Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Space Norway AS	)	
	)	
Petition for a Declaratory Ruling	)	File No.
Granting Access to	)	
the U.S. Market for the	)	
Arctic Satellite Broadband Mission	)	
	)	

PETITION FOR DECLARATORY RULING

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November 15, 2016

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PETITION FOR DECLARATORY RULING OF SPACE NORWAY AS

Space Norway AS ("Space Norway"), in accordance with Section 25.137 of the Commission's Rules,[1] hereby files this Petition for Declaratory Ruling ("PDR"), requesting authorization for Space Norway's highly elliptical orbit ("HEO"), non-geostationary orbit ("NGSO") satellite system, the Arctic Satellite Broadband Mission ("ASBM") to access the U.S. market. In addition, Space Norway requests to be considered in the processing round initiated by the Commission in connection with WorldVu Satellites Limited's (d/b/a OneWeb) petition to obtain authority to provide fixed-satellite service in the U.S. market using a proposed NGSO satellite constellation authorized by the United Kingdom.[2]

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[1] 47 C.F.R. § 25.137.

[2] *See* Satellite Policy Branch Information: OneWeb Petition Accepted for Filing, Public Notice, DA 16-804 (July 15, 2016); *WorldVu Satellites Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb System*, IBFS File No. SAT-LOI-20160428-00041 (filed April 28, 2016) ("OneWeb PDR").

I. BACKGROUND

Space Norway is a new entrant in the field of satellite communications that intends to provide high-speed broadband Internet connectivity services to end users in the Arctic region – a region that is in dire need of such services. Traditional geostationary orbit ("GSO") communications satellites have not been sufficient to meet the connectivity needs of the region and other conventional methods for internet access, such as terrestrial networks, are not yet developed enough to provide consistent and reliable connectivity. ASBM will be capable of providing reliable, high-quality coverage to areas in the Artic that have limited or no access to telecommunications services.

Formed in 1995, Space Norway is a Norwegian limited liability company, which is a wholly-owned subsidiary of the Norwegian Ministry of Trade, Industry and Fisheries, and has its headquarters in Oslo, Norway. Relevant Ku- and Ka- spectrum for the ASBM system has been filed as NORSAT-H1 with the International Telecommunication Union ("ITU") by the Norwegian Communications Authority ("Nkom").

II. ASBM

ASBM will include two satellites that will operate in Three-Apogee ("TAP") HEO with 16-hour period. The satellites will be separated by 180 degrees and will be capable of providing Pan-Artic coverage above 55 degrees North Latitude through seven partially overlapping user beams in the Ku- and Ka-bands. Each satellite will have two steerable Ka-band spot beams – one of these spot beams will serve as a gateway beam for anchoring the Ku- and Ka-band user beams, while the second will serve as a backup gateway beam. In addition, each satellite will operate on channels of 115 MHz each with one channel allocated per beam.

ASBM will be supported by a centralized satellite earth station in Tromsø, Norway that will serve as a hub for satellite users, in addition to being a gateway to terrestrial communications networks. The ground segment for ASBM will also include telemetry, tracking and command ("TT&C") and satellite monitoring and control operations.

ASBM is discussed in more detail in Schedule S and the *Technical Narrative* accompanying this PDR.

III. THE PUBLIC INTEREST WILL BE SERVED BY AUTHORIZING ASBM TO SERVE THE U.S. MARKET

In order to be granted, a request for authority to access the U.S. market by a non-U.S. satellite system must be in the public interest.[3] The Commission takes into account several factors when determining if such requests for authority are in the public interest, including the effect on competition in the United States, spectrum availability, eligibility and operational requirements, and concerns related to national security, law enforcement, foreign policy, and trade.[4] Additionally, requests for U.S. market access for non-U.S. licensed space stations must contain the legal and technical information required to be provided by U.S. applicants for space station licenses under Part 25 of the Commission's Rules, including Section 25.114.[5]

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[3] *Amendment of the Commission's Regulatory Policies to Allow Non-U.S. Licensed Space Stations to Provide Domestic and International Satellite Service in the United States*, 12 FCC Rcd 24094, ¶ 29 (1997) ("*DISCO II Order*"), *on reconsideration,* 15 FCC Rcd 7207, ¶ 5 (1999).

[4] *See id*.

[5] 47 C.F.R. § 25.137(2)(b); *see also In the Matter of Amendment of the Commission's Space Station Licensing Rules and Policies; Mitigation of Orbital Debris,* First Report and Further Notice of Proposed Rulemaking in IB Docket No. 02-34, and First Report and Order in IB

As discussed in detail below, Space Norway satisfies the criteria for obtaining authority to operate ASBM. Space Norway also demonstrates below, and in Schedule S and the *Technical Narrative* accompanying this PDR, that it is legally and technically qualified to use ASBM to serve the U.S. market.

A. Effect on Competition in the United States

An applicant seeking access to the U.S. market for a non-U.S. licensed satellite system is entitled to a presumption in favor of U.S. market access if the applicant is licensed by a World Trade Organization ("WTO") member country to provide satellite services covered by U.S. commitments under the WTO Basic Telecommunications Agreement (the "WTO Agreement").[6] ASBM is licensed by Norway, a member of the WTO, and Space Norway seeks authority to provide satellite services that are covered by the WTO Agreement. Thus, Space Norway is entitled to a presumption in favor of market entry for ASBM, and it is not required to make an effective competitive opportunities showing.[7]

B. Spectrum Availability

Spectrum availability is another factor that the Commission considers in

Docket No. 02-54, 18 FCC Rcd 10760, ¶ 288 (2003) *("Space Station Licensing Reform Order")*.

[6] *DISCO II Order* at ¶ 39 ("We adopt our proposal to apply a presumption in favor of entry in considering applications to access non-U.S. satellites licensed by WTO Members to provide services covered by the U.S. commitments under the WTO Basic Telecom Agreement. Specifically, we will presume that satellite systems licensed by WTO Members providing WTO-covered services satisfy the competition component of the public interest analysis.").

[7] *See* 47 C.F.R. § 25.137(a)(2).

determining whether to permit a non-U.S. licensed satellite to serve the U.S. market.[8] In connection with such determination, the Commission assesses whether grant of access would create the potential for harmful interference with U.S.-licensed satellite and terrestrial systems.

ASBM will share spectrum with GSO satellites without causing harmful interference to such satellites. The satellites of ASBM will be orbiting in a high elliptical orbit and will not be active (transmitting or receiving) throughout all parts of the orbit. The satellites will only be active during a time interval centered on the apogee and operating in a manner that results in significant isolation from GSO satellites and earth stations during the satellite's active orbital path. The Commission has adopted technical sharing criteria for NGSO FSS and GSO FSS operations in all bands, which focuses on single-entry and aggregate equivalent power flux density ("EPFD") limits on uplink and downlink communications.[9] The EPFD limits adopted by the Commission are similar to the ITU's EPFD requirements for NGSO/GSO co-frequency sharing.[10]

Space Norway will comply with the Commission's Rules and the ITU's requirements regarding EPFD limits and sharing of Ku- and Ka-band spectrum with GSO systems, as demonstrated in Schedule S and the *Technical Attachment* accompanying this

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[8] *DISCO II Order*, at ¶ 149.

[9] *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, First Report and Order and Further Notice of Proposed Rulemaking, 16 FCC Rcd. 4096 (2000) ("*First Report and Order*").

[10] *See id.*; *see also* Resolution 76 of the Radio Regulations of the International Telecommunication Union.

PDR. Space Norway is also prepared to work with other NGSO systems operators in order to ensure compliance with such EPFD limits. Furthermore, Space Norway will seek to reach coordination agreements with other NGSO system operators to allow for the greatest flexibility possible among the systems in the use of all authorized spectrum, consistent with the Commission's Rules.[11]

Space Norway demonstrates in Schedule S and the *Technical Attachment* that ASBM would not create the potential for harmful interference to U.S.-licensed satellite and terrestrial systems. Thus, granting U.S. market access to ASBM is in accord with the Commission's spectrum availability policies for non-U.S. licensed satellites.

C. National Security, Law Enforcement, Foreign Policy, and Trade Issues

The Commission also considers the issues of national security, law enforcement, foreign policy, and trade in evaluating requests for market access for non-U.S. licensed satellites.[12] However, the Commission has stated that such issues are likely to arise only in "very rare circumstances."[13] The Commission further stated that it will defer to the

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[11] *See generally Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-Band*, Report and Order and Further Notice of Proposed Rulemaking, FCC 02-123, 17 FCC Rcd. 7841, 7843 (2002) ("*Ku-Band Sharing Order*") (deciding the means for intra-service sharing among prospective NGSO FSS licensees in the Ku-band); *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-band,* Report and Order, 18 FCC Rcd 14708, 14709 (2003) (deciding the means for sharing among existing and prospective NGSO FSS licensees in certain Ka-band frequencies).

[12] *DISCO II Order* ¶ 29.

[13] *Id.* at ¶ 180 ("We emphasize, however, that we expect national security, law enforcement, foreign policy and trade policy concerns to be raised only in very rare circumstances.").

expertise of the Executive Branch in identifying and interpreting issues of this nature.[14] Space Norway's request for authority to operate ASBM in the U.S. market raises no such issues. Therefore, this element of the Commission's public interest analysis is satisfied.

D. Eligibility and Operational Requirements

As noted above, an applicant for U.S. market access must provide the legal and technical information for its non-U.S. licensed satellite system that is required by Part 25 of the Commission's Rules.[15] The information set forth in this legal narrative, the *Technical Attachment*, Schedule S, and the accompanying FCC Form 312 demonstrates compliance with the applicable requirements of Part 25 of the Commission's Rules. Space Norway sets forth below its compliance with certain significant Part 25 Rules:

Section 25.145(e) – Prohibition Against Exclusive Arrangements

Section 25.145(e) of the Commission's Rules precludes the Commission from granting a Ka-band FSS space station license to any applicant if it (or its affiliates) has or acquires an exclusive right to construct or operate space segment or earth stations, or to interchange traffic, for the purpose of handling traffic to or from the United States, its territories, or possessions.[16] Space Norway confirms that it has no such exclusive right, and that it will not acquire any such exclusive right in the future.

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[14] *Id.*

[15] *See* 47 C.F.R. § 25.137(b). *See also DISCO II Order* at ¶ 189.

[16] 47 C.F.R. § 25.145(e).

Sections 25.137(d)(1) & 25.164(b) – Milestones

The Commission requires NGSO system licensees to launch and operate the complete NGSO constellation within six years of grant.[17] Space Norway expects to launch and operate ASBM within six years of grant of this PDR and to be in compliance with the Commission's milestone schedule for NGSO system licensees. In addition, Space Norway will provide the Commission with the necessary information to demonstrate compliance with the applicable milestone schedule for NGSO systems.[18]

Sections 25.137(d)(4) & 25.165 – Escalating Bond

Recipients of U.S. market access grants for non-U.S. licensed NGSO satellite systems are required to post an initial bond amount of $1 million to provide for payment in the event that such NGSO system licensee fails to meet the launch-and-operation milestone.[19] The payment amount due under the bond will "increase, *pro rata*, in proportion to the time that has elapsed since the license was granted to the time of the launch and operate milestone."[20] Ultimate potential bond payment liability is $5 million for NGSO systems six years after grant.[21]

Space Norway intends to post the required initial bond amount of $1 million within

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[17] Section 25.164(b). *See also Comprehensive Review of Licensing and Operating Rules for Satellite Services*, IB Docket No. 12-267, Second Report and Order, FCC 15-167, ¶ 63 (2015) ("*Second Report and Order*").

[18] *See* 47 C.F.R. § 25.164(f).

[19] *See* 47 C.F.R. § 25.165(a)(1); 47 C.F.R. § 25.137(d)(4); *Second Report and Order*, ¶¶ 70, 80-81.

[20] *See id*. ¶ 80.

[21] *Id*. ¶¶ 70, 81.

30 days of grant of this PDR, as required by the Commission's Rules. [22] Space Norway will also increase the bond amount as necessary in order to maintain compliance with the Commission's bond requirement.

<u>*Section 25.114(d)(14) – End-of-Life Disposal*</u>

Section 25.114(d)(14) of the Commission's Rules requires applicants requesting U.S. market access for non-U.S.NGSO systems to provide certain information describing the design and operational strategies that will be used to mitigate orbital debris.[23]

The TAP orbit has a perigee with altitude greater than the LEO protected region[24] and an apogee location and eccentricity that ensures no intersection with the GEO protected region. It does however intersect with the MEO region populated by radio navigation satellites (circular orbits with approximately 21,000 km altitude), but the collision risk is estimated to be very low.

At end of life, the ASBM satellites will be de-orbited and after 13 years they will undergo atmospheric re-entry. The ASBM satellites will re-enter close to the location of the perigee, around 60 degrees South Latitude, and any parts surviving re-entry would most likely reach the surface of the earth in oceanic or uninhabited areas, thereby minimizing the risk of human casualty and any material damages. More details on collision risk and re-entry are given in the *Technical Narrative* accompanying this PDR.

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[22] *See* 47 C.F.R. § 25.165(a), *as amended* by the *Second Report and Order*. *See also id.* § 25.165(b).

[23] *Id.* § 25.114(d)(14)(i)-(iv).

[24] Inter-Agency Space Debris Coordination Committee, IADC Space Debris Mitigation Guidelines (2007), *available at* http://www.iadc-online.org/Documents/IADC-2002-01,%20IADC%20Space%20Debris%20Guidelines,%20Revision%201.pdf

1. Waiver Requests

The Commission may grant a waiver of a Rule if special circumstances indicate that a departure from the Rule would better serve the public interest than would strict application.[25] In such circumstances, the Commission may grant the waiver if it does not undermine the policy objective of the rule and if the waiver otherwise serves the public interest.[26] Space Norway requests certain waivers below and demonstrates that there is good cause for the Commission to grant such waivers.

NGSO FSS Use Restriction in the 10.7-11.7 GHz Band

In the *First Report and Order*, the Commission adopted note 12 to Section 25.202(a) to limit NGSO FSS use in the 10.7-11.7 GHz band to gateway earth stations because deployment of NGSO FSS service links in the 10.7-11.7 GHz band could deter future co-frequency FS service deployment in that band.[27] In 2012, the Commission removed note 12 to Section 25.202(a) to avoid redundancy with band-specific restrictions in Section 2.106.[28] But there is no restriction in Section 2.106 limiting use of the 10.7-11.7 GHz band to gateway earth stations. Space Norway intends to operate its user terminals in the 10.7-11.7 GHz band. Thus, to the extent necessary, Space Norway respectfully requests a waiver of the NGSO FSS use restriction in the 10.7-11.7 GHz band for the reasons set

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[25] *Northeast Cellular Telephone Co. v. FCC,* 897 F.2d 1164, 1166 (D.C. Cir. 1990).

[26] *WAIT Radio v. FCC*, 418 F.2d 1153, 1157 (D.C. Cir. 1969).

[27] *First Report and Order*, 16 FCC Rcd. at 4111 ¶¶ 29, 71.

[28] *2006 Biennial Regulatory Review—Revision of Part 25*, Report and Order, 27 FCC Rcd 11585, 11589-90, ¶ 18 (2012).

forth below and in the *Technical Attachment* accompanying this PDR.[29]

Space Norway will operate its user terminals in the 10.7-11.7 GHz band on an unprotected basis to ensure that FS operators will be able to expand service in the 10.7-11.7 GHz band in the future without any restrictions. Additionally, the downlink transmissions in the 10.7-11.7 GHz band to Space Norway's user terminals will comply with the PFD limits in Section 25.208(b) of the Commission's rules. The Commission has recognized that compliance with such PFD limits is sufficient to protect FS operators from interference from satellite downlinks.[30]

Therefore, for the reasons set forth above and in the *Technical Attachment*, the Commission should grant a waiver of the NGSO FSS use restriction in the 10.7-11.7 GHz band (to the extent necessary).

Sections 25.145(c)and 25.146(i) – Geographic Coverage

Sections 25.145(c) and 25.146(i) of the Commission's Rules requires applicants for NGSO systems to demonstrate that their proposed system can provide service coverage (i) to all locations as far north as 70 degrees North Latitude and as far south as 55 degrees South Latitude for at least 75% of every 24-hour period and (ii) on a continuous basis throughout the fifty states, Puerto Rico and the U.S. Virgin Islands.

As noted above, ASBM is a system for pan-Arctic coverage, designed and targeted for coverage above 55 degrees North Latitude. The provision of Fixed-Satellite Service on a continuous basis throughout the fifty states, Puerto Rico and the U.S. Virgin Islands is

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30 *See id.*, ¶ 39.

therefore not feasible within the technical design of the system, nor part of the intended target markets. Although ASBM's technical design means that it cannot meet the requirements of Section 25.145(c) and 25.146(i), a waiver of such requirements is warranted in this case because noncompliance would not undermine the purpose of the rule and would, in fact, advance it.

The Commission adopted the NGSO geographic coverage requirements to foster a seamless global communications network and to ensure that every state in the United States is provided with reliable communications services.[31] The Arctic region, which includes Alaska, lacks high-quality Internet connectivity services and ASBM is designed to address this issue – Space Norway intends to bring reliable connectivity services to a region of the world that is largely unserved or underserved thereby helping to ensure that no region of the world suffers from a lack of connectivity.

Because the ASBM will provide connectivity to the Arctic region and Alaska, the ASBM will be invaluable to the Commission's efforts to foster a global communications network and ensure reliable connectivity for every state in the United States. Accordingly, Space Norway respectfully requests that the Commission grants a waiver of the geographic coverage requirements in Section 25.145(c) and 25.146(i) to allow Space Norway to use the ASBM to serve the U.S. market.

E. <u>Grant of Space Norway's PDR Is in the Public Interest</u>

Grant of Space Norway's PDR is in the public interest because Space Norway will

[31] *See Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services,* 12 FCC Rcd 22310, at ¶ 34 (1997).

provide high-speed broadband Internet services to the Arctic region, a region of the world that has a critical need for such services. ASBM will be capable of providing broadband internet access to users who have poor or no connection to GSO satellite systems or terrestrial networks. The need exists for users located in regions from 55 degrees North Latitude and further North depending on the user group and the type of user terminal. ASBM end-users will be able to utilize their existing GSO-terminals – only a software upgrade will be needed.

ASBM will provide critical support services to several industries, including the maritime, oil and gas, safety, search and rescue and aeronautical. For example, it is expected that ASBM will be used to assist: (i) the maritime sector in addressing its need for remote supervision of, and control over, technical installations on board; (ii) the oil and gas industry with test-drilling, given that test-drilling requires high-quality broadband internet; (iii) the U.S. Coast Guard in responding to critical maritime safety situations in the U.S. Search and Rescue zone, which includes Alaska; and (iv) the aeronautical industry address a growing need for internet connectivity services in flights across the pan-Artic region.

Moreover, and perhaps most importantly, ASBM will help address Alaska's need for high-quality connectivity services due to a lack of terrestrial system infrastructure and because the Alaskan terrain blocks the line of sight to GSO satellite systems. The Governor of Alaska has recognized the critical need in Alaska for broadband infrastructure and high-speed capacity and ASBM can be utilized to address this need.[32] In the

[32] Comments of the State of Alaska, File No. SAT-LOI-20160428-00041 (filed Aug. 9, 2016).

Telecommunications Act of 1996,[33] Congress mandated the Commission to devise methods to ensure that consumers in all regions of the United States have access to affordable telecommunications services – by providing telecommunications services to Alaska, ASBM will be invaluable in helping to achieve this goal.[34]

IV. <u>CONCLUSION</u>

As explained above and in the attached materials, Space Norway fully satisfies the Commission's requirements for U.S. market access, and ASBM fully complies with Part 25 of the Commission's Rules. Therefore, Space Norway respectfully requests that the Commission issue a Declaratory Ruling authorizing ASBM to access the U.S. market.

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[33] Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (Feb. 8, 1996), *codified as amended* in scattered sections of 15 and 47 U.S.C. The 1996 Act amends the Communications Act of 1934, 47 U.S.C. §§ 151 *et seq.*

[34] Specifically, Congress directed the Commission to devise methods to ensure that "[c]onsumers in all regions of the Nation, including low-income consumers and those in rural, insular, and high cost areas . . . have access to telecommunications and information services. . . .". 47 U.S.C. § 254(b)(3).

Respectfully submitted,

SPACE NORWAY AS

By:
Jostein Rønneberg
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Space Norway AS

November 15, 2016

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FCC Form 312, Response to Questions 30 – 33:
Identification of the aliens or foreign entities, their nationality, their relationship to the applicant, and the percentage of stock they own or vote

The applicant Space Norway AS ("Space Norway"), is a Norwegian limited liability company. The capital stock of Space Norway is owned and voted by:

Name	**Place of Incorporation**	**Address**	**Shares**	**Percent**
The Norwegian Ministry of Trade, Industry and Fisheries	Oslo	Kongens gate 8, PO Box 8090, Dep. 0032 Oslo	2.600.000	100%

FCC Form 312, Response to Question 40:
Officers, Directors, and Ten Percent or Greater Shareholders

The applicant Space Norway AS, is a Norwegian limited liability company. The company address is: Drammensveien 165, PO Box 66, 0212 Oslo, Norway.

