



Earth Station Performance Requirements

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TABLE OF CONTENTS

1. INTRODUCTION	4
1.1. SCOPE	4
1.2. MANDATORY AND RECOMMENDED CRITERIA	4
1.3. REQUIREMENTS & RECOMMENDATIONS FOR RF PARAMETERS.....	5
1.4. FREQUENCY CRITERIA.....	5
1.5. FREQUENCY BANDS	5
1.6. FREQUENCY RESOLUTION	6
1.7. SATELLITE TRANSPONDER TRANSLATION FREQUENCY TOLERANCE	6
1.8. INCLINED ORBIT OPERATIONS.....	6
2. POLARISATION CRITERIA	7
2.1. TRANSMIT AND RECEIVE CROSS POLARISATION ISOLATION	7
2.2. TRANSMIT CO-POLAR AND CROSS-POLAR SIDELOBES	8
2.2.1. <i>Co-Polar Sidelobes</i>	8
2.2.2. <i>Cross-Polar Sidelobes</i>	8
2.3. ANTENNA RECEIVE CO-POLAR AND CROSS POLAR PATTERN	9
2.4. POINTING STABILITY	9
2.5. LINEAR POLARISATION ANGLE	9
2.5.1. <i>Inclined Orbit Operations</i>	10
2.5.2. <i>Transportable Stations</i>	10
2.6. TRANSMISSION TIME DELAY VARIATIONS DUE TO SATELLITE MOTION.....	10
3. EIRP REQUIREMENTS	11
3.1. EIRP ADJUSTMENT	11
3.2. UPLINK POWER SPECTRAL DENSITY LIMITS.....	11
3.2.1. <i>Station Size Limitations for 13.75 - 14.0 GHz Band</i>	12
3.3. EIRP STABILITY.....	12
3.4. IN- BAND EMISSIONS	12
3.5. OUT OF BAND EMISSIONS	13
3.6. INTERMODULATION PRODUCTS	13
3.7. SPECTRAL OCCUPANCY	14
3.8. TRANSPORTABLE EARTH STATIONS	14
3.9. BEACON FREQUENCIES	14
3.10. LOCAL CONTROL AND MONITORING	15

1. INTRODUCTION

1.1. SCOPE

This document identifies the characteristics and the performance requirements which must be guaranteed by stations accessing the SES satellite system. These requirements have been developed in order to ensure satisfactory operation of systems entering the SES network as well as providing a mutually agreeable interference scheme amongst SES and other satellite system users.

The primary concern of this document is the performance of the radio frequency (RF) subsystem.

1.2. MANDATORY AND RECOMMENDED CRITERIA

Certain earth station requirements are considered mandatory. Such parameters are categorised in this way in order to guarantee the protection and performance of the SES system and their customers, or to meet internationally agreed standards.

Other requirements in this document are recommendations, based upon best engineering practice and are included in order to ensure the quality of customer's services. Non compliance with these parameters may not preclude the use of an earth station within the SES network but may lead to acceptable service restrictions. SES will evaluate such instances on a case by case basis.

SES are responsible for maintaining the integrity of the overall network, which necessarily involves the planning and protection of users from each other's transmissions. SES is therefore responsible for

- the definition of the earth station performance criteria
- providing a test environment in order that stations may make the necessary service entry and earth station performance measurements.
- analysis and acceptance of Earth Station test results.

The customer is requested to provide SES with detailed performance parameters for those parameters which SES judges necessary for ensuring satisfactory system performance. This will allow SES' Satellite engineering personnel to estimate the link performance that is available with the proposed earth station, and to correctly handle interference assumption from and to SES systems to other satellite systems.

1.3. REQUIREMENTS & RECOMMENDATIONS FOR RF PARAMETERS

SES does not operate nor formally recognise a Type Approval process. However, there are clearly a large number of Earth stations and systems which have been developed and Type Approved for other satellite systems and which use similar technical criteria as SES.

Recognising this fact, the four foreseen routes to entering an earth station into the SES network are:

- verification testing performed with the SES Payload Management and Operations Center (PMOC) using SES' satellite capacity,
- verification testing performed with or without the SES PMOC on another satellite system. Such testing may be agreed with SES specifically for the purpose of earth station verification, or may involve the provision of historical data, which SES can assess.
- reduced, or exemption from, verification testing of an earth station, which meets an acceptable Type Approval process.
- Demonstration that the system can have no negative impact upon other users.

