



ECC Report **251**

The impact of UWB applications on board aircraft in the band 6-8.5 GHz on FS links used around airports and on EESS earth stations

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0 EXECUTIVE SUMMARY

This report studies the compatibility between UWB on board aircrafts and FS links plus EESS earth stations in the frequency range 6-8.5 GHz.

The impact on FS links

The most critical situation would be when an aircraft is crossing the main beam of a FS antenna. Such events are quite common in countries like Norway where the topography favours the use of microwave systems instead of cable in airfield areas.

It has been shown that aircrafts in motion would not give interference events which exceeds 10 consecutive seconds. It can thus be considered as performance degradation, where the FS short term interference protection criterion used in Recommendation ITU-R SF.1650 [1] has been selected, based on the advice from SE19. Concerning the interference from a stationary aircraft, the long term interference protection criterion in Recommendation ITU-R F.758 [2] has been applied.

Based on the ITU-R recommended systems parameters to be used in such compatibility studies – as shown in Table 2– the worst case minimum protection distance between an aircraft and a FS receiver is estimated to be about 150 m and 14 km for in motion and stationary aircrafts respectively.

With on a minimum separation of 150 m only it can be concluded that, except for helicopters, an aircraft in motion with UWB on board should not cause any interference problems to FS links. It is also assumed that interference from UWB on board a stationary aircraft to FS links would be a seldom if ever case. A Norwegian investigation, based on the impact on total 64 FS links in airport areas, where the actual systems parameters has been used in the calculation of the expected interference level, is conforming these findings.

The impact on EESS earth stations

The impact on EESS earth stations from UWB interference on board aircrafts has been studied by means of dynamic analysis tools in order to evaluate the occurrence of events where an aircraft is within the main beam of a receiving earth station, depending on the fuselage attenuation considered.

This simulation has shown that these events would happen for very small fraction of time only.

A simple calculation indicates that there may be cases where UWB on board aircraft might exceed the long-term protection criterion of -145 dBW/10 MHz set forth in Recommendation ITU-R SA.1026 [3]. However, this criterion refers to at least 20% of the time and thus not valid for these few short interference events. The short-term protection criterion contained in the same recommendation would never be exceeded. Similarly, the protection criteria defined when considering a 1% apportionment usually considered for UWB would never be exceeded.

It can therefore be concluded that there is no compatibility issue between EESS and UWB on board aircraft in the band 8 025-8 400 MHz.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
CEPT	European Conference of Postal and Telecommunications Administrations
DB	Direct broadcast
dB_i	Decibel isotropic
dB_{ic}	Decibel isotropic radiator circularly polarized
DR_o	Direct Readout
ECC	Electronic Communications Committee
EESS	Earth Exploration Satellite Service
e.i.r.p.	equivalent isotropically radiated power
ES	Errored Second
ESA	European Space Agency
FS	Fixed Service
FSS	Fixed Satellite Service
ILS	Instrument Landing System
ITU	International Telecommunication Union
KSAT	Kongsberg Satellite Services
MATLAB	Matrix Laboratory
MS	Mobile Service
SFCG	Space Frequency Coordination Group
STK	System Tool Kit
TT&C	Telemetry, Tracking & Command
UWB	Ultra-wideband
WAIC	Wireless Avionics Intra Communications
WRC	World Radiocommunication Conference

1 INTRODUCTION

The impact of UWB on board aircraft in the band 6-8.5 GHz on FS links used around airports and on EESS earth stations using the band 8025-8400 MHz will be analysed in this report. This is a complementary work to ECC Report 175 [4].

2 THE IMPACT OF UWB APPLICATIONS ON BOARD AIRCRAFTS

This chapter consists of two parts; the first dealing with the impact on FS links and the second part dealing with the impact on EESS earth stations.

2.1 THE IMPACT ON FS LINKS

In ECC Report 175 [4] the UWB-FS compatibility study is based on the ITU-R long-term interference criterion which is valid when the interfering signal is present for more than about 20 % of the time. As most FS are to be affected by such interfering signals for a very short period of time (i.e. when the aircraft is in motion) also short-term interference criteria must be included in such an analysis.

The ES (Errored Seconds) criterion applied in Recommendation ITU-R SF.1650 [1] has been used in the study of the 5925-6425 MHz band between in-motion earth stations located vessels and FS.

2.1.1 Interference criteria

The following interference criteria has been used to protect the FS in the 6 to 8.5 GHz band from time varying aggregate interference from UWB onboard aircrafts:

- 1 for the long- term, the I/N at the input of the FS receiver should not exceed –20 dB for more than 20 % of the time;
- 2 for the short- term, the I/N at the input of the FS receiver should not exceed +19 dB for more than 0.00045 % of the time for ES (Errored Seconds)

2.1.2 Interference characteristics

The quality of a FS transmission circuit is characterized by limits for both performance and availability degradations. In order to get degradation of the availability an interference event must have duration of at least 10 consecutive seconds. Shorter interference events can cause performance degradations only. It is thus necessary to have information available on the typical consecutive length of an UWB on board aircraft interference period.

From a Norwegian study it has been concluded that in order to get harmful interference an aircraft must be in the landing and and/or departure of the mode of the flight movements, where the aircraft has a velocity down to about 200 km/hour. The aircraft must be situated within the main beam of the FS antenna and at the same time the separation distance between the aircraft and antenna is quite short.

With the assumptions of a 40 m long aircraft body and a FS antenna gain of 42 dBi, the length of an interference event has been estimated as shown in Table 1.

Table 1: Example of the duration of an interference event

Aircraft-FS antenna separation distance (km)	Aircraft velocity (km/seconds)	Length of aircraft body (m)	FS antenna gain (dBi)	15 dB beam-width (deg.)	Interference event duration (seconds)
1	200	40	42	3	1.7

It is not likely that a harmful UWB interference event from an aircraft in motion would exceed 10 seconds. It can therefore be concluded that only the performance would be affected and thus that the defined short term interference criterion can be applied.

In contrast to this situation interference from a stationary aircraft has to be considered as long-term interference. It is also assumed that a helicopter could cause long-term interference even when it is in motion.

2.1.3 Interference calculation methodology

The flight path during arrival and departure is quite precise described in the ILS navigation charts. This is illustrated as shown in Figure 1 where a FS path is crossing a distance just above the flight path.