The following individuals serve as officers and directors of Space Norway and can be contacted through the address listed above:

Name	Title	Nationality
Asbjørn Birkeland	Chairman of the Board	Norwegian
Jostein Rønneberg	Director and Chief Executive Officer	Norwegian
Stein Torvet	Director Business and Development	Norwegian
Kjell Ove Skare	Director Strategy and Analysis	Norwegian
Hans Christian Haugli	Chief Innovation and Development	Norwegian
Bjørn Roger Andersen	Chief Technology Officer	Norwegian
Gro Undrum	Chief Financial Officer	Norwegian

The names, addresses, and citizenship of stockholders of records directly or indirectly owning and/or voting 10% or more of Space Norway voting stock are:

Name	Place of Incorporation	Address	Shares	Percent
The Norwegian Ministry of Trade, Industry and Fisheries	Oslo	Kongens gate 8, PO Box 8090, Dep. 0032 Oslo	2.600.000	100%

No other individuals or entities directly or indirectly hold a 10% or greater ownership or voting interest in Space Norway.

SPACE NORWAY NON-GEOSTATIONARY SATELLITE SYSTEM

ATTACHMENT A

TECHNICAL INFORMATION TO SUPPLEMENT SCHEDULE S

A.1 SCOPE AND PURPOSE

This attachment contains the information required by §25.114(d), §25.146 and other sections of the FCC's Part 25 rules that cannot be captured by the Schedule S software.

A.2 OVERALL DESCRIPTION OF SYSTEM FACILITIES, OPERATIONS AND SERVICES AND EXPLANATION OF HOW UPLINK FREQUENCY BANDS ARE CONNECTED TO DOWNLINK FREQUENCY BANDS (§25.114(d)(1))

A.2.1 Introduction

The Arctic Satellite Broadband Mission ("ASBM"), shown in Figure 1, is a system for broadband services with pan-Arctic coverage. The pan-Arctic satellite coverage will be provided 24/7 using two satellites operating in a highly elliptical orbit ("HEO").

The fundamental architecture for the satellite communications system is a star network topology, with a centralized satellite gateway that serves as a hub for the satellite users, as well as being teleport for the satellite users to the terrestrial communications networks. The system is therefore planned with a gateway station to be located in Tromsø, Norway.

The system will be operated as a hub-spoke system, where the different satellite users in the system will be inter-connected through the gateway (double hop). The satellite access solutions will be based on TDM/TDMA (shared access), SCPC and CDMA. The system architecture also facilitates satellite-to-satellite handover and beam-top beam handover for seamless connectivity when a user changes from user beam to another user beam.

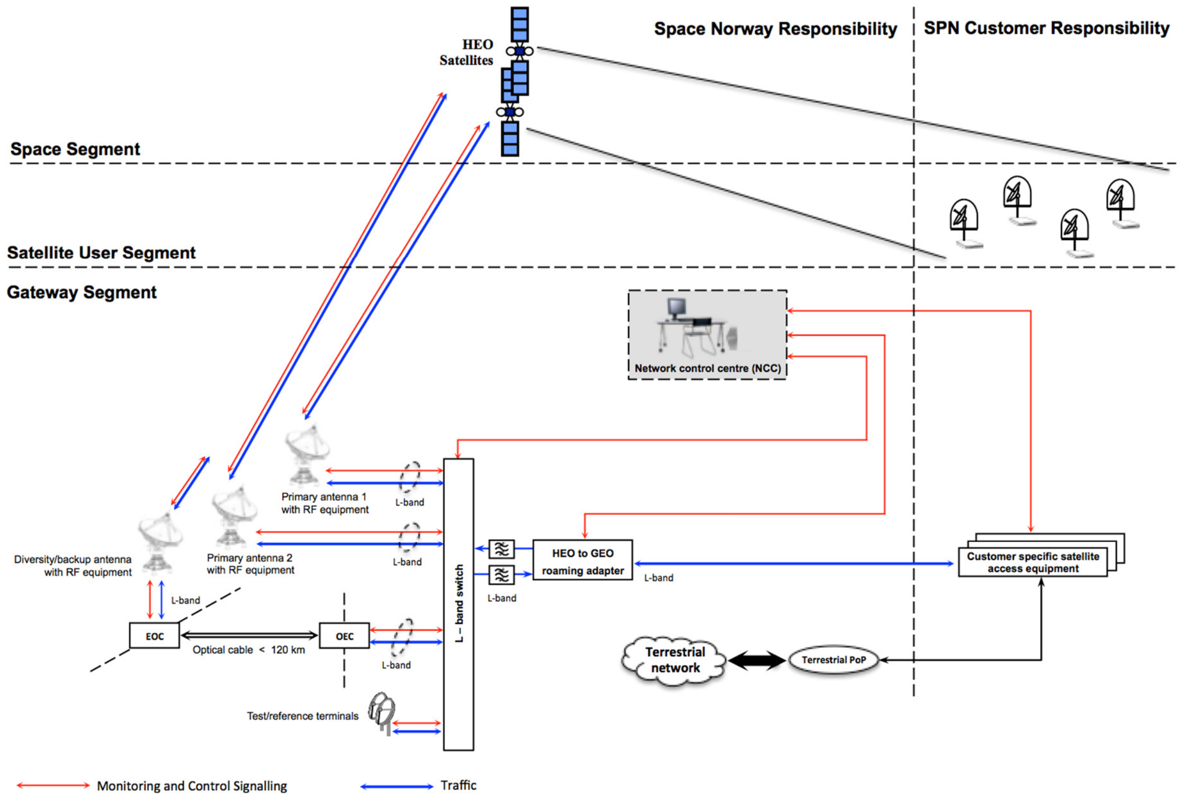


Figure 1 System overview of Arctic Satellite Broadband Mission.

A.2.2 Space Segment

The space segment will have communications payloads operation in both Ku-band and Commercial Ka-band. In addition to the two communications satellites, the space segment will also include telemetry, tracking and command ("TT&C") ground segment, and satellite monitoring and control ground segment, both associated with operations of the satellites.

Service Area

ASBM will service users in the entire Arctic, north of 55°N, as illustrated in Figure 2.

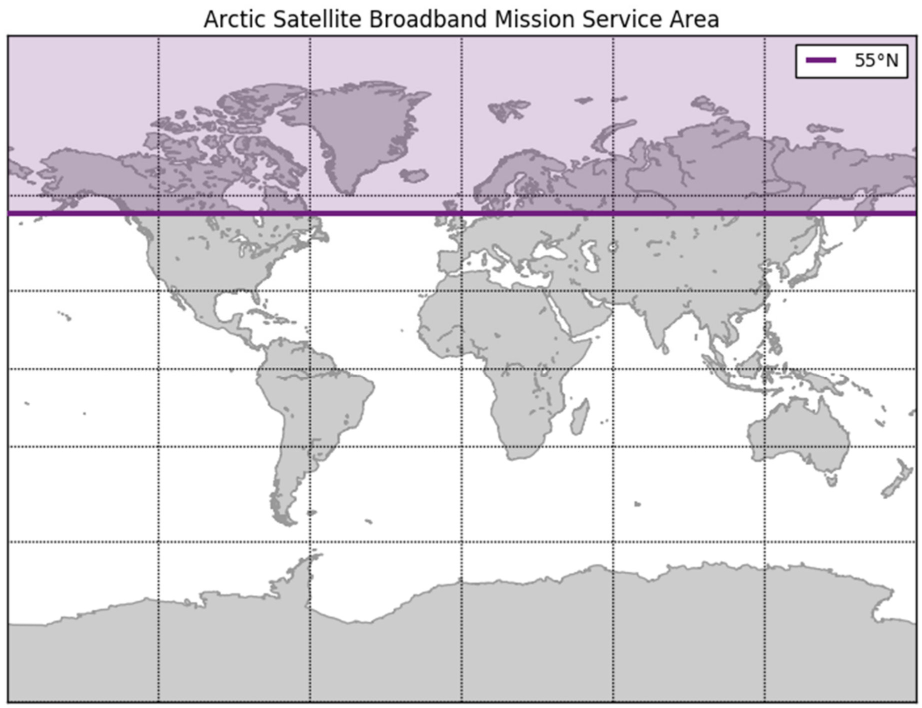


Figure 2: ASBM Service Area.

Constellation

The constellation consists of 2 satellites in a triple apogee highly elliptical orbit (TAP HEO), as shown in Figure 3. The satellites are in the same orbital plane, phased apart 180° mean anomaly. The orbital parameters are given in Table 1.

Table 1: Orbital parameters for ASBM.

Parameters	Value
Orbit period	2/3 sidereal days (approx. 16 hours)
Apogee	43509 km
Perigee	8089 km
Inclination	63.4°
Argument of perigee	270°
RAAN	Variable (280° initially)
Longitude of apogee	19°E, 139°E and 259°E
Operational lifetime	15 years

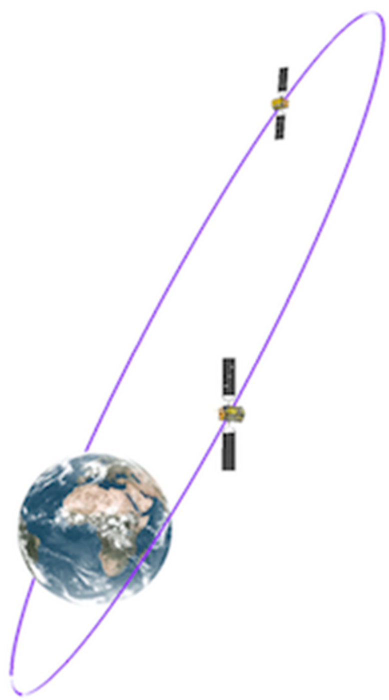


Figure 3: TAP HEO Constellation

TAP Orbit Ground Track

Over the orbit, the satellites will trace the ground track in Figure 4. The hourly position for each satellite is labeled next to the track.

Each satellite will be active for 8 hours of the orbit, centered 4 hours around apogee. There will be a period where both satellites are operating at the same time (handover). This period will be at least 15 minutes long, with a maximum of 2 hours. For 6 hours of the orbit, centered around perigee, the satellite payloads will be off (muted). The satellites will automatically cease emissions when not in the active part of the orbit (south of the sub-satellite point at approximately 35 degrees North Latitude). This also ensures that the separation angle to the GSO arc, from any earth station location on earth, is at least 35.4 degrees.

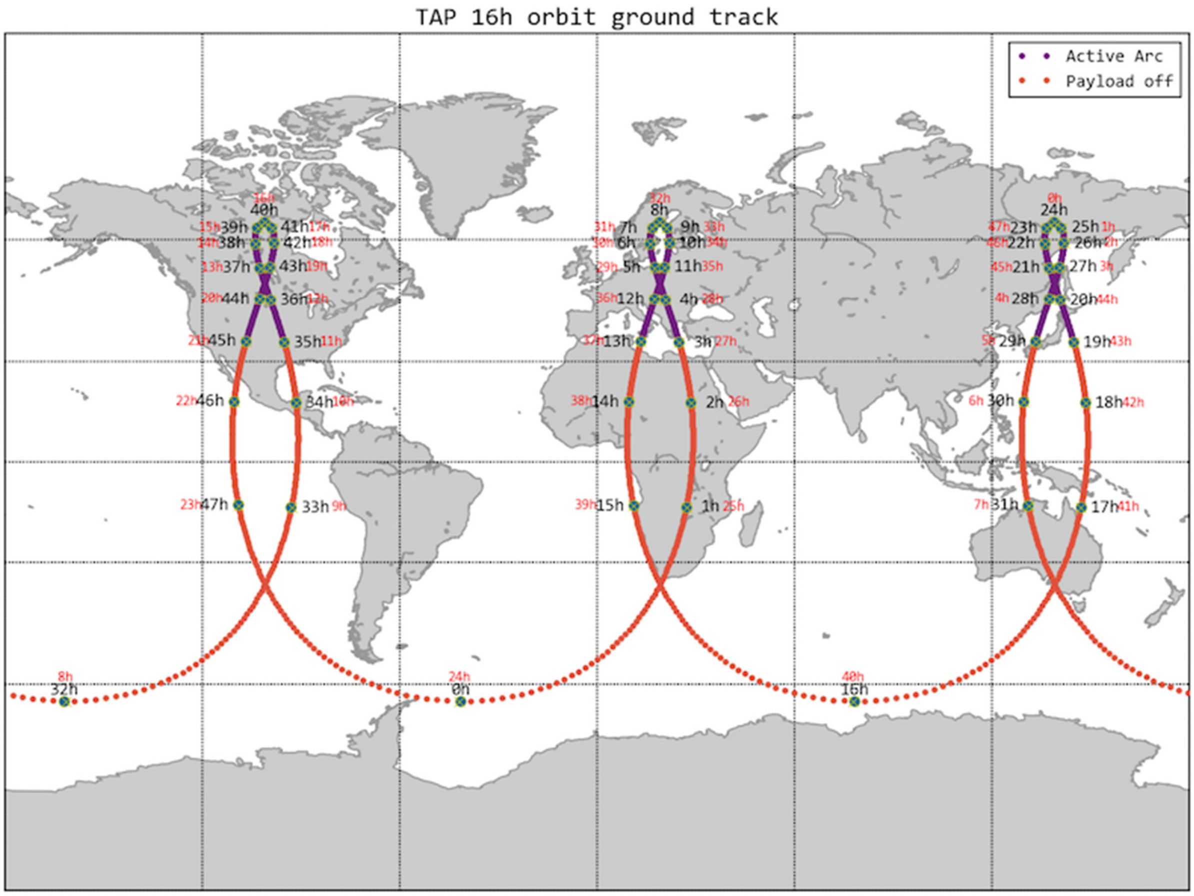


Figure 4: TAP Orbit Ground Track.

<u>Satellite Coverage Areas</u>

The Ku- and Ka-band payloads will both provide Pan-Arctic user coverage by means of a cluster of 7 spot beams, as shown in Figure 5 and Figure 6 (blue color). The individual 3 dB beamwidth is 3° degrees, giving a maximum outer edge at 8.2°.

In addition, there will be a single steerable spot beam (red color) to be pointed towards island Bjørnøya (19°E, 74.5°N). The steerable beam will be used for gateway traffic at Ka-band.

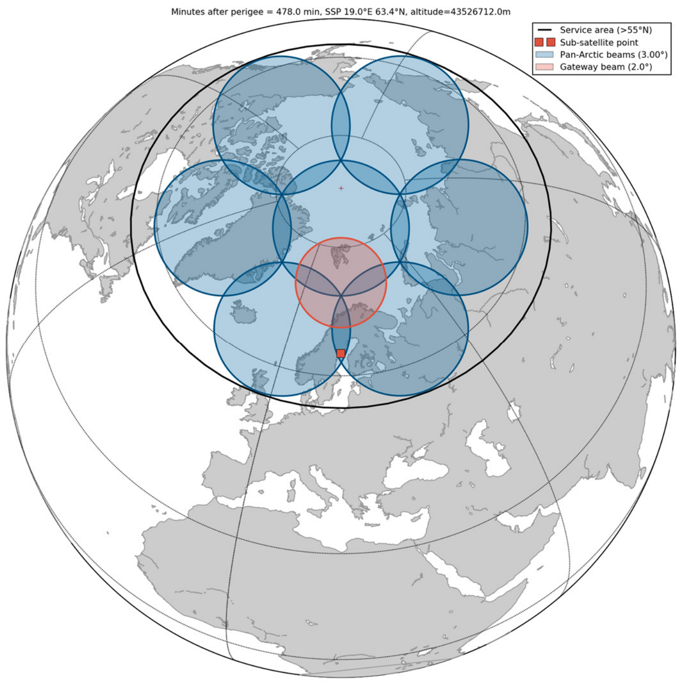


Figure 5 Seven-Beam Coverage at Apogee

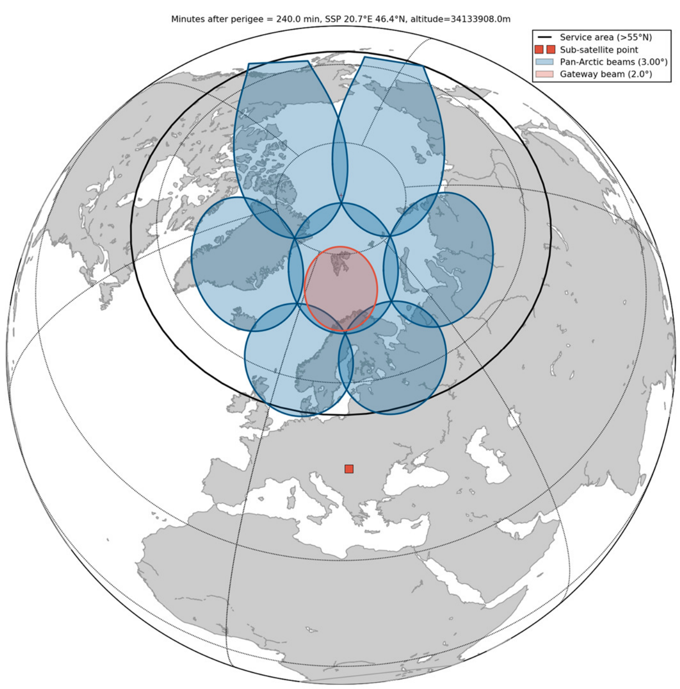


Figure 6 Seven-Beam Coverage at Handover

Satellite Repeater Architecture

Each satellite will carry capacities at Ku-band and Commercial Ka-band. At Ku-band, there will be 7 partially overlapping user beams, designated SKu1, …, SKu7, providing Pan-Arctic coverage above 55° North Latitude. Similarly, at Ka-band, there will be 7 partially overlapping user beams, designated SKa1, …, SKa7, also providing Pan-Arctic coverage above 55° North Latitude. In addition, there will be two steerable Ka-band spot beams, designated SKa8 and SKa9. One of these spot beams (SKa8) will serve as a gateway beam for anchoring the Ku- and Ka-band user beams at the gateway, while the second one will be a backup gateway beam (SKa9). The capacities in Ku-band and Ka-band are defined by means of communications channels.

Forward Link

In the Forward Link, which is from Gateway to Users, there will 7 channels in Ku-band and 7 channels in Ka-band. The 7 Ku-band forward link channels are designated FCKa1, …, FCKa7, while the 7 Ka-band channels are designated FCKa1, …, FCKa7. All channels, in both the Ku-band and Ka-band, have a bandwidth of 115 MHz. For the Feeder U/L the 7 Ku-band channels are connected to Gateway beam SKa8 utilizing LHCP, while the 7 Ka-band channels are connected to SKa8 utilizing RHCP.

With respect to the User D/L the 7 Ku-band channels are allocated to the 7 Ku-band beams SKu1, …, SKu7, with one channel per beam. Furthermore, the 7 Ka-band channels are allocated to the 7 Ka-band beams SKa1, …, Ska7, with one channel per beam. All channel-to-beam allocations are fixed. The channel center frequencies, polarizations and channel-to-beam connections are summarized in Figure 7 and in Table 2. Communications carriers received by the satellite in the gateway beam will directed to the respective user beams in accordance with the connectivity plans shown in Table 2.

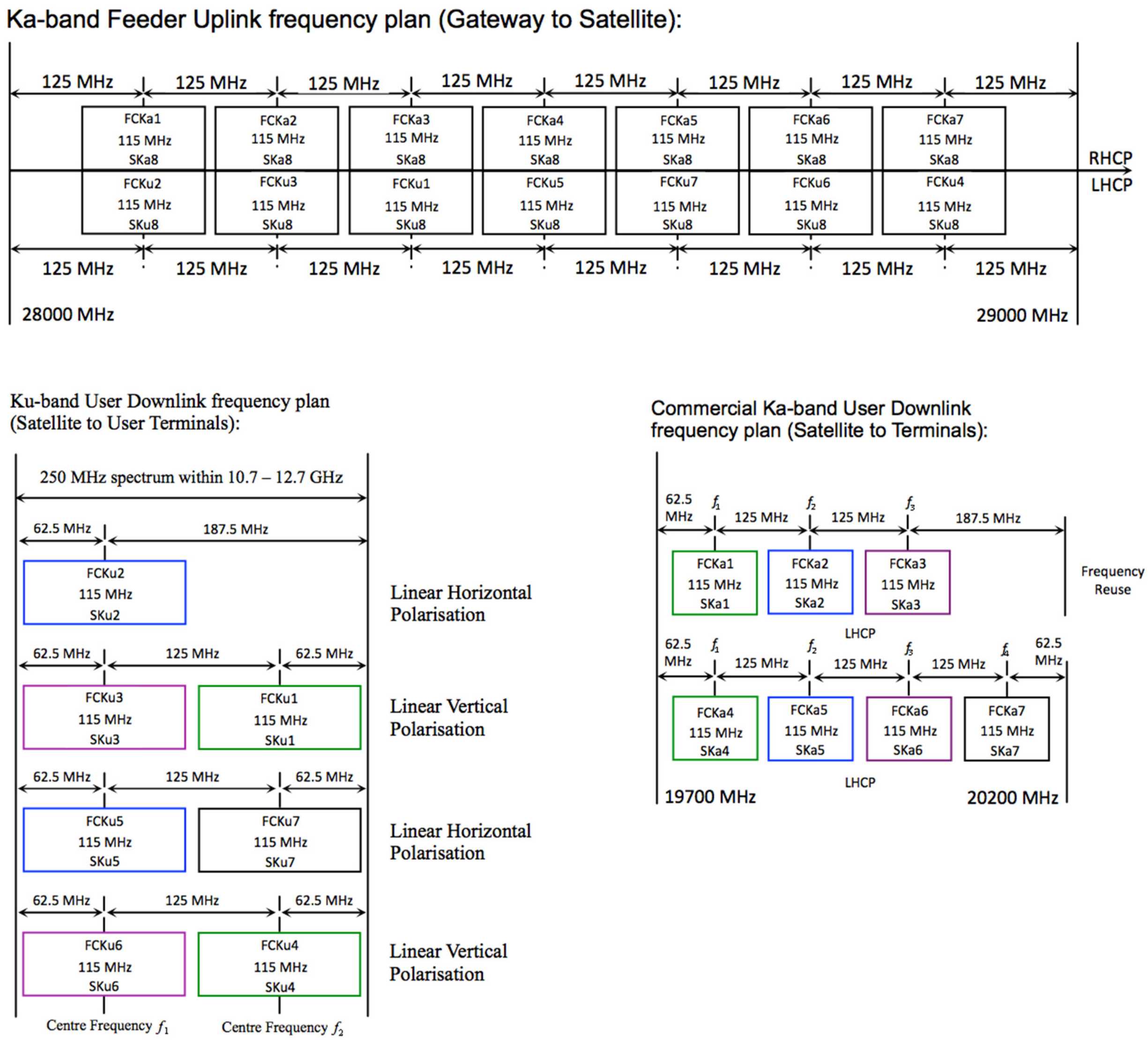


Figure 7: Forward Link frequency and connectivity plans.