1.4. FREQUENCY CRITERIA

SES presently operate both C-, Ku- and Ka-band transponder capacity, with cross-connection between the C- and Ku-bands in some circumstances. Additionally each spacecraft offers a slightly different set of uplink and downlink frequencies and coverage/connectivity options.

Earth Stations may be single band only or may offer (through multiple antenna options or otherwise) dual band capability. Detailed descriptions of the SES satellite characteristics can be found on the SES website (<http://www.ses.com>). Under certain circumstances SES may need to adjust customer's frequency allocations, for example to restore traffic during interference or transponder failure. It is therefore in customer's interest to equip for the maximum frequency flexibility. Ku-band users should equip for the applicable ITU bands for their region.

Note that due to the connectivity of certain coverages it should not be assumed that an uplink station will have the ability to receive its own downlink transmission. However, the SES PMOC is in a position to monitor user's transmissions and to perform any necessary performance measurements upon request from users.

1.5. FREQUENCY BANDS

Station engineers wishing to access SES' satellites in any particular region should ideally be able to operate over the full band frequency ranges.

Earth view contours and where appropriate outline coverage areas are provided from each orbital location in order for stations to determine the spacecraft coverages applicable to each satellite. Note that parameters for SES satellites under

construction and additional frequencies can be obtained on request from the SES Frequency Co-ordination Department.

All antenna performances apply over the required bandwidth of operation of the satellites. It is recommended for wideband operations, especially at Ku- and Ka-band that high, mid and low band measurements are taken.

1.6. FREQUENCY RESOLUTION

It is *recommended* that Earth Stations accessing the SES system should have transmit and receive equipment that allows the carrier frequency to be set independently. In practice the required step size is related to the bandwidth of the transmitted and received signals.

It is recommended that for general capability a step size of no greater than 2.5 kHz be provided.

1.7. SATELLITE TRANSPONDER TRANSLATION FREQUENCY TOLERANCE

The translation frequency tolerance (for all bands) due to the satellite should be assumed to be no worse than ± 25 kHz for the SES satellites over their lifetime.

The tolerance over any one month is typically ± 2.5 kHz.

1.8. INCLINED ORBIT OPERATIONS

As a method of contingency planning, SES may unavoidably make use of inclined orbit spacecraft. Therefore, all stations are encouraged to give consideration to the advantages of providing service to inclined orbit spacecraft.

Stations which operate with inclined orbit spacecraft will experience greater Doppler uncertainty and Range variation than stations operating to non-inclined orbit spacecraft. Additionally, the worst case performance of the spacecraft coverages, which occurs at least once per day may become significant and could require additional earth station EIRP and G/T margins.

2. POLARISATION CRITERIA

SES' satellites operate with both linear and circular polarizations in uplink and downlink at C-band and linear orthogonal polarisations at Ku- and Ka-band. .

2.1. TRANSMIT AND RECEIVE CROSS POLARISATION ISOLATION

As SES' satellites typically re-use frequencies over both applicable polarisations, a satisfactory transmit and receive polarisation isolation is required. Poor transmit isolation can lead to interference to other users as well as increasing the operators susceptibility to receive interference. Hence, a mandatory polarisation discrimination requirement is applied for C-band and Ku-band stations larger than 2.5m diameter.

For smaller stations these figures should be used as design objectives but stations not meeting the requirements may be considered acceptable by SES.

The **required** values of transmit polarisation discrimination, for stations greater than 2.5m diameter are:

Band	Performance
C-Band – circular	Voltage Axial Ratio = 1.09
C-Band – linear	XPD = 30 dB
Ku-Band	XPD = 35 dB

Polarisation discrimination here is quoted excluding the effects of polarisation plane misalignment due to installation and atmospheric effects.

The required values should be met at antenna boresight and within

- $\pm 15\%$ of the half power beamwidth or
 - the linear sum of the antenna installation, pointing and tracking errors;
- whichever is greater.

It is recommended that stations exhibit the same receive polarisation isolation as transmit. SES is unable to allocate additional resources to stations that do not meet the cross-polar performance requirements.

2.2. TRANSMIT CO-POLAR AND CROSS-POLAR SIDELOBES

To avoid interference to and from adjacent satellites, a defined transmit co-polarised sidelobe pattern is required for earth stations accessing the SES' satellites.

