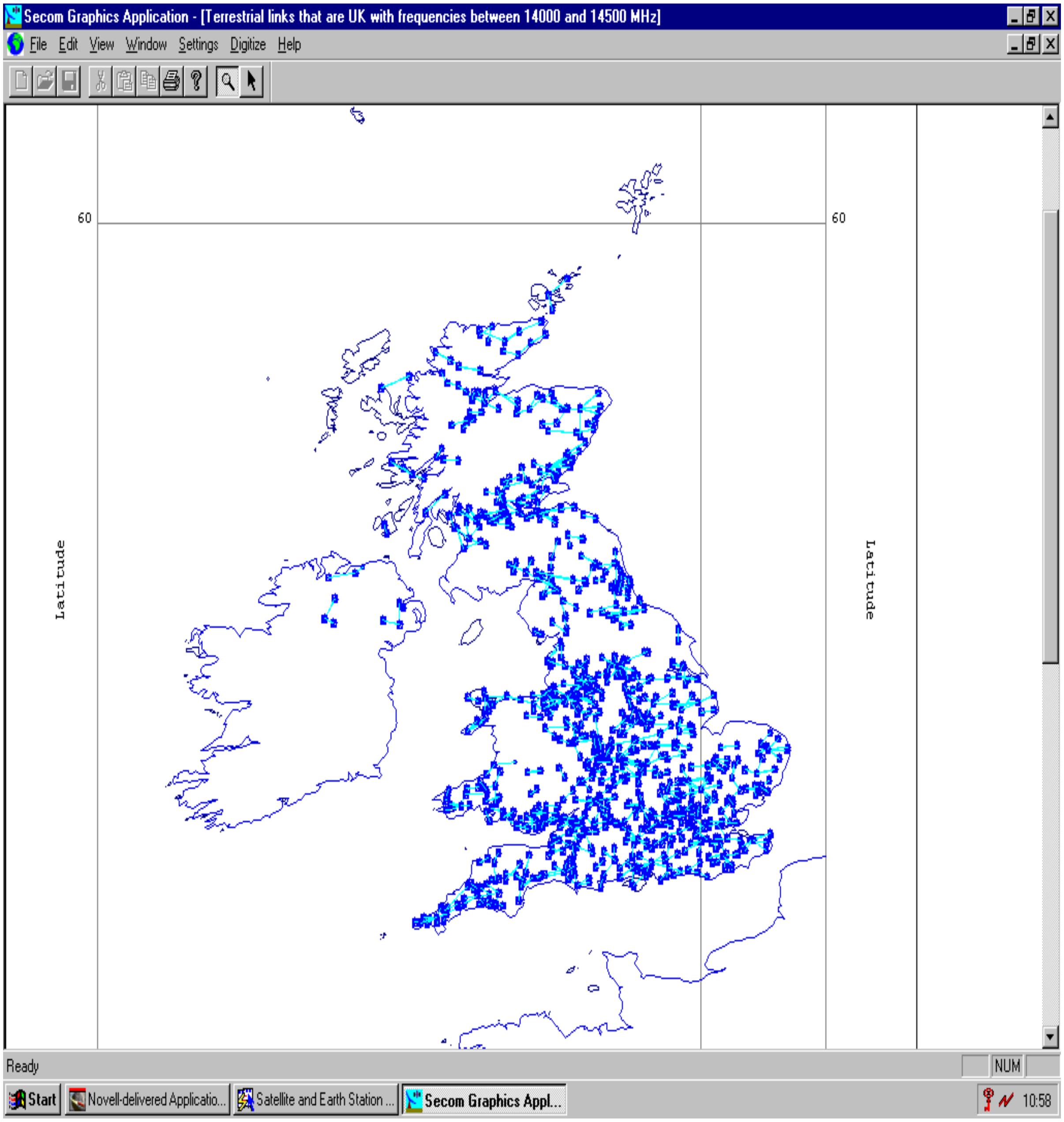

Figure A 2: UK fixed link deployment in the band 14.25 – 14.5 GHz

A 1. 2 UK Fixed Link statistics

A 1.2. 1 Rx gain versus Rx elevation (Figure A 3)