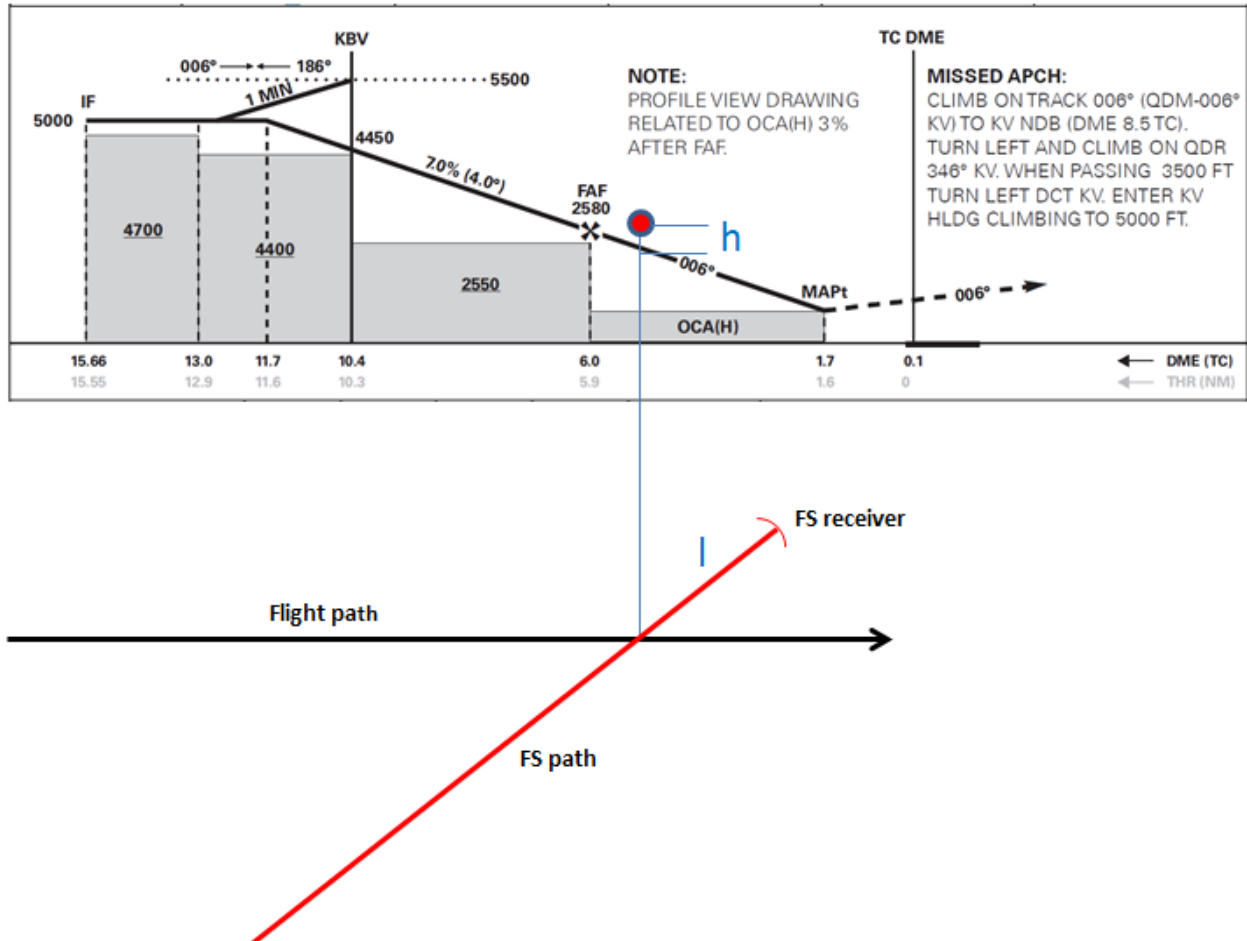


Figure 1: Flight path

The level of UWB interference (I) into the FS receiver is calculated as follows:

$$I = P - AS - AF + G$$

where:

- P is the UWB e.i.r.p. (dbm/MHz);
- AS is the airplane screening attenuation (dB);
- The values should be based Report ITU-R M.2283 [6];
- AF is the free space loss (dB) for path length I (i.e. between crossing-point and FS receiver);
- G is the FS antenna gain in the direction to the aircraft (dBi).

The gain and its pattern for the actual antenna should be used. If not available “typical” antenna pattern for sharing studies is given in Recommendation ITU-R F.699 [7].

The angle parameter in the antenna diagram is calculated from the following formula:

$$\text{Angle} = \frac{180}{3.14} \times \frac{h}{l} \text{ (}^\circ\text{)}$$

where:

h and l (m) is the distances as shown in Figure 1.

2.1.4 Blocking factor

When the aircraft is passing is through the main beam of the FS antenna the wanted signal is reduced by diffraction loss because of the aircraft is blocking parts of the Fresnel zone area. An estimate of this diffraction loss, which is often named “the blocking factor”, can be done in the following way:

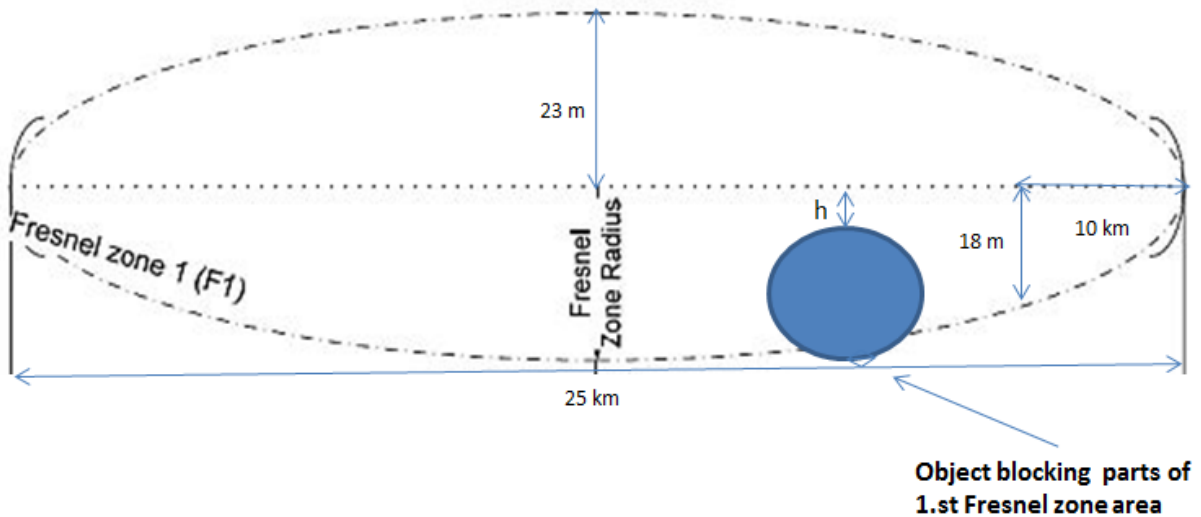


Figure 2: Fresnel zone area

Assume a 50 km long path with the extent of the 1.st Fresnel zone area for 7 GHz as shown in Figure 2. If an object is obstructing parts of the 1.st Fresnel zone area then the blocking factor can be estimated from Figure 3 which is based on empirical diffraction data (as given in Recommendation ITU-R P.530 [5]). Because of the size of the 1.st Fresnel zone area (which in practice is valid for frequencies up to 10-15 GHz) compared with the extent of the aircraft body it is not likely that an aircraft can obstruct more than 50 % of the full 1.st Fresnel zone area. The maximum blocking factor (using the empirical diffraction curve) is therefore estimated to be about 10 dB.