Table 2: Forward Link Channel Specifications.

Forward Link Channel specifications						
	Feeder beam U/L connections			**User beam D/L connections**		
Channel	**Centre frequency**	**Polarization**	**Beam**	**Centre frequency**	**Polarization**	**Beam**
FCKa1	28125 MHz	RHCP	SKa8	19762.5 MHz	LHCP	SKa1
FCKa2	28250 MHz	RHCP	SKa8	19887.5 MHz	LHCP	SKa2
FCKa3	28375 MHz	RHCP	SKa8	20012.5 MHz	LHCP	SKa3
FCKa4	28500 MHz	RHCP	SKa8	19762.5 MHz	LHCP	SKa4
FCKa5	28625 MHz	RHCP	SKa8	19887.5 MHz	LHCP	SKa5
FCKa6	28750 MHz	RHCP	SKa8	20012.5 MHz	LHCP	SKa6
FCKa7	28875 MHz	RHCP	SKa8	20137.5 MHz	LHCP	SKa7
FCKu2	28125 MHz	LHCP	SKa8	11012.5 MHz	LHP	SKu2
FCKu3	28250 MHz	LHCP	SKa8	11012,5 MHz	LVP	SKu3
FCKu1	28375 MHz	LHCP	SKa8	11137,5 MHz	LVP	SKu1
FCKu5	28500 MHz	LHCP	SKa8	11012,5 MHz	LHP	SKu5
FCKu7	28625 MHz	LHCP	SKa8	11137.5 MHz	LHP	SKu7
FCKu6	28750 MHz	LHCP	SKa8	11012,5 MHz	LVP	SKu6
FCKu4	28875 MHz	LHCP	SKa8	11137.5 MHz	LVP	SKu4

Return Link

In the Return Link, which is from the Users to the Gateway, there will be 7 Ku-band channels and 7 Ka-band channels. The Ku-band channels are designated RKu1, …, RKu7, while the Ka-band channels are designated RKa1, …, RKa7. All channels in both Ku-band and Ka-band have a bandwidth of 115 MHz.

For the User U/L the 7 Ku-band channels are connected to the 7 Ku-band beams SKu1, …, SKu7, one channel per beam. Likewise, the 7 Ka-band beams are connected to the 7 Ka-band beams SKa1, …, Ska7, one channel per beam.

For the Feeder D/L the 7 Ku-band channels are all connected to the Gateway beam SKa8 utilizing RHCP, while the 7 Ka-band channels are all connected to SKa8 utilizing LHCP.

The channel center frequencies, polarizations and channel to-beam connections are summarized in Figure 8 and in Table 3. Communications carriers received in each user beam will be directed to the gateway beam according to the connectivity plan in Table 3.

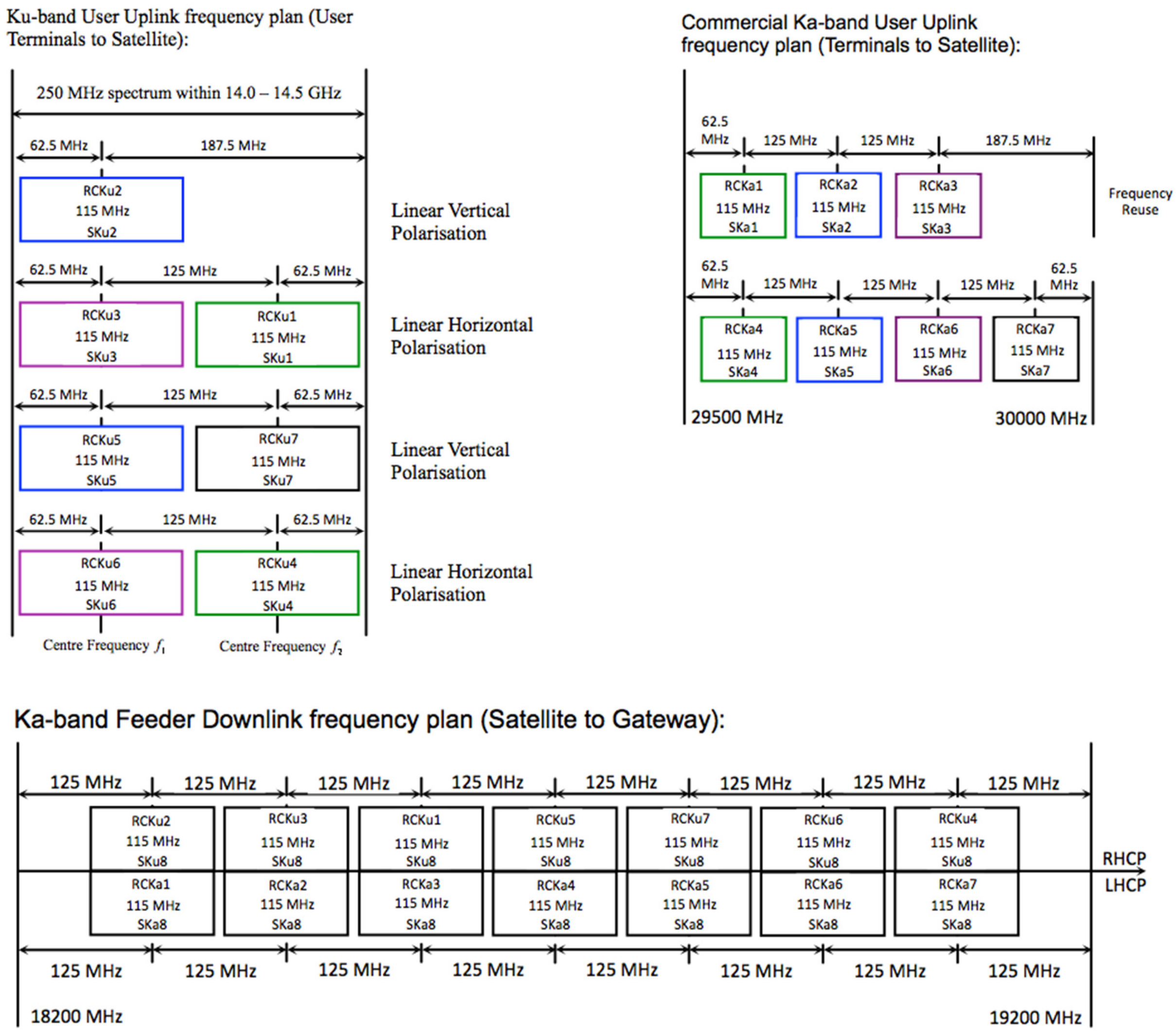


Figure 8: Return Link frequency and connectivity plans.

Table 3: Return Link Channel Specifications.

Return Link Channel specifications						
	User beam U/L connections			**Feeder beam D/L connections**		
Channel	**Centre frequency**	**Polarization**	**Beam**	**Centre frequency**	**Polarization**	**Beam**
RCKa1	29562.5 MHz	RHCP	SKa1	18325 MHz	LHCP	SKa8
RCKa2	29687.5 MHz	RHCP	SKa2	18450 MHz	LHCP	SKa8
RCKa3	29812.5 MHz	RHCP	SKa3	18575 MHz	LHCP	SKa8
RCKa4	29562.5 MHz	RHCP	SKa4	18700 MHz	LHCP	SKa8
RCKa5	29687.5 MHz	RHCP	SKa5	18825 MHz	LHCP	SKa8
RCKa6	29812.5 MHz	RHCP	SKa6	18950 MHz	LHCP	SKa8
RCKa7	29937.5 MHz	RHCP	SKa7	19075 MHz	LHCP	SKa8
RCKu2	14062,4 MHz	LVP	SKu2	18325 MHz	RHCP	SKa8
RCKu3	14062,4 MHz	LHP	SKu3	18450 MHz	RHCP	SKa8
RCKu1	14187,5 MHz	LHP	SKu1	18575 MHz	RHCP	SKa8
RCKu5	14062,4 MHz	LVP	SKu5	18700 MHz	RHCP	SKa8
RCKu7	14187,5 MHz	LVP	SKu7	18825 MHz	RHCP	SKa8
RCKu6	14062,4 MHz	LHP	SKu6	18950 MHz	RHCP	SKa8
RCKu4	14187,5 MHz	LHP	SKu4	19075 MHz	RHCP	SKa8

Spectrum Utilization

In order to utilize satellite spectrum in an efficient manner, frequency reuse is applied when designing the Ku-band and Ka-band payloads. In the Ku-band payload, by utilizing space diversity amongst the user beams, as well as utilizing both LVP and LHP, two frequencies in both U/L and D/L are reused four times, hence requiring a total of 250 MHz spectrum at both U/L and D/L. The resulting total bandwidth is 805 MHz in Forward Link, and 805 MHz in the Return Link. In the Ka-band payload, by utilizing space diversity amongst the user beams, four frequencies in both U/L and D/L are reused twice, hence requiring a spectrum of 500 MHz. The resulting total bandwidth is 805 MHz in Forward Link, and 805 MHz in the Return Link.

Notes to beam configuration in Schedule S

In Ku-band, the ASBM system requires the use of 250 MHz of contiguous spectrum in the 10.7-12.7 GHz band. In Schedule S, the seven Ku-band user downlink channels have been placed in the 10.95-11.2 GHz band, which is the preferred band. Space Norway may choose to use a different 250 MHz band in the 10.7-12.7 GHz region. In order to have the option to move the 250 MHz to another location in the Ku-band downlink, placeholder beams and channels have been created in Schedule S (X1, X2, X3, X4, and X5). For the avoidance of doubt, just one of the beam/channel combinations would be used, aggregating as noted to 250 MHz of contiguous spectrum.

Tracking, Telemetry and Command (TT&C) Ground Segment

The TT&C will operate at Ka-band, using a part of the frequency band planned for the gate beam. The TT&C ground segment will include two primary TT&C terminals, one terminal for each satellite, and which will be co-located with the gateway station in Tromsø. In addition there will be a backup and site diversity TT&C terminal at Bardufoss. All three TT&C terminals will be used for On-Station TT&C, as well as Emergency and LEOP TT&C.

The TT&C ground segment will have an associated satellite monitoring and control ground segment for operations of the satellites.

A.2.3 Gateway Segment

This consists of two primary earth station Ka-band antennas, one antenna per satellite. Furthermore, there is a back-up and diversity antenna that will be located at Bardufoss, Norway.

There will be a network operation center (NOC) for monitoring and control of the gateway elements, and for monitoring and control of the telecommunications links and associated satellite user equipment. It may be located at the same facilities as the anchor station.

A.2.4 Satellite User Segment

The satellite user segment will include all end users accessing the Arctic Satellite Broadband Communications Infrastructure. Each user will be equipped with a satellite access terminal, which will be operated in accordance with regulatory guidelines, and in accordance with the operational instructions provided by Space Norway.

A.3 COMPLIANCE WITH LICENSING AND OPERATING RULES SPECIFIED IN §25.146.

Space Norway will comply with the licensing and operating rules specified in §25.146. A detailed explanation, including the EPFD levels produced by the ASBM system in Ku-Band, is given in ANNEX 1 to this Attachment.

In addition, a detailed explanation, including the EPFD levels produced by the ASBM system in Ka-Band, is given in ANNEX 3 to this Attachment.

A.4 MITIGATION OF ORBITAL DEBRIS (§25.114(d)(14))

Compliance with Norwegian Regulations

Since there are no Norwegian regulations regarding space objects, Space Norway cannot claim §25.114(d)(14)(v). We will therefore describe the collision risk in TAP orbit, our collision mitigation strategy and disposal of the satellites after end of life.

Normal Operations

Since the perigee of ASBM is more than 8000 km throughout its operational lifetime, it will not intersect with the LEO protected region[1]. The high altitude of the apogee and the eccentricity of the orbit is such that there will be no intersection with the GEO protected region.

The spacecraft will however intersect with the MEO region and in particular the orbits used by radio-navigation satellites (circular orbits with altitudes around 21 000 km) three times per day.

With regards to collisions with other spacecrafts, regardless of their orbital parameters, it is our view that there will be no risk of collision as long as our satellites are operational and capable of orbital maneuvers.

Loss of Orbital Maneuvering Capability – Collision Risk

Assuming that the Space Norway satellites and satellites in MEO have no capability of orbital maneuvers, simple statistical analysis shows that with 100 objects (Galileo, Glonass and GPS constellations) in MEO at around 21 000 km altitude the probability for one collision per ASBM spacecraft per year is $1.2\text{x}10^{-9}$ (one collision per 833 million years).

$$P_{collison\ per\ crossing\ of\ MEO} = \frac{N_{objects\ in\ MEO} \times A_{collision\ cross\ section}}{A_{total\ surface\ MEO}}$$

$$= \frac{100\ x\ \ 100\ m^2}{4 \times \pi \times (27\,000\,000\ m)^2}$$

[1] http://www.iadc-online.org/Documents/IADC-2002-01,%20IADC%20Space%20Debris%20Guidelines,%20Revision%201.pdf

$$P_{collision\ 1\ year} = 1 - P_{no\ collision\ 1\ year} = 1 - \left(P_{no\ collison\ 1\ day}\right)^{365}$$

$$= 1 - \left(P_{no\ collision\ per\ crossing\ of\ MEO}{}^{3}\right)^{365}$$

$$= 1 - \left(1 - P_{collison\ per\ crossing\ per\ MEO}\right)^{1095}$$

$$= 1 - \left(1 - \frac{100\,x\ 100\,m^2}{4 \times \pi \times (27\,000\,000\,m)^2}\right)^{1095} = 1.195 \times 10^{-9}$$

Taking into account all objects down to 10 cm with orbital altitudes between 48 000 km and 8000 km will of course increase the collision risk.

Assuming that all 3600 objects[2] is in a circular orbit 9000 km in altitude and a 100 m^2 collision cross section, results in a collision probability of $1.4x10^{-7}$ (one collision per seven million years).

Space Norway is of the opinion that the TAP orbit represents very low risk with regards to collision with spacecrafts and debris.

End of Life

As the satellites approach end of life, a de-orbit burn will be performed at perigee. By adding a Δv of approximately 80 m/s (47 kg propellant required), the apogee altitude will increase with approximately 6000 km. Lunar-solar gravitational perturbations will then cause the perigee altitude to decrease to zero within 13 years, see Figure 9.

[2] https://www.space-track.org

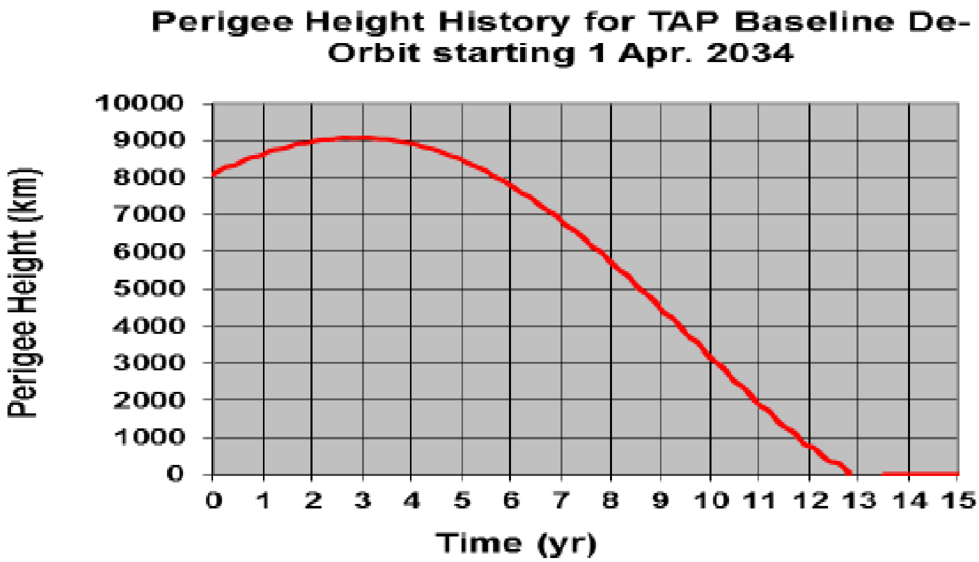


Figure 9 Perigee Height Decrease After De-Orbit Maneuver

As soon as the de-orbit maneuver has been successfully performed, all stored energy will be released and battery charging terminated in order to minimize the risk of break-ups caused by onboard explosions or similar.

The satellites will never overlap with the GEO protected region in the period between the de-orbit maneuver and re-entry, see Figure 10.

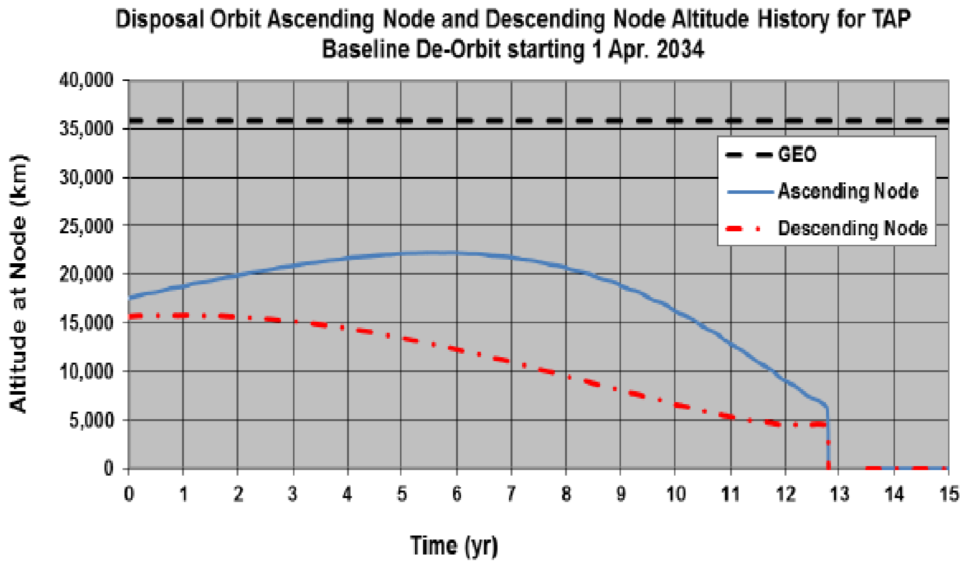


Figure 10 Altitudes of the Nodes After De-Orbit Maneuver

Atmospheric Re-entry

The perigee at end of life is located at 63 degrees South Latitude and the point of re-entry is predicted to be close to 60 degrees South Latitude. Figure 11 illustrates the predicted latitude of the perigee after the de-orbit maneuver.

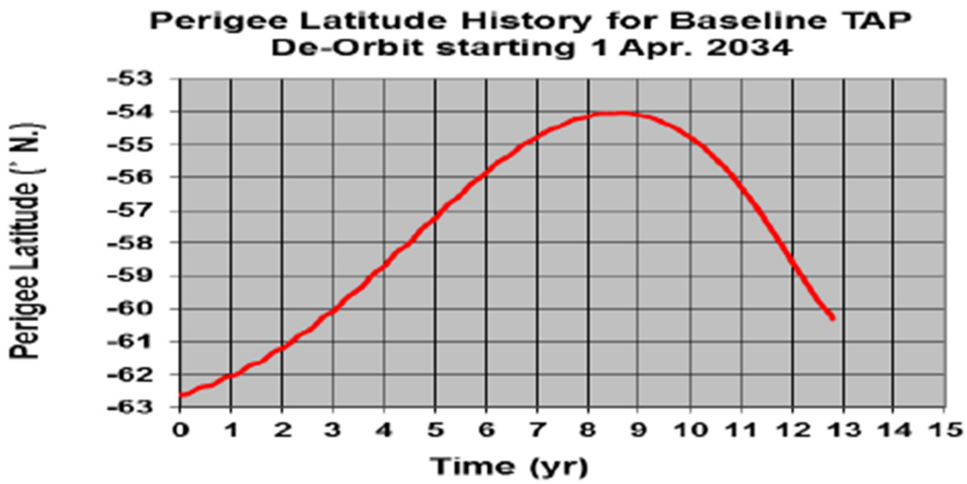


Figure 11 Predicted Latitude of the Perigee After De-Orbit Maneuver

In case any parts of the satellites survive re-entry, they will most likely reach the surface of the earth in oceanic or uninhabited areas, thereby minimizing the risk of human casualty and any material damages.

A.5 PREDICTED SPACE STATION ANTENNA GAIN CONTOURS (§25.114(c)(4)(vi)(B))

The antenna gain contours for the Space Norway satellite receive and transmit beams, as required by §25.114(c)(4)(vi)(B), are embedded in the associated Schedule S submission.

