# ECC Report 217

The Use of Land and Maritime Earth Stations on Mobile Platforms Operating with NGSO FSS Satellite Systems in the Frequency Range 17.3-20.2 GHz, 27.5-29.1 GHz and 29.5-30.0 GHz

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# 0 EXECUTIVE SUMMARY

Land and Maritime Earth Stations On Mobile Platforms (ESOMPs)[1] are operating in Ka-band Fixed Satellite Service (FSS) non-Geostationary (NGSO) satellite systems. The ECC Report 184 [1], adopted in February 2013 examined the regulatory and technical aspects applicable to the use of ESOMPs operating in Ka-band GSO networks, making references to similar developments in the C-band and Ku-band where mobile terminals have operated for many years in Geostationary (GSO) FSS networks, under certain technical and regulatory conditions. While the ECC Report 184 [1] examination included Land, Maritime and Aeronautical ESOMPs operating Ka-band GSO networks, this Report however, limits its examination to the equivalent regulatory and technical aspects applicable to the use of Land and Maritime ESOMPs operating in Ka-band NGSO satellite systems.

With the technical conditions given in this Report, ESOMPs may be treated in a similar fashion to uncoordinated FSS earth stations. This Report offers a technical analysis similar to that carried out in the ECC Report 184 [1] for GSO ESOMPs, and recommends that ESOMPs should be authorised in the Ka-band frequencies already identified by CEPT administrations for the operation of uncoordinated FSS earth stations, with the necessary technical conditions to ensure protection of other satellite and terrestrial services.

This Report identifies certain technical, operational and regulatory requirements that may be included in an ECC Decision on Ka-band ESOMPs operating to FSS NGSO satellite systems. Such technical requirements are necessary to ensure, among other things, that ESOMPs antennas maintain a high pointing accuracy and do not cause interference to other satellite networks and systems. It should be noted that, in the case of NGSO satellite systems, the pointing accuracy also takes into account that the ESOMPs antenna will need to track the NGSO satellites as they move across the sky. Furthermore, in some cases, for example where one country has authorised a particular band for uncoordinated FSS earth stations and another has authorised the same band for fixed service networks, cross-border interference issues could potentially occur. To address these issues, for maritime ESOMPs a Power Flux Density (PFD) threshold applicable to the low-water mark of the territory of an administration is necessary and for aircraft ESOMPs a PFD threshold at the ground applicable to the territory of a country is needed. This Report identifies the applicable PFD thresholds to be met by maritime ESOMPs.

In the downlink FSS bands (17.3-20.2 GHz), ESOMPs would receive the same protection from interference as equivalent uncoordinated FSS earth stations. In some instances, this means that the ESOMPs would operate on a non-protected basis.

ESOMPs may be deployed globally for land and maritime applications. The ITU has developed ITU-R Report S.2261 [2] on technical and operational requirements for ESOMPs operating to Ka-band NGSO satellite systems. This ITU Report also notes the need for operators to implement methodologies to comply with technical and operational requirements placed on the deployment of ESOMPs by administrations.

[1] It should be noted that ESOMPs mentioned in this report without a qualification refer to Land and Maritime ESOMPs operating to NGSO satellite systems. Aeronautical ESOMPs operating to NGSO satellite systems are not considered in this Report. When a reference is made to ESOMPs operating to GSO networks, it is referenced as “GSO ESOMPs”.

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# LIST OF ABBREVIATIONS

| Abbreviation | Explanation |
|---|---|
| **AES** | Aircraft Earth Station |
| **AMSS** | Aeronautical Mobile-Satellite Service |
| **CEPT** | European Conference of Postal and Telecommunications Administrations |
| **CPM** | Conference Preparatory Meeting (ITU) |
| **EPFD** | Equivalent power flux-density |
| **ECC** | Electronic Communications Committee |
| **ESOMPs** | Earth Station On Mobile Platforms |
| **ESV** | Earth Station on board Vessel |
| **ETSI** | European Telecommunications Standards Institute |
| **e.i.r.p.** | equivalent isotropically radiated power |
| **FS** | Fixed Service |
| **FSS** | Fixed-Satellite Service |
| **GSO** | Geostationary Satellite Orbit |
| **G/T** | Gain to system noise temperature ratio (of a receiving earth station) |
| **HEST** | High e.i.r.p. Satellite Terminals |
| **HDFSS** | High-Density applications in the Fixed Satellite Service |
| **ITU** | International Telecommunication Union |
| **LEST** | Low e.i.r.p. Satellite Terminals |
| **MS** | Mobile Service |
| **MSS** | Mobile-Satellite Service |
| **NGSO** | Non-Geostationary Satellite Orbit |
| **NCF** | Network Control Facility |
| **PFD** | Power Flux Density |
| **P-MP** | Point-to-Multipoint |
| **PP** | Point-to-Point |
| **R&TTE** | Radio equipment and Telecommunications Terminal Equipment |
| **VSAT** | Very Small Aperture Terminal |
| **WRC** | World Radiocommunication Conference |

# 1 INTRODUCTION

The growing need for broadband communications will be addressed by, amongst others, non-Geostationary satellite systems operating in the Ka-band. Terminals described as Earth Stations mounted on Mobile Platforms (ESOMPs) will be an integral part of the NGSO satellite systems. ESOMPs will be deployed to provide telecommunications services to ships, trains and other vehicles. ESOMPs are currently deployed with C-, Ku- and Ka-band GSO satellite networks and Ka-band NGSO satellite systems. The deployments of Ka-band GSO networks and NGSO systems are relatively recent, however they demonstrate that operators concerned expect there to be a significant demand for broadband applications, for which ESOMPs will be used. It is also noted that ESOMPs operating to NGSO systems are being deployed within Europe to meet the demand for such applications.

The advances in satellite earth station antenna technology have contributed to the rapid deployment of ESOMPs in the FSS. Over the years, stabilised antennas capable of maintaining a high degree of pointing accuracy while on moving platforms have been perfected, and such developments, which also allow for maintaining very stable pointing characteristics, enabled ESOMPs to comply with the interference requirements. These have led to the deployment of ESOMPs within the same interference environment as fixed terminals, while complying with same regulatory constraints as those for typical uncoordinated FSS earth stations.

The ITU Reports ITU-R S.2223 [3] and ITU-R S.2261 [4] describe the technical and operational requirements for ESOMPs operating in Ka-band with GSO and NGSO satellites respectively. WRC-03 adopted technical, operational and regulatory provisions for Aeronautical Mobile Satellite Service (AMSS) systems and Earth Stations on-board Vessels (ESVs) to allow these systems to operate in FSS frequencies in the C- and Ku-bands. Since 2003, numerous networks have been operating successfully under these provisions. The ESOMPs for GSO networks and NGSO systems in the Ka-band are similar to those mobile earth stations, like ESVs operating in the C- and Ku-bands.

This Report examines the operation of ESOMPs with NGSO satellite systems in the Ka-band frequencies and identifies the necessary technical and regulatory conditions to offer protection to other satellite or terrestrial services sharing the same frequency bands. Such technical and regulatory conditions may be used by the CEPT as the basis for a regulatory approach to be included in an ECC Decision.

The ECC Report 184 [1] on GSO ESOMPs, which identified the technical and operational requirements for Ka-band GSO ESOMPs, including the criteria for the protection of other services, provided the basis for preparation of the ECC Decision (13)01 [5] on GSO ESOMPs titled “the harmonised use, free circulation and exemption from individual licensing of Earth Stations On Mobile Platforms (ESOMPs) within the frequency bands 17.3-20.2 GHz and 27.5-30.0 GHz”. The criteria used for the protection of other services from Ka-band GSO ESOMPs have been considered as directly applicable for the protection of same services from Ka-band NGSO ESOMPs, and therefore used in this Report.

ESOMPs operating within NGSO satellite systems may utilise the frequency bands 17.3-20.2 GHz (space to Earth) and 27.5-29.1 GHz, 29.5-30.0 GHz (Earth to space).

## 2 THE USE OF THE BANDS 27.5-29.1 GHz, 29.5- 30.0 GHz AND 17.3-20.2 GHz BY NGSO ESOMPS

Ka-band NGSO ESOMPs utilise the frequency bands:

- 17.3 to 20.2 GHz band is used for space to Earth links. The use of these frequencies is not the subject of this Report and therefore not considered further.
- 27.5 to 29.1 GHz and 29.5-30.0 GHz bands are used for Earth to space links, i.e. transmissions form NGSO ESOMPs.

ECC Report 152 [6], on the use of the frequency bands 27.5-30.0 GHz and 17.3-20.2 GHz by satellite networks, identified a number of reasons, listed below, why some satellite operators and service providers are moving from Ku-band to Ka-band. In fact, some of the reasons, such as the ability to use smaller user terminals, are particularly relevant to the mobile markets served by ESOMPs, where the size and weight of the user antenna are critical considerations. Ka-band systems provide:

- Improved spectrum efficiency, due to the use of narrow spot beams;
- Better coverage and higher satellite antenna gain (for the same sized aperture), compared to lower frequency bands;
- Smaller user terminal size, due to higher satellite e.i.r.p. and G/T;
- Higher system capacity;
- Greater amount of spectrum available for FSS systems.