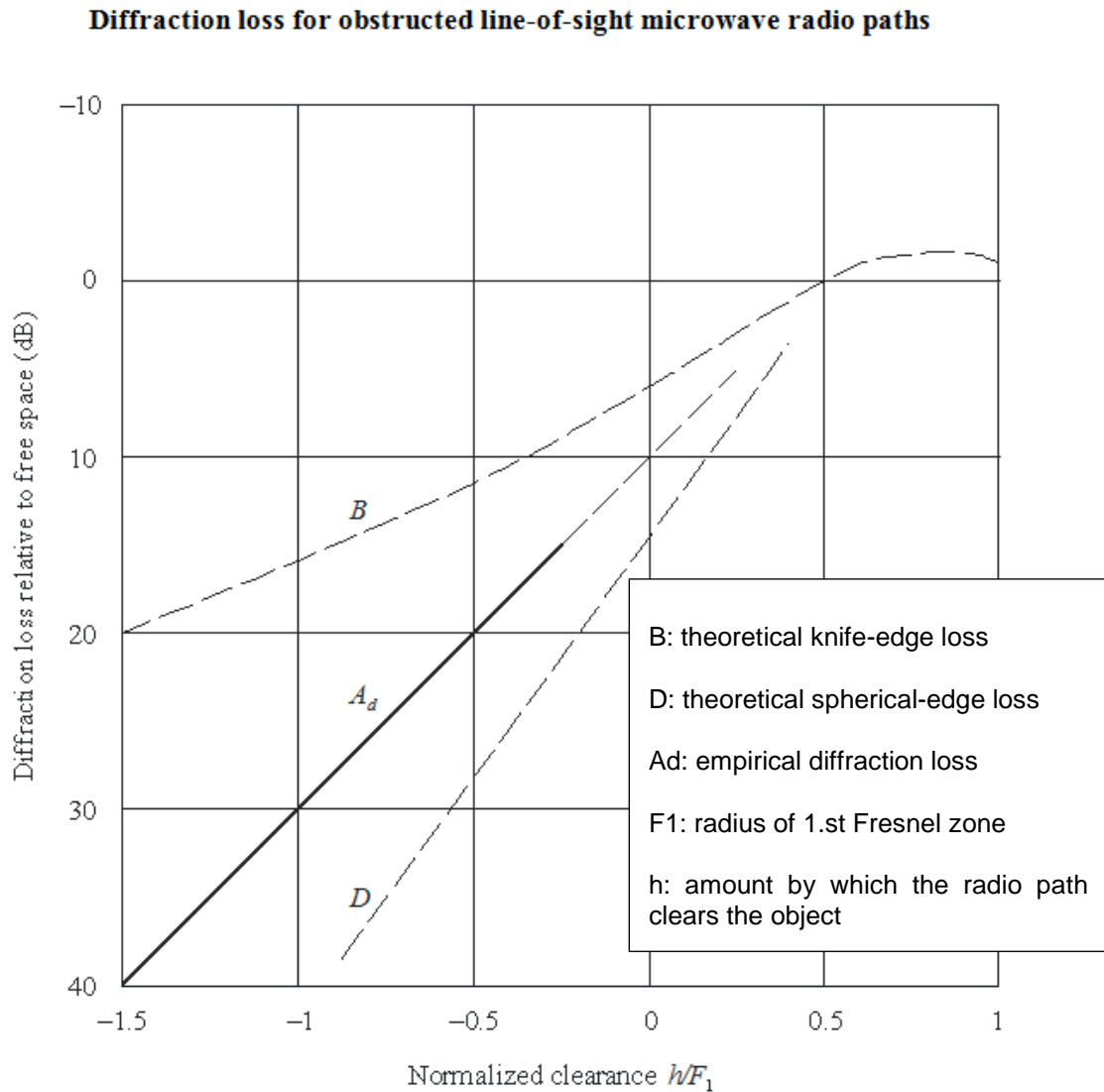


Figure 3: Diffraction loss

In comparison to this theoretical estimate of the blocking factor 5 critical radio paths were picked out in Norway and the signals have been monitored for several days and correlated with the actual (regular) air traffic in the area.

Attenuation caused by aircrafts during this period has been detected on one of these paths only as shown in Figure 4.

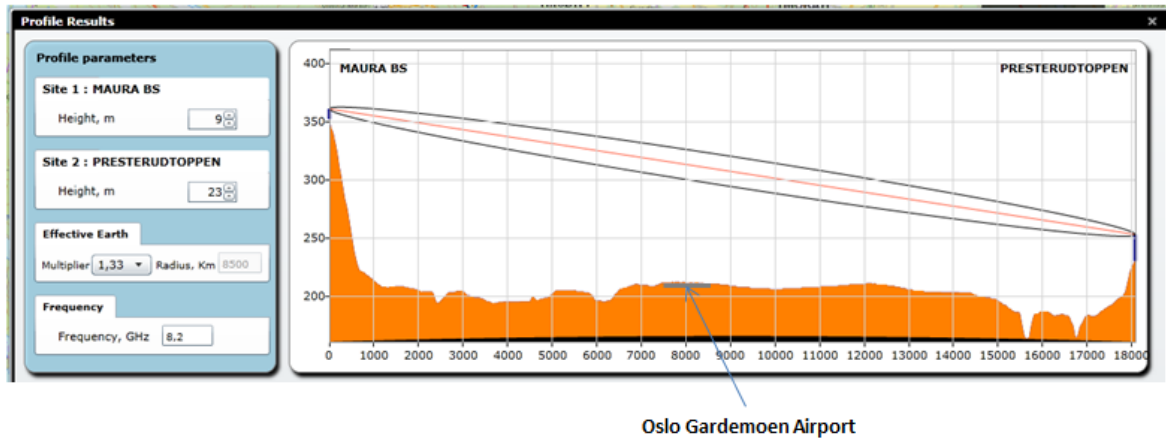


Figure 4: Example of path profile with possible blocking

The link is using the 8.2 GHz band and the maximum aircraft attenuation during the measuring period is 6 dB.