A.6 CESSATION OF EMISSIONS (§25.207)

Each active satellite transmission chain (channel amplifiers and Travelling Wave Tube Amplifiers) can be individually turned on and off by ground command, thereby causing cessation of emissions from the satellite, as required by §25.207 of the Commission's rules. Also, the satellites will automatically cease emissions when not in the active part of the orbit (south of the sub-satellite point at approximately 35 degrees North Latitude).

A.7 COMPLIANCE WITH PFD LIMITS (§25.208(b), §25.208(c), §25.208(d), §25.208(e) and §25.208(o))

The ASBM system's compliance with the applicable FCC PFD limits is explained below.

A.7.1 Downlink PFD Limits in Ku-band

FCC §25.208(b): 10.7-11.7 GHz for NGSO FSS Space Stations

The FCC's Ku-band downlink PFD limits which apply to each satellite of ASBM, and which apply across the 10.7-11.7 GHz band, are given in §25.208(b) and are as follows:

(1)

- 0° - 5°: -150 dBW/m^2/4kHz
- 5° -25°: -150 +0.5(δ-5) dBW/m^2/4kHz (δ= Angle of Arrival)
- 25°-90°: -140 dBW/m^2/4kHz

(2)

- 0° - 5°: -126 dBW/m^2/MHz
- 5° -25°: -126 +0.5(δ-5) dBW/m^2/MHz (δ= Angle of Arrival)
- 25°-90°: -116 dBW/m^2/MHz

Below is shown the ASBM system's compliance with (2). (1) is then also fulfilled.

The maximum Ku-band downlink EIRP density in the ASBM system is **32.4 dBW/MHz**.

The spread loss is 10*LOG(4πR^2) dB. (R is the distance from satellite to the actual spot on the Earth's surface). R increases with lower elevation angle (Angle of Arrival) and with the altitude of the satellite.

In the calculations leading to Figure 12 below, the following altitudes for the satellite are used:

Highest altitude, satellite at apogee: **43,500 km**

Lowest altitude, satellite at hand-over: **28,454 km**

With the parameters explained above, the PFD values are compared with the FCC requirements in Figure 12

Conclusion: The ASBM system is fully compliant with FCC §25.208(b).

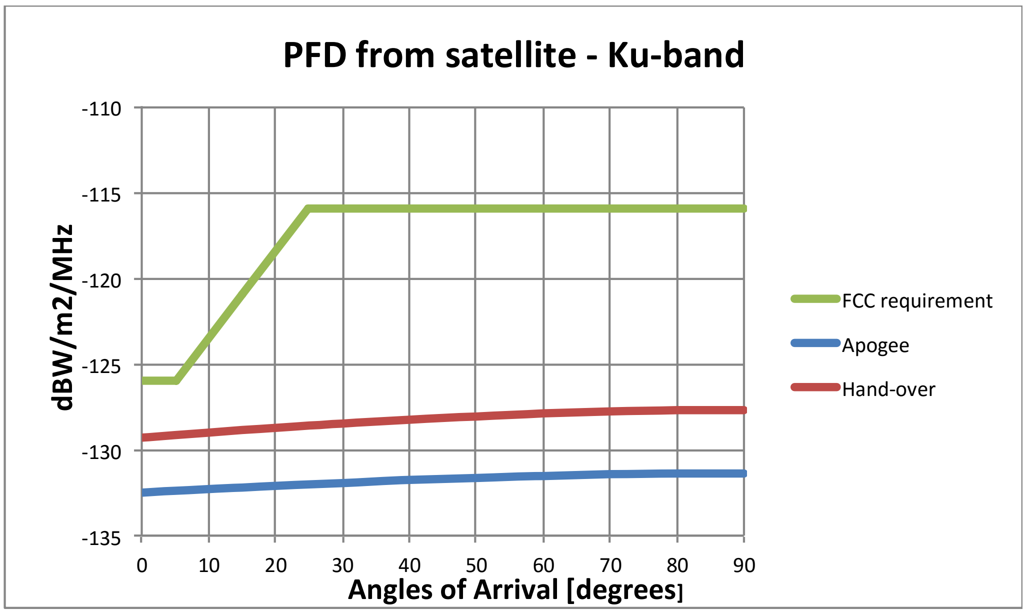


Figure 12 Comparing the Maximum Ku-Band PFD Levels of ASBM with FCC §25.208(b).

Apogee: Satellite altitude 43,500 km

Hand-over: Satellite altitude 28,454 km

Satellite EIRP: 32.4 dBW/MHz

§25.208(o): 12.2-12.7 GHz

In the band 12.2-12.7 GHz, for NGSO FSS space stations, the specified low-angle power flux-density at the Earth's surface produced by emissions from a space station shall not be exceeded into an operational MVDDS receiver:

(1) −158 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 2 degrees above the horizontal plane; and

(2) −158 + 3.33(δ−2) dB(W/m^2) in any 4 kHz band for angles of arrival (δ) (in degrees) between 2 and 5 degrees above the horizontal plane.

The preferred band for ASBM, as stated in Section A.2.2 will be 10.95-11.2 GHz. In case the 12.2-12.7 GHz is used, the EIRP density will be reduced by 5 dB to comply with the FCC PFD requirements above.

For the band 12.2-12.7 GHz the maximum Ku-band downlink EIRP density in the ASBM system is then **27.4 dBW/MHz.**

The spread loss is $10*LOG(4\pi R^2)$ dB. (R is the distance from satellite to the actual spot on the Earth’s surface). R increases with lower elevation angle (Angle of Arrival) and with the altitude of the satellite.

In the calculations leading to Figure 13 below, the following altitudes for the satellite are used:

Highest altitude, satellite at apogee: **43,500 km**

Lowest altitude, satellite at hand-over: **28,454 km**

With the parameters explained above, the PFD values are compared with the FCC requirements in Figure 13.

Conclusion: The ASBM system will be able to meet the requirements in §25.208(o).

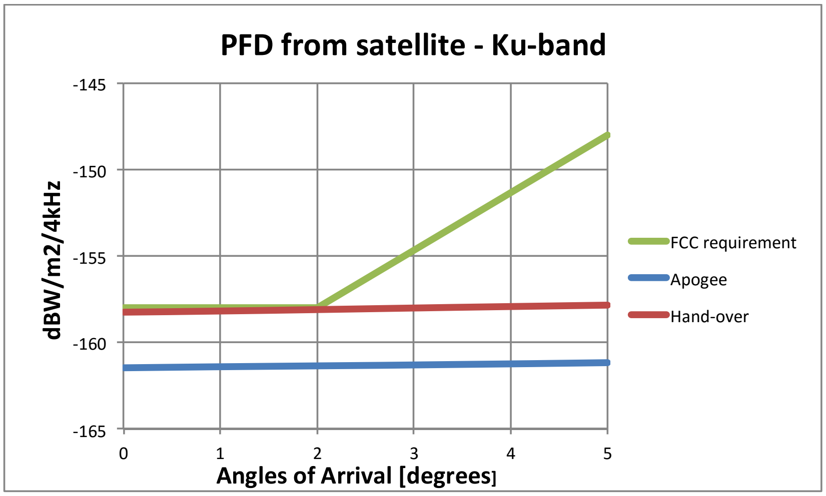


Figure 13 Comparing the Maximum Ku-Band PFD Levels of ASBM with FCC §25.208(o)

Apogee: Satellite altitude 43,500 km

Hand-over: Satellite altitude 28,454 km

Satellite EIRP: 27.4 dBW/MHz

A.7.2 Downlink PFD Limits in Ka-band

§25.208(c): 17.7-17.8 GHz, 18.3-18.8 GHz, 19.3-19.7 GHz, 22.55-23.00 GHz, 23.00-23.55 GHz, 24.45-24.75 GHz

The FCC's Ka-band downlink PFD limits which apply to each satellite of ASBM, are given in §25.208(c) and are as follows:

- 0° - 5°: -115 dBW/m^2/MHz
- 5° -25°: -115 +0.5(δ-5) dBW/m^2/MHz (δ= Angle of Arrival)
- 25°-90°: -105 dBW/m^2/MHz

The ASBM system feeder links at Ka-band can be within the §25.208(c) frequency range.

The maximum EIRP density is **34 dBW/MHz**.

The spread loss is 10*LOG(4πR^2) dB. (R is the distance from satellite to the actual spot on the Earth's surface). R increases with lower elevation angle (Angle of Arrival) and with the altitude of the satellite.

In the calculations leading to Figure 14 below, the following altitudes for the satellite are used:

Highest altitude, satellite at apogee: **43,500 km**

Lowest altitude, satellite at hand-over: **28,454 km**

With the parameters explained above, the PFD values are compared with the FCC requirements in Figure 14.

Conclusion: The ASBM system is fully compliant with FCC §25.208(c).

25.208(d): 18,6-18,8 GHz

Requirement: The power flux density across the 200 MHz band at the earth´s surface shall not exceed -95 dBW/m^2 for all angles of arrival.

The ASBM system feeder links at Ka-band are within the §25.208(d) frequency area.

GW located in Tromsø, Norway.

The maximum EIRP is 33,7 dBW/MHz, corresponding to 56,7 dBW over 200 MHz.

For satellite at Hand-over (altitude 28,454 km) the PFD is -105.0 dBW/m^2 for 0° and -103.4 dBW/m^2 for 90° angle of arrival.

Conclusion: The ASBM system is fully compliant with FCC §25.208(d).

25.208(e): 18.8-19.3 GHz

When the number of satellites is less than 50, the requirements in 25.208(e) and 25.208(c) are identical. The number of satellites in the ASBM system is 2.

Conclusion: The ASBM system is fully compliant with FCC §25.208(e).

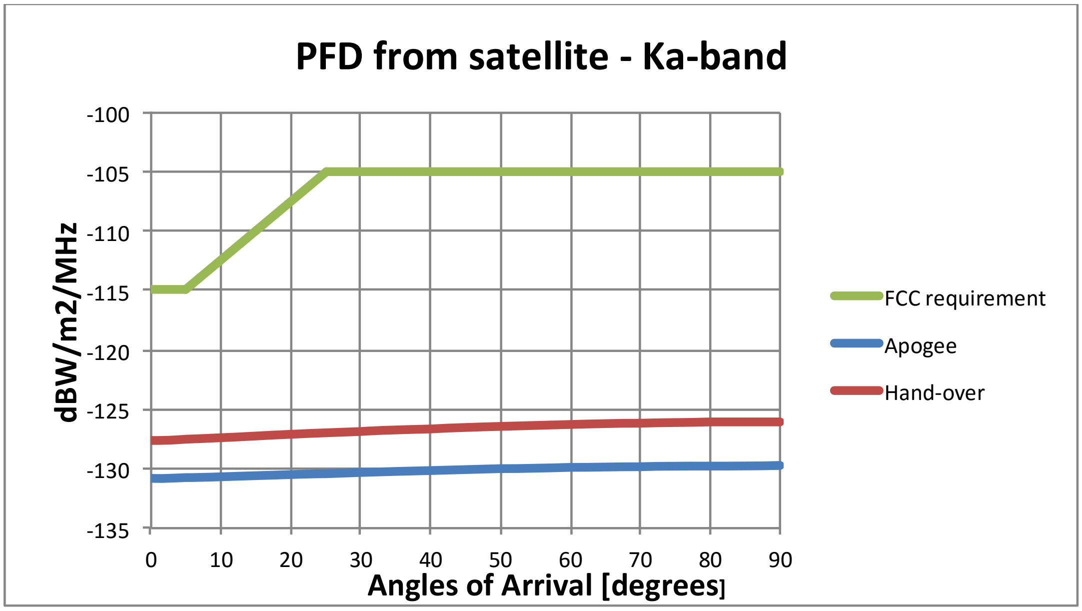


Figure 14 Comparing the Maximum Ka-Band PFD Levels of ASBM with FCC §25.208(c).

Apogee: Satellite altitude 43,500 km

Hand-over: Satellite altitude 28,454 km

Satellite EIRP: 34.0 dBW/MHz

A.8 INTERFERENCE ANALYSES

A.8.1 Interference Protection for GSO Satellite Networks

The ASBM NGSO satellite system has been designed to provide the necessary interference protection to GSO satellite networks in both Ku-band and Ka-band as required under Article 22 of the ITU Radio Regulations. A detailed explanation is given in ANNEX 2 to this Attachment.

A.8.2 Protection of and Sharing with Terrestrial Stations in Non-Satellite Services

<u>Protection of the Radio Astronomy Service (RAS) in the band 10.6-10.7 GHz</u>

According to footnote US131 in the FCC Online Table of Frequency Allocations (TFA), NGSO FSS operators operating in the band 10.7-11.7 GHz shall coordinate with a defined set of RAS stations and achieve a mutually acceptable agreement before commencement of operations.

Space Norway will ensure that such agreements are in place with all radio astronomy observatories listed in footnote US131 before commencing any operations over US territory. Space Norway is committed to protect RAS from harmful interference both now and in the future.

Co-existence with the Fixed Service (FS) in the band 10.7-11.7 GHz

According to the TFA, the band 10.7-11.7 GHz is allocated to FSS and FS on a primary basis. As stated in section A.7, the ASBM system will comply with both ITU and FCC power flux density (PFD) limits. Compliance with these limits shall ensure sufficient protection for FS stations.

User terminals in the ASBM system will in most use cases be Earth Stations Aboard Aircrafts (ESAA). Due to the geometries involved, interference from FS into operational ESAA is highly unlikely.

Based on the reasons above, user terminals in the ASBM will be able to operate on a non-protected basis with respect to the FS.

Co-existence with the Fixed Service in the band 12.2-12.7 GHz

According to the TFA, the band 12.2-12.7 GHz is allocated to FS and Broadcasting Satellite Service (BSS) on a primary basis. NGSO FSS is granted a primary allocation through footnote 5.487A. As stated in section A.7, the ASBM system will comply with both ITU and FCC power flux density (PFD) limits. Compliance with these limits shall ensure sufficient protection for FS stations.

User terminals in the ASBM system will in most use cases be ESAAs. Due to the geometries involved, interference from FS into operational ESAAs is highly unlikely.

Based on the reasons above, user terminals in the ASBM system will be able to operate on a non-protected basis with respect to the FS.

Multichannel Video Distribution and Data Service (MVDDS) in the band 12.2-12.7 GHz

Sharing between ASBM user terminals and MVDDS stations will be ensured through compliance with the coordination and information sharing requirements in 47 CFR §25.139 and the low angle PFD-limits in 47 CFR §25.208(o).

Protection of Space Research Service in the band 14-14.2 GHz

According to the TFA, the band 14-14.2 GHz is allocated to the FSS on primary basis and to the Mobile Satellite Service (MSS) and Space Research Service on a secondary basis. However, footnote US133 requires that operation of ESAAs within radio line-of-sight is coordinated through NTIA prior to commencement of operation to ensure that the TDRSS sites specified in 47 CFR §25.226(c)(2) are protected.

Any coordination required through footnote US133 will be performed in accordance with the appropriate procedure to ensure protection of TDRSS sites now and in the future.

Protection of Radio Astronomy Service in the band 14.47-14.5 GHz

According to the TFA the band 14.47-14.5 GHz is allocated to the FSS on primary basis and to MSS, FS and Mobile Service (MS) on a secondary basis. However, footnote US133 requires that operation of ESAAs within radio line-of-sight of RAS stations specified in 47 CFR §25.226(d)(2) to be coordinated with the National Science Foundation.

Any coordination required through footnote US133 will be performed in accordance with the appropriate procedure to ensure protection of RAS stations. Space Norway is committed to protect RAS from harmful interference both now and in the future.

ANNEX 1

Demonstration of EPFD Compliance in Ku-Band

ANNEX 1 - DEMONSTRATION OF EPFD COMPLIANCE IN KU-BAND

This annex provides a detailed explanation of the EPFD levels produced by the ASBM system in Ku-Band. Compliance with the single-entry EPFD limits in §25.146(a) is shown.

The ASBM system will not exceed the validation equivalent power flux-density (EPFD) limits in Ku-Band as specified in §25.208 (g), (k) and (l) for $EPFD_{down}$ and $EPFD_{up}$.

We are using the latest validation software approved by the ITU:

Equivalent Power Flux-Density Limits Validation Software
Test Version
BR ITU, June 2016
Version 1.02
Update to Transfinite EPFD, September 2016

ITU has supplied software from both Transfinite and Agenium as options. Space Norway is using the Transfinite software.

$EPFD_{down}$

Space Norway is supplying the Commission with a power-flux density (PFD) mask file applicable for the band 10.7-12.75GHz. This mask has been developed in accordance with the specifications in the most recent version of ITU-R Recommendation S.1503 (S.1503-2 issued in December 2013). This PFD mask is one of the data inputs to the EPFD validation software program required to calculate the $EPFD_{down}$ levels in Ku-Band.

The PFD mask defines the maximum satellite downlink PFD in Ku-Band over the surface of the Earth that is visible to the satellite and is a function of the sub-satellite latitude. The PFD mask is also a function of the azimuth (Az) and elevation (El) angles as viewed from the satellite towards the Earth relative to nadir direction.

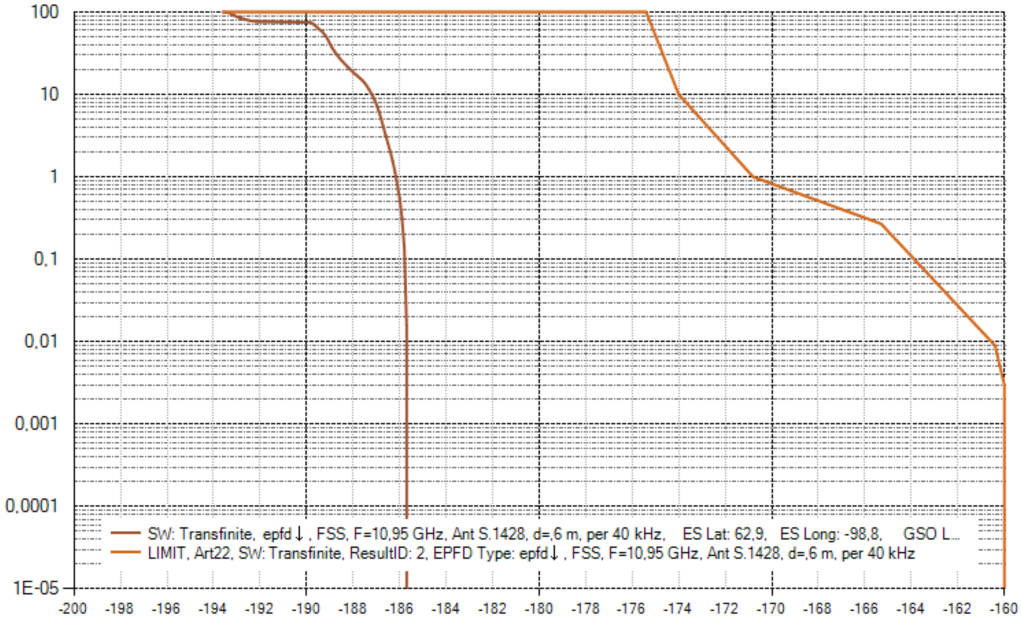
As we will not start transmitting before we reach sub-satellite latitude of 35.53 degrees North, the PFD values are zero for sub-satellite latitudes south of this. The maximum sub-satellite latitude is 63.38 degrees North.

The other necessary input in addition to the PFD mask file is the relevant part of the ITU´s SRS database file. We use our ITU filing Norsat-H1 (115520104) from ITU BRIFIC 2818.

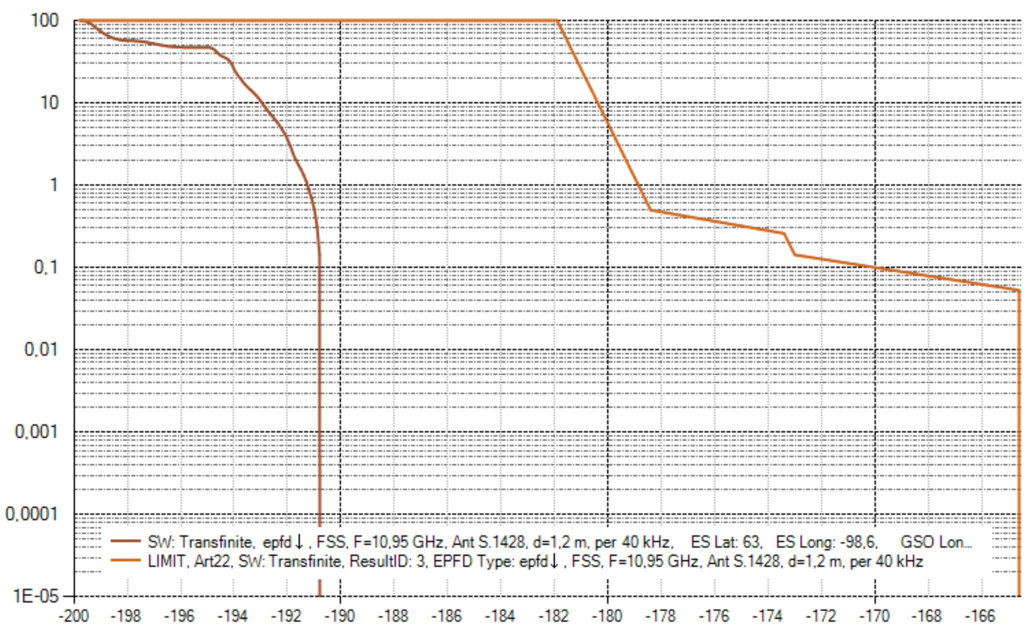
We are using the latest validation software approved by the ITU as described above.