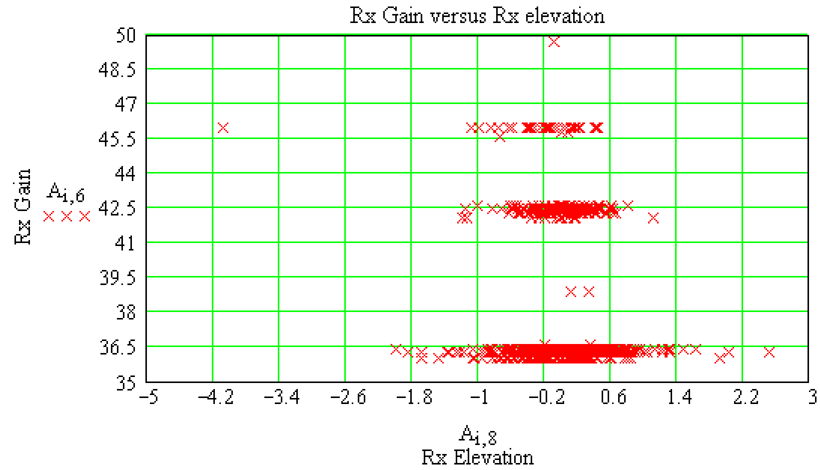

Figure A 3

A 1.2. 2 Tx gain versus hop distance (Figure A 4)

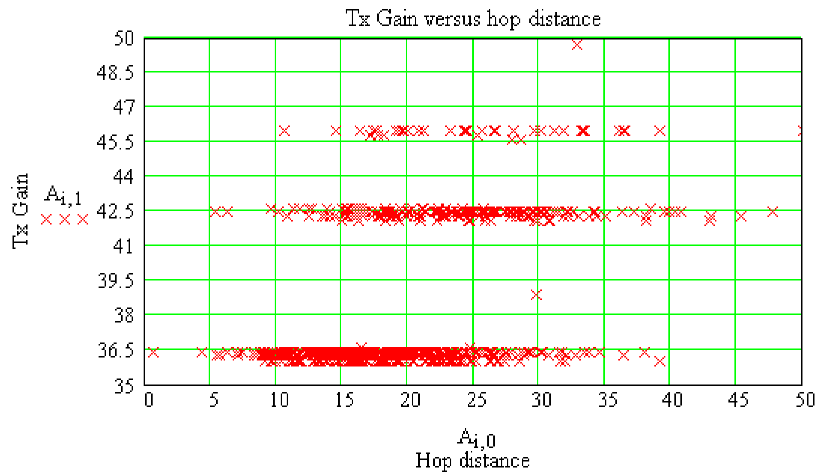

Figure A 4

A 1.2. 3 Hop distance versus Rx elevation (Figure A 5)

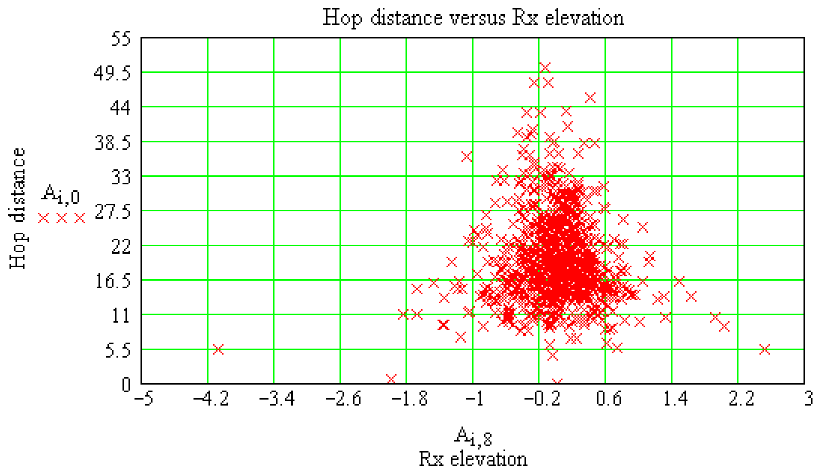

Figure A 5

A 1.2. 4Tx gain versus EIRP (Figure A 6)