2.2.1. Co-Polar Sidelobes

It is **mandatory** that the off-axis transmit antenna co-polarised gain of the earth station at an angle θ measured between the main beam electrical boresight and the direction considered shall be no higher than the following values:

Antenna	CoPolar Gain in direction θ	Off Axis Angle θ
$D/\lambda \geq 100$	$29 - 25.\log \theta$ dBi ¹	$1^\circ \leq \theta \leq 20^\circ$
	-3.5 dBi	$20^\circ \leq \theta \leq 26.3^\circ$
	$32 - 25.\log \theta$ dBi	$26.3^\circ \leq \theta \leq 48^\circ$
	-10 dBi	$\theta > 48^\circ$
$D/\lambda < 100$	$29 - 25.\log \theta$ dBi	$100 \cdot \frac{\lambda}{D} \leq \theta \leq 20^\circ$
	-3.5 dBi	$20^\circ \leq \theta \leq 26.3^\circ$
	$32 - 25.\log \theta$ dBi	$26.3^\circ \leq \theta \leq 48^\circ$
	-10 dBi	$\theta > 48^\circ$

Table 1 – C-Band, Ku-and Ka-Band Antenna Transmit Co-Polar Off Axis Gain

2.2.2. Cross-Polar Sidelobes

The off-axis transmit antenna cross-polarised gain of the earth station for all antenna shall not exceed the levels defined below for antenna cross-polar gain over the angular range shown:²

Cross Polar Gain in direction θ	Off Axis Angle θ
$19 - 25.\log \theta$ dBi	for $2.5^\circ \leq \theta \leq 7^\circ$

Table 2 – C Band, Ku and Ka Band Antenna Transmit Cross-Polar Off Axis Gain

¹ As a mandatory requirement a relaxation of 3 dB giving $32 - 25.\log \theta$ over the range $1^\circ \leq \theta \leq 48^\circ$ with a floor of -10 dBi is possible.

² For NSS-6, antennas shall, as a minimum, have an off-axis cross-pol isolation discrimination performance compliant with the ITU-R Recommendations S.727 S.731 from 1.4° off-axis angle.

2.3. ANTENNA RECEIVE CO-POLAR AND CROSS POLAR PATTERN

There are no mandatory receive performance requirements. Therefore, as a design objective the receive co-polar and cross-polar performances shall be the same as the transmit. However, in the case that the receive performance requirements are not met, users should note that they may be unavoidably susceptible to interference from adjacent satellites.

2.4. POINTING STABILITY

It is **mandatory** that the uplink antenna pointing stability shall be such that environmental conditions, both internal and external to the uplink earth station, will not cause sufficient antenna movement to produce more than a ± 1 dB change in operational flux density at the satellite under clear sky conditions.

To protect adjacent satellites from excess interference, and to meet EIRP stability requirements in the direction of the SES satellite system, the pointing stability of the uplink antenna must be provided by manufacturers.

Under no pointing conditions may the earth station violate cross-polarisation isolation requirements of section 2.1 "Transmit and Receive Cross Polarisation Isolation".

The station keeping limits which may be assumed for the SES Spacecraft are as identified below:

North-South	East-West	Eccentricity
$\pm 0.05^\circ$	$\pm 0.05^\circ$	0.0003

Table 3 – Spacecraft Station-Keeping Parameters

Note that especially towards the end of spacecraft lifetime, SES may decide to operate any satellite with a higher inclination than specified. This will have the effect of increasing the N-S errors over time. Customers may assume that for the purpose of continuous operations, that the maximum inclination required for operation will be $\pm 3.5^\circ$.

Spacecraft may also be relocated at any time, particularly under contingency conditions or once replacement space segment has been made available. SES will however attempt to maintain at all times the necessary coverage and connectivities for each orbital location with minimum impact upon Earth Station requirements.

2.5. LINEAR POLARISATION ANGLE

SES' satellites operate in the Ku-, Ka-band and on certain C-band frequencies on certain spacecraft with linear polarisation. Stations making use of linear polarised uplinks and downlinks must be able to set their polarisation to match the local polarisation angle at the point of reception. This angle changes with location.

It is recommended that all stations provide a polarisation angle capability of:

Initial range	$\pm 90^\circ$.
Setting Accuracy	$\pm 1.0^\circ$.

For station transmitting linear polarised uplinks, the ability to correctly set uplink polarisation directly affects the achieved link XPD. For example, a station exhibiting a polarisation discrimination due to feed and reflector geometry of 33 dB will achieve an effective antenna discrimination of 30dB, with a polarisation alignment error angle of 1.28° , best case.

The receive polarisation of the station on linearly polarised downlinks is required to be carefully adjusted. By far the most accurate means for achieving this is using a null technique on the orthogonal polarisation. However as the plane of transmit and receive polarisations may not be perfectly aligned, the transmit discrimination shall be optimised whenever possible. (Note that, in certain configurations, uplink stations will not be able to monitor their own downlink transmissions). In all circumstances, adjustments must be performed under PMOC control.