The Ku-Band $EPFD_{down}$ results, using the input data as explained, are shown below. The overall output of the computer program is PASS, meaning we are fully compliant with the FCC limits given in §25.208.

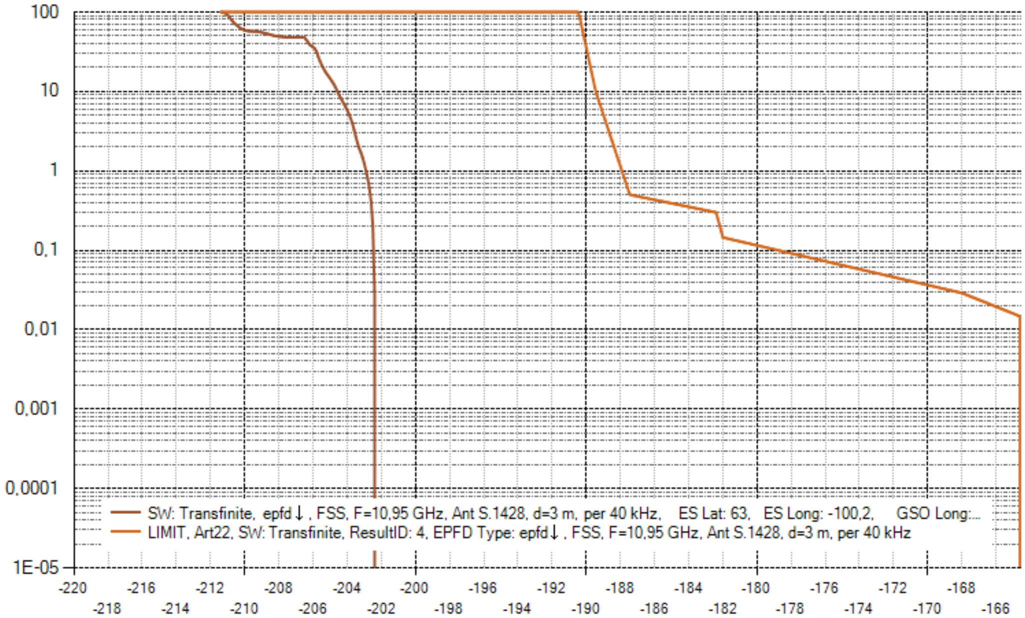
Each of the plots shown corresponds to one of the GSO reference earth station antenna sizes from the EPFD limits (§25.208). The EPFD validation software has determined the worst-case geometry. On each diagram the EPFD level is shown together with the applicable mask. The mask is given as percentage of time during which the $EPFD_{down}$ may not be exceeded. As can be seen, due to the large minimum separation angle (alpha angle) of 35.4 degrees we have towards the GSO arc, we have good margin to the FCC limits.



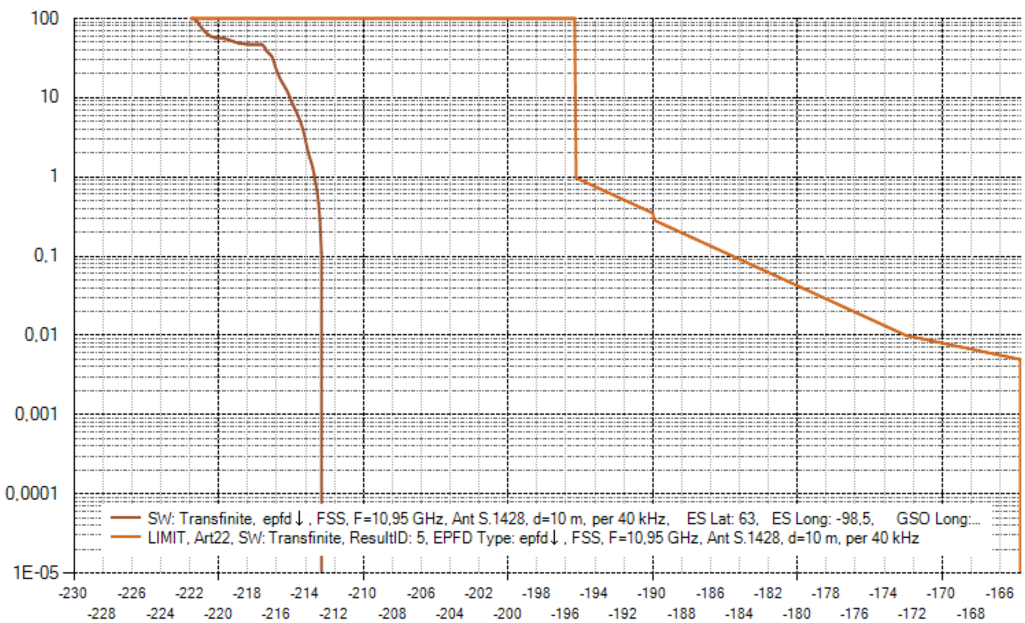
EPFD$_{down.}$ FSS reference antenna 60cm



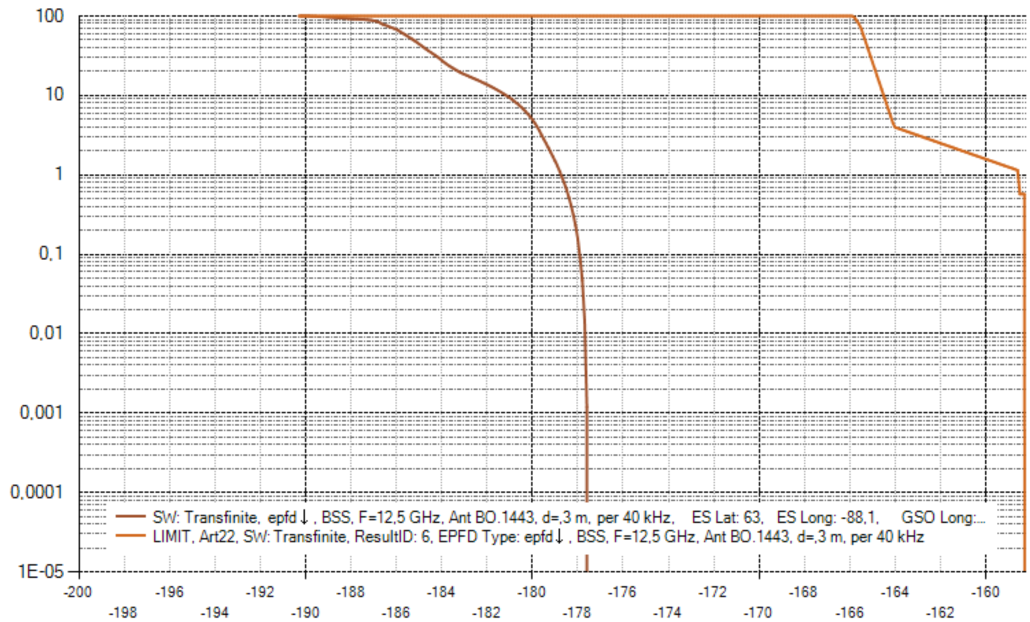
EPFD$_{down.}$ FSS reference antenna 1.2m



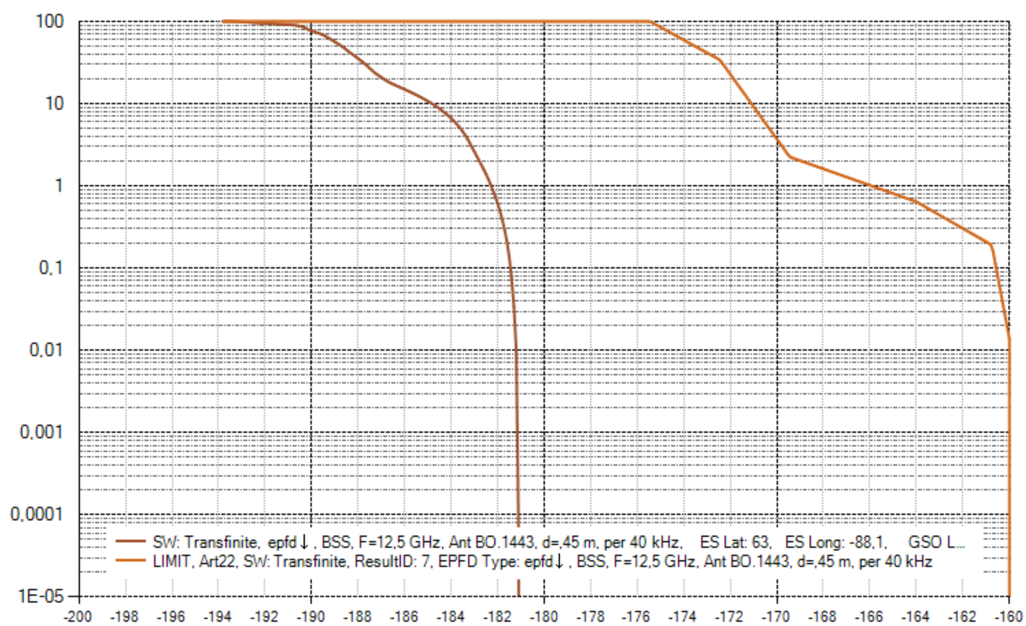
EPFD$_{down.}$ FSS reference antenna 3m



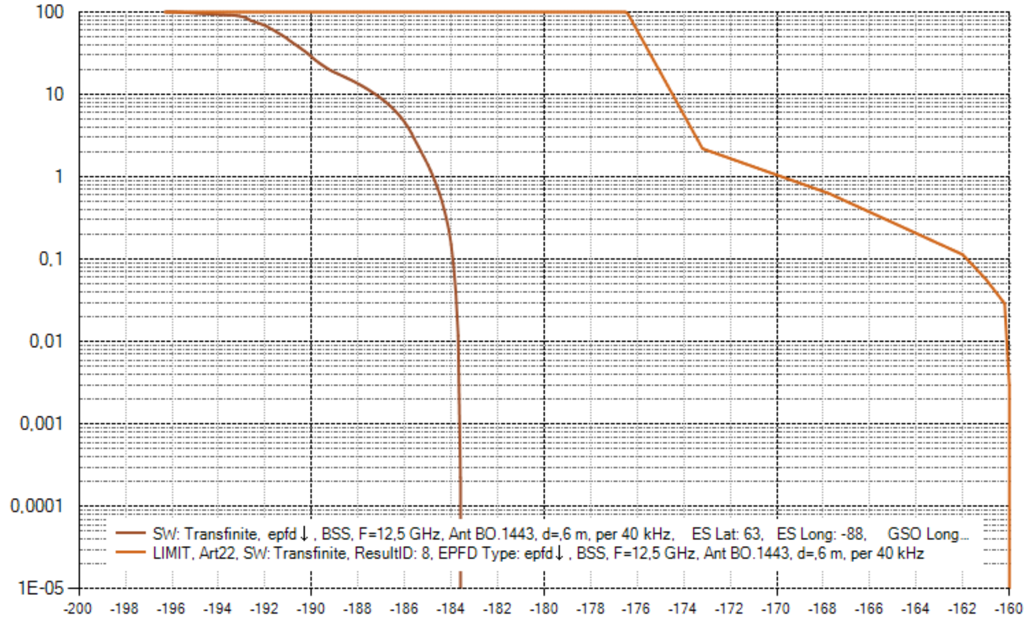
EPFD$_{down.}$ FSS reference antenna 10m



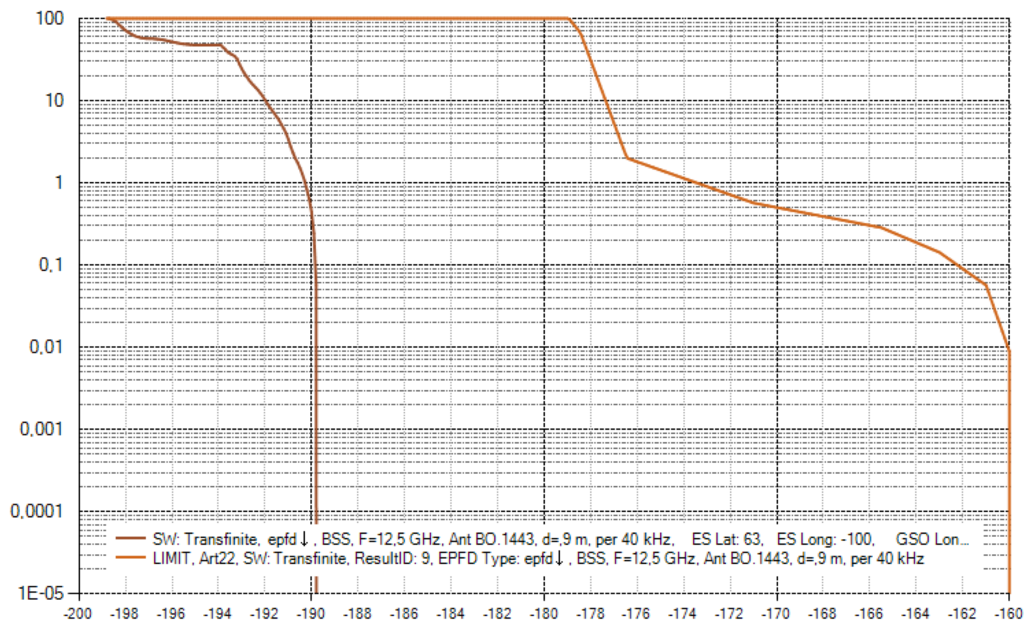
EPFD$_{down}$. BSS reference antenna 30cm



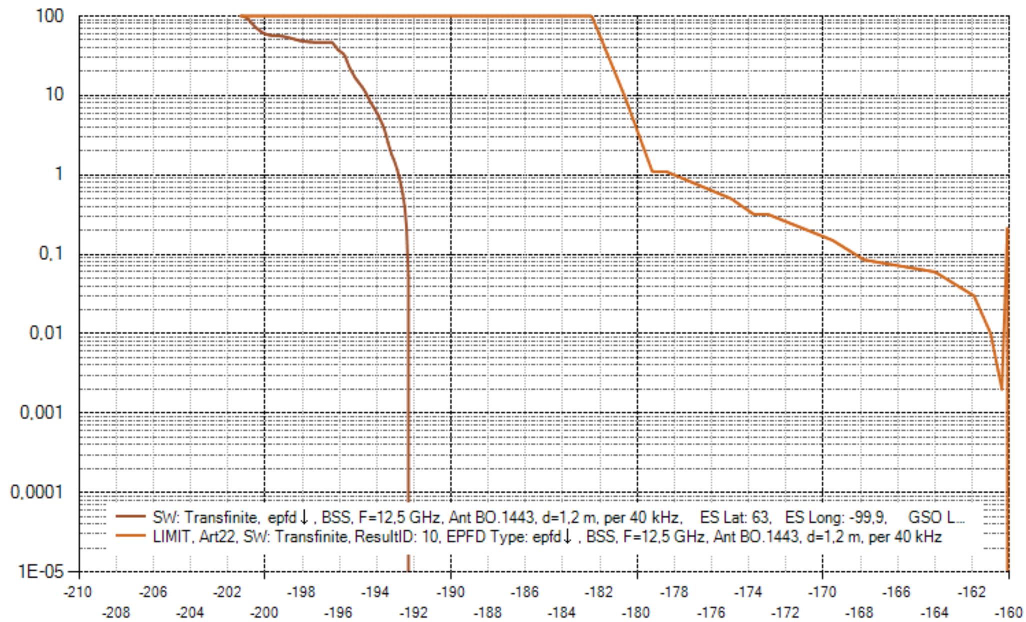
EPFD$_{down}$. BSS reference antenna 45cm



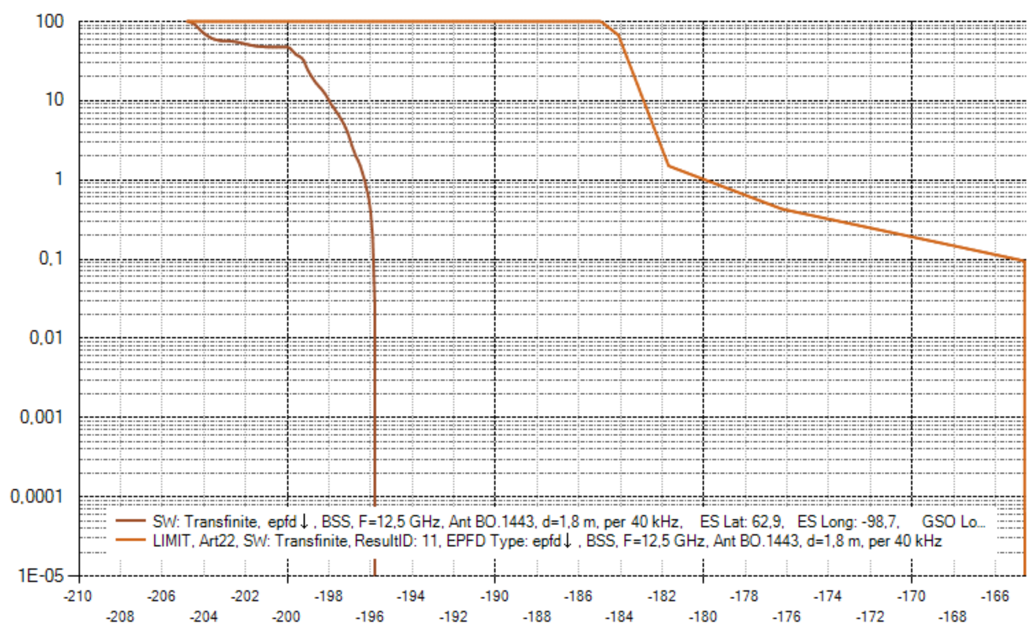
EPFD$_{down}$. BSS reference antenna 60cm



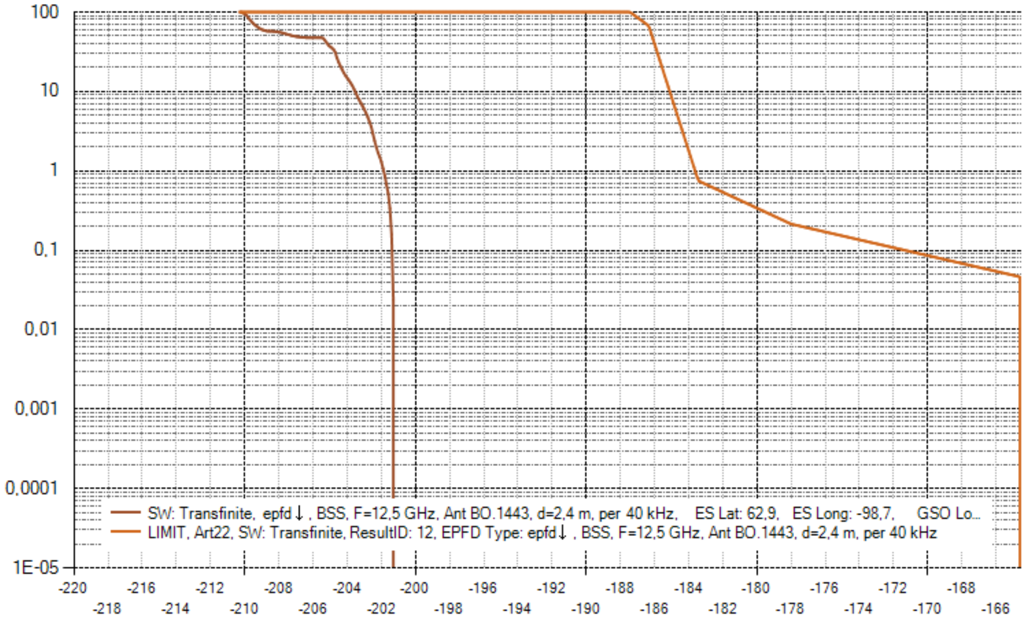
EPFD$_{down}$. BSS reference antenna 90cm



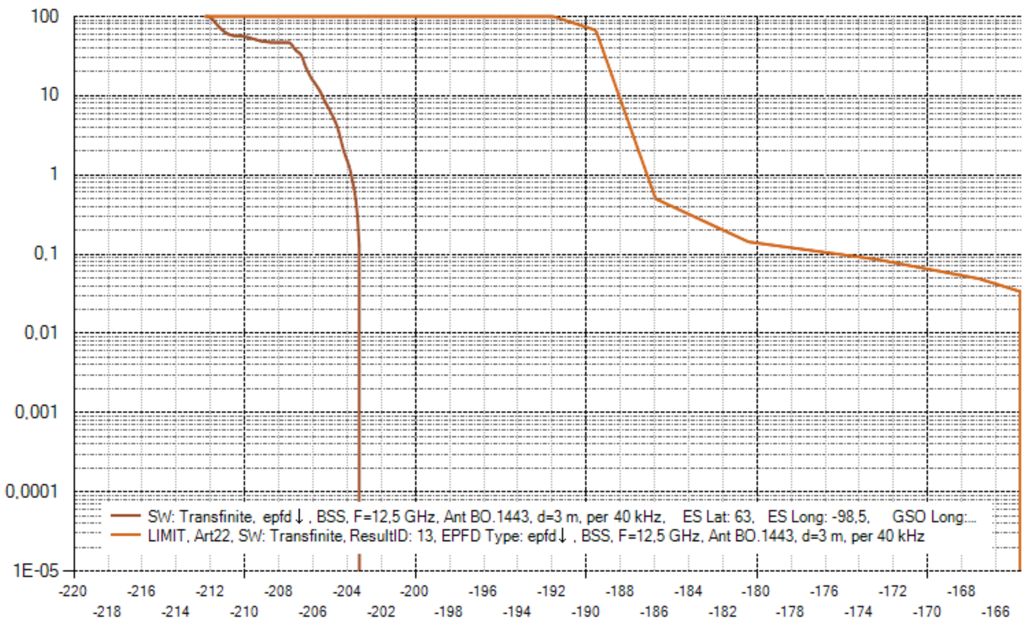
EPFD$_{down.}$ BSS reference antenna 120cm



EPFD$_{down.}$ BSS reference antenna 180cm



EPFD$_{down.}$ BSS reference antenna 240cm



EPFD$_{down.}$ BSS reference antenna 300cm

EPFD$_{up}$

Space Norway is supplying the Commission with Ku-Band earth station maximum off-axis EIRP mask files applicable for the band 14.0-14.5GHz. These masks have been developed in accordance with the specifications in the most recent version of ITU-R Recommendation S.1503 (S.1503-2 issued in December 2013). The EIRP masks are part of the data inputs to the EPFD validation software program required to calculate the EPFD$_{up}$ levels in Ku-Band.