2.1.5 FS protection distances

The aircraft to FS protection distances can be estimated based on the system parameters as shown in Table 2.

Table 2: FS and UWB parameters

Frequency (F), GHz	6.77	
FS receiver noise (N), dBm/MHz	-109	From Recommendation ITU-R F.758
Aircraft blocking factor (AB), dB	6	From Norwegian measurements
FS antenna gain (G), dBi	45	From Recommendation ITU-R F.758
I/N long term criterion (I/NLT), dB	-20	From Recommendation ITU-R F.758
I/N short term criterion (I/NST), dB	+19	From Recommendation ITU-R SF.1650
UWB e.i.r.p. (P), dBm/MHz	-41.3	From ECC Decision (06)04 [8]
Number of simultaneous UWB devices	2	
Aircraft screening attenuation (AS), dB	10	From Report ITU-R M.2283
P aircraft e.i.r.p. (PA), dBm/MHz	-48.3	

The formula for the calculation of the protection distance D (km):

$$D = 10^{\uparrow} (PA + G + AB - N - I/N - 20 \cdot \log F - 92,4) / 20$$

2.1.5.1 Worst case protection distances

UWB on board aircrafts in motion:

$$D = 10^{(-48.3 + 45 + 6 + 109 - 19 - 20 \cdot \log 6.77 - 92.4)/20}$$

$$D = 0.153 \text{ km}$$

UWB on board a stationary aircrafts:

$$D = 10^{(-48.3 + 45 + 6 + 109 + 20 - 20 \cdot \log 6.77 - 92.4)/20}$$

$$D = 13.627 \text{ km}$$

The study in ANNEX 1: based on real links in Norway confirms that an aircraft in motion would not cause any interference problems to FS.

2.2 THE IMPACT ON EESS EARTH STATIONS

2.2.1 EESS Earth stations characteristics

The band 8 025-8 400 MHz is heavily used by all space agencies, including government and private companies, to download data obtained by EESS satellites. Future EESS missions will continue to use this band. The Space Frequency Coordination Group (SFCG) maintains a database on a best effort basis to provide an overview of all EESS missions operating in the 8025-8400 MHz range. This database includes mainly Administration-sponsored and space agencies scientific missions, and cover commercial missions to a limited extent. The SFCG database currently includes more than 180 EESS satellites using X-Band for payload data downlink: 110 are operational missions, plus dozens of missions in development phase.

There are two types of EESS users of that band, one requiring wideband communications (several hundred megabits/second) and the other requiring moderate data rates (15-20 megabits/sec).

2.2.1.1 Wideband, high data-rate science data downlinks

The wideband data links are crucial to the Earth observing community as they are used to transmit the payload data collected and stored on-board EESS satellites to the ground, where it can be processed and analysed. The stored data are transmitted at rates up to 1200 megabits/second. As the data include error-correcting coding, bandwidths of up to 375 MHz may be required. Earth stations with wideband capability typically require antennas at least 10 meters in diameter and have both receive and transmit capabilities, although the TT&C operations (commanding and reception of housekeeping telemetry) is done in S-band. The ESA Estrack network uses 13 and 15 m earth stations in X-band.

These stations are the primary data downlink stations for the EESS satellites that they service. Their locations are known, and they are expected to remain a permanent part of the EESS communications infrastructure.

2.2.1.2 Narrow-band, moderate data-rate science data downlinks

These links provide real-time data transmitted directly from the satellite to any earth station with a direct line-of-sight to the satellite. These real-time data systems are called "direct readout" (DRO) or "direct broadcast" (DB) systems. Their data-rates are 15 to 20 megabits/second, and the required antenna is typically 3 meters in diameter. Such EESS earth station systems are commercially available, and they include everything from the antenna system through the data processing equipment (both hardware and software). Over 130 direct readout earth stations are known to be in use today.

These systems provide immediate observations of the local environment and are used for tasks ranging from forecasting weather to monitoring plant health to directing fire fighters battling wildland fires. As these are receive-only stations, they need not be licensed and hence all of their locations may not be known.

The overall characteristics are summarised in Table 3

Table 3: Parameters of EESS earth stations

EESS Parameter	Values	Units
Frequency	8025-8400	MHz
Min. tracking angle	5	deg
Antenna diameter	2.4 to 15	m
Antenna Height	5 to 20	m
Antenna gain pattern	ITU RR AP 8-10 Annex III	

2.2.2 Protection criterion

Recommendation ITU-R SA.1026 [3] provides the relevant protection criteria for EESS earth stations in the band 8025-8400 MHz, which are recalled in Table 4.

Table 4: Protection criteria from recommendation ITU-R SA.1026

Frequency band	Type of earth station	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 0.0125% of the time
8 025-8 400 MHz	54.8 dBic antenna gain Recorded data playback	-145 dBW per 10 MHz	-133 dBW per 10 MHz
	41.7 dBic antenna gain Recorded data playback	-135 dBW per 10 MHz	-127 dBW per 10 MHz
	42.5 dBic antenna gain Direct data readout	-139 dBW per 10 MHz	-129 dBW per 10 MHz

The EESS already shares the band with FS and MS, as well as FSS. The receiving earth stations may therefore receive interference from these services, on top of other operating EESS satellites. As usual for studies involving UWB devices, a 1% apportionment in level should be considered for the long-term protection criterion. The same apportionment should be considered on the percentage of time associated with the short-term criterion, since the short-term events would aggregate in time.

Table 5: Proposed protection criteria vs UWB when considering apportionment

Frequency band	Type of earth station	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 0.0001% of the time.
8 025-8 400 MHz	54.8 dBic antenna gain Recorded data playback	-165 dBW per 10 MHz	-133 dBW per 10 MHz
	41.7 dBic antenna gain Recorded data playback	-155 dBW per 10 MHz	-127 dBW per 10 MHz
	42.5 dBic antenna gain Direct data readout	-159 dBW per 10 MHz	-129 dBW per 10 MHz

2.2.3 Dynamic analysis

A calculation is provided in ANNEX 2: showing some potential issues when an aircraft is within the main beam of a receiving earth station, depending on the fuselage attenuation considered.

Since the main beam of the antenna is unlikely to be pointed towards an EESS satellite and an aircraft passing by at the same time, such high interference levels should be rare. A simulation has been developed using STK and MATLAB to evaluate the occurrence of such events.