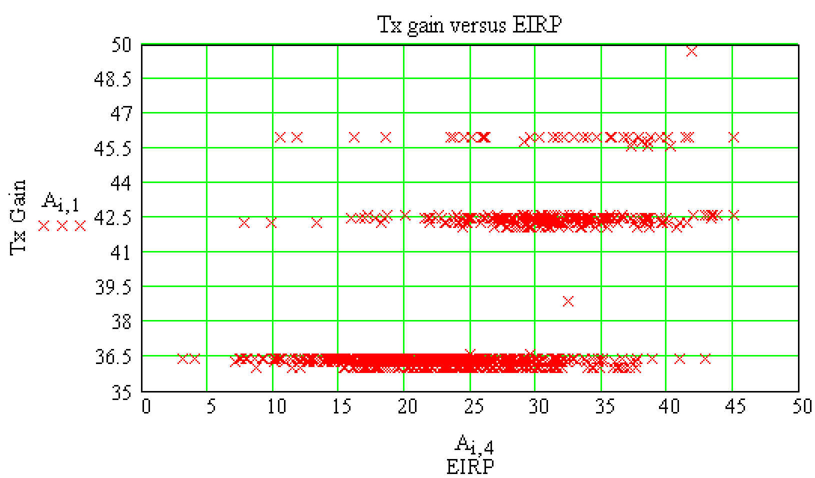

Figure A 6

A 1.2. 5 EIRP versus hop distance (Figure A 7)

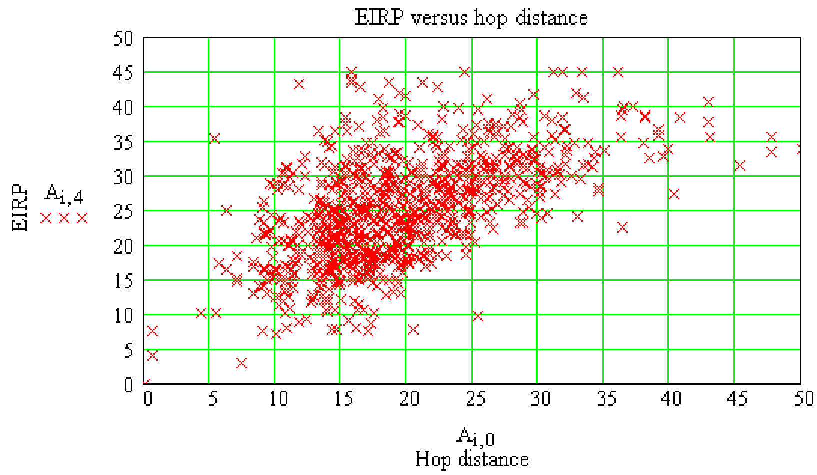

Figure A 7

A 2 FS systems in France

The 14.25 - 14.5 GHz band is used in France for medium capacity point-to-point (P-P) fixed links. There are currently around 600 links in the 14.25 - 14.5 GHz band.

The global deployment of these links as well as their general characteristics are given in the following Figure A 8, Figure A 10 and Table A 2.