The EIRP masks define the off-axis EIRP density of the Ku-Band transmitting earth stations as a function of off-axis angle. They were derived for typical Earth Station antennas of 0.6m, 1.0m and 2.4m. We assume the same EIRP masks for all Earth Stations having latitude north of 55 degrees North. No Earth Stations are transmitting at latitudes south of 55 degrees North.

We are using the latest validation software approved by the ITU as described earlier.

The other necessary input in addition to the EIRP mask files is the relevant part of the ITU´s SRS database file. We use our ITU filing Norsat-H1 (115520104) from ITU BRIFIC 2818.

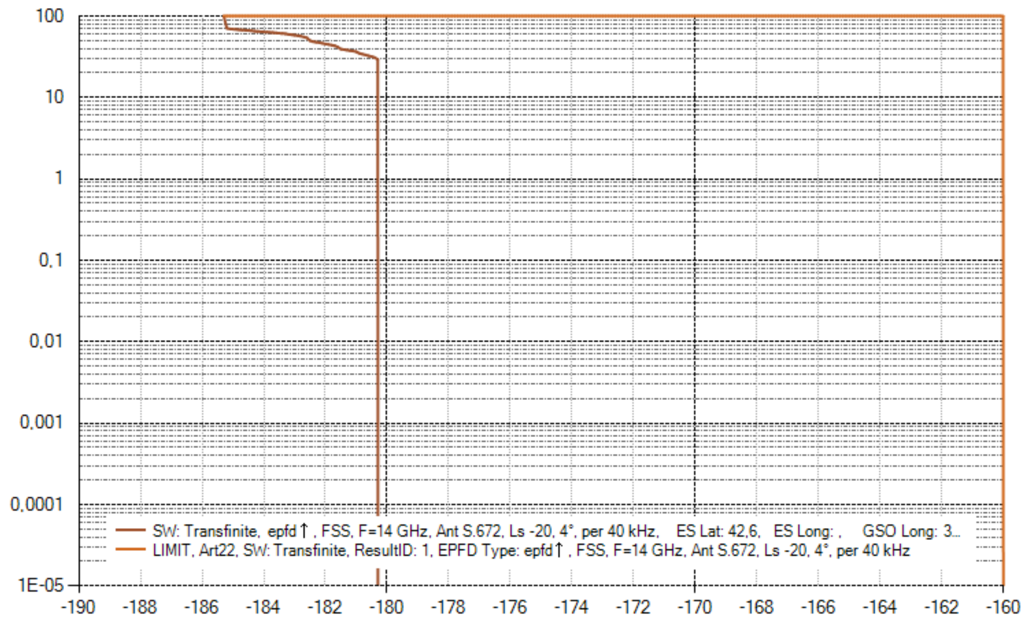
The parameter entitled "density" in ITU-R Recommendation S.1503-2 (In ITU Radio Regulations: A.4.b.7.b) is set to 0.000001 (1/km^2) representing two times frequency re-use within a cell of 1415km x 1415km.

The parameter "average distance" in ITU-R Recommendation S.1503-2 (In ITU Radio Regulations: A.4.b.7.c) is correspondingly set to 1000km. This gives an average distance of 1000km between co-frequency transmitting earth stations.

The minimum elevation angle is set to 0 degrees.

The Ku-Band EPFD$_{up}$ results, using the input data as explained, are shown below. The overall output of the computer program is PASS, meaning we are fully compliant with the FCC limits given in §25.208.

The EPFD validation software has determined the worst-case geometry. On the diagram the EPFD level is shown together with the applicable mask. As can be seen, due to the large minimum separation angle (alpha angle) of 35.4 degrees we have towards the GSO arc, we have a good margin to the FCC limit of -160 dBW/m^2 per 40kHz.



$EPFD_{up}$. Reference antenna beam-width: 4 degrees. Antenna pattern S.672-4, L_s=-20

$EPFD_{is}$

The FCC rules applicable to Ku-Band NGSO FSS systems do not include any reference to the $EPFD_{is}$ limits (Table 22-3 in the ITU Radio Regulations). However, we have included an $EPFD_{is}$ simulation for completeness.

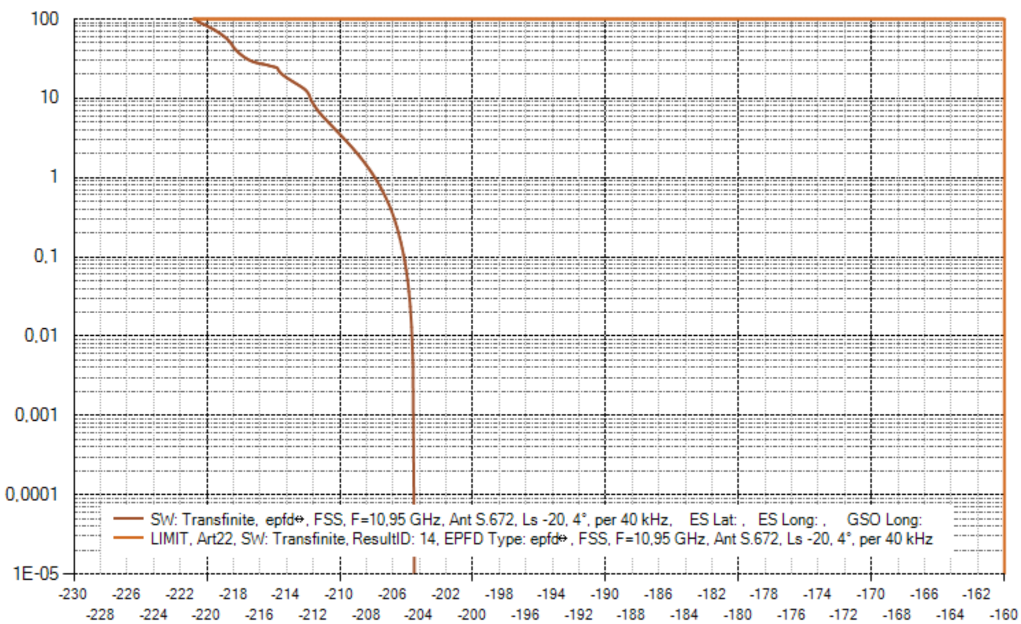
An EIRP mask file is found according to ITU 1503-2 (latest version). This EIRP mask file is using satellite antenna off-axis gain values calculated from a reference antenna diagram, ITU-R S.1528, with L_n=-20dB (near-in side-lobe). Far-out side-lobe level is 0dBi and the back-lobe level is ca. 4dBi.

We are using the latest validation software approved by the ITU as described earlier.

The other necessary input in addition to the EIRP mask file is the relevant part of the ITU´s SRS database file. We use our ITU filing Norsat-H1 (115520104) from ITU BRIFIC 2818.

The Ku-Band $EPFD_{is}$ results, using the input data as explained, are shown below. The overall output of the computer program is PASS.

The EPFD validation software has determined the worst-case geometry. On the diagram the EPFD level is shown together with the applicable mask. We have a good margin to the ITU limit of -160 dBW/m^2 per 40kHz.



$EPFD_{is}$. Reference antenna beam-width: 4 degrees. Antenna pattern S.672-4, L_s=-20

Other general EPFD rules

Space Norway will comply at the appropriate time with the rule sections §25.146(b) and §25.146(g) which require additional submissions on the part of Space Norway ninety days prior to the initiation of service to the public.

Space Norway confirms (consistent with §25.146(e)) that it is not claiming interference protection from GSO FSS and BSS networks operating in accordance with the FCC Part 25 rules and the ITU Radio Regulations.

Space Norway confirms it will coordinate with the very large GSO FSS earth stations in the 10.7-12.75GHz band under the conditions described in §25.146(f).

ANNEX 2

Interference Protection to GSO Satellite Networks

ASBM angular separation to GSO systems

Space Norway AS

November 9, 2016

1 Active arc of the HEO-system

The Arctic Satellite Broadband Mission (ASBM) satellites will not be active (transmitting or receiving) during all parts of the orbit. The satellites will only be active during a time interval centered around the apogee. Details of the orbit is given in Table 1.

Table 1: Active arc of ASBM

	TAP
Start of active period	Apogee -5 hours
End of active period	Apogee +5 hours
Duration of active period	10 hours
Duration of inactive period	6 hours
Minimum sub-satellite point latitude when active	35°N
Minimum height (above sea level) when active	28400 km
Minimum angle α	35.4°

An illustration with satellite ground tracks showing the active parts of the orbit is given in Figure 1.

2 Alpha angle/separation angle

ITU defines the separation-angle or alpha angle (α) as "The minimum angle at the GSO earth station between the line to the non-GSO satellite and the lines to the GSO arc", ref. figure 48 in Rec. ITU-R S.1503-2, also shown in Figure 2.

Table 2: Minimum Alpha angle for TAP orbit

Orbit	Orbital period	Operational arc	α_{min}
TAP	2/3 sidereal day	Apogee +/- 5 hours	35.4°

The minimum separation angle (Alpha-angle, α) between the ASBM satellites and any GSO satel-

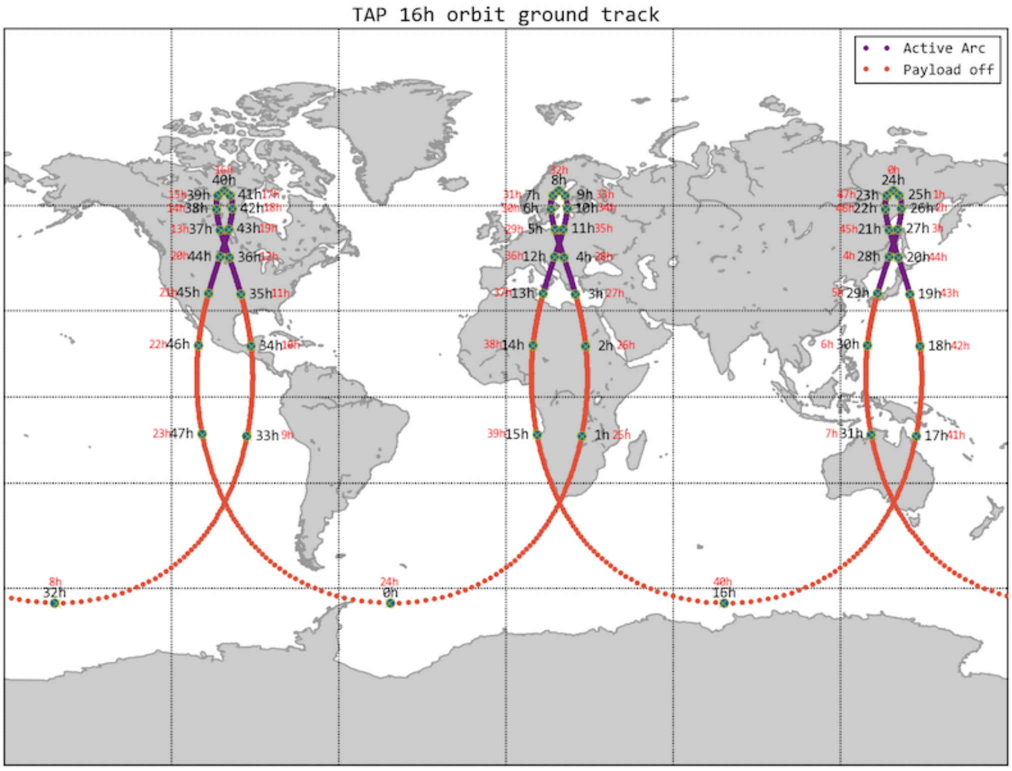


Figure 1: TAP ground track

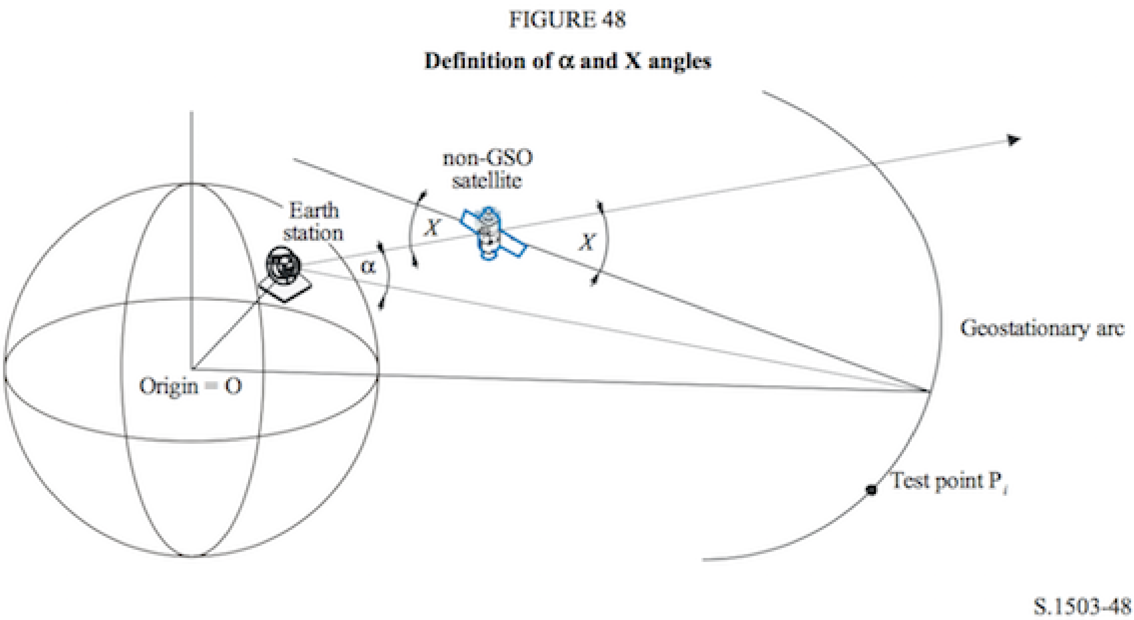


Figure 2: Definition of alpha angle from ITU-R S.1503-2

lite from any location of the surface on the earth is given in Table 2.

3 Isolation between ASBM and GSO satellites/terminals

The following assumptions and parameters have been used when assessing the interference level between ASBM and a GEO system:

- The interference level has been calculated for the complete geostationary orbital arc, showing worst case.
- For TAP, the minimum separation is 35.4° and the minimum distance is 28400 km.
- The calculations use the maximum emission levels
- A standard set of 3 GEO satellite antenna beams have been used: 0.5 degree beams, 2 degree beams, and 5 degree beams.
- The system temperature of a GEO antenna/payload system has been set to 500K.

3.1 Results

Recommendation ITU R-S.465-6 (and ITU-R S.580-6) states the following template for radiation pattern for earth stations to be used for coordination purposes:

$$\begin{aligned} G(\phi) &= 32 - 25\log\phi\,\mathrm{dBi} && \text{for } \phi < 48° \\ G(\phi) &= -10\,\mathrm{dBi} && \text{for } 48° \leq \phi \leq 180° \end{aligned}$$

where ϕ is the angle between the direction considered and the axis of the main beam. Interference will be at angles from main beam boresight: $\phi \geq \alpha$.

Thus $G \leq -9.5\,\mathrm{dBi}$ will be used in the analyses for Molniya, and $G \leq -6.7\,\mathrm{dBi}$ will be used for TAP.

The following scenarios have been analysed:

- Interference from ASBM Gateway into GEO Satellite
- Interference from ASBM Terminal into GEO Satellite
- Interference from ASBM Satellite into GEO Terminal

Tables 3-5 show the results for the ASBM orbit

Table 3: TAP interference from NORSAT-H1 Gateway into GEO Satellite

f [GHz]	P_0 [dB W Hz^{-1}]	$G_{\text{GW}} \rightarrow$ GSO [°]	d [km]	L_{path} [dB]	$\theta_{3\,\text{dB}}$ [°]	$G_{\text{GSO, max}}$ [dBi]	I_0 [dB W Hz^{-1}]	$T_{\text{sys, GSO}}$ [K]	N_0 [dB W Hz^{-1}]	$\frac{I_0}{N_0}$ [dB]	$\frac{I_0}{N_0}$ [%]	$\frac{C}{N_0}$ degr [dB]
30	−48.0	−6.7	36000	213.1	0.5	50.2	−217.61	500	−201.6	−16.0	2.51%	0.108
30	−48.0	−6.7	36000	213.1	2.0	38.2	−229.65	500	−201.6	−28.0	0.16%	0.007
30	−48.0	−6.7	36000	213.1	5.0	30.2	−237.61	500	−201.6	−36.0	0.03%	0.001
14	−63.0	−6.7	36000	206.5	0.5	50.2	−225.99	500	−201.6	−24.4	0.36%	0.016
14	−63.0	−6.7	36000	206.5	2.0	38.2	−238.03	500	−201.6	−36.4	0.02%	0.001
14	−63.0	−6.7	36000	206.5	5.0	30.2	−245.99	500	−201.6	−44.4	0.00%	0.000
7	−61.0	−6.7	36000	200.5	0.5	50.2	−217.97	500	−201.6	−16.4	2.31%	0.099
7	−61.0	−6.7	36000	200.5	2.0	38.2	−230.01	500	−201.6	−28.4	0.14%	0.006
7	−61.0	−6.7	36000	200.5	5.0	30.2	−237.97	500	−201.6	−36.4	0.02%	0.001

Table 4: TAP interference from NORSAT-H1 terminals into GEO Satellite

f [GHz]	P_0 [dB W Hz^{-1}]	$G_{\text{terminal}} \rightarrow$ GSO [°]	d [km]	L_{path} [dB]	$\theta_{3\,\text{dB}}$ [°]	$G_{\text{GSO, max}}$ [dBi]	I_0 [dB W Hz^{-1}]	$T_{\text{sys, GSO}}$ [K]	N_0 [dB W Hz^{-1}]	$\frac{I_0}{N_0}$ [dB]	$\frac{I_0}{N_0}$ [%]	$\frac{C}{N_0}$ degr [dB]
30	−47.0	−6.7	36000	213.1	0.5	50.2	−216.61	500	−201.6	−15.0	3.16%	0.135
30	−47.0	−6.7	36000	213.1	3	34.7	−232.17	500	−201.6	−30.6	0.09%	0.004
30	−47.0	−6.7	36000	213.1	5	30.2	−236.61	500	−201.6	−35.0	0.03%	0.001
14	−50.0	−6.7	36000	206.5	0.5	50.2	−212.99	500	−201.6	−11.4	7.28%	0.305
14	−50.0	−6.7	36000	206.5	3	34.7	−228.55	500	−201.6	−26.9	0.20%	0.009
14	−50.0	−6.7	36000	206.5	5	30.2	−232.99	500	−201.6	−31.4	0.07%	0.003
7	−52.0	−6.7	36000	200.5	0.5	50.2	−208.97	500	−201.6	−7.4	18.36%	0.732
7	−52.0	−6.7	36000	200.5	3	34.7	−224.53	500	−201.6	−22.9	0.51%	0.022
7	−52.0	−6.7	36000	200.5	5	30.2	−228.97	500	−201.6	−27.4	0.18%	0.008

Table 5: TAP interference from NORSAT-H1 satellite into GEO terminals

f [GHz]	P_0 [dB W Hz^{-1}]	$G_{\text{HEO}} \rightarrow$ terminal [°]	d [km]	L_{path} [dB]	$G_{\text{GSO terminal}}$ [dBi]	I_0 [dB W Hz^{-1}]	$T_{\text{sys, GSO}}$ [K]	N_0 [dB W Hz^{-1}]	$\frac{I_0}{N_0}$ [dB]	$\frac{I_0}{N_0}$ [%]	$\frac{C}{N_0}$ degr [dB]
20	−55.5	38.5	28400	207.5	−6.7	−231.3	100	−208.6	−22.7	0.54%	0.024
11	−52.0	35.0	28400	202.3	−6.7	−226.1	100	−208.6	−17.5	1.79%	0.077
7	−61.0	35.5	28400	198.4	−6.7	−230.6	100	−208.6	−22.0	0.63%	0.027

ANNEX 3

Demonstration of EPFD Compliance in Ka-Band

ANNEX 3 - DEMONSTRATION OF EPFD COMPLIANCE IN KA-BAND

This annex provides a detailed explanation of the EPFD levels produced by the ASBM system in Ka-Band. Compliance with the single-entry EPFD limits in ITU Article 22, tables 22-1B and 22-1C, for $EPFD_{down}$, table 22-2 for $EPFD_{up}$ and table 22-3 for $EPFD_{is}$ is shown.