Users and businesses requiring communication services on mobile platforms, such as on aircraft, ships, trains and other vehicles, often have no other broadband access alternatives besides satellites.

A number of Ka-band systems described in ECC Report 152 [6] have been brought into use, or about to be deployed, in Europe and elsewhere in the world.

# 3 REGULATORY FRAMEWORKS ESTABLISHED FOR RELATED FSS SYSTEMS AND THEIR RELEVANCE FOR NGSO ESOMPS

Several regulatory frameworks have been established by the ITU-R and CEPT for the deployment of Earth Stations on board Vessels (ESVs) in C- and Ku-bands, and for aircraft Earth stations (AESs), for maritime and aeronautical applications, respectively. These AESs and ESVs are the forerunners to Ka-band ESOMPs The regulatory frameworks adopted for AESs and ESVs are presented in this section for information.

In addition the regulatory frameworks established for the FS in the Ka-band have a significant relevance to the development of regulations on Ka-band ESOMPs. This is because FSS and FS usually carry co-primary allocations, and in subject to CEPT regulations on band plans or band segmentation. These regulations relating FS are also discussed in this section.

## 3.1 ITU-R

### 3.1.1 WRC-03 Decisions on a secondary allocation for AMSS in the 14.0-14.5 GHz band

Extensive work was carried out by ITU-R study groups prior to WRC-03 under Resolution 216 [7] (Rev.WRC-2000 and abrogated in 2003), which *invited the ITU-R*:

> “to complete, in time for WRC-03, the technical and operational studies on the feasibility of sharing of the band 14.0-14.5 GHz between the services referred to in considering c) [above] and the aeronautical mobile-satellite service, with the latter service on a secondary basis.”

Working Party 4A carried out technical studies which identified several essential requirements that an AMSS system should meet in order to protect FSS. In the case where an AMSS system was implemented within FSS assignments, the ITU-R concluded that the interference levels reaching GSO satellites must at all times be no more than the levels agreed to in coordination. These agreed levels are based on stable antenna platforms with well-defined antenna patterns and aggregate levels that are not to be exceeded. To achieve this goal, the ITU-R identified several requirements that should be placed on AMSS systems to protect FSS:

- Aggregation of off-axis power from multiple aircraft where applicable, for example in systems using spread spectrum multiple access;
- Antenna gain pattern;
- Antenna capture by adjacent satellites;
- Input power to the antenna;
- Antenna mis-pointing.

These factors formed the basis of a Recommendation on use of this band by AMSS and these were adopted as part of Recommendation ITU-R M.1643 [8].

The CPM Report to WRC-03 concluded that sharing with the FSS was possible in the 14.0-14.5 GHz frequency band, “provided aggregate co-frequency AES emissions in the direction of adjacent satellites are limited to levels that are equal to or less than the levels that have been accepted by other satellite networks.”[2]

Because several administrations have implemented Fixed Service (FS) networks in the 14.0-14.5 GHz band, studies were also carried out within former WP-8D to examine the feasibility of sharing between AMSS and the FS. Recommendation ITU-R M.1643 [8] adopted a PFD mask to protect FS networks in the 14.0-14.5 GHz band.  In practice, sharing between AMSS and FS networks operating in the 14.0-14.5 GHz band has proven to be more difficult when the services are operating in the same geographic area.

[2] CPM Report to the 2003 World Radiocommunication Conference (WRC-03) at 2.4.2.

### 3.1.2 WRC-03 Decisions on ESVs operating at C-Band and Ku-Band

In the case of Earth Stations on board Vessels, the former WP-4-9S was the leading working party for studies. Unlike AMSS, ESVs were treated from the start as operating in the FSS.

The CPM report to WRC-03 concluded that ESVs could protect other FSS networks so long as they complied with the off-axis e.i.r.p. limits given in Recommendation ITU-R S.524 [9] WRC-03 added a new footnote in Article 5 to clarify that ESVs shall be considered as operating in the FSS:

> "**5.457A** In the bands 5 925-6 425 MHz and 14.0-14.5 GHz, earth stations located on board vessels may communicate with space stations of the fixed-satellite service. Such use shall be in accordance with Resolution 902 [10] (WRC-03)"

WRC-03 adopted Resolution 902 (WRC-03), which included technical and operational constraints to avoid interference from ESVs into terrestrial networks.

Resolution 902 is likely to be revised at WRC-15 under AI 1.8 and Resolution 909 (WRC-12) [11]. There is no linkage of the Resolution 902 to the Ka-Band and hence, no impact is expected on the ESOMPs harmonisation measure within the CEPT.

### 3.1.3 WRC-03 Decisions on HDFSS

WRC-03 adopted Resolution 143 (Rev.WRC-07) [12] "Guidelines for the implementation of high-density applications in the Fixed-Satellite Service in frequency bands identified for these applications". As described by Resolution 143 (Rev.WRC-07), "HDFSS are characterised by flexible, rapid and ubiquitous deployment of large numbers of cost-optimised earth stations employing small antennas and having common technical characteristics."

Resolution 143 (Rev.WRC-07) recognises "that co-frequency sharing between transmitting HDFSS earth stations and terrestrial services is difficult in the same geographical area" and that administrations implementing HDFSS should take into account "that HDFSS deployment will be simplified in bands that are not shared with terrestrial services."

WRC-03 adopted a footnote which identified bands for use by HDFSS:

> **"5.516B** the following bands are identified for use by high-density applications in the fixed-satellite service:
>
> 17.3-17.7 GHz (space-to-Earth) in Region 1,
>
> 18.3-19.3 GHz (space-to-Earth) in Region 2, 19.7-20.2 GHz (space-to-Earth) in all Regions,
>
> 39.5-40 GHz (space-to-Earth) in Region 1,
>
> 40-40.5 GHz (space-to-Earth) in all Regions,
>
> 40.5-42 GHz (space-to-Earth) in Region 2,
>
> 47.5-47.9 GHz (space-to-Earth) in Region 1,
>
> 48.2-48.54 GHz (space-to-Earth) in Region 1,
>
> 49.44-50.2 GHz (space-to-Earth) in Region 1,
>
> and
>
> 27.5-27.82 GHz (Earth-to-space) in Region 1,
>
> 28.35-28.45 GHz (Earth-to-space) in Region 2,
>
> 28.45-28.94 GHz (Earth-to-space) in all Regions,
>
> 28.94-29.1 GHz (Earth-to-space) in Region 2 and 3,
>
> 29.25-29.46 GHz (Earth-to-space) in Region 2,
>
> 29.46-30.0 GHz (Earth-to-space) in all Regions,
>
> 48.2-50.2 GHz (Earth-to-space) in Region 2.

This identification does not preclude the use of these bands by other FSS applications or by other services to which these bands are allocated on a co-primary basis and does not establish priority in the Radio Regulations among users of the bands. Administrations should take this into account when considering regulatory provisions in relation to these bands. See Resolution 143 (Rev.WRC-07)" [12]

#### 3.1.4 Study Group 4 Work on NGSO Ka-band ESOMPs

The ITU-R WP4A produced Report ITU-R S.2261 [4] containing technical and operational requirements for earth stations on mobile platforms operating in NGSO FSS systems in the frequency bands from 17.3 to 19.3, 19.7 to 20.2, 27 to 29.1 and from 29.5 to 30.0 GHz, describing how such earth stations operating in these frequency bands must be designed and operated to meet the existing technical and/or operational requirements applicable to FSS earth stations. Further work has been initiated at WP 4A to address protection of terrestrial services from such operations.

### 3.2 CEPT

#### 3.2.1 CEPT Regulatory Framework for HDFSS

As a result of the WRC-03 identification of bands for HDFSS, the ECC adopted ECC/DEC/(05)08 [13] which makes available for HDFSS deployment, subject to market demand, the following bands:

- 17.3-17.7 GHz and 19.7-20.2 GHz (space-to-Earth);
- 29.5-30.0 GHz (Earth-to-space).

ECC/DEC(06)02 [14] and ECC/DEC(06)03 [15] were also developed, providing exemption from individual licensing of Low e.i.r.p. Satellite Terminals (LESTs) and High e.i.r.p. Satellite Terminals (HESTs). The exemption requires the terminals to have an e.i.r.p. not exceeding 34 dBW for LESTs and 50-60 dBW for HESTs.

The LEST and HEST Decisions do not contain specific off-axis e.i.r.p. limits. Instead, they require compliance with ETSI EN 301 459 [16] or ETSI EN 301 428 [17] or equivalent technical specifications. These Harmonised European Standards contain requirements and test methods for ensuring compliance with the off-axis e.i.r.p. limits contained in Recommendation ITU-R S.524 [9].

Also following the WRC-03 identification of bands for HDFSS, through ECC/DEC/(05)01 [18] (which replaced ERC/DEC/(00)09 [19]) the CEPT administrations in conjunction with industry decided to "segment" the frequency band 27.5-29.5 GHz between the FS and the FSS (uncoordinated FSS earth stations). The frequency bands 27.5-27.8285 GHz, 28.4445-28.8365 GHz and 29.4525-29.5 GHz were designated for the use of uncoordinated FSS earth stations (including transportable terminals). This represents 768 MHz available for uncoordinated FSS earth stations: one block of 328.5 MHz, one block of 392 MHz and one block of 47.5 MHz.