Channel bandwidth (MHz)	10	14	14
RX Bandwidth (MHz)	10	28	14
Bit rate (Mbit/s)	8	34	34
Modulation	4PSK	4PSK	16QAM
Noise figure (dB)	4.5	7.5	4.5
Receiver noise KTBF (dBW)	-129.5	-125	-128
Reference sensitivity for BER 10^{-6} (dBW)	-119	-106	-107
Sensitivity for BER 10^{-3} (dBW)	-122	-109	-110
Nominal long-term interference (dBW)	-153	-153	-150
Average Antenna Gain	43 dBi		
Feeder Loss	3 dB		

Table A 2: Parameters for fixed service systems in France in the 14.25 - 14.5 GHz

A2.1 FS deployment in France in the frequency band 14.25 - 14.5 GHz (FIGURE A 8)

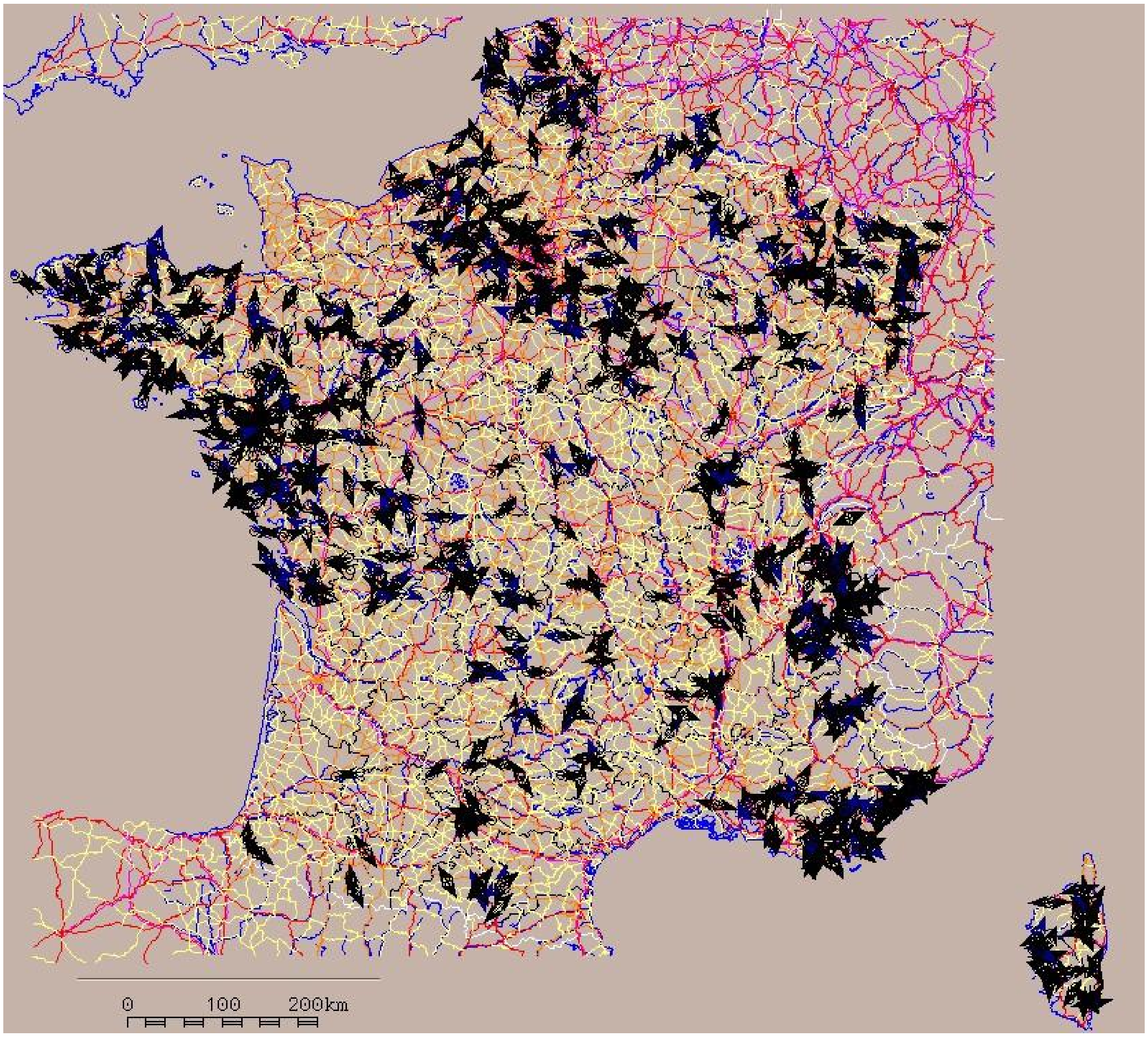

Figure A 8

A2.1 French Fixed Link statistics

A2.1.1 Hop length distribution for the French Fixed links in the frequency band 14.25 - 14.5 GHz (FIGURE A 9)