STK is used to simulate the trajectory of an EESS satellite on a sun-synchronous polar orbit and determine the pointing direction of the EESS earth station over time. MATLAB is then used to simulate the passage of thousands of aircraft in visibility of the earth station over the simulation time and calculate the aggregate interference produced in the EESS earth station. The trajectory of each aircraft corresponds to actual air routes. A similar tool has been used in the studies involving WAIC and FS under WRC-15 AI 1.17. The FS station has simply been replaced by an EESS receiving earth station.

The parameters used for the simulation are given in Table 6.

Table 6: Parameters used for the simulation

Earth station latitude	43.4292°	Aussaguel (France – Toulouse area)
Earth station longitude	1.4972°	
Earth station antenna gain	55 dBi	10-11 m dish
Satellite tracked	Sun-synchronous, 600 km	
Frequency	8 200 MHz	
Number of aircraft in visibility	Variable (about 360 per day – 3600 in total)	
Altitude of aircraft	7000, 9000, 11000m	Randomly attributed
UWB eirp	-38.3 dBm/MHz	2 UWB devices each -41.3 dBm/MHz, no fuselage attenuation
Protection criteria	See Table 2 and Table 3	

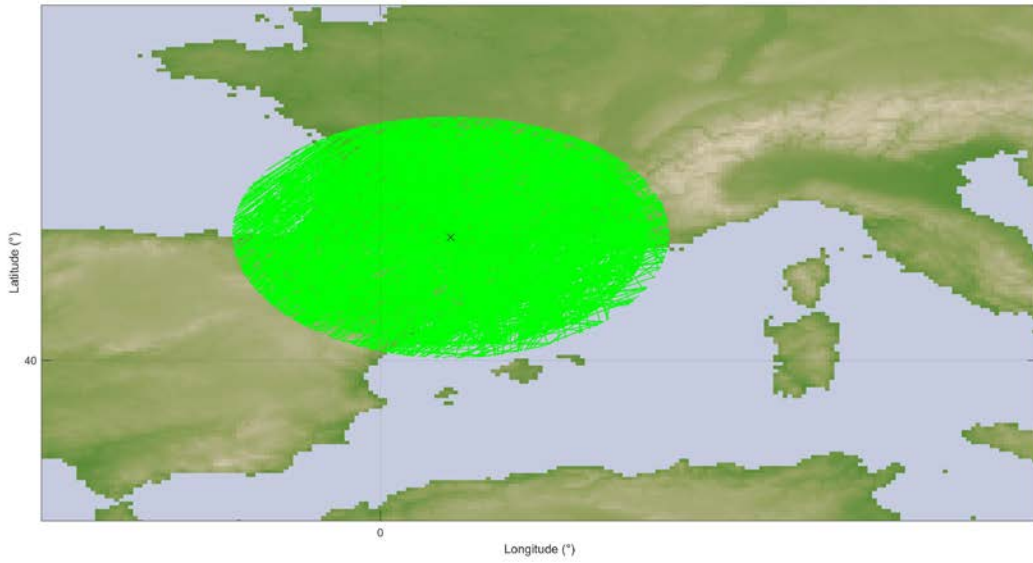


Figure 5: Aircraft trajectories simulated over 10 days

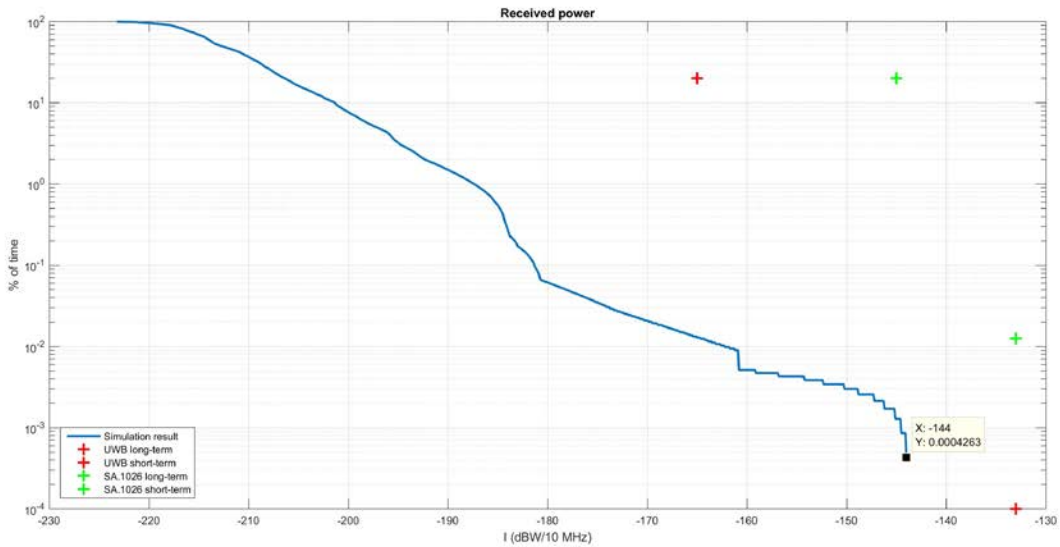


Figure 6: Aggregate Interference cumulative distribution function

This result confirm that the protection criterion of -145 dBW/10 MHz (or -125 dBm/MHz) – upper green cross) would be exceeded when considering no fuselage attenuation. However it also shows that this would happen for very low percentage of time (0.0004% of the time the satellite is in visibility of its earth station which is 0.1 second over 10 days). In all cases the short-term protection criterion is never reached. Additional margins would exist when considering additional losses due to fuselage attenuation.

3 CONCLUSIONS

3.1 THE IMPACT ON FS LINKS

It is shown in section 2.1 that UWB interference from an aircraft in motion can be characterized as short-term interference which a FS system in most cases is able to withstand, thanks to its high fade margin (above 30 dB). The worst case minimum protection distance between an aircraft in motion and a FS receiver would be about 150 m.

In contrast to this, UWB interference from a stationary aircraft is characterized as long-term interference where the worst case minimum separation distance would be about 14 km.

The study in ANNEX 1: based on real links in Norway confirms that an aircraft in motion would not cause any interference problems to FS. It is also assumed in general, except for helicopters, that an aircraft would not pass a FS antenna closer than 150 m.

In the study in ANNEX 1: also possible UWB interference from a stationary aircrafts has been investigated without finding any actual case. However, this is a situation which can happen elsewhere.

3.2 THE IMPACT ON EESS EARTH STATIONS

Although a simple calculation indicates that there may be cases where UWB on board aircraft might exceed the long-term protection criterion of -145 dBW/10 MHz set forth in Recommendation ITU-R SA.1026 [3] a dynamic simulation has shown that this would happen for only a very small fraction of time. The short-term protection criterion contained in the same recommendation would never be exceeded. Similarly, the protection criteria defined when considering a 1% apportionment usually considered for UWB would never be exceeded.