Also, through Decision ECC/DEC/(05)01 [18] the frequency band 28.8365-28.9485 GHz was designated for the use of uncoordinated FSS earth stations, without prejudice to the FS systems licensed in this band in some countries before the date of adoption of this Decision. This represents an additional 112 MHz within which no new FS stations can be deployed except in countries which make use of Decides 2) and 4) of this Decision.

It should be noted that as of September 2014, Decision ECC/DEC/(05)01 has been declared as having been implemented by 30 CEPT administrations (including 4 administrations that had partly implemented the Decision). Additionally, 2 additional administrations are committed to implementation, with 3 "Not Implemented", 2 "Implementation Under Study", and 10 "No Information".

It should be noted that the NGSO ESOMPs in the Ka-band do not fall within the definitions of HDFSS nor within the definitions of LEST and HEST. Therefore, the e.i.r.p. and off-axis e.i.r.p. limitations stipulated in above mentioned ECC Decisions or the ETSI standards mentioned above do not apply.

### 3.2.2 CEPT Regulatory Framework for AESs and ESVs

Under established international law, national sovereignty over radio spectrum resources extends above the national territory up to the limits of the atmosphere. Any aeronautical earth station operating over the territory of a country must therefore be duly authorised by that country. Under maritime law, national sovereignty extends out to 12 nautical miles from the low-water mark of the coast. Consequently, any earth station on vessels operating in the territorial waters of a country must be duly authorised by that country.

Three ECC Decisions were adopted following WRC-03 to allow for the free circulation of Aircraft Earth Stations (AESs) and ESVs. The Decisions are ECC/DEC/(05)09 [20] and ECC/DEC/(05)10 [21] for ESVs operating in the C- and Ku-bands respectively. Also ECC/DEC/(05)11 [22] was adopted for Aircraft Earth Stations (AESs) operating in the Ku-band.

These ECC Decisions included technical, operational and regulatory requirements which ensured that the ESVs and AESs had the same interference characteristics as a typical uncoordinated FSS earth station. Since the adoption of these ECC Decisions, hundreds of ESVs and AESs have operated successfully in European waters and airspace. Similar conditions could be adopted and applied to the ESOMPs in parts of the Ka-band identified for uncoordinated FSS operations.

### 3.2.3 Applicability of Previous Frameworks to NGSO ESOMPs in the Ka-band

The previous frameworks adopted for ESVs in the C- and Ku-bands served the purpose well, and demonstrated that ESV terminals could be deployed without causing interference to other services. These frameworks set the background for the adaption of suitable technical and regulatory measures for the deployment of maritime ESOMPS operating to NGSO systems in the Ka-band.

NGSO ESOMPs operating in the Ka-band present a sharing environment similar to that found in the 14.0-14.5 GHz band for ESV and VSAT networks, but with an added element of time variability due to the movement of the satellite across the sky and the ESOMPs terminal tracking it.

ESOMPs in parts of the Ka-band shared between FSS and FS are similar to ESV and VSAT networks, in that sharing between such earth stations and co-frequency FS networks which are located in the same geographic area is difficult for all types of earth stations because they could be located anywhere within the operational area of such an FS network. Such deployment of ESOMPs should be managed carefully to ensure the protection of FS.

Technical, operational and regulatory requirements have been adopted within the ITU-R to ensure that the ESVs operating between 14.0 GHz and 14.5 GHz have the same interference characteristics as typical FSS earth stations. Regulators have ensured that Ku-band ESVs operate only in bands which have no use or limited use by terrestrial services. Since the adoption of these regulations, hundreds of ESVs have operated successfully worldwide on ships.

Taking into account the success of the previous ECC Decisions, a similar regulatory framework could be adopted in the Ka-band for ESOMPs. The suggested Ka-band frequencies within which ESOMPs may operate within national territory are those identified for uncoordinated FSS earth stations, in particular those identified in ECC/DEC/(05)01 [18] and ECC/DEC(05)08 [13], thereby limiting potential interference to terrestrial services only to some instances of cross-border interference. Technical requirements have been developed to ensure that ESOMPs operating in the Ka-band frequencies identified for uncoordinated FSS operations have the equivalent interference characteristics of typical uncoordinated FSS earth stations and do not cause unacceptable interference to any terrestrial services operating in the same bands.

Any regulatory framework adopted in these bands to accommodate ESOMPs should also ensure that it does not prejudice the use of these bands by other FSS and terrestrial applications operating in conformance with other ECC Decisions. It should be noted that specifically the band 28.6-29.1 GHz, according to RR 5.523A, is subject to the application of the provisions of RR 9.11A, and this means all satellite networks are subject to coordination, including the current and future non GSO or GSO FSS networks.

# 4 CONSIDERATIONS ON THE OPERATION OF ESOMPS IN FSS NGSO SATELLITE SYSTEMS

Several options were considered in deciding on the most appropriate regulatory provisions for ESOMPs. One option was to treat ESOMPs as an application in the Mobile-Satellite Service (MSS), which would need a new MSS allocation in the FSS band(s). Another was to change the definition of FSS to include service to mobile platforms. A third option, which has been finally endorsed, was to treat ESOMPs as an application in the FSS.

ESOMPs represent one of many examples of service convergence that CEPT administrations are experiencing. In the past, any earth station that moved while transmitting was considered to be part of the MSS. Historically, there were significant technical differences between the MSS and FSS, for example MSS antennas were often non-directional, making co-frequency sharing with other MSS systems difficult. Also, MSS systems operated in exclusively allocated bands that were much lower in frequency than those used by FSS systems. Changes in technology have allowed ESOMPs to operate in bands allocated to the FSS.

The issue of convergence is a serious matter for CEPT administrations to consider since it is applicable both in satellite and terrestrial services. The approach adopted by the ECC for ESOMPs should be neutral to both existing and new users. The ECC should also strive to the extent possible to adopt a consistent approach both for satellite and terrestrial services.

Regarding the radio service classification of ESOMPs, several considerations should be taken into account:

- ESOMPs are assumed to be designed and operated in compliance with the existing rules for FSS. No rules exist for MSS in bands above 17 GHz, making implementation as MSS problematic;
- Requiring compliance with existing FSS rules provides FSS operators with certainty that existing systems will be protected;
- While MSS allocations exist in the bands above 17 GHz, the majority of these are secondary allocations or reserved for non-civilian applications. In Region 1, 2 x 100 MHz of co-primary spectrum for MSS is available at 29.9-30.0 GHz / 20.1-20.2 GHz. These allocations are not considered adequate by ESOMPs system operators for five reasons:

    1. the existing MSS allocations above 17 GHz are in bands that are subject to Article 22 EPFD limits which further constraints the usability for ESOMPs
    2. If ESOMPs networks were required to operate only in the 2x100 MHz allocated to the MSS on a co-primary basis with the FSS, the result would in any case be that they should coordinate with existing and future FSS networks, leading to the same technical constraints as if they were treated as FSS. Hence, there is no benefit to other services or systems by operating ESOMPs in a smaller frequency band;
    3. The key-feature of the systems that have been launched or planned to be launched soon is that they will be capable of offering to European citizens travelling on mobile platforms connectivity and network performance similar to those they can experience with terrestrial wired and wireless solutions, where data rates of up to 100 Mbit/s are planned. If only 2 x 100 MHz were available, allowing for the need to assign different frequencies in adjacent beams, only a few 10s of MHz could be made available in each beam, shared among multiple users within it. To allow data rates comparable to terrestrial systems in a satellite system, with sufficient users to support the business case for building and launching a satellite network, at least 2 x 500 MHz of available spectrum would be required;
    4. The capital and operating costs of an ESOMPs network operating in 2 x 100 MHz would be similar to those for an ESOMPs network operating in, for example, 2 x 500 MHz. However the capacity of the system (in terms of number of users of comparable data requirements) is increased five-fold. Hence, the cost of the service to end users is significantly lowered if the system can operate in a larger frequency band, benefiting both the operator and the end users.
    5. All systems currently planning to provide ESOMPs services in Europe would be technically capable of operating at least in 2 x 500 MHz FSS spectrum;

- Treating ESOMPs as FSS provides ESOMPs operators and regulators with a well-established and proven set of rules for authorising these earth stations;
- NGSO ESOMPs must comply with the same EPFD limits as typical uncoordinated FSS earth stations operating to NGSO systems;
- In many planned networks, ESOMPs will operate on the same networks and frequencies as stationary earth stations. If ESOMPs are classified as MSS and stationary earth stations are classified as FSS, there may be situations where terminals using the same network and frequencies must comply with different rules simply because one type is in motion and the other is not.

So long as ESOMPs on an aggregate basis per NGSO system are designed and operated in compliance with the same requirements (such as EPFD limits) as those placed on uncoordinated NGSO earth stations, no sharing issues exist between the ESOMPs and other FSS networks.

Taking all of the above into account, it is concluded that all ESOMPs are to be treated as typical uncoordinated FSS earth stations and therefore they shall operate in bands available to uncoordinated FSS earth stations.