We are using the latest validation software approved by the ITU:

Equivalent Power Flux-Density Limits Validation Software
Test Version,
BR ITU, June 2016
Version 1.02
Update to Transfinite EPFD, September 2016

ITU has supplied software from both Transfinite and Agenium as options. Space Norway is using the Transfinite software.

$EPFD_{down}$

Space Norway is supplying the Commission with power-flux density (PFD) mask files applicable for the bands 17.8-18.6GHz and 19.7-20.2GHz. These masks have been developed in accordance with the specifications in the most recent version of ITU-R Recommendation S.1503 (S.1503-2 issued in December 2013). The PFD masks are one part of the data inputs to the EPFD validation software program required to calculate the $EPFD_{down}$ levels in Ka-Band.

The PFD masks define the maximum satellite downlink PFD in Ka-Band over the surface of the Earth that is visible to the satellite and is a function of the sub-satellite latitude. The PFD masks are also a function of the azimuth (Az) and elevation (El) angles as viewed from the satellite towards the Earth relative to nadir direction.

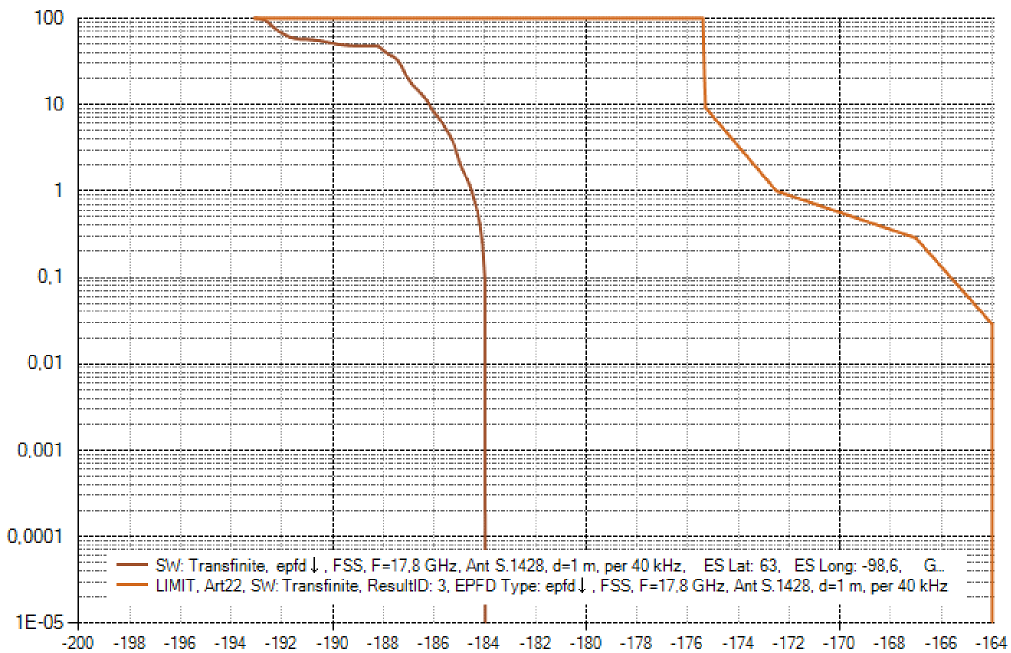
As we will not start transmitting before we reach sub-satellite latitude of 35.53 degrees North, the PFD values are zero for sub-satellite latitudes south of this. The maximum sub-satellite latitude is 63.38 degrees North.

The other necessary input in addition to the PFD mask files is the relevant part of the ITU´s SRS database file. We use our ITU filing Norsat-H1 (115520104) from ITU BRIFIC 2818.

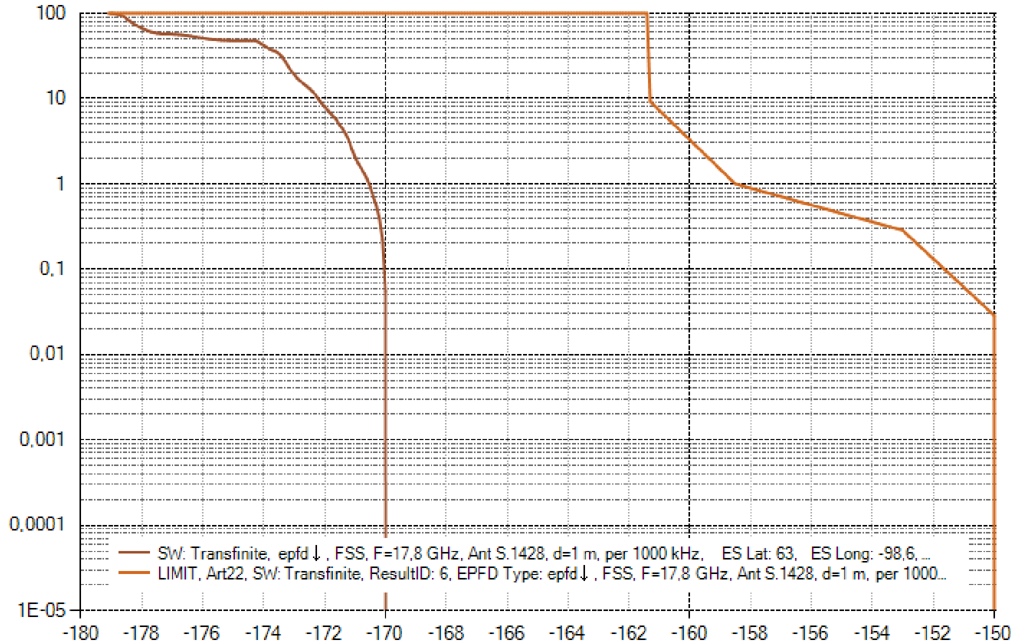
We are using the latest validation software approved by the ITU as described above.

The Ka-Band EPFD$_{down}$ results, using the input data as explained, are shown below. The overall output of the computer program is PASS, meaning we are fully compliant with the ITU limits given in Article 22.

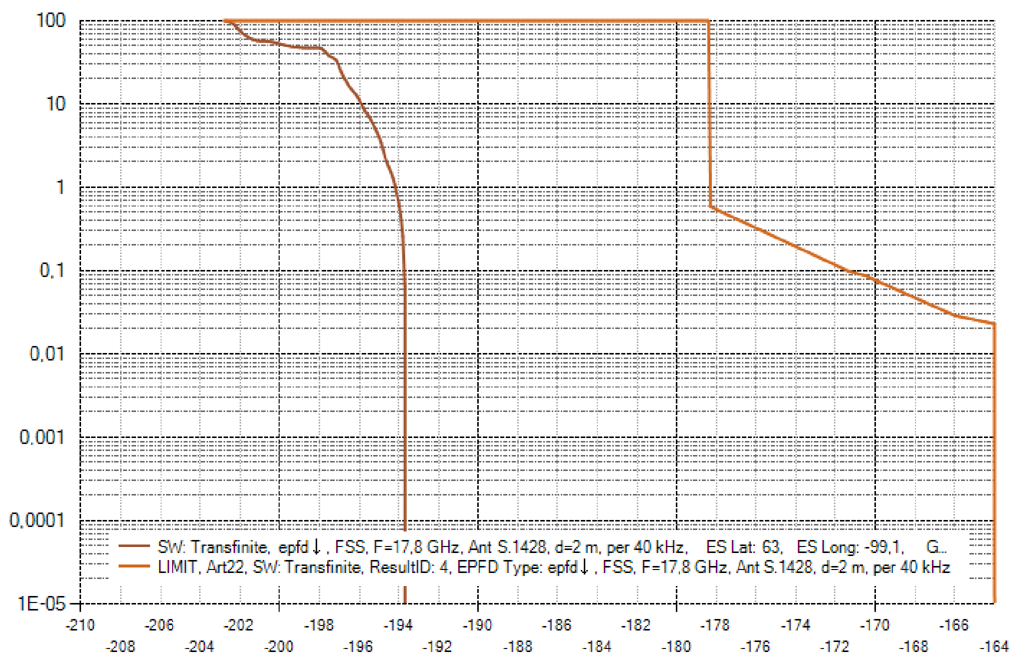
Each of the plots shown corresponds to one of the GSO reference earth station antenna sizes from the EPFD limits (ITU Article 22, Tables 22-1B and 22-1C) and the reference bandwidth (40kHz and 1000kHz). The EPFD validation software has determined the worst-case geometry. On each diagram the EPFD level is shown together with the applicable mask. The mask is given as percentage of time during which the EPFD$_{down}$ may not be exceeded.



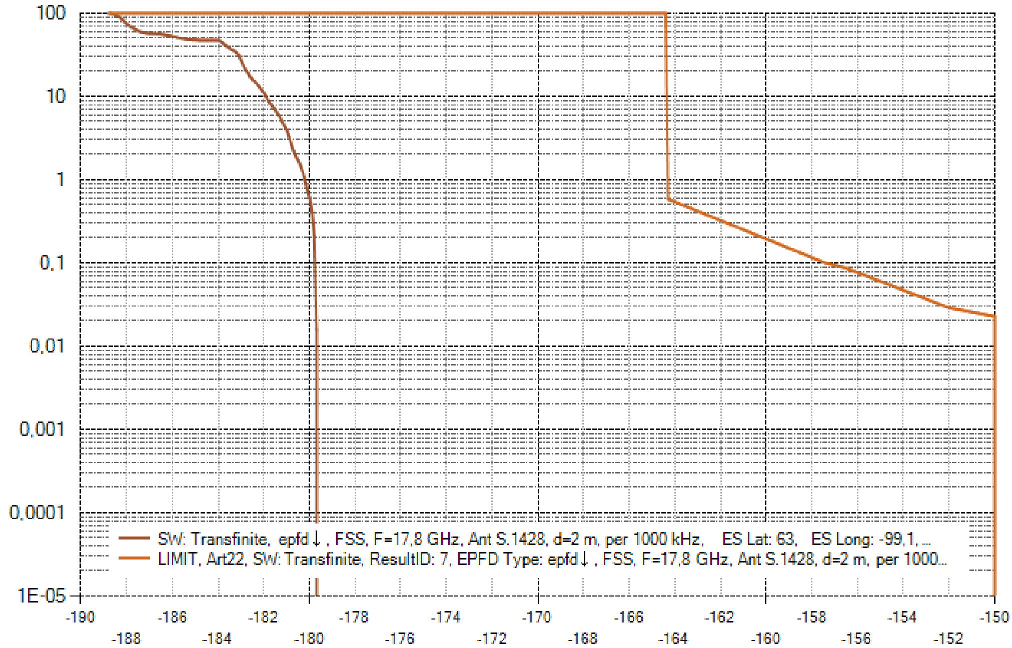
EPFD$_{down}$. 17.8-18.6GHz. Reference antenna 1m. Reference bandwidth 40kHz



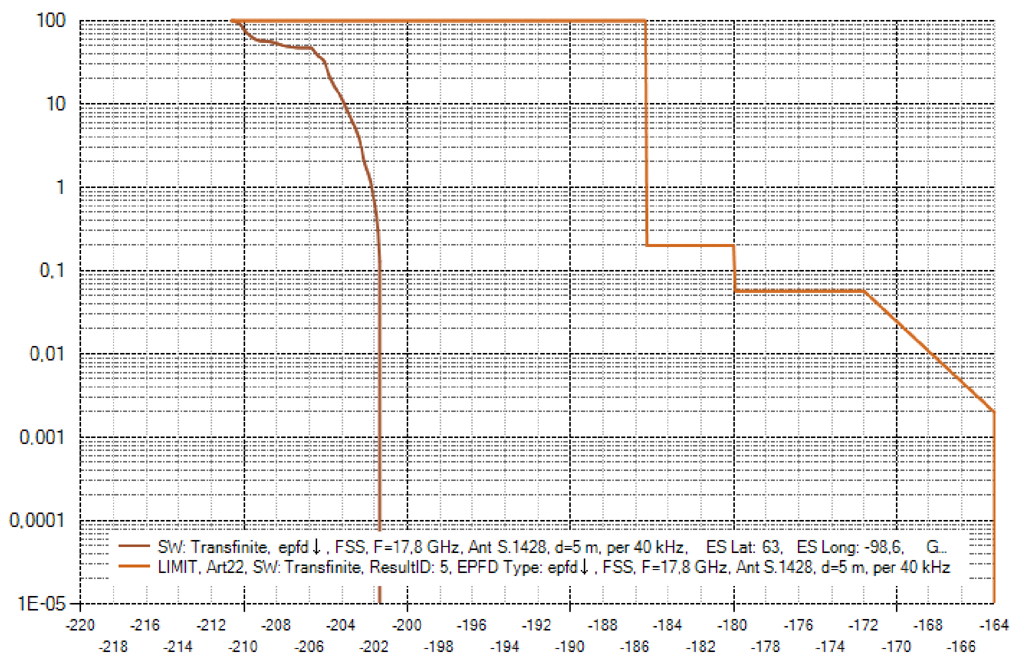
EPFD$_{down}$. 17.8-18.6GHz. Reference antenna 1m. Reference bandwidth 1000kHz



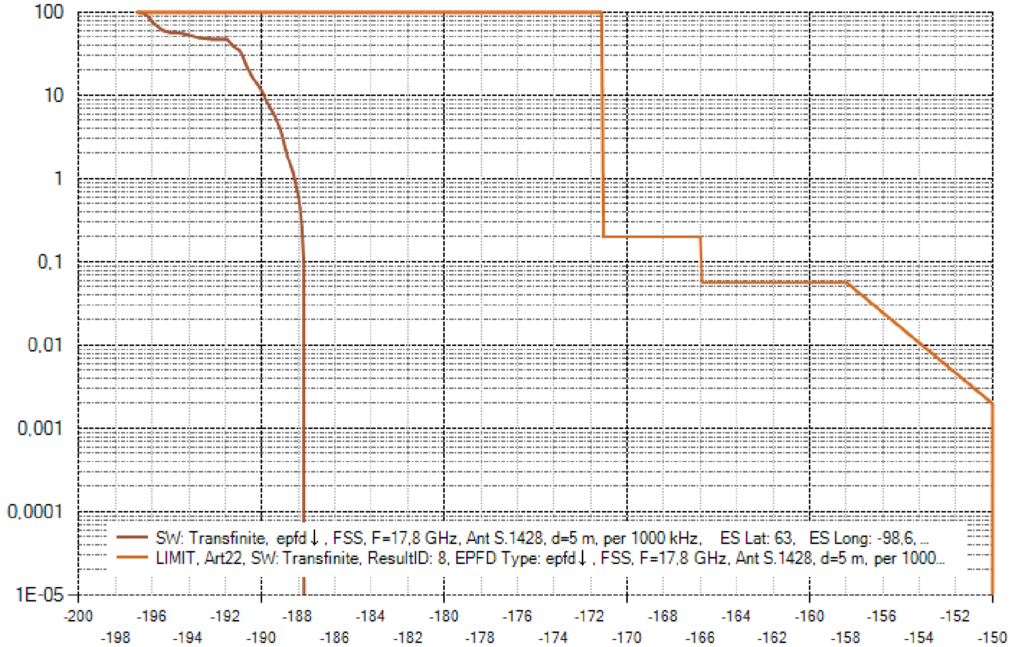
EPFD$_{down}$. 17.8-18.6GHz. Reference antenna 2m. Reference bandwidth 40kHz



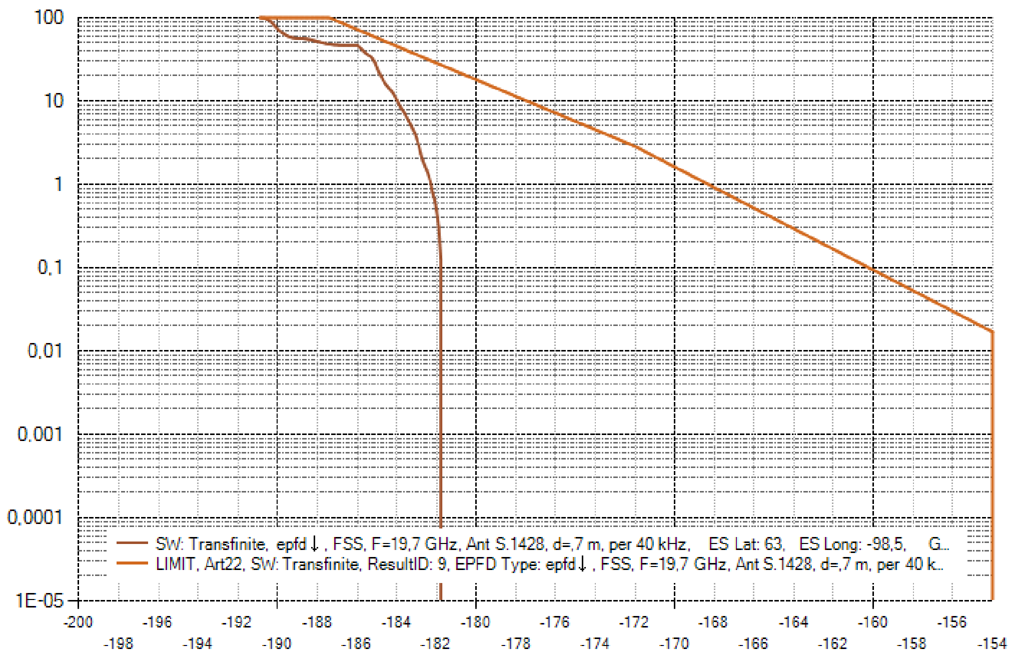
EPFD$_{down.}$ 17.8-18.6GHz. Reference antenna 2m. Reference bandwidth 1000kHz



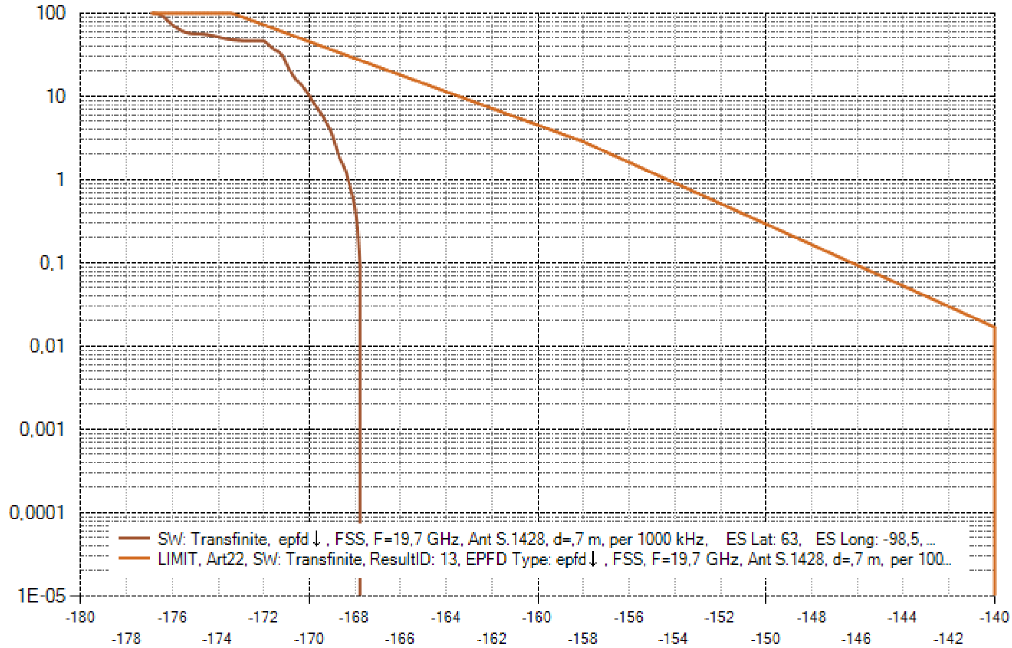
EPFD$_{down.}$ 17.8-18.6GHz. Reference antenna 5m. Reference bandwidth 40kHz



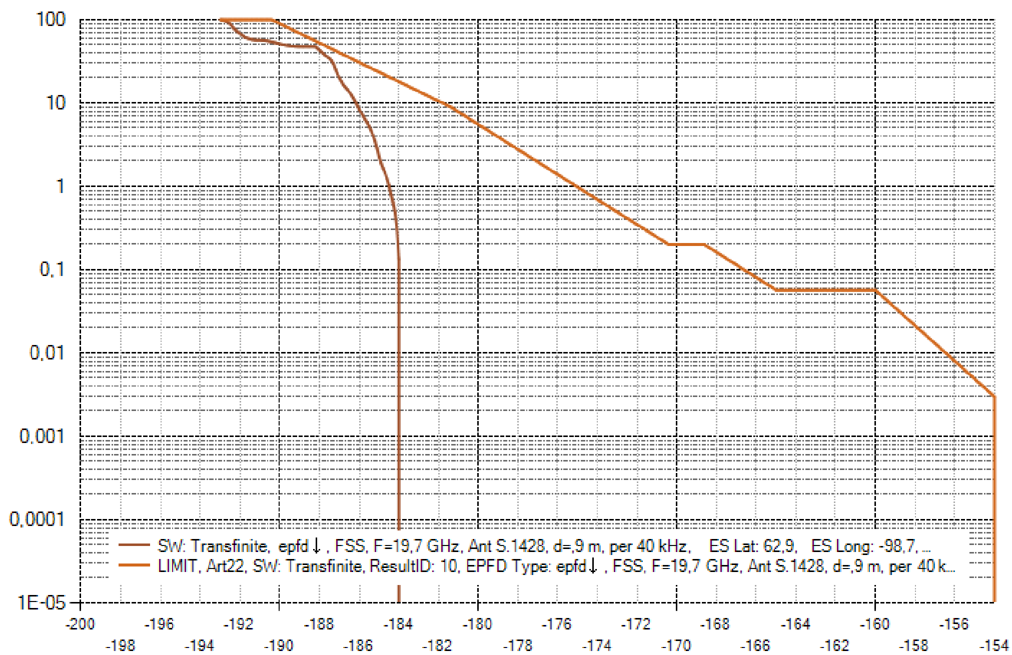
EPFD$_{down}$. 17.8-18.6GHz. Reference antenna 5m. Reference bandwidth 1000kHz