2.5.1. Inclined Orbit Operations

For inclined orbit spacecraft there is a significant yaw component introduced by the inclination which can lead to a diurnal variation in the polarisation angle approximately equal to the inclination angle.

Furthermore, for stations which are required to maintain performance when operating to inclined orbit spacecraft, it is recommended that polarisation tracking is implemented with a polarisation tracking range of $\pm 5.0^\circ$.

2.5.2. Transportable Stations

For linear polarised transportable earth stations, it is *recommended* that a $\pm 90^\circ$ motorised polarisation adjustment be provided to allow the polarisation angle to be adjusted to the required value from any location on the visible earth.

The time allowed for occasional use users to perform line-up measurements is strictly limited and manual adjustment of the feed may reduce the amount of time available for transmissions.

2.6. TRANSMISSION TIME DELAY VARIATIONS DUE TO SATELLITE MOTION

If digital carriers are to be interfaced with synchronous data networks, it will be necessary to provide buffering of the downlink data to account for variations in the time delay due to the satellite motion. The major components of the variation arise from satellite station-keeping tolerances especially for older spacecraft where the inclination of the orbit can increase to a few degrees.

3. EIRP REQUIREMENTS

3.1. EIRP ADJUSTMENT

The SES transponders are specified to operate over a wide range of gain settings. At the time of entry into service and from time to time thereafter, stations may be required to adjust their uplink EIRP. Operational EIRP values are decided by SES. Due to operational requirements the PMOC may ask a station to make an EIRP adjustment at ANY TIME.

Ideally stations will have access to a calibrated uplink path for direct measurement of EIRP on a per carrier basis. This is not a mandatory requirement and, where this is not the case or in case of disagreement, the SES PMOC is responsible for establishing when the required uplink EIRP is correctly set.

Stations should be able to adjust the EIRP on a per carrier basis with a resolution of 0.5dB over the full range of HPA output power.

3.2. UPLINK POWER SPECTRAL DENSITY LIMITS

The maximum allowable uplink EIRP values which may be assumed for transmission planning and operational purposes are as described in the Table below.³

Ku-Band	
EIRP PSD	Off-Axis Angle
$33 - 25 \cdot \log \theta$ dBW/40kHz	$2.5^\circ \leq \theta \leq 7.0^\circ$
+12 dBW/40kHz	$7.0^\circ < \theta \leq 9.2^\circ$
$36 - 25 \cdot \log \theta$ dBW/40kHz	$9.2^\circ < \theta \leq 48^\circ$
-6 dBW/40kHz	$48 < \theta \leq 180^\circ$

C-Band	
EIRP PSD	Off-Axis Angle
$32 - 25 \cdot \log \theta$ dBW/4kHz	$2.5^\circ \leq \theta \leq 7.0^\circ$
+11 dBW/4kHz	$7.0^\circ < \theta \leq 9.2^\circ$
$35 - 25 \cdot \log \theta$ dBW/4kHz	$9.2^\circ < \theta \leq 48^\circ$
-7 dBW/4kHz	$48 < \theta \leq 180^\circ$

Table 4 – Earth Station EIRP Limitations

Compliance with the above is achieved through a combination of the antenna pattern performance and the modulation parameters associated with the uplinks.

³ Uplink spectral density limits for transmission planning in the Ka band will be addressed on a case-by-case basis.

SES will normally estimate compliance with the above parameters in the development or assessment of transmission plans.

Note that in the case where large degrees of frequency reuse are implemented, SES may reduce uplink EIRP levels in order to keep aggregate interference within acceptable limits. Hence small terminals intended for operation with high G/T spacecraft may be operated with margin on the above figures on the assumption that multiple stations will be reusing frequencies simultaneously.

The use of uplink power control is not permitted on SES' satellites without the explicit permission of the Operations department at SES. Details on the suitable characteristics of the UPC will be communicated at the time that agreement is reached.

3.2.1. Station Size Limitations for 13.75 - 14.0 GHz Band

It is mandatory that: Earth stations operating in the 13.75-14.0 GHz band be a minimum diameter of 1.2m.⁴

3.3. EIRP STABILITY

To guarantee the earth station user the service quality specified in the contract, and also to protect the SES satellite system from excessive unbalancing among the carriers transmitted into each transponder, it is required that proper stability of the earth station's EIRP be guaranteed.