# 5 TECHNICAL REQUIREMENTS FOR ESOMPS

## 5.1 SHARING WITH TERRESTRIAL SERVICES

As a general consideration, it should be noted that the work done within both the ITU-R and CEPT has shown that co-frequency sharing between uncoordinated FSS earth stations (primarily considering GSO networks) and terrestrial networks in the same geographic area is difficult to accomplish. The same conclusion holds true for ESOMPs working to NGSO systems. Since implementation of land use of ESOMPs is only contemplated in bands where uncoordinated FSS earth stations are allowed, ESOMPs should not represent any increased interference risk to FS or Mobile Service (MS) networks beyond that presented by uncoordinated FSS earth stations. If administrations conclude that implementation of uncoordinated FSS earth stations is permissible in a band, introduction of NGSO ESOMPs in the same band should not raise any additional interference concern to FS or MS networks.

Like uncoordinated FSS earth stations, ESOMPs receiving in the frequency range 17.7-19.7 GHz shall not claim protection from stations of the FS; see ERC/DEC/(00)07 [23].

There is the possibility that neighbouring countries could implement different allocations, in the 27.5 -29.1 GHz and 17.7-19.7 GHz bands, either to uncoordinated FSS or to FS applications. Furthermore ESOMPs operating in international waters could also operate in any of the above frequencies, subject to not causing interference to terrestrial systems.

Therefore, the aim of this section is to address any sharing issue that could arise with terrestrial systems in the band 27.5-29.1 GHz. Noting that no applications of the MS[3] have been identified in the frequency ranges 17.7-19.7 GHz and 27.5-29.1 GHz, only FS characteristics are used for the terrestrial applications. Sharing studies in this range of frequencies have considered both point-to-point and point-to-multipoint FS systems with the FS characteristics shown in Table 1.

[3] There is no common European allocation (ERC Report 25) to the MS in these bands, which is present in the national allocation table of some CEPT administrations.

**Table 1: FS characteristics for the band 27.5-29.5 GHz**

| Parameter | FS1 (PP) | FS2 (PP) | FS3 (PP) | FS4 (P-MP) | FS5 (PP based on Rec. ITU-R 758-5) | FS6 (P-MP based on Rec. ITU-R 758-5) | Notes |
|---|---|---|---|---|---|---|---|
| RX antenna height (m) | 20 | 20 | 20 | 20 | Not specified, 20 m is suggested | Not specified, 20 m is suggested | |
| RX antenna pattern | Rec. ITU-R F.1245 | Rec. ITU-R F.1245 | Rec. ITU-R F.1245 | Rec. ITU-R F.1336 [25] | Rec. ITU-R F.1245 [24] | Rec. ITU-R F.1336 [25] | Rec. ITU-R F.758-5 [26] |
| Receiver noise figure, NF (dB) | 6 | 6 | 6 | 6 | 8 | 8 | See note (1) |
| RX frequency (GHz) | 28 GHz | 28 GHz | 28 GHz | 28 GHz | 24.25-29.50 GHz | 24.25-29.50 GHz | |
| RX elevation angle (degrees) | 0 | 5 | 10 | 0 | Not specified, 10° is suggested | Not specified, 0° is suggested | |
| RX peak gain (dBi) | 45 | 43 | 35 | 18 | 31.5 | 6.5 | See note (2) |

(1) The System noise power density (N0 in dB(W/Hz)) shall be obtained from the following equation: N0 = NF + 10*log10(kT0) where : T0 = 290 K, NF is the noise figure (dB) and k is the Boltzmann constant it results: N0 = NF– 204 (dB(W/Hz))
(2) The difference between the peak gain values of stations FS1 and FS2 comes from the fact that a typical PP FS station with high elevation angle (10°) is usually employed for short-range links near hilly areas.

### 5.1.1 ESOMPS installed on land platforms

ESOMPs installed on land platforms do not differ substantially from typical uncoordinated stationary FSS stations. The Recommendation ITU-R SF.1707 [27] provides methods and means to facilitate the implementation of large numbers of earth stations operating in the GSO FSS in areas where terrestrial services are also deployed. This Recommendation could therefore be considered a basis for coordination procedures between NGSO ESOMPs and neighbouring administrations implementing different allocations in this band.

Section 7 of this document provides an overview of a possible approach for resolving cross-border coordination requirements.

### 5.1.2 ESOMPS installed on maritime platforms

ESOMPs on-board vessels or other mobile maritime platforms have the potential to cause interference to any FS or MS applications deployed in parts of the band 27.5-29.1 GHz. FS or MS systems operating near the coast could receive interference from a maritime ESOMPs, which could be operating in the territorial waters of another administration, or at international sea (i.e. beyond 12 nautical miles from the low-water mark of the concerned administration).

A PFD threshold at the coast of any country, combined with a suitable mandatory automatic mechanism to regulate the ESOMPs power, dependent on its position, has been studied that would provide adequate protection to FS or MS systems deployed. The PFD threshold could be exceeded only if the concerned administration agreed. The ESOMPs would be able to take into account its actual antenna gain pattern, its pointing and transmitter power to comply with the PFD threshold.

It is recommended to use a PFD threshold at the coastline, taking the same method and corresponding assumptions as in Recommendation ITU-R SF.1650 [28] dealing with ESV in the bands 5 925-6 425 MHz and 14.0-14.5 GHz.

In the case of ESOMPs operating in the band 27.5-29.1 GHz, this PFD threshold (see ANNEX 2:) is -109 dB(W/m²) expressed in a reference bandwidth of 14 MHz at a height of 20 m above sea level. In addition, the percentage of time that should be used in the propagation model, when assessing compliance with this PFD threshold, is 0.007%.

This PFD threshold would apply to the frequencies of the band 27.5-29.1 GHz designated to the FS in the CEPT.

### 5.1.3 Protection of aircrafts near airfields

The ECC Report 066 [33] notes that high power satellite earth stations with e.i.r.p in excess of 50 dBW are to be used for satellite systems utilising the GSO, and such earth stations may be deployed within or close to the airport perimeter. To facilitate such deployments of earth stations, the ECC Report 066 [33] provides methodology for the calculation of a coordination area around the airfield that would provide for the protection of aircraft when such aircraft follows a conventional 3° glide slope in alignment with the runway. The Report then concludes that there is no necessity to impose an absolute e.i.r.p. or power limit on earth stations, provided that the necessary coordination area is made a function of the e.i.r.p. of the earth station. It adds that such coordination area should not been considered as an area where any earth station deployment is forbidden, but as an area within which coordination should be effected with the relevant aeronautical authority.

The protection criterion specified in the ECC Report 066 [33] is an electric field strength of 20V/m. The electric filed created by an ESOMPs near an airfield should not exceed this figure. The Report then elaborates the methodology for calculating the coordination area for a satellite terminal with a given e.i.r.p at a fixed location operating to a satellite in the GSO,

The Report illustrates the situation when an aircraft crosses the main beam of a satellite earth station as shown in the Figure 1 below.

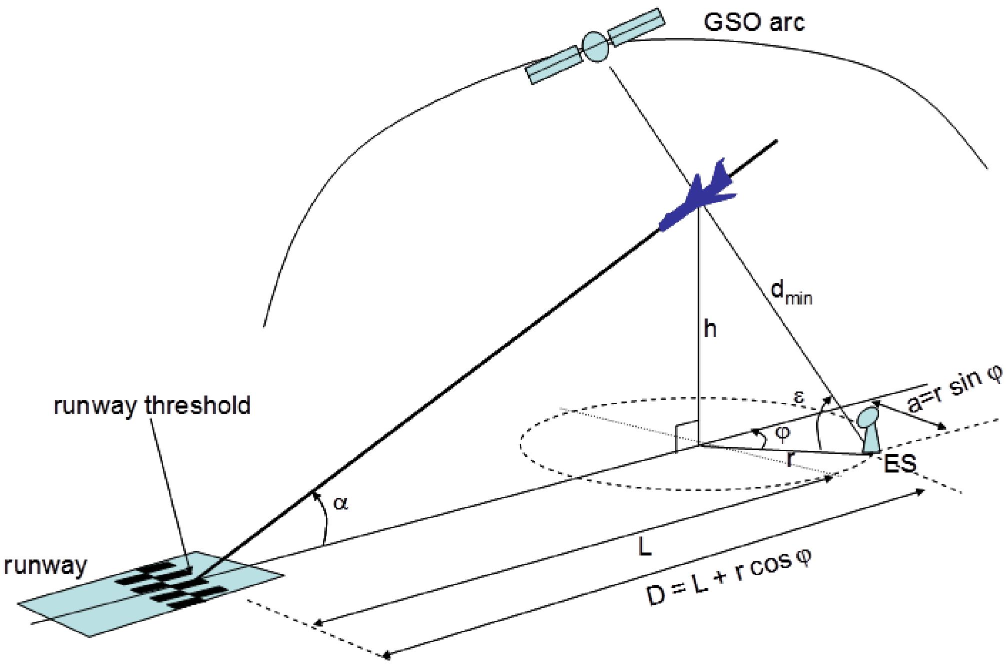


**Figure 1: Scenario when aircraft crosses the main beam of an earth station**

The distance $d_{min}$ is the distance from the earth station (ESOMPs) to the aircraft, and the factors $d_{min}$ and e.i.r.p. determine the field strength at the aircraft. In other words, it could be said that the coordination area (shown as D in the Figure 1) for the protection of aircraft is a function of $d_{min}$ and the e.i.r.p. of the ESOMPs.