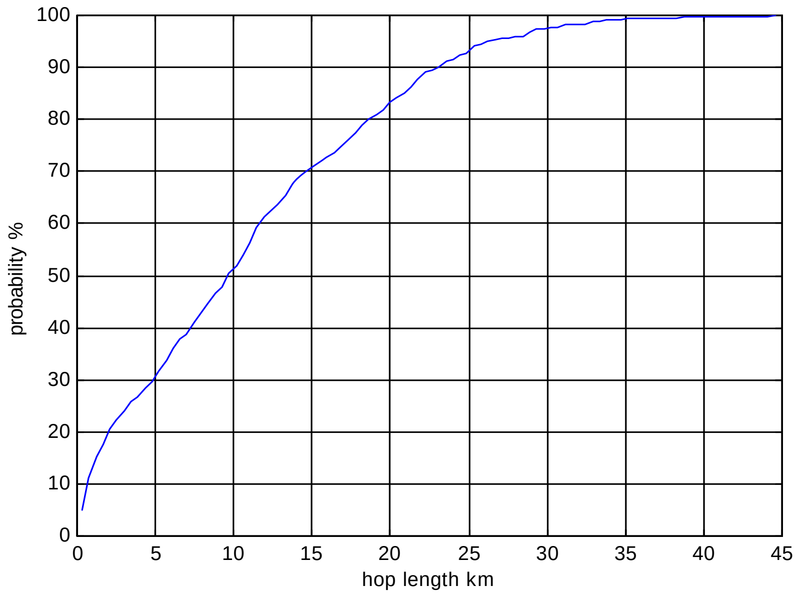

Figure A 9

A2.1.2 Elevation angle distribution for the French Fixed links in the frequency band 14.25 - 14.5 GHz (50% value = 0.6 °, mean value = 2.3 °),

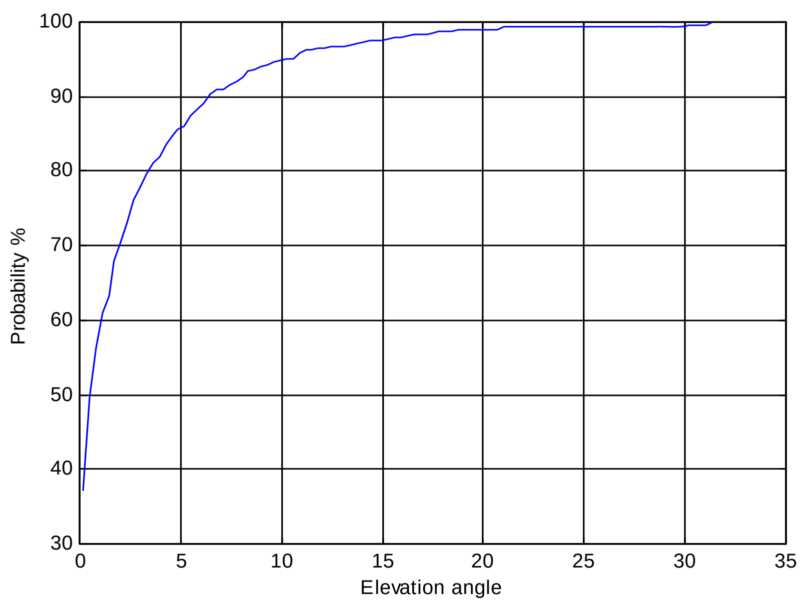

Figure A 10

A 3 Simulation methodology between the aeronautical mobile satellite and the fixed services

Long term interference analysis have been performed for the three previous pfd mask models based on the FS and AES characteristics presented respectively in section 3.2 and 2 and using the following methodology :