It can therefore be concluded, based on the studies, that there is no compatibility issue between EESS and UWB on board aircraft in the band 8 025-8 400 MHz.

ANNEX 1: MAXIMUM IMPACT OF UWB ON FS

Worst case UWB impact from aircrafts (in motion) to FS systems close to Norwegian airports is calculated in the following Table 7. The calculations are based on the actual FS system parameters.

Table 7: Worst case calculations

Airport area	Disturbed radio path	Distance to disturbed link-site (m)	Crossing path height difference (m)	Antenna discrim. angle (Deg)	Antenna diameter (m)	Antenna gain (dBi)	Antenna discrim. Loss (dB)	Frequency band (GHz)	Path loss (dB)	Fuselage attenua. (dB)	e.i.r.p aggregated power for 2 act. dev. (dBm/MHz)	Interference level for 2 act. dev. (dBm/MHz)	Short term (0.00045 %) permissible interference level (dBm/MHz)	Assumed blocking factor (dB)	Interference margin (dB)
Vadsø	Torsvarden Lyngberget	3650	35	0.5	2.4	43.8	1	8.2	121.9	10	-48.3	-127.4	-90	6	31.4
Vadsø	Torsvarden Svartaksla	3650	15	0.2	4.5	46.9	0	6.7	120.2	10	-48.3	-121.6	-90	6	25.6
Vadsø	Melkevarden Lyngberget	1276	5	0.2	3.0	43.6	0	6.2	110.4	10	-48.3	-115.1	-90	6	19.1
Båtsfjord	Hamnefjell Domen	5190	30	0.3	3.7	45.6	0	6.7	123.2	10	-48.3	-125.9	-90	6	29.9
Berlevåg	Trollhetta Hamnefjell	35600	200	0.3	3.7	45.6	0	6.7	140.0	10	-48.3	-142.7	-90	6	46.7
Mehavn	Trollhetta -Oksen	11100	10	0.1	3.0	43.6	0	6.7	129.8	10	-48.3	-134.5	-90	6	38.5
Honningsvåg	Honningsvåg fj. Oksen	22000	20	0.1	3.0	43.6	0	6.7	135.8	10	-48.3	-140.5	-90	6	44.5
Hammerfest	Hammerfjell Torskefjell	1040	10	0.6	3.0	42.4	1	6.2	108.6	10	-48.3	-115.5	-90	6	19.5
Lakselv	Lakselv - Jekkir	2000	0	0.0	1.8	39.6	0	6.7	114.9	10	-48.3	-123.6	-90	6	27.6
Lakselv	Jekkir-Siribekken	23500	50	0.1	3.0	45.3	0	8.2	138.1	10	-48.3	-141.1	-90	6	45.1
Hasvik	Håen Breivikeidet REFL	1070	100	5.4	4.5	47.5	22	6.7	109.5	10	-48.3	-132.3	-90	6	36.3
Hasvik	Fuglen - Nuvsvåg	16700	30	0.1	1.2	36.4	0	6.2	132.7	10	-48.3	-144.6	-90	6	48.6

Airport area	Disturbed radio path	Distance to disturbed link-site (m)	Crossing path height difference (m)	Antenna discrim. angle (Deg)	Antenna diameter (m)	Antenna gain (dBi)	Antenna discrim. Loss (dB)	Frequency band (GHz)	Path loss (dB)	Fuselage attenua. (dB)	e.i.r.p aggregated power for 2 act. dev. (dBm/MHz)	Interference level for 2 act. dev. (dBm/MHz)	Short term (0.00045 %) permissible interference level (dBm/MHz)	Assumed blocking factor (dB)	Interference margin (dB)
Alta	Hjemmeluft - Stifjell	6300	70	0.6	4.5	47.4	8	6.7	124.9	10	-48.3	-133.8	-90	6	37.8
Alta	Komsa - Helligfjell	3400	90	1.5	1.2	37.5	4	8.2	121.3	10	-48.3	-136.1	-90	6	40.1
Sørkjosen	Bertelfjell-Rappesvarre	2100	0	0.0	3.0	43.6	0	6.2	114.7	10	-48.3	-119.4	-90	6	23.4
Tromsø	Stalheim RL-Kvitbergfjell	1450	0	0.0	4.5	46.9	0	6.7	112.1	10	-48.3	-113.5	-90	6	17.5
Bardufoss	Johaugen-Kistefjell	7700	200	1.5	1.8	41.4	5	8.2	128.4	10	-48.3	-140.3	-90	6	44.3
Andøya	Ramnan-Grunnfarnes	6100	180	1.7	1.2	37.3	3	8.2	126.4	10	-48.3	-140.4	-90	6	44.4
Andøya	Ramnan-Kaldfarnes	6300	170	1.5	1.8	40.6	5	8.2	126.7	10	-48.3	-139.4	-90	6	43.4
Evenes	Håfjell-Samaåsen	11400	100	0.5	3.7	44.7	1	6.7	130.1	10	-48.3	-134.7	-90	6	38.7
Bodø	Rønvikfjell Vest-Sørarnøy TVO	6100	50	0.5	1.8	41.1	0	8.2	126.4	10	-48.3	-133.6	-90	6	37.6
Bodø	Rønvikfjell Vest-Kunna	5400	35	0.4	3.7	44.7	0	6.7	123.6	10	-48.3	-127.2	-90	6	31.2
Bodø	Rønvikfjell Vest-Salten	4800	60	0.7	2.4	41.3	0	6.2	121.9	10	-48.3	-128.9	-90	6	32.9
Stokmarknes	Storheia-Sortland TVO	7000	150	1.2	1.8	41.1	3	8.2	127.6	10	-48.3	-137.8	-90	6	41.8
Stokmarknes	Storheia-Eidet TVO	4850	30	0.4	1.8	41.1	0	8.2	124.4	10	-48.3	-131.6	-90	6	35.6
Stokmarknes	Storheia-Eidet Vesterålen	4850	50	0.6	2.4	41.3	1	6.2	122.0	10	-48.3	-130.0	-90	6	34.0