This methodology given in ECC Report 066 [33] has been used to derive the coordination area for the protection of aircraft from GSO ESOMPs, and these results can be found in Annex 3 of the ECC/DEC/(13)01[5].

Although this methodology was originally devised primarily for GSO applications, it can be seen that the same methodology could also be used to determine the coordination area for ESOMPs operating to NGSO systems. Such determination of the coordination area will be based on the specific characteristics of the orbital parameters and the e.i.r.p of the ESOMPs deployed, and therefore it will not be possible to compute a generic coordination area for ESOMPs operating to any NGSO system.

Annex 1 of this report details the coordination areas calculated using the methodology given in the ECC Report 066 [33] for a specific NGSO system, where satellites operate in the Equatorial plane at an altitude of 8 062 km. Annex 1 also offers the coordination areas for what could be considered to be the worst case for NGSO satellite system. The worst case is when an ESOMPs is transmitting to a NGSO satellite located the zenith of the ESOMPs. In this scenario if an aircraft crosses the signal path it will be subject to the maximum field strength arising from the ESOMPs. This worst case information is offered as general guidance for administrations.

This Annex 1 may be updated from time to time to record coordination areas calculated for other NGSO satellite systems.

## 5.2 ETSI standards

Under the R&TTE Directive [29], all radio equipment placed on the market in the EU must meet the essential requirements defined in the Directive. In most cases, the requirements are met by compliance with the relevant ETSI Harmonised European Standard.

Consequently, a new Harmonised European Standard for ESOMPs operating to NGSO systems in the bands within 27.5-29.1 GHz and 29.5-30.0 GHz will be required. Preparation of a harmonised European standard (ETSI EN 303 979 [34]) for Ka-band NGSO ESOMPs is currently underway within ETSI Technical Committee SES (Satellite Earth Stations).

The R&TTE Directive will be replaced with the Radio Equipment Directive that comes into force in June 2016. This new Directive requires certain receiver parameters to be included for conformance testing. It is expected that the ETSI standard for the Ka-band NGSO ESOMPs will be updated in due course to comply with the requirements placed by the new Directive.

## 5.3 OTHER TECHNICAL REQUIREMENTS FOR Ka-BAND ESOMPs

The protection of GSO FSS networks operating in 27.5-28.6 GHz and 29.5-30.0 GHz from ESOMPs operating to NGSO networks is achieved by complying with the EPFD. Limits stipulated in No. 22.5D of the Radio Regulations [30]. The provision of the Radio Regulations is reproduced below:

> **22.5D** 3) The equivalent power flux-density (epfd) produced at any point in the geostationary-satellite orbit by emissions from all the earth stations in a non-geostationary satellite system in the fixed-satellite service in the frequency bands listed in Table 22-2, for all conditions and for all methods of modulation, shall not exceed the limits given in Table 22-2 for the specified percentages of time. These limits relate to the equivalent power flux-density which would be obtained under free-space propagation conditions, into a reference antenna and in the reference bandwidth specified in Table 22-2, for all pointing directions towards the Earth's surface visible from any given location in the geostationary-satellite orbit.

Hence, from the perspective of potential uplink interference to other satellite networks, these requirements will ensure that ESOMPs are essentially equivalent to stationary FSS earth stations.

It should be noted that in the band 28.6-29.1 GHz RR 5.523A states

> “The use of the bands 18.8-19.3 GHz (space-to-Earth) and 28.6-29.1 GHz (Earth-to-space) by geostationary and non-geostationary fixed-satellite service networks is subject to the application of the provisions of No. 9.11A and No. 22.2 does not apply.”

Therefore no additional conditions are placed on the use of this band in the sharing between GSO & NGSO FSS systems.

The level of protection provided to ESOMPs from other satellite networks will be determined through coordination among the concerned administrations/satellite operators, following the same rules and processes as those applicable to all FSS networks. ESOMPs terminals will be protected to the same extent as FSS earth stations included in the inter-system coordination. As there are no limitations on antenna sizes or antenna patterns in these bands for FSS today, there is also no need to define any such additional requirements for ESOMPs.

When considering the level of protection provided to other satellite networks from ESOMPs, technical requirements should be adequately defined in order to prevent mis-pointed or poorly controlled Ka-band terminals (whether fixed or mobile) from causing unacceptable interference to other Ka-band FSS satellites and so prejudice the provision of Ka-band FSS services to European consumers. Furthermore, the use of low-gain antennas and their potential impact on other satellite networks should not be an issue, since any ESOMPs, in order to be able to operate, shall be compliant with the relevant provisions of the Radio Regulations, which stipulate EPFD limits, and with the other instruments such as relevant ITU-R Recommendations or frequency coordination agreements.

Realising that ESOMPs operate in a dynamic environment, it is important to address this aspect in specifying an essential set of technical and operational requirements. The design, coordination and operation of ESOMPs should be such that, the interference levels generated by such earth stations account for the following factors:

- **Mis-tracking of the NGSO satellite by the earth station antenna.** Where applicable, this includes, at least, motion-induced antenna pointing errors, effects caused by bias and latency of their pointing systems, tracking error of open or closed loop tracking systems, misalignment between transmit and receive apertures for systems that use separate apertures, and misalignment between transmit and receive feeds for systems that use combined apertures
- **Variations in the antenna pattern of the earth station antenna.** Where applicable, this includes, at least, effects caused by manufacturing tolerances, ageing of the antenna and environmental effects. Networks using certain types of antennas, such as phased arrays, should account for variation in antenna pattern with scan angles (elevation and azimuth). Networks using phased arrays should also account for element phase error, amplitude error and failure rate;
- **Variations in the transmit e.i.r.p. from the earth station.** Where applicable, this includes, at least, effects caused by measurement error, control error and latency for closed loop power control systems, and motion-induced antenna pointing errors.

Earth stations on mobile platforms that use closed loop tracking of the satellite signal need to employ an algorithm that is resistant to capturing and tracking other satellite signals. Such earth stations must be designed and operated such that they immediately inhibit transmission when they detect that unintended satellite tracking has occurred or is about to occur. Such earth stations must also immediately inhibit transmission when their mis-pointing would result in EPFD levels above those stipulated in No. 22.5D of the Radio Regulations or with any other limits coordinated with other satellite networks.

In addition to these autonomous capabilities, earth stations on mobile platforms will need to be subject to the monitoring and control by a Network Control Facility (NCF) or equivalent facility and these earth stations should be able to receive at least “enable transmission” and “disable transmission” commands from the NCF. It will need to be possible for the NCF to monitor the operation of the earth station to determine if it is malfunctioning.

ESOMPs that comply with these requirements will not create unacceptable levels of interference to other FSS systems and terminals operating in the same bands or sub-bands. It is assumed that any ESOMPs operating in the territory of a CEPT administration will have to comply with any relevant CEPT requirements, e.g. a new ECC Decision. Any use of non-compliant equipment would be unlawful and subject to national enforcement provisions and sanctions.

# 6 REGULATORY FRAMEWORK NEEDED TO TREAT AND OPERATE ESOMPS AS FSS IN THE BANDS 27.5-29.1 GHz, 29.5-30.0 GHz AND 17.3-20.2 GHz

Under the recommended approach of this report, a new ECC Decision would be developed to authorise the use of ESOMPs in the Ka-band frequencies operating to NGSO systems, without any change to the Radio Regulations. The Decision would provide a framework for such ESOMPs to operate in FSS NGSO systems and would establish technical and regulatory requirements.

While, for ESOMPs terminals installed on land, authorisation is managed by the single administrations, in the case of ESOMPs on maritime platforms, a process based on mutual recognition of licences and free circulation may be considered.

Figure 2 outlines the process through which a new ECC Decision (and ETSI Harmonised European Standard) could be used for authorising ESOMPs to operate in those parts of the Ka-band allocated to uncoordinated FSS earth Stations.