It is therefore *mandatory* that the EIRP of any carrier transmitted in the direction of the SES satellite system, measured in a continuous 24 hour period, shall not vary by more than 0.5 dB.

Stations authorised to employ uplink power control shall not exceed authorised satellite flux densities at the spacecraft by more than 1 dB at any time.

3.4. IN- BAND EMISSIONS

For emissions outside the earth station's assigned transponder but within the relevant operating band, it is *required that* the emissions radiated by an earth station antenna which fall outside of the assigned transponder bandwidth must not exceed 4 dBW in any 4 kHz band. This figure excludes the contribution of intermodulation products.

⁴ In addition to this minimum antenna size, certain restrictions, in terms of meeting certain PFD levels at the coastline, or at the border with an adjacent country apply. Please refer to ITU-R Radio Regulation No. 5.502 and 5.503. For further information the customer is advised to consult with the SES Frequency Co-ordination group.

3.5. OUT OF BAND EMISSIONS

At the time of introduction into the SES network and as a minimum whenever a change in station configuration occurs thereafter, stations should perform a wideband out of band emissions check.

Limits apply over the frequency band specified below, and at off-axis angles greater than 7° (for Ku-band terminals) and 11° (for C-band terminals), providing the band is outside of the user's allocation(s)

- 3.4 – 10.7 55 dBpW/100kHz
- 10.7 – 11.7 61 dBpW/100kHz
- 11.7 – 21.2 78 dBpW/100kHz
- 21.2 – 25.5 67 dBpW/100kHz

These requirements apply at all conditions from no HPA drive to full operational load and include all periodic and random components of emission including re-radiation of external interferences and harmonics, spurious signals, intermodulation, and noise.

3.6. INTERMODULATION PRODUCTS

The spectral density of intermodulation products is coverage and spacecraft dependent and is given in the table below. These limits apply to intermodulation products according to the uplink coverage in which the intermodulation will fall.

Uplink Transponder Impacted by Intermodulation Product	Limit (dBW/4kHz)
Hemi and Zone (all S/C)	21
Global and C Spot (all S/C)	18
All other Ku Band	16

Table 5 - Intermodulation Product EIRP Density Limits

3.7. SPECTRAL OCCUPANCY

The modulated spectrum of the QPSK spectrum normalised to the channel symbol rate should meet the spectrum defined below. This specification shall apply to all modulation schemes using Nyquist filtering up to and less than 40%. The peak of the spectrum should be calculated from the mean of the 5% of normalised bandwidth either side of the nominal channel centre frequency.

Normalised Offset f/Rs	Level wrt mean channel centre (dBc)
1.0	26
0.7	16
0.6	9

Table 1 - QPSK Spectral Mask

3.8. TRANSPORTABLE EARTH STATIONS

Transportable earth stations, whether operating at C-band, Ku-band or Ka-band are subject to the above requirements. However, stations infrequently accessing the SES space segment or requiring access at short notice may not be required to perform a full set of verification tests. Transportable stations are however required to register with the SES Sales Engineering group. When making reservations for occasional use, the stations are requested to provide details on:

- Service type (associated modulation parameters)
- Antenna diameter
- Uplink EIRP capability – or HPA size.
- Location of the uplink
- Point of contact.

SES will perform the necessary checks to ensure non-interference from/into the transportable station.

3.9. BEACON FREQUENCIES

Based on the nominal station-keeping limits and the earth station antenna beamwidth, the User should determine whether some form of tracking mechanism is required, taking into account the EIRP stability and axial ratio requirements.

Users requiring a beacon for tracking purposes should confirm with SES the operational frequency of the beacon on the satellite of interest.

3.10. LOCAL CONTROL AND MONITORING

It is a contractual requirement that earth stations accessing the SES' satellites are either manned or provide a means of remotely controlling the HPAs. For unmanned stations, the use of remote diagnostics should also be considered.

Ideally, manned stations will have access to a calibrated uplink path for direct measurement of EIRP on a per carrier basis.

Additionally, stations are encouraged to have available a suitable spectrum analyser in order to be able to monitor the overall transmitted spectrum and the occupied bandwidth and signal characteristics of individual carriers. A spectrum analyser is also required for G/T testing.

ANNEX A - ACRONYMS

Acronym	Interpretation
DVB	Digital Video Broadcast
EIRP	Effective Isotropic Radiated Power
G/T	Gain/Noise Temperature
HPA	High Power Amplifier
IM	Intermodulation
PMOC	SES Payload Management and Operations Center
XPD	Cross-Polar Discrimination
UPC	Uplink Power Control