1) Select a pfd mask for elevation angles close to and below aircraft horizon.
2) Set up FS receive stations with a random azimuth angle and an elevation angle of 0° spread over a countries territory (Every 0.5° in longitude and latitude).
3) Place a specific number of aircrafts over a country on the selected air routes based on the known traffic at time t = 0.
4) Taking into account the AMSS aircraft and FS characteristics, compute interference into each FS station.
5) Simulate aircraft movements with sufficient time resolution (30 s) and at each time sample repeat step 4.
6) Increase FS station elevation angle by 1° and repeat steps 3 to 6.
7) Repeat step 6 until FS station elevation angle equals 5°.
8) Analyse time domain statistics of the interference calculated in steps 6 and 7 and compare with interference criteria.

The simulations were based on the example of United Kingdom territory and take into account the characteristics of the existing FS systems, but not explicitly their locations because protection will be required for existing and future systems, and future systems may be located anywhere in the UK while keeping comparable characteristics.

In order to have realistic results in the study, FS stations have been distributed on the UK territory every 0.5 deg in latitude and longitude that allows a full coverage of the UK.

A3.1 Air-traffic model parameters

A3.1.1 Aircraft routes

The simulations were based on traffic situation over United Kingdom for which 10 OTS (Organized Track System) routes and 3 polar routes were considered plus domestic UK, French and Belgian routes and short haul UK-Europe routes.

Figure A 11 below shows the routes considered in the study.

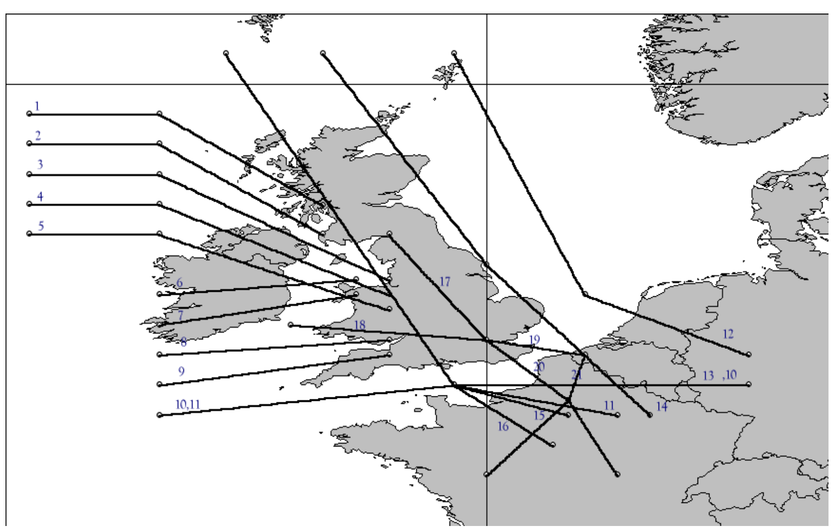

Figure A 11: Modeled air traffic routes

A3.1.2 Aircraft speed, altitude and typical flight profiles

In the simulation, each aircraft was assumed to be flying at 800 km/hr on a level flight path situated 8100 m above the ground. The simulation does not take into account the movements of the aircraft in a vertical plane. The aircraft tracking accuracy of nominal air route has not been taken into account in the simulations, as it does not have any effect on the statistical results. Aircrafts always move on the routes in the same direction. Considering the two directions would not impact the results as the pfd mask of the transmitting antenna is symmetrical and does not depend on the aircraft direction.

Note: The altitude/velocity may be considered worst-case in respect of the sharing environment.

A3.1.3 Aircraft traffic simulation

The worst-case average number of aircrafts in I-path transmitting in co-frequency can be determined as follows:

$$Ni = C_{max}\ P_{geo}\ P_{i\text{-}path}$$

where:

C_{max} = Maximum capacity of the AMSS system in a given coverage area within a frequency channel shared with FS.