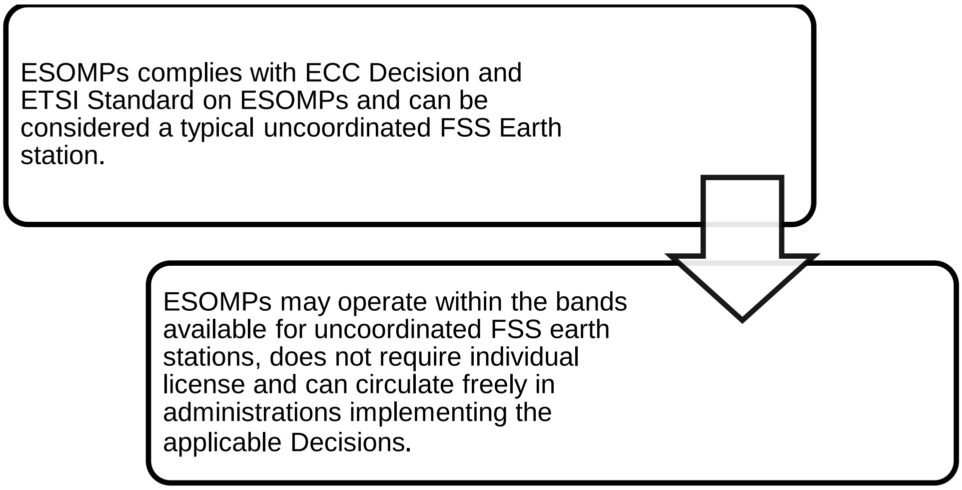


**Figure 2: Proposed treatment of ESOMPs in CEPT**

The aforementioned ECC Decisions on AESs and ESVs (ECC/DEC/(05)09, ECC/DEC/(05)10 and ECC/DEC/(05)11 as well as the WRC Resolution 902 [10] and ITU-R Recommendations on which they are based, provide a basis for developing the requirements for inclusion in such a new Decision. The following table summarises the requirements from these Decisions, Resolutions and Recommendations that may be used for developing criteria for determining whether a mobile platform communicating with an FSS network may be treated as a typical uncoordinated FSS earth station.

**Table 2: Requirements for C-band and Ku-band ESOMPs to be considered for inclusion in new Regulations on Ka-band ESOMPs**

| Requirement | Source |
|---|---|
| The network must operate under the control of a network control facility (NCF). | Recommendation ITU-R M.1643 [8] |
| The network should be coordinated and operated in such a manner that the aggregate off-axis e.i.r.p. levels produced by all co-frequency earth stations within the network are no greater than the interference levels that have been published and coordinated for the specific and/or typical earth station(s) pertaining to the FSS networks where FSS transponders are used.<br>(Note that the comparable position for K band NGSO ESOMPS is the compliance with No. 22.5D of the Radio Regulations.) | Recommendation ITU-R M.1643 [8]<br>Recommendation ITU-R S.524 [9] |
| The design, coordination and operation of the earth stations should take into account:<br>▪ Antenna mis-pointing;<br>▪ Variations in antenna pattern of the earth station;<br>▪ Variations in the transmit e.i.r.p. from the earth station. | Recommendation ITU-R M.1643 [8] |
| Earth stations that use close loop tracking of the satellite signal need to employ an algorithm that is resistant to capturing and tracking adjacent satellite signals. Earth stations must immediately inhibit transmissions when they detect that unintended satellite tracking has happened or is about to happen. | Recommendation ITU-R M.1643 [8] |
| The earth station should be self-monitoring and, should a fault which can cause harmful interference to FSS networks or terrestrial services be detected, the earth station must immediately cease emissions. | Recommendation ITU-R M.1643 [8]<br>Resolution 902 [10] |

Some of these requirements are contained in the ETSI Harmonised European Standard being developed for NGSO Ka-band ESOMPs. Other requirements may need to be included in an ECC Decision.

Establishment of harmonised conditions for the protection of satellite and terrestrial services would allow maritime and aeronautical ESOMPs to comply with such harmonised conditions and benefit from free circulation and licence exemption within the CEPT.

## 7 CROSS-BORDER COORDINATION

The Ka-band frequencies identified for uncoordinated FSS earth stations have been harmonised throughout CEPT by ECC Decisions ECC/DEC/(05)01 and ECC/DEC/(05)08. Hence, in the general case, the bands available for ESOMPs operating within national territory will be common throughout Europe, and there would be no cross-border interference issues. However in some cases, for example on the borders of CEPT or in the case of ESOMPs operating in the band 28.8365-28.9485 GHz[4], a band identified for uncoordinated FSS earth stations by one administration could be used for terrestrial services by a neighbouring administration.

The issue of potential cross-border interference caused by the use of uncoordinated FSS earth stations in one country into FS stations in a neighbouring country has been addressed by Recommendation ITU-R SF.1707 which, among other things, provides an example, based on worst case assumptions, of how to develop a single transmit and a single receive coordination distance for consideration as a means to ease bilateral agreements for a given geographical area. Also, Recommendation ITU-R SF.1719 [31] has examined interference using more typical assumptions and indicates that far smaller separation distances are applicable in most practical cases.

In those cases when ESOMPs mounted on vessels are operated in international waters, the frequency band used by these ESOMPs might be used by FS systems in the surrounding countries. The values proposed in sections 5.1.2 would ensure protection of the potentially affected FS systems and are to be used as threshold values for triggering coordination among the concerned administrations and those satellite operators (or related administrations) which might wish to operate above the specified levels.

In the coordination process, the likelihood of interference caused by ESOMPs into FS stations should be assessed by considering the real deployment of FS links. The following provides an example of mitigation factors that may alleviate the level of potential interference:

1. FS stations in one country deployed near the coast not pointing toward the open sea;
2. Countries that have not deployed fixed links in the band 27.5-29.1 GHz;
3. Real FS links which have less sensitive characteristics to interference than those assumed in the sharing studies.

Presence of clutter/terrain blockage and rain/cloud attenuation, which may introduce additional attenuation for the interference path, should be taken into account in cross-border coordination.

In addition the protection of aircrafts near airfields as described in section 5.1.3 should also be taken into consideration when affecting cross-border coordination.

[4]Through ECC/DEC/(05)01 [18], the band 28.8365-28.9485 GHz is designated for uncoordinated FSS earth stations, but is used by legacy FS systems in some countries.

# 8 CONCLUSIONS

ESOMPs operating to Ka-band NGSO systems are operated in Europe. This report has examined possible technical and regulatory requirements to facilitate the authorisation of ESOMPs by CEPT administrations. It is proposed that an ECC Decision for ESOMPs, operating to Ka-band NGSO systems should contain the following elements:

- The ESOMPs are an application within the FSS;
- The frequency bands to be used by ESOMPs operating in national territory are limited to the Ka-band frequencies designated by the responsible administration for uncoordinated FSS earth stations;
- ESOMPs operating in international waters (which may transmit within the range 27.5-29.1 GHz and 29.5-30.0 GHz), shall ensure protection of fixed service systems deployed by administrations within the CEPT;
- Technical and operational requirements are necessary for ESOMPs to avoid causing harmful interference to other services and systems, as described in section 5 of this Report. These include the requirement to have an automatic mechanism (under the control of an NCF) for the management of the interference environment and to meet the PFD levels where applicable;
- ESOMPs are exempted from individual licensing and enjoy free circulation and use within CEPT, subject to national licensing requirements.

Taking into account that one Ka-band NGSO system employing ESOMPs has already been deployed[5], it could be in the interest of operators, users and the CEPT regulators to have an agreed framework in place to harmonise such operations as soon as possible.

As maritime ESOMPs operations in particular are international in nature, the work initiated with the ITU-R Report S.2261 on NGSO systems needs to be developed further with the adoption of relevant Reports or Recommendations specific to maritime ESOMPs operating in 17.3-20.2 GHz, 27.5-29.1 GHz and 29.5-30.0 GHz.

[5] See Annex 1

## ANNEX 1: PROTECTION OF AIRCRAFT FROM ESOMPS OPERATING ON THE EARTH SURFACE IN THE VICINITY OF AN AIRFIELD

The ECC Report 066 [33] provides methodology for the calculation of a coordination area that would provide for the protection for aircraft when such aircraft follows a conventional 3° glide slope in alignment with the runway. This methodology has been applied to a NGSO system with the characteristics listed below and the resulting coordination areas are listed in Table 3 below. Table 4 refers to the worst case coordination area for the NGSO case.

Table 3 lists the coordination area for a NGSO satellite system called O3b. The satellites in this system operate in an equatorial orbit with following characteristics:

| | |
|---|---|
| Description of the orbit: | Equatorial plane at an altitude of 8062 km |
| e.i.r.p. of ESOMPs: | Maximum e.i.r.p. of 70 dBW (under rain fade conditions)<br>Nominal e.i.r.p. 60.6 dBW,<br>e.i.r.p. under clear sky condition 61.9 dBW |

### Table 3: Calculated coordination areas for O3B system

| **ESOMPs** | >40 dBW | >45 dBW | >50 dBW | >55 dBW | >60 dBW | >61 dBW | >62 dBW | >68 dBW |
|---|---|---|---|---|---|---|---|---|
| **e.i.r.p. range** | >45 dBW | >50 dBW | >55 dBW | >60 dBW | >61 dBW | >62 dBW | >68 dBW | >70 dBW |
| **ESOMP Latitude** | Coordination Area | Coordination Area | Coordination Area | Coordination Area | Coordination Area | Coordination Area | Coordination Area | Coordination Area |
| >$50^0$N | 288 m | 511 m | 909 m | 1614 m | 1814 m | 2036 m | 4062 m | 5113 m |
| $45^0$-500 | 378 m | 673 m | 1197 m | 2128 m | 2388 m | 2679 m | 5346 m | 6730 m |
| $40^0$-$50^0$N | 465 m | 827 m | 1471 m | 2616 m | 2936 m | 3294 m | 6572 m | 8274 m |
| $35^0$-$40^0$N | 547 m | 973 m | 1730 m | 3076 m | 3451 m | 3872 m | 7726 m | 9726 m |
| $30^0$-$35^0$N | 646 m | 1149 m | 2044 m | 3635 m | 4079 m | 4576 m | 9131 m | 11495 m |

Table 4 lists the coordination area that could be defined as the worst case coordination area for NGSO systems. This information in Table 4 may be of assistance to administrations for the protection of aircrafts in the vicinity of airfields from ESOMPs operating to a NGSO system for which the coordination areas have not been determined using the methodology given in ECC Report 066 [33].