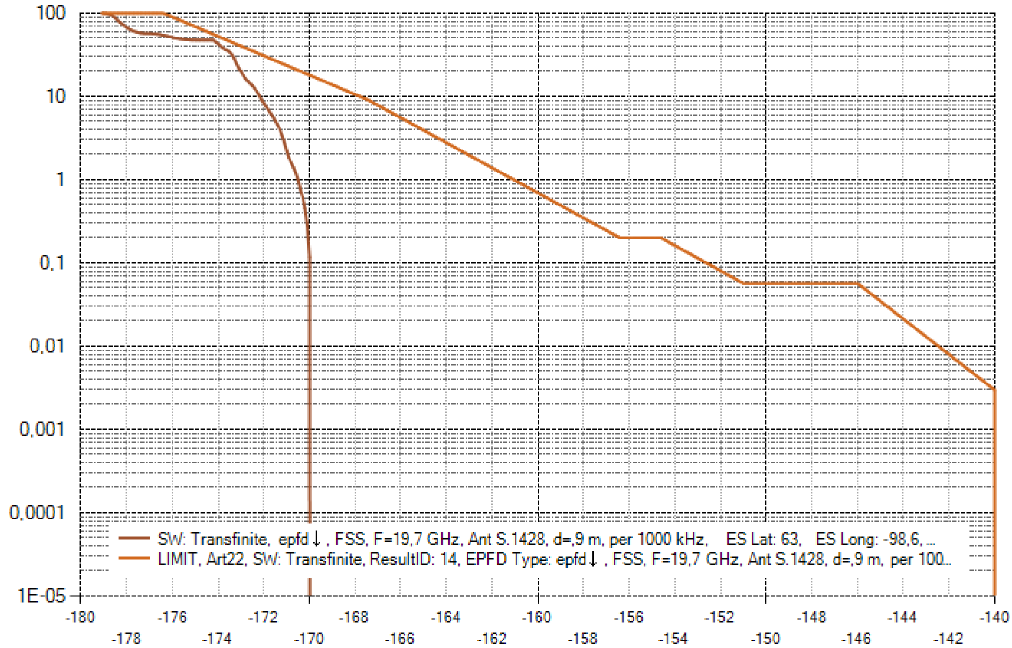
EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 70cm. Reference bandwidth 40kHz



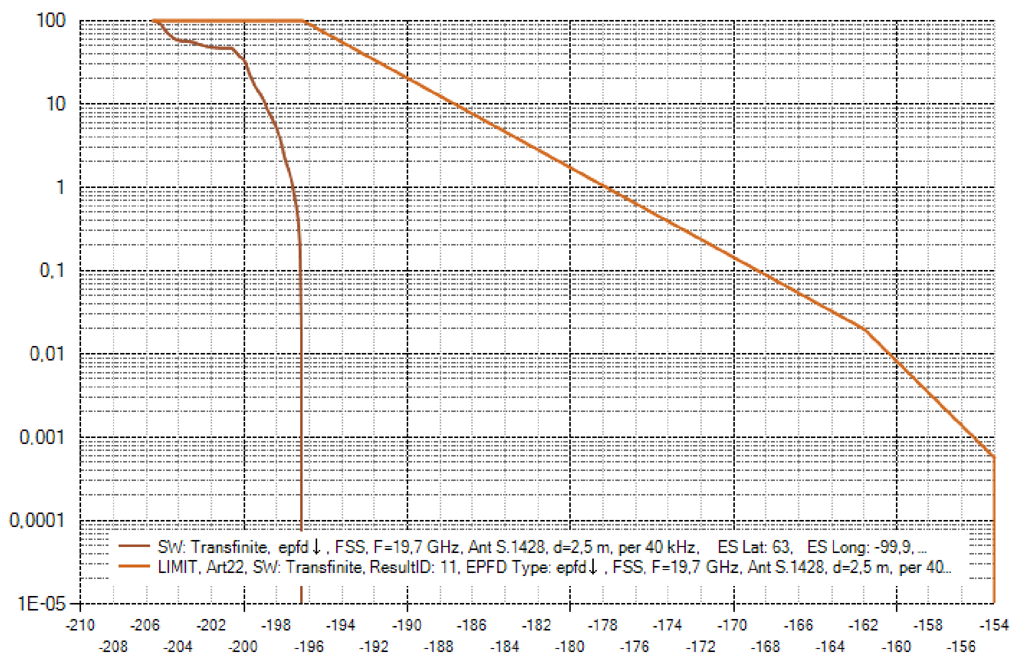
EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 70cm. Reference bandwidth 1000kHz



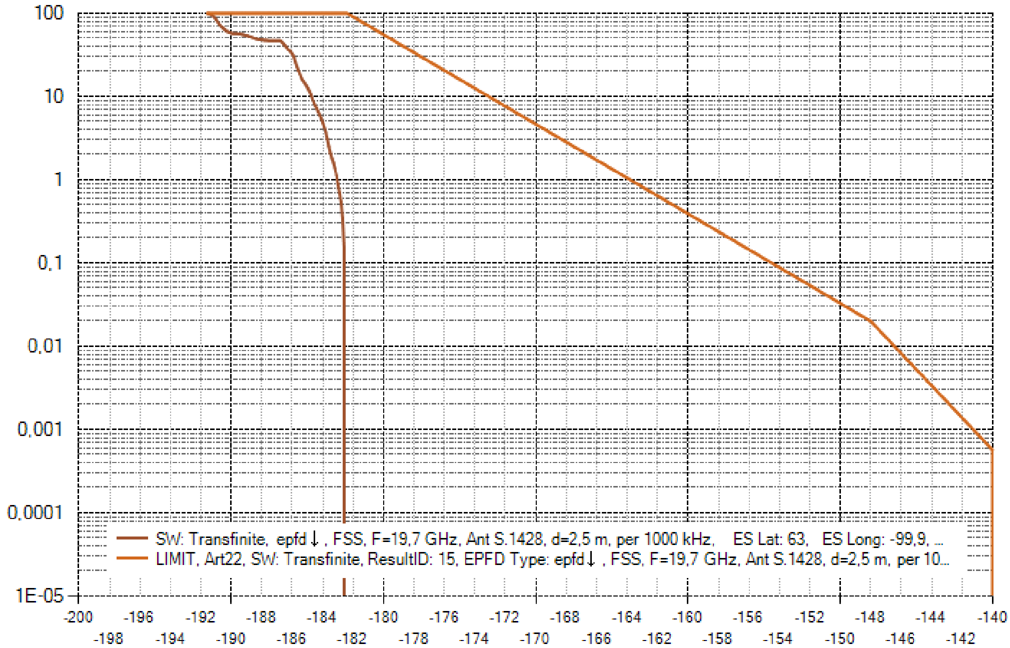
EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 90cm. Reference bandwidth 40kHz



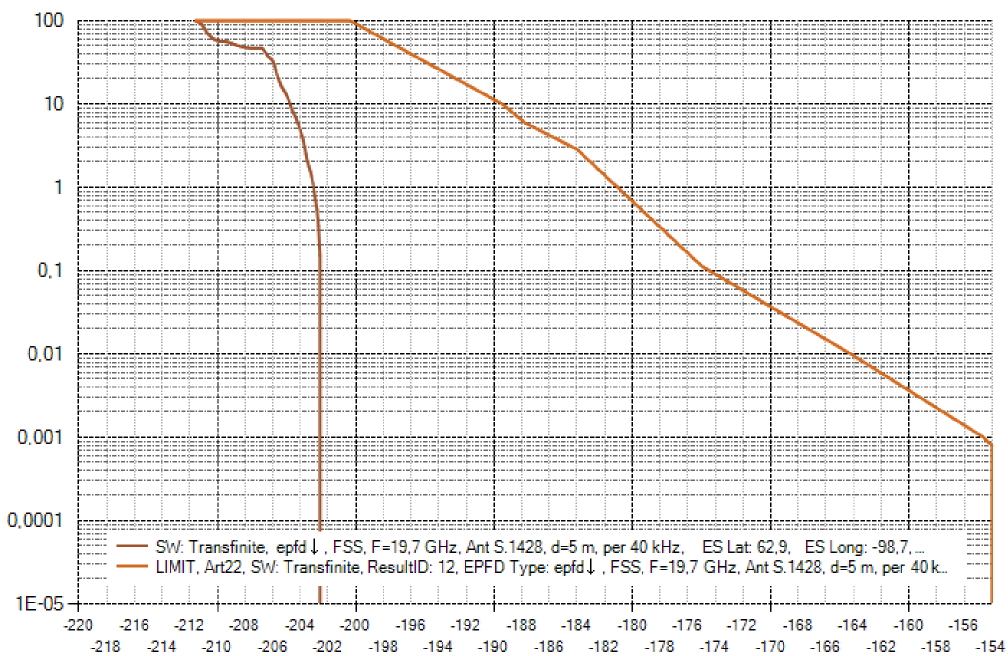
EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 90cm. Reference bandwidth 1000kHz



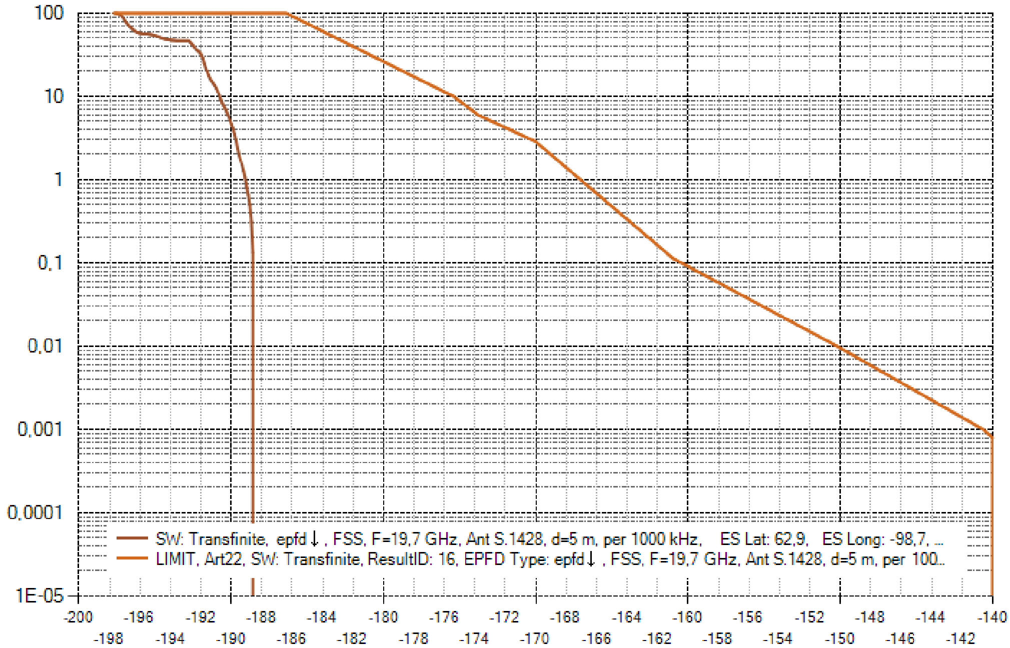
EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 2.5m. Reference bandwidth 40kHz



EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 2.5m. Reference bandwidth 1000kHz



EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 5m. Reference bandwidth 40kHz



EPFD$_{down}$. 19.7-20.2GHz. Reference antenna 5m. Reference bandwidth 1000kHz

EPFD$_{up}$

Space Norway is supplying the Commission with Ka-Band earth station maximum off-axis EIRP mask files applicable for the bands 27.5-28.6GHz and 29.5-30GHz. These masks have been developed in accordance with the specifications in the most recent version of ITU-R Recommendation S.1503 (S.1503-2 issued in December 2013). The EIRP masks are part of the data inputs to the EPFD validation software program required to calculate the EPFD$_{up}$ levels in Ka-Band.

The EIRP masks define the off-axis EIRP density of the Ka-Band transmitting earth stations as a function of off-axis angle. They were derived for typical Earth Station antennas of 0.6m, 1.0m, 2.4m and 9m. We assume the same EIRP masks for all Earth Stations having latitude north of 55 degrees North. No Earth Stations are transmitting at latitudes south of 55 degrees North.

We are using the latest validation software approved by the ITU as described earlier.

The other necessary input in addition to the EIRP mask files is the relevant part of the ITU´s SRS database file. We use our ITU filing Norsat-H1 (115520104) from ITU BRIFIC 2818.

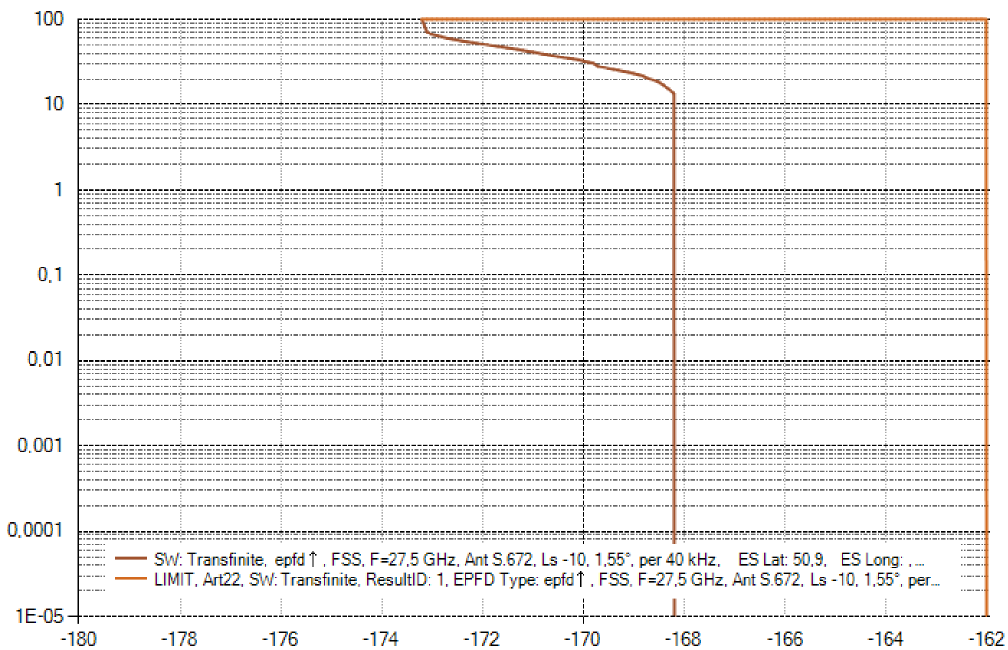
The parameter entitled “density” in ITU-R Recommendation S.1503-2 (In ITU Radio Regulations: A.4.b.7.b) is set to 0.000001 (1/km^2) representing two times frequency re-use within a cell of 1415km x 1415km.

The parameter “average distance” in ITU-R Recommendation S.1503-2 (In ITU Radio Regulations: A.4.b.7.c) is correspondingly set to 1000km. This gives an average distance of 1000km between co-frequency transmitting earth stations.

The minimum elevation angle is set to 0 degrees.

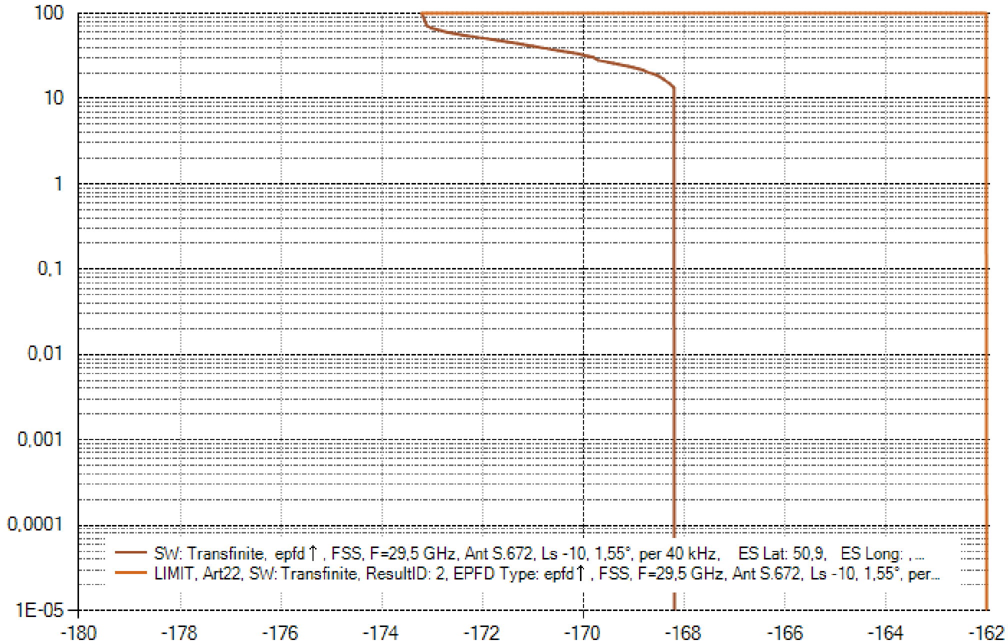
The Ka-Band EPFD$_{up}$ results, using the input data as explained, are shown below. The overall output of the computer program is PASS, meaning we are fully compliant with the ITU limits given in ITU Article 22, Table 22-2.

The EPFD validation software has determined the worst-case geometry. On the diagram the EPFD level is shown together with the applicable mask. As can be seen, due to the large minimum separation angle (alpha angle) of 35.4 degrees we have towards the GSO arc, we have a good margin to the ITU limit of -162 dBW/m^2 per 40kHz.



EPFD$_{up}$. 27.5-28.6GHz.

Reference antenna beam-width: 1.55 degrees. Antenna pattern S.672-4, L_s=-10



$EPFD_{up.}$ 29.5-30GHz

Reference antenna beam-width: 1.55 degrees. Antenna pattern S.672-4, L_s=-10

$EPFD_{is}$

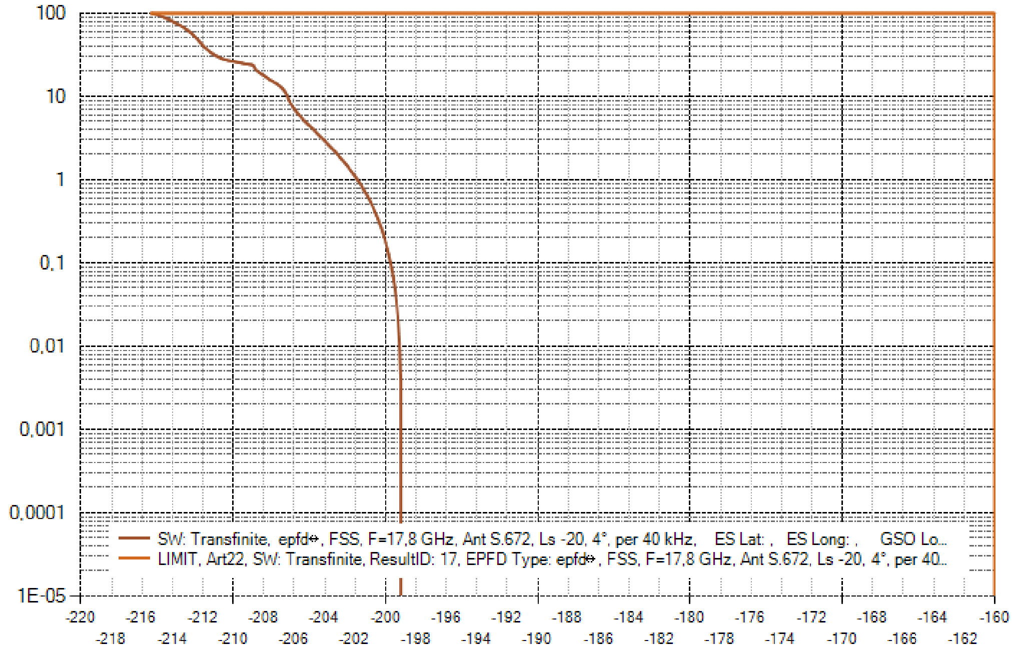
An EIRP mask file is found according to ITU 1503-2 (latest version). Frequency band is 17.8-18.4GHz. This EIRP mask file is using satellite antenna off-axis gain values calculated from a reference antenna diagram, ITU-R S.1528, with Ln=-20dB (near-in side-lobe). Far-out side-lobe level is 0dBi and the back-lobe level is ca. 4dBi.

We are using the latest validation software approved by the ITU as described earlier.

The other necessary input in addition to the EIRP mask file is the relevant part of the ITU´s SRS database file. We use our ITU filing Norsat-H1 (115520104) from ITU BRIFIC 2818.

The Ka-Band EPFDis results, using the input data as explained, are shown below. The overall output of the computer program is PASS.

The EPFD validation software has determined the worst-case geometry. On the diagram the EPFD level is shown together with the applicable mask. As can be seen, we have a good margin to the ITU limit of -160 dBW/m2 per 40kHz.



$EPFD_{is.}$ 17.8-18.4GHz

Reference antenna beam-width: 4 degrees. Antenna pattern S.672-4, L_s=-20

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application and that it is complete and accurate to the best of my knowledge and belief.

Bjørn Roger Andersen
Chief Technology Officer
Space Norway AS