P_{geo} = Probability that the terminal is transmitting from a simulated airspace. This could be calculated as the ratio of the simulated airspace area and the satellite foot print area.

$P_{i\text{-}path}$ = Probability that the terminal is transmitting on a given path. This could be calculated by taking the ratio of the aircraft traffic on this path with the total considered traffic.

The maximum capacity in a given coverage area is calculated as

$$C\text{max} = N_T.\left(\frac{Maximum.data.rate.per.transponder}{Average.data.rate.per.aircraft}\right)$$

Where N_T is the maximum number of co-frequency transponders from all AMSS service providers in a given coverage area. In the simulation, the value of N_T is equal to 12 (recommended value in Att. 10 to Doc. 8D/140(Rev.1), which is a worst case), the maximum data rate per transponder of 36 MHz is 3 Mbps and the Average data rate per aircraft is 64 kbps.

Those values bring to a maximum capacity of 562 aircrafts.

P_{geo} can be estimated as being close to 0.1 for the considered area.

- The $P_{i\text{-}path}$ is calculated as:

$$\text{Pi-path} = \frac{length.of.route.i}{\sum_{j=0}^{20} Length.of.route.j}$$

On this basis, the average number of aircrafts transmitting over the United Kingdom in co-frequency is hence:

$$N = C_{max}\ P_{geo} = 56$$

To provide valid statistics, time dependent interference analysis over a period of 250 minutes is taken. The aircrafts have been moved on the routes every 30s.

The total number of aircrafts at a time T is kept to be close to the N value calculated above.

A3.2 Simulations results

Tables 4 to 6 below present results related to the three different pfd masks defined in section 4.1.1 above representing more than 50 simulation runs and hence are representative of almost all possible cases.

Table A 3: FDP values for model 1

FS elevation angle (^{o})	Average FDP (%)	Max. FDP (%)
0	0.63	2.88
1	1.08	3.31
2	0.47	1.75
3	0.31	0.75
4	0.15	0.42
5	0.09	0.17

Table A 4: FDP values for model 2

FS elevation angle (^{o})	Average FDP	Max. FDP
0	0.59	2.17
1	0.88	2.21
2	0.42	1.36
3	0.26	0.69
4	0.16	0.28
5	0.11	0.23

Table A 5: FDP values for model 3

FS elevation angle (^{o})	Average FDP	Max. FDP
0	0.66	2.78
1	0.93	3.44
2	0.60	1.99
3	0.29	0.72
4	0.17	0.34
5	0.10	0.20

It can be seen from these tables that results for the three models are almost equivalent and that models 2 and 3 do not present any higher interference potential compared to model 1.

For the three masks, the average FDP is much lower than the 1% criteria where in some cases and for elevation lower than 2°, FDP levels up to 3.44 % are experienced and can be accepted as they only represent exceptional cases.

These levels should be compared with the one in table 7 below which have been obtained increasing both high and low elevation pfd by 5 dB and show that such mask would have a direct impact on the average FDP level up to percentages that are well above the criteria. It is also obvious that it would lead to maximum FDP values above 10%
.

FS elevation (°)	FDP (%) for model 1	FDP (%) for model 1 increased by 5 dB
0	0.63	1.84
1	1.08	3.44
2	0.47	1.61
3	0.31	0.84
4	0.15	0.52
5	0.09	0.31

Table A 6: Average FDP values for model 1 increased by 5 dB

Therefore, the general conclusion that can be drawn from these results is that the lower elevation angle of the pfd mask, derived from the short-term criteria have also a direct impact on the long-term FDP value.

On the contrary, results are almost not impacted by higher elevation pfd levels than those specified in model 1.

This is explained by the fact that planes seen by the FS station with a high elevation angles (higher pfd values) are close to the FS location which means that the probability to have such case is very low. In addition, the interference from the concerned plane is produced in the side lobes of the FS, which decreases the interference level compared to an interference produced in the main beam, even at lower pfd.

Hence low I/N level associated with low probability means that it has almost no effect on the FDP final values.

On the other hand, low elevation angles (between 0° and 10°) correspond to geometric cases where most of the planes are seen and can hence produce harmful interference on both short and long term, and thus should be protected.

A 4 Derivation of EIRP limits

In testing AMSS equipment to determine if it meets the pfd mask, it may be useful to determine an equivalent e.i.r.p. mask that can be used for testing purposes.

The pfd mask, pfd(θ)

where: θ is the angle of arrival (elevation angle) at the Earth's surface, can be used to mathematically determine an e.i.r.p. mask.

The e.i.r.p mask, e.i.r.p.(γ, H)

where: γ is the angle below the local horizontal plane and

H is the altitude of the aircraft.

This conversion proceeds in two steps. First, γ is converted to an equivalent angle of arrival, θ. Then the length of the propagation path for angle of arrival θ 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, θ, from γ and H:

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

where:

θ	=	Angle of arrival
R_e	=	Earth radius (6378 km)
H	=	Altitude of the aircraft in km
γ	=	Angle below the horizon.

NOTE – If the argument of the arccos function is greater than 1, the propagation path in the direction of the angle γ does not intersect the Earth. In this case, which occurs for values of γ of about 3.5 degrees or less, a value for θ 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(θ):

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

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

where:

d is the distance between the AES and the considered point on the Earth's surface, in km

pfd(θ) is in dB(W/m^2) in 1 MHz

e.i.r.p. is in dBW in 1 MHz.

The graph in Figure A 12 shows this function for various aircraft altitudes based on the pfd mask provided in section 5.1.

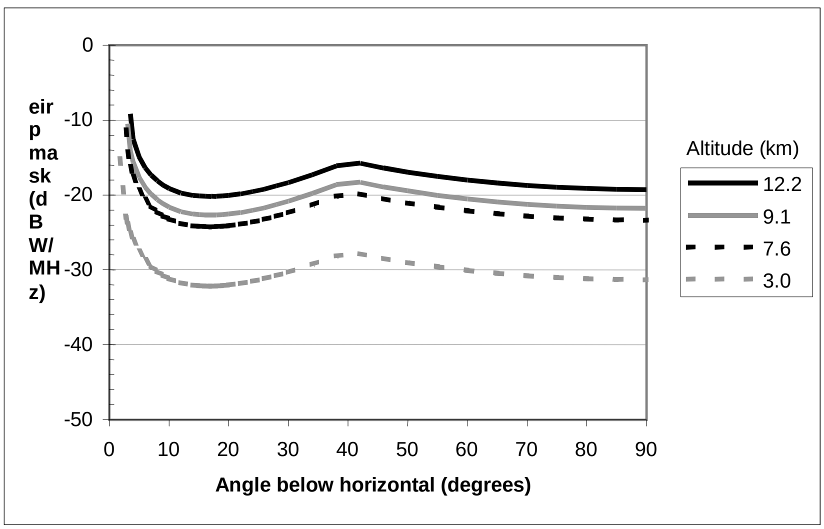

Figure A 12: e.i.r.p. mask derived from pfd mask

A5 Radio astronomy stations in CEPT that operate at ~14 GHz, as of January 2003

Country	RAS station	Location		Height above sea level (m)	Diameter (m)	Minimum elevation (°)
		Longitude	Latitude			
Germany	Effelsberg	06°53'00”	50°31'32"	369	100	7
Russia	Badari	102°13'16"	51°45'27"	832	32	-5
	Kalyazin	37° 54'01"	57°13'22"	195	64	0
				200	22	6
	Svetloe	29° 46'54"	61°05'	80	32	-5
	Zelenchukskaya	41° 35'32"	43°49'53"	1000	32	-5
United Kingdom	Cambridge	00° 02'20"	52°09'59"	24	interferometer	0

Table A 7

Radio astronomy interest is for spectral line observations of formaldehyde and continuum observations. Usually the observations are undertaken in single dish mode. In Russia, the frequency band 14.47 - 14.5 GHz is also used for VLBI observations.