### Table 4: Worst case coordination area for the NGSO case

| **ESOMPs e.i.r.p.** | >40 dBW | 50 dBW | >55 dBW | >60 dBW |
|---|---|---|---|---|
| Note: These coordination areas are not dependent on the latitude of the ESOMPs | Coordination Area | Coordination Area | Coordination Area | Coordination Area |
| | 500 m to 1500 m | 1500 m to 3000 m | 3000 m to 6000 m | 6000 m and beyond |

The worst case is when an ESOMPs is transmitting to a NGSO satellite located at the zenith of the ESOMPs. In this case if an aircraft on a 3$^o$ glide path (i.e. aircraft at a 3$^o$ elevation) crosses the ESOMP's signal path, then it will be subjected to the maximum field strength arising from the main beam of the ESOMPs. Report 066 [33] states that aircraft is certified to a maximum field strength of 20 V/m. The coordination areas relating to this scenario are identified in the Figure 3:

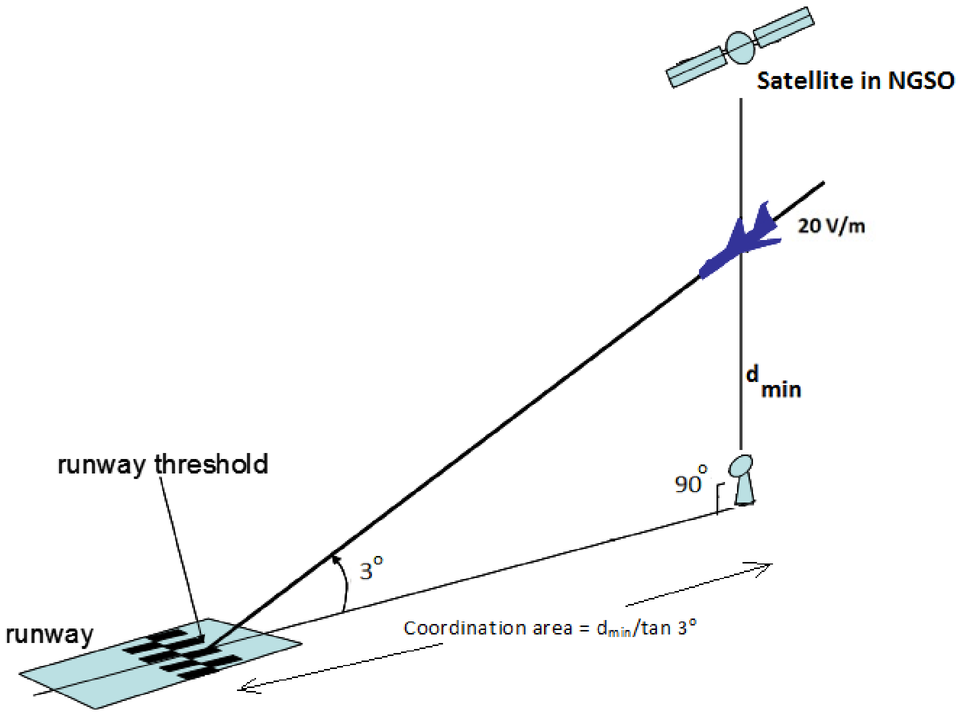


**Figure 3: Scenario when aircraft crosses the main beam of an earth station**

The calculation of the worst case coordination area is based on following assumptions being in agreement with findings of ECC report 066 [33]:

- maximum elevation angle of earth station antenna of NGSO ESOMPs is equal to 90°;
- earth station antenna height (H) is 0m;
- glide path angle (α) is 3°. straight forward task, as shown below in the figure.

The coordination area in case of a single earth station operating towards a satellite assumes a terminal height (H) of 0 m and a glide path angle (α) of a landing aircraft is 3°. This value assumed to be the typical inclination of the approach path, but there may be cases when an aircraft may be below because of particular flight conditions. In applying these results, allowance must be made for aircraft which do not exactly follow this 3° straight trajectory (see section 5 of ECC Report 066 [33]).
The relevant formulae are stated below.

$$d_{\min} = \frac{\sqrt{30.EIRP}}{E}$$ (equation 9 of the ECC Report 066 [33])

$d_{min}$ is the distance from the ESOMPs to the aircraft. Field strength E (in this case 20V/m) at the aircraft is generated by the ESOMPs operating with a given e.i.r.p.

The coordination area is:

$$D = (d_{min} + H)/\tan(\alpha)$$

The calculated coordination areas for various e.i.r.p. levels up to 60dBW are given in Table 4.

## ANNEX 2: ASSUMPTIONS AND METHODOLOGY USED FOR THE CALCULATION OF THE PFD THRESHOLD FOR MARITIME ESOMPS

Following a worst case scenario approach, the FS station characterised by the parameters contained in Table 5 has been considered to be the victim of the interference caused by a maritime ESOMPs operating in international waters (those studies were performed in support of development of ECC/DEC/(13)01 [5] covering Earth Stations on Mobile Platforms in the Ka-band).

**Table 5: Parameters for victim FS stations operating in the 27.5-29.1 GHz band (see FS1 in Table 1)**

| Parameter | FS1 (PP) |
|---|---|
| RX antenna height | 20 m |
| RX antenna pattern | Recommendation ITU-R F.1245 [24] |
| Receiver noise figure, F | 6 dB |
| RX frequency | 28 GHz |
| RX elevation angle | 0° |
| RX peak gain | 45 dBi |

The potentially affected receiving FS station is assumed to operate on the coast line, oriented towards the open sea, as illustrated in the Figure below.

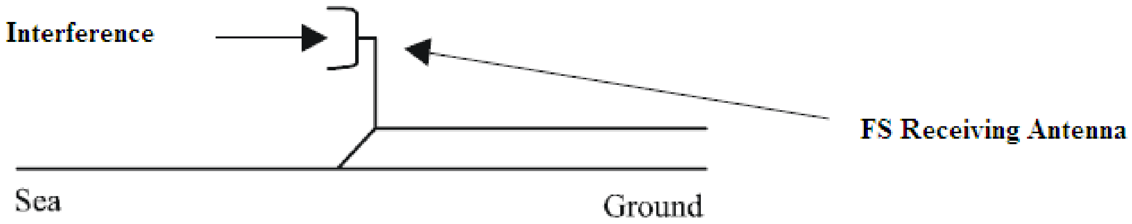


**Figure 4: Worst-case interference scenario**

The calculation which follows determines a maximum PFD an ESOMPs can radiate on the coast (and farther inland) of the affected administration, in order to protect FS1 and, consequently, any FS network.

Following the same methodology illustrated in Recommendation ITU-R SF.1650 [28][28], only a short-term criterion is needed for the aim of this study. A short-term interference criterion of I/N= +9 dB has been considered; this level shall not be exceeded for more than $p_s$ = 2.7 x $10^{-4}$ % of the time[6].

The following calculation in Table 6, related to the thermal noise at the input of the receiver used in station FS1, applies.

**Table 6: Noise characterisation for FS1 receiver**

| Parameter | Value | Unit |
|---|---|---|
| Receiver equivalent noise bandwidth ($B_{Rx}$) | 14 | MHz |
| Receiver Noise Figure (NF) | 6 | dB |
| Thermal Noise at the input of the receiver (*N*) | -126.5 | dBW |

[6] This short-term interference time percentage is the same as that used for the Ku-band case in Recommendation ITU-R SF.1650-1 [28].

The following equations can then be used for obtaining the requested PFD value:

$$I_{max} = N + 9, \quad \text{(dBW)}$$

where:

- $I_{max}$ is the maximum allowed power interfering with the FS station (dBW);

- *N* is the noise power calculated in Table 6 (dBW).

Furthermore:

$$PFD = I_{max} - G_{Avg} - A_{eff} + L_{pol}, \ \text{(dB(W/m}^2\text{))}$$

where:

- *PFD* is the requested power flux density (dB(W/m$^2$));
- $G_{Avg}$ is the average gain of the receiving antenna within its -10 dB beamwidth (dBi);
- $A_{eff}$ is the effective area (10 log($\lambda^2/4\pi$)) of the receiving antenna (dB(m$^2$)); $\lambda$ the wavelength (m);
- $L_{pol}$ is the polarisation advantage (dB).

The following calculation is then performed by applying these formulas.