Airport area	Disturbed radio path	Distance to disturbed link-site (m)	Crossing path height difference (m)	Antenna discrim. angle (Deg)	Antenna diameter (m)	Antenna gain (dBi)	Antenna discrim. Loss (dB)	Frequency band (GHz)	Path loss (dB)	Fuselage attenua. (dB)	e.i.r.p aggregated power for 2 act. dev. (dBm/MHz)	Interference level for 2 act. dev. (dBm/MHz)	Short term (0.00045 %) permissible interference level (dBm/MHz)	Assumed blocking factor (dB)	Interference margin (dB)
Leknes	Ballstad TVO-Borge TVO	2770	40	0.8	1.2	37.5	1	8.2	119.5	10	-48.3	-131.3	-90	6	35.3
Røst	Røst-Værøyfjell	200	90	25.8	1.8	41.4	34	8.2	96.7	10	-48.3	-137.6	-90	6	41.6
Sandnessjøen	Åsen RL-Gulsvåg fjell	11900	100	0.5	3.7	45.5	3	6.7	130.4	10	-48.3	-136.2	-90	6	40.2
Brønnøysund	Brønnøysund-Gulsvåg fjell	600	110	10.5	0.9	35.5	22	8.2	106.2	10	-48.3	-141.0	-90	6	45.0
Rørvik	Falkhetta-Rørvik Lufthavn	5800	5	0.0	0.9	35.5	0	8.2	125.9	10	-48.3	-138.7	-90	6	42.7
Namsos	Spillumsaksla-Munken	3030	60	1.1	2.4	43.8	6	8.2	120.3	10	-48.3	-130.8	-90	6	34.8
Namsos	Forbordfjell-Sundal BS	13400	30	0.1	1.2	37.3	0	8.2	133.2	10	-48.3	-144.2	-90	6	48.2
Namsos	Forbordefjell-Kirkebyfjell REP	10000	240	1.4	1.8	41.4	5	8.2	130.7	10	-48.3	-142.6	-90	6	46.6
Ørland	Kopparen-Myrafjellet	16000	90	0.3	1.8	40.6	0	8.2	134.8	10	-48.3	-142.5	-90	6	46.5
Ørland	Kopparen-Opphaug	17000	150	0.5	2.4	42.4	2	6.7	133.5	10	-48.3	-141.4	-90	6	45.4
Røros	Røros-Hummelfjell	1200	0	0.0	1.8	38.6	0	6.2	109.8	10	-48.3	-119.5	-90	6	23.5
Krisiansund	Varden-Reinsfjell	2250	80	2.0	1.2	37.5	6	8.2	117.7	10	-48.3	-134.5	-90	6	38.5
Krisiansund	Norlandet BS-Reinsfjell	950	70	4.2	3.0	44.2	24	6.7	108.5	10	-48.3	-136.6	-90	6	40.6
Molde	Tusten-Gamlemsveten	7500	0	0.0	3.7	45.7	0	6.7	126.4	10	-48.3	-129.0	-90	6	33.0
Molde	Tusten-Tresfjord 1	4575	55	0.7	1.8	41.1	1	8.2	123.9	10	-48.3	-132.1	-90	6	36.1

Airport area	Disturbed radio path	Distance to disturbed link-site (m)	Crossing path height difference (m)	Antenna discrim. angle (Deg)	Antenna diameter (m)	Antenna gain (dBi)	Antenna discrim. Loss (dB)	Frequency band (GHz)	Path loss (dB)	Fuselage attenua. (dB)	e.i.r.p aggregated power for 2 act. dev. (dBm/MHz)	Interference level for 2 act. dev. (dBm/MHz)	Short term (0.00045 %) permissible interference level (dBm/MHz)	Assumed blocking factor (dB)	Interference margin (dB)
Molde	Tusten-Tomrefjord 1	8670	120	0.8	1.8	41.1	3	8.2	129.4	10	-48.3	-139.6	-90	6	43.6
Molde	Tusten-Torvikveten	3890	50	0.7	1.8	40.6	1	8.2	122.5	10	-48.3	-131.2	-90	6	35.2
Ørsta-Volda	Kaldsethola-Nerlandsøy	4800	50	0.6	1.2	37.4	0	8.2	124.3	10	-48.3	-135.2	-90	6	39.2
Florø	Kinn-Ramsdalsheia	6990	70	0.6	3.0	45.5	5	8.2	127.6	10	-48.3	-135.4	-90	6	39.4
Florø	Storåsen-Skredvarden REFL	990	70	4.1	3.7	45.6	24	6.7	108.8	10	-48.3	-135.5	-90	6	39.5
Sogndal	Storehogen-Geisdalsåsen REFL	6470	100	0.9	2.4	43.6	5	8.2	126.9	10	-48.3	-136.6	-90	6	40.6
Sogndal	Storehogen-Lærdalsøyri	5400	140	1.5	1.8	40.6	8	8.2	125.3	10	-48.3	-141.0	-90	6	45.0
Sogndal	Sogndal Lufthavn-Holmåsén REFL	150	0	0.0	0.9	35.5	0	8.2	94.2	10	-48.3	-107.0	-90	6	11.0
Bergen	Ulriken-Knappefjell	11960	40	0.2	1.2	37.5	0	8.2	132.2	10	-48.3	-143.0	-90	6	47.0
Stord	Siggjo-Fitjar RL	7920	105	0.8	0.9	35.2	0	8.2	128.7	10	-48.3	-141.7	-90	6	45.7
Stord	Siggjo-Kattnakken	5160	80	0.9	1.2	34.4	0	6.2	122.5	10	-48.3	-136.4	-90	6	40.4
Stavanger	Ullandhaug RL-Urdalsnipa	10100	230	1.3	3.0	44.0	10	6.7	129.0	10	-48.3	-143.3	-90	6	47.3
Kristiansand	Odderøya-Risdalsheia	9000	170	1.1	3.0	43.6	8	6.7	128.0	10	-48.3	-140.7	-90	6	44.7
Skien	Vealøs-Bronane	6700	115	1.0	3.0	45.3	8	8.2	127.2	10	-48.3	-138.2	-90	6	42.2