**Table 7: Detailed calculation of the pfd limit**

| Description | Parameter | Value | Unit |
|---|---|---|---|
| Rx equivalent noise bandwidth | $B_{Rx}$ | 14 | MHz |
| Rx Noise Figure | F | 6 | dB |
| Reference Temperature | $T_0$ | 290 | K |
| Thermal noise power | N | -126.5 | dBW |
| Interference Criterion | $(I/N)_{max}$ | 9 | dB |
| Maximum allowed interference power | $I_{max}$ | -117.5 | dBW |
| Transmitter frequency | F | 29.25 | GHz |
| Wavelength | $\lambda$ | 0.01 | m |
| Rx antenna peak gain | $G_{Avg}$ | 42.2 | dB |
| Antenna effective area (10 log($\lambda^2/4\pi$)) | $A_{eff}$ | -51 | dB(m$^2$) |
| Polarisation advantage | $L_{pol}$ | 0 | dB |
| ***Maximum PFD on the coast*** | ***PFD*** | ***-108.7*** | ***dB(W/m$^2$)*** |

It is then concluded that a PFD value of -109 dB(W/m$^2$) expressed in a reference bandwidth of 14 MHz at a height of 20 m above sea level is adequate for protecting FS systems from interference caused by maritime ESOMPs.

In addition, compatibly with the methodology contained in Recommendation ITU-R SF.1650-1, the percentage of time p that should be used, when assessing compliance with this PFD threshold, is 0.007%.

For the case of ESOMPs transmitting to NGSO FSS systems, the value of p must take into account the combined effect of the propagation loss and of the ESOMPs transmit antenna gain towards the affected fixed terminal, since both variables are time-dependent.

In fact, the protection criterion may be translated into a minimum value of the variable $L(p_L) - G_{TX}(p_G)$ where:
$L(p_L)$ - is the minimum path loss value which can only be violated during $p_L$ % of the time, and

$G_{TX}(p_G)$ - is the value of the gain of the ESOMPs transmit antenna gain towards the affected fixed terminal not exceeded for more than $p_G$ % of the time.

This limit will be referred to here as $(L – G_{TX})_{REQ}$.

Since these variables are statistically independent, the % probability of any two values of $L(p_L)$ and $G_{TX}(p_G)$ occurring is the product $p_L$ $p_G$/100 %, and it is this product that must be equal to p.

The methodology to determine the statistics of $G_{TX}(p_G)$ for earth station antennas operating with NGSO satellite systems is described in item 3 of Annex 1 of Recommendation ITU-R S.1430-0 [32] (Determination of the coordination area for earth stations operating with non-geostationary space stations with respect to earth stations operating in the reverse direction in frequency bands allocated bidirectionally to the fixed-satellite service).

This Recommendation also contains two methods for the calculation of the coordination distance for these operations which could be adapted to determine the impact of ESOMPs mounted on vessels sailing in international waters and operating in NGSO FSS systems.

Application of these methods relies on the fact that, given the route of a vessel equipped with an ESOMPs, the distances d to the coastline of the affected country are known for all azimuths towards the coast.

## ANNEX 3: LIST OF REFERENCE


[1] ECC Report 184. The Use of Earth Stations on Mobile Platforms Operating with GSO Satellite Networks in the Frequency Range17.3-20.2 GHz and 27.5-30.0 GHz.

[2] ITU-R Report S.2261. Technical and operational requirements for earth stations on mobile platforms operating in non-GSO FSS systems in the frequency bands from 17.3 to 19.3, 19.7 to 20.2, 27 to 29.1 and from 29.5 to 30.0 GHz.

[3] ITU-R Report S.2223. Technical and operational requirements for GSO FSS earth stations on mobile platforms in bands from 17.3 to 30.0 GHz.

[4] ITU-R Report S.2261. Technical and operational requirements for earth stations on mobile platforms operating in non-GSO FSS systems in the frequency bands from 17.3 to 19.3, 19.7 to 20.2, 27 to 29.1 and from 29.5 to 30.0 GHz.

[5] ECC Decision (13)01. ECC Decision of 8 March 2013 on the use, free circulation, and exemption from individual licensing of Earth stations on mobile platforms (ESOMPs) in the frequency bands available for use by uncoordinated FSS Earth stations within the ranges 17.3-20.2 GHz and 27.5-30.0 GHz.

[6] ECC Report 152. The use of the frequency bands 27.5-30.0 GHz and 17.30-20.2 GHz by satellite networks.

[7] Resolution 216 (Rev.WRC-2000) Possible broadening of the secondary allocation to the mobile-satellite service (Earth-to-space) in the band 14-14.5 GHz to cover aeronautical applications (abrogated at WRC-03).

[8] Recommendation ITU-R M.1643. Determination of the coordination area for earth stations operating with NON-GSO space stations with respect to Earth stations operating in the reverse direction in frequency bands allocated bidirectionally to the FSS.

[9] Recommendation ITU-R S.524. Maximum permissible levels of off-axis e.i.r.p. density from earth stations in the fixed-satellite service transmitting in the 6 and 14 GHz frequency bands.

[10] Resolution 902 (WRC-03). Provisions relating to earth stations located on board vessels which operate in fixed-satellite service networks in the uplink bands 5925-6425 MHz and 14-14.5 GHz.

[11] Resolution 909 (WRC-12). Provisions relating to earth stations located on board vessels which operate in fixed-satellite service networks in the uplink bands 5 925-6 425 MHz and 14-14.5 GHz.

[12] Resolution 143 (Rev. WRC-07). Guidelines for the implementation of high-density applications in the fixed-satellite service in frequency bands identified for these applications.

[13] ECC Decision (05)08. The availability of frequency bands for high density applications in the Fixed-Satellite Service (space-to-Earth and Earth-to-space).

[14] ECC Decision (06)02. Exemption from Individual Licensing of Low e.i.r.p. Satellite Terminals (LEST) operating within the frequency bands 10.70–12.75 GHz or 19.70–20.20 GHz space-to-Earth and 14.00–14.25 GHz or 29.50–30.00 GHz Earth-to-Space.

[15] ECC Decision (06)03 on Exemption from Individual Licensing of High e.i.r.p. Satellite Terminals (HEST) with e.i.r.p. above 34 dBW operating within the frequency bands 10.70 - 12.75 GHz or 19.70 - 20.20 GHz space-to-Earth and 14.00 - 14.25 GHz or 29.50 - 30.00 GHz Earth-to-space.

[16] ETSI EN 301 459. Transmitting towards satellites in geostationary orbit in the 29,5 GHz to 30,0 GHz frequency bands covering essential requirements.

[17] ETSI EN 301 428. Transmit-only, transmit/receive or receive-only satellite earth stations operating in the 11/12/14 GHz frequency bands covering essential requirements.

[18] ECC Decision (05)01. The use of the band 27.5-29.5 GHz by the Fixed Service and uncoordinated Earth stations of the Fixed-Satellite Service (Earth-to-space).

[19] ERC Decision (00)09. The use of the band 27.5 – 29.5 GHz by the fixed service and uncoordinated Earth stations of the fixed-satellite services (Earth-to-space) (withdrawn by ECC/DEC/(05)01).

[20] ECC Decision (05)09. The free circulation and use of Earth Stations on board Vessels operating in Fixed Satellite service networks in the frequency bands 5 925-6 425 MHz (Earth-to-space) and 3 700-4 200 MHz (space-to-Earth).

[21] ECC Decision (05)10. The free circulation and use of Earth Stations on board Vessels operating in fixed satellite service networks in the frequency bands 14-14.5 GHz (Earth-to-space), 10.7-11.7 GHz (space-to-Earth) and 12.5-12.75 GHz (space-to-Earth).

[22] ECC Decision (05)11. The free circulation and use of Aircraft Earth Stations (AES) in the frequency bands 14-14.5 GHz (Earth-to-space), 10.7-11.7GHz (space-to-Earth) and 12.5-12.75 GHz (space-to-Earth).

[23] ERC Decision (00)07. The shared use of the band 17.7 - 19.7 GHz by the fixed service and Earth stations of the fixed-satellite service (space-to-Earth).

[24] Recommendation ITU-R F.1245. Mathematical model of average and related radiation patterns for line-of-sight point-to-point radio-relay system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz.
[25] Recommendation ITU-R F.1336. Reference radiation patterns of omnidirectional, sectoral and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz.
[26] Recommendation ITU-R F.758-5. 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.
[27] Recommendation ITU-R SF.1707. Guidelines for the implementation of high-density applications in the fixed-satellite service in frequency bands identified for these applications.
[28] Recommendation ITU-R SF.1650. 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.
[29] 1999/05/EC: Radio and telecommunications terminal equipment (R&TTE).
[30] ITU Radio Regulations – 2012 Edition, ITU-R.
[31] Recommendation ITU-R SF.1719. Sharing between point-to-point and point-to-multipoint fixed service and transmitting earth stations of GSO and non-GSO FSS systems in the 27.5-29.5 GHz band.
[32] Recommendation ITU-R S.1430-0. Determination of the coordination area for earth stations operating with NON-GSO space stations with respect to Earth stations operating in the reverse direction in frequency bands allocated bi-directionally to the FSS.
[33] ECC Report 066. Protection of aircraft from Satellite Earth Stations operating on the ground in the vicinity of airfields.
[34] ETSI EN 303 979: Harmonized European Standard for fixed Earth Stations and Earth Stations on Mobile Platforms (ESOMP) transmitting towards satellites in non-geostationary orbit in the 27.5 GHz to 29.1 GHz and 29.5 GHz to 30.0 GHz band (under development).