Airport area	Disturbed radio path	Distance to disturbed link-site (m)	Crossing path height difference (m)	Antenna discrim. angle (Deg)	Antenna diameter (m)	Antenna gain (dBi)	Antenna discrim. Loss (dB)	Frequency band (GHz)	Path loss (dB)	Fuselage attenua. (dB)	e.i.r.p aggregated power for 2 act. dev. (dBm/MHz)	Interference level for 2 act. dev. (dBm/MHz)	Short term (0.00045 %) permissible interference level (dBm/MHz)	Assumed blocking factor (dB)	Interference margin (dB)
Skien	Vealøs-Trollfjell	10700	140	0.8	1.2	37.4	0	8.2	131.3	10	-48.3	-142.2	-90	6	46.2
Torp	Kamfjordåsen-Frodeåsen tele	2400	160	3.8	1.8	41.4	16	8.2	118.3	10	-48.3	-141.2	-90	6	45.2
Notodden	Jonsknuten-Bronane	20000	270	0.8	3.7	45.4	5	6.7	134.9	10	-48.3	-142.8	-90	6	46.8
Rygge	Ramberg-Sprinklerfjell	6000	180	1.7	1.2	37.3	4	8.2	126.2	10	-48.3	-141.2	-90	6	45.2
Kjeller	Røverkollen-Runddelen	7900	130	0.9	1.8	40.6	1	8.2	128.6	10	-48.3	-137.3	-90	6	41.3
Oslo (Gardemoen)	Mistberget-Tryvannstårnet	9500	130	0.8	3.7	45.5	3	6.7	1/28.5	10	-48.3	-134.3	-90	6	38.3
Oslo (Gardemoen)	Maura BS-Presterudstoppen	8150	90	0.6	0.9	35.5	0	8.2	128.9	10	-48.3	-141.7	-90	6	45.7
Oslo (Gardemoen)	Mistberget-Presterudtoppen	6300	290	2.6	1.2	34.4	5	6.2	124.2	10	-48	-143	-90	6	47.1

ANNEX 2: CALCULATED UWB IMPACT ON EESS EARTH STATIONS

Table 8: EESS earth station parameters for a 10m antenna

UWB e.i.r.p. figures for 2 units in different damping sectors			
Basic e.i.r.p for 2 units is		-38.3	dBm/MHz
X-Band Downlink 7.750-8.400 GHz		8.075	GHz
Hor. Distance (km)	0.5		
Altitude (km)	10		
Range (km)	10.01	Elevation	87.14
Ant. Gain (dB)	55.376	10m ant	
Syst. G/T (dB/K)	33.165		
Syst. N Temp (dB)	22.211		
Ant. Noise (dBm/MHz)	-116.389		
Allowed I (dBm/MHz)	-124	Req. I/N	-7.61

Table 9: Worst case interference level for a 10m antenna

Att sector	Attenuation (dB)	Actual e.i.r.p. (dBm)	Range (km)	Dist. Loss (dB)	Ant. Gain (dBic)	Rec. Signal (dBm)	Ant noise (dBm/MHz)	I/N (dB)	I/N Margin (dB)
Case 3 a,b,c	45	-83.3	10.01	130.60	55.38	-158.53	-116.39	-42.14	34.53
Case 1 b,c	35	-73.3	10.01	130.60	55.38	-148.53	-116.39	-32.14	24.53
Case 1 a	25	-63.3	10.01	130.60	55.38	-138.53	-116.39	-22.14	14.53
Case 2 a	10	-48.3	10.01	130.60	55.38	-123.53	-116.39	-7.14	-0.47
Case 4 a	5	-43.3	10.01	130.60	55.38	-118.53	-116.39	-2.14	-5.47
Case 4 b	0	-38.3	10.01	130.60	55.38	-113.53	-116.39	2.86	-10.47

Table 10: EESS earth station parameters for a 5m antenna

Ant. Gain	50	5m ant	
Syst. G/T	28.24 (dB/K)		
Syst. N Temp	21.76 (dBK)		
Ant. Noise	-116.84 (dBm/MHz)		
Allowed I	-124 (dBm/MHz)	Req. I/N	-7.16 (dB)

Table 11: Worst case interference level for a 5m antenna

Att sector	Attenuation (dB)	Actual e.i.r.p (dBm)	Range (km)	Dist. Loss (dB)	Ant. Gain (dBic)	Rec. Signal (dBm)	Ant noise (dBm/MHz)	I/N (dB)	I/N Margin (dB)
Case 3 a,b,c	45	-83.3	10.01	130.60	50.00	-163.90	-116.84	-47.06	39.90
Case 1 b,c	35	-73.3	10.01	130.60	50.00	-153.90	-116.84	-37.06	29.90
Case 1 a	25	-63.3	10.01	130.60	50.00	-143.90	-116.84	-27.06	19.90
Case 2 a	10	-48.3	10.01	130.60	50.00	-128.90	-116.84	-12.06	4.90
Case 4 a	5	-43.3	10.01	130.60	50.00	-123.90	-116.84	-7.06	-0.10
Case 4 b	0	-38.3	10.01	130.60	50.00	-118.90	-116.84	-2.06	-5.10

Table 12: EESS earth station parameters for a 2.4m antenna

Ant. Gain	43	2.4m ant	
Syst. G/T	24 (dB/K)		
Syst. N Temp	19 (dBK)		
Ant. Noise	-119.6 (dBm/MHz)		
Allowed I	-124 (dBm/MHz)	Req. I/N	-4.4 (dB)

Table 13: Worst case interference level for a 2.4m antenna

Att sector	Attenuation (dB)	Actual e.i.r.p (dBm)	Range (km)	Dist. Loss (dB)	Ant. Gain (dBic)	Rec. Signal (dBm)	Ant noise (dBm/MHz)	I/N (dB)	I/N Margin (dB)
Case 3 a,b,c	45	-83.3	10.01	130.60	43.00	-170.90	-119.60	-51.30	46.90
Case 1 b,c	35	-73.3	10.01	130.60	43.00	-160.90	-119.60	-41.30	36.90
Case 1 a	25	-63.3	10.01	130.60	43.00	-150.90	-119.60	-31.30	26.90
Case 2 a	10	-48.3	10.01	130.60	43.00	-135.90	-119.60	-16.30	11.90
Case 4 a	5	-43.3	10.01	130.60	43.00	-130.90	-119.60	-11.30	6.90
Case 4 b	0	-38.3	10.01	130.60	43.00	-125.90	-119.60	-6.30	1.90

ANNEX 3: LIST OF REFERENCE

- [1] Recommendation ITU-R SF.1650-1: The minimum distance from the baseline beyond which in-motion earth stations located on board vessels would not cause unacceptable interference to the terrestrial service in the bands 5 925-6 425 MHz and 14-14.5 GHz
- [2] Recommendation ITU-R F.758-6: System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference
- [3] Recommendation ITU-R SA.1026-4: Aggregate interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit
- [4] ECC Report 175: Co-existence study considering UWB applications inside aircraft and existing radio services in the frequency bands from 3.1 GHz to 4.8 GHz and from 6.0 GHz to 8.5 GHz
- [5] Recommendation ITU-R P.530-16: Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
- [6] Recommendation ITU-R M.2283: Technical characteristics and spectrum requirements of Wireless Avionics Intra-Communications systems to support their safe operation
- [7] Recommendation ITU-R F.699: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz
- [8] ECC Decision (06)04: The harmonised conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz