



**Report ITU-R S.2357-0**  
(06/2015)

**Technical and operational guidelines  
for earth stations on mobile platforms  
communicating with geostationary space  
stations in the fixed-satellite service in  
the frequency bands 19.7-20.2 GHz and  
29.5-30.0 GHz**

**S Series**  
**Fixed-satellite service**

## Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

## Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

### Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
<b>BO</b>	Satellite delivery
<b>BR</b>	Recording for production, archival and play-out; film for television
<b>BS</b>	Broadcasting service (sound)
<b>BT</b>	Broadcasting service (television)
<b>F</b>	Fixed service
<b>M</b>	Mobile, radiodetermination, amateur and related satellite services
<b>P</b>	Radiowave propagation
<b>RA</b>	Radio astronomy
<b>RS</b>	Remote sensing systems
<b>S</b>	<b>Fixed-satellite service</b>
<b>SA</b>	Space applications and meteorology
<b>SF</b>	Frequency sharing and coordination between fixed-satellite and fixed service systems
<b>SM</b>	Spectrum management

*Note: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

*Electronic Publication*  
Geneva, 2015

© ITU 2015

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

## REPORT ITU-R S.2357-0

**Technical and operational guidelines for earth stations on mobile platforms communicating with geostationary space stations in the fixed-satellite service in the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz**

(2015)

## TABLE OF CONTENTS

	<i>Page</i>
1 Introduction .....	2
2 Technical Guidelines .....	2
3 Operational Guidelines .....	3
4 Conclusions.....	3
Annex 1: Off-axis e.i.r.p. density levels for earth station on mobile platforms communicating with geostationary space stations in the fixed-satellite service operating in the frequency band 29.5-30.0 GHz .....	4
Annex 2: Satellite tracking and pointing techniques of earth stations on mobile platforms communicating with geostationary space stations in the fixed-satellite service operating in the frequency band 29.5-30.0 GHz.....	8

## 1 Introduction

There is an increasing need for broadband communications. This need is not location specific and includes requirements on vessels, aircraft and land vehicles that operate at fixed locations and while in motion, often in very remote parts of the globe. Earth stations on mobile platforms (ESOMPs) that communicate with geostationary (GSO) fixed-satellite service (FSS) networks can meet this need. Satellites provide secure and essential communication services often when there are no other alternatives available. This Report provides technical and operational guidelines to administrations wishing to use ESOMPs communicating with GSO space stations in the FSS in the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz<sup>1</sup>. The primary intention of this Report is to aid administrations that want to authorise ESOMPs by assisting in the prevention of unacceptable interference to other GSO FSS networks and systems of other services operating in the same frequency bands.

ESOMPs as considered in this Report are not intended to be used to provide safety-of-life services/applications.

## 2 Technical Guidelines

It is important to ensure that ESOMPs using this new technology are compatible with other GSO FSS networks and systems of other services operating in the frequency bands below.

The 29.5-30.0 GHz is the uplink band where the ESOMP transmits to the GSO FSS satellite. Since the GSO FSS network communicating with an ESOMP is likely to operate adjacent to GSO FSS networks communicating with earth stations at a fixed location, the ESOMP must employ multiple-axis stabilized directional antennas that allow for high pointing accuracy towards the wanted GSO FSS satellite and must ensure that the radiation towards adjacent satellites on the GSO is similar to that of FSS earth stations at fixed locations.

Annex 1 of this Report provides a set of off-axis e.i.r.p. density levels that an ESOMP operating in the frequency band 29.5-30.0 GHz should comply with. These emission levels are based on the relevant levels in Recommendation ITU-R S.524-9 that were derived using a statistical methodology and using parameters that may not be representative of all FSS networks operating in this frequency band. However, it is noted that other emission levels may be mutually agreed between satellite operators and administrations during network coordination in order to take into account the actual parameters of the respective networks and ensure compatibility.

Under RR No. **5.542** there is an additional allocation to fixed and mobile services on a secondary basis in a number of countries. Therefore, in some geographical areas in Regions 1 and 3, there is a need to manage the potential interference from transmitting ESOMPs into terrestrial receivers operating under the additional secondary allocation in the frequency band 29.5-29.9 GHz. Administrations which notify GSO networks intended to be used by maritime and aeronautical ESOMPs in these frequency bands should ensure that such operations do not cause unacceptable interference to any terrestrial systems operating in the countries listed in RR No. **5.542**. This may be accomplished through consultation between relevant administrations.

The 19.7-20.2 GHz frequency band is the downlink band where the ESOMP receives transmission from the GSO FSS satellite. In this case, the signal transmitted from the GSO FSS satellite would be in the service area and be consistent with the technical parameters submitted by the responsible Administration to the Radiocommunication Bureau. There would be no additional potential interference to other services that operate in this frequency band simply because the transmitted signal is being received by an earth station in motion, i.e. the reception by an ESOMP of a signal that is

---

<sup>1</sup> This Report further elaborates the technical and operational requirements provided in Report ITU-R S.2223 for ESOMPs specifically operating in the sub-bands 19.7-20.2 GHz and 29.5-30.0 GHz.

already being transmitted does not change the interference into other services. Under RR No. **5.524** there is an additional allocation to the fixed and mobile service on a primary basis in a number of countries in the frequency band 19.7-21.2 GHz. As a consequence, receiving ESOMPs cannot claim protection from potential interference caused by terrestrial transmitters operating in accordance with RR No. **5.524**.

### **3 Operational Guidelines**

Satellite tracking and pointing accuracy by ESOMPs are essential requirements for the proper operation of ESOMPs in order to avoid unacceptable interference to adjacent satellites. ESOMPs employ relatively high gain directional antennas with multiple-axis stabilization that allows the signal quality of the link between the earth station antenna and the wanted GSO FSS satellite (and vice-versa) to be appropriate to close the link. To maintain the signal quality and to allow sharing with adjacent satellites it is necessary for these earth stations to maintain high pointing accuracy towards the wanted GSO FSS satellite. Annex 2 describes algorithms that may be employed by earth stations that operate in motion for tracking of the wanted satellite as well as pointing techniques that reduce the possibility of capturing and tracking an adjacent unwanted satellite.

In addition to these capabilities, ESOMPs should be subject to permanent monitoring and control by a Network Control and Monitoring Center (NCMC) or equivalent facility. It should be possible for the NCMC to monitor the operation of an ESOMP to determine if it is malfunctioning. The ESOMP terminal should be capable of receiving and acting upon at least an “enable transmission” and “disable transmission” command from the NCMC. Operators of ESOMPs terminals should have the ability to immediately reduce or cease transmission if the terminal’s antenna mis-pointing would result in exceeding the levels referred to in Annex 1.

### **4 Conclusions**

Administrations that wish to authorize the operation of ESOMPs should take into account the guidelines provided in this Report and ensure the protection of all networks and systems of other services operating in these frequency bands in accordance with the relevant provisions of the Radio Regulations. The notifying administration for the satellite network should require ESOMP operators to provide a point of contact for the purpose of tracing any suspected cases of interference from ESOMPs. Neither the guidelines provided in this Report nor the operation of ESOMPs communicating with FSS GSO space stations operating in the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz create or address any regulatory status for ESOMPs under the Radio Regulations.

## Annex 1

### Off-axis e.i.r.p. density levels for earth station on mobile platforms communicating with geostationary space stations in the fixed-satellite service operating in the frequency band 29.5-30.0 GHz

This Annex provides a set of off-axis e.i.r.p. levels that ESOMPs operating in the frequency band 29.5-30.0 GHz should comply with. However other levels may be mutually agreed between satellite operators and administrations during coordination in order to take into account the actual parameters of the respective networks and ensure compatibility.

ESOMPs communicating with GSO space stations in the FSS transmitting in the frequency band 29.5-30.0 GHz should be designed in such a manner that at any angle<sup>2</sup>,  $\theta$ , which is  $2^\circ$  or more from the vector from the earth station antenna to the wanted satellite (see Figures 1a and 1b below for the reference geometry, compared with that of Recommendation ITU-R S.524-9), the e.i.r.p. density in any direction within  $3^\circ$  of the GSO, should not exceed the following values:

Angle $\theta$	Maximum e.i.r.p. per 40 kHz
$2^\circ \leq \theta \leq 7^\circ$	$(19 - 25 \log \theta)$ dB(W/40 kHz)
$7^\circ < \theta \leq 9.2^\circ$	-2 dB(W/40 kHz)
$9.2^\circ < \theta \leq 48^\circ$	$(22 - 25 \log \theta)$ dB(W/40 kHz)
$48^\circ < \theta \leq 180^\circ$	-10 dB(W/40 kHz)

For any direction in the region outside  $3^\circ$  of the GSO, the above levels may be exceeded by no more than 3 dB. Studies are being conducted which may lead to revision of this value.

NOTE 1 – The values above should be maximal values under clear-sky conditions. In case of networks employing uplink power control, these levels should include any additional margins above the minimum clear-sky level necessary for the implementation of uplink power control. When uplink power control is used and rain fades makes it necessary, the levels stated above may be exceeded for the duration of that period. When uplink power control is not used and the e.i.r.p. density levels given above are not met, different values could be used in compliance with the values agreed to through bilateral coordination of GSO FSS satellite networks.

NOTE 2 – The e.i.r.p. density levels for angles of  $\theta$  less than  $2^\circ$  may be determined from GSO FSS coordination agreements taking into account the specific parameters of the two GSO FSS satellite networks.

<sup>2</sup> It should be noted that the definition of angle  $\theta$  is different to that of angle  $\phi$  contained in Recommendation ITU-R S.524-9. The angle  $\theta$  is introduced to address possible mis-pointing from earth stations on mobile platforms, which is not a consideration in Recommendation ITU-R S.524-9.

NOTE 3 – For GSO space stations in the FSS with which the ESOMPs are expected to transmit simultaneously in the same 40 kHz band, e.g., employing code division multiple access (CDMA), the maximum e.i.r.p. density values should be decreased by  $10 \log(N)$  dB, where N is the number of ESOMPs that are in the receive satellite beam of the satellite with which these earth stations are communicating and that are expected to transmit simultaneously on the same frequency.

NOTE 4 – Potential aggregate interference from ESOMPs operating with satellites using multi-spot frequency reuse technologies should be taken into account in agreements between the GSO FSS satellite operators and their administrations.

NOTE 5 – ESOMPs operating in the frequency band 29.5-30.0 GHz that have lower elevation angles to the GSO will require higher e.i.r.p. levels relative to the same terminals at higher elevation angles to achieve the same power flux-densities (pfd) at the GSO due to the combined effect of increased distance and atmospheric absorption. Earth stations with low elevation angles may exceed the above levels by the following amount:

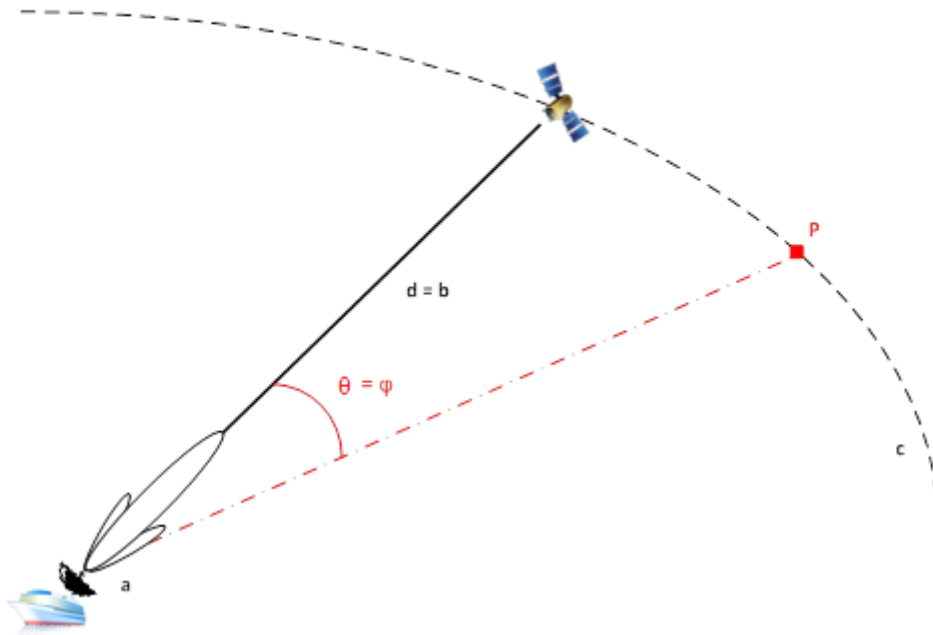
Elevation angle to GSO ( $\epsilon$ )	Increase in e.i.r.p. spectral density (dB)
$\epsilon < 5^\circ$	2.5
$5^\circ < \epsilon \leq 30^\circ$	$3 - 0.1 \epsilon$

Figure 1 below illustrates the reference geometry that is addressed throughout this document<sup>3</sup>. In this figure, “a” represents the earth station that will be in motion and communicating with the wanted GSO satellite. Ideally, using a satellite tracking mechanism, the earth station maintains the pointing of the earth station in the direction of the vector, shown as “d”, from the ESOMP to the wanted satellite. However, due to the motion of the earth station, its antenna could mis-point by an off-axis angle (in the figure depicted as  $\theta$ , as an example) that could cause interference to adjacent GSO satellite networks.

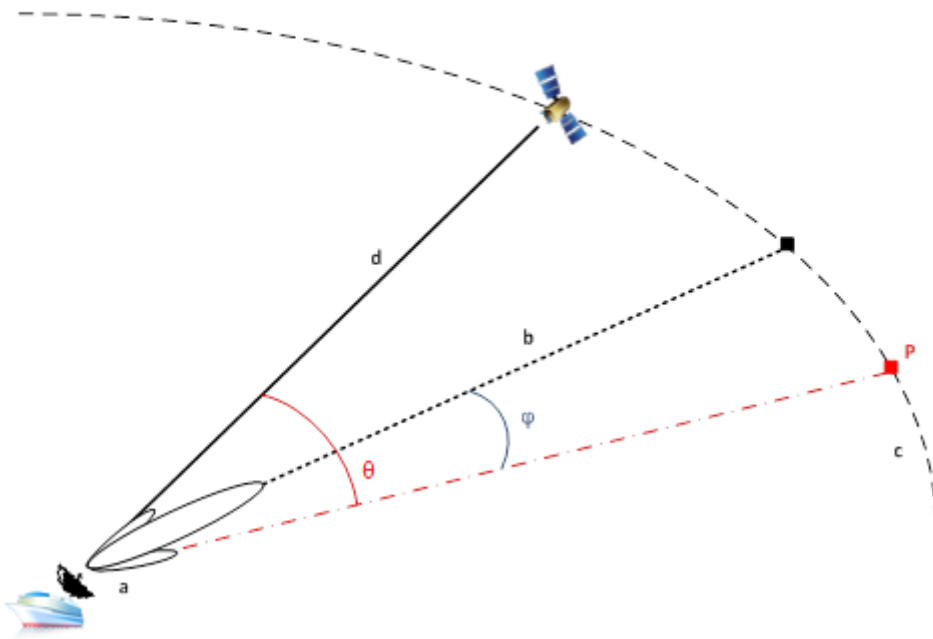
---

<sup>3</sup> In Fig. 1 proportions are illustrative and not to scale.

FIGURE 1  
Reference geometry compared to that of Recommendation ITU-R S.524-9



a)



b)



where:

- a represents the ESOMP;
- b represents the boresight of the antenna;
- c represents the geostationary orbit (GSO);
- d represents the vector from the ESOMP to the wanted satellite;
- $\varphi$  represents the angle between the boresight of the antenna and a point P on the GSO arch;
- $\theta$  represents the angle between the vector d and point P on the GSO arch;
- P represents a generic point on the GSO arc which angles  $\theta$  and  $\varphi$  are referred to.

Figure 1a illustrates that for an ESOMP perfectly pointed to its wanted satellite, the boresight of the antenna and vector d coincide, and angles  $\theta$  and  $\varphi$  are equal. Figure 1b illustrates the case in which the ESOMP is temporarily mis-pointed away from its wanted satellite. In this case, vector d and the boresight of the antenna lie on two different directions, and angle  $\theta$  would be equal to angle  $\varphi$  plus the antenna mis-pointing in degrees. Because of potential mis-pointing, any limit on the e.i.r.p. spectral density is defined with respect to angle  $\theta$  and not to angle  $\varphi$ .

## Annex 2

### Satellite tracking and pointing techniques of earth stations on mobile platforms communicating with geostationary space stations in the fixed-satellite service operating in the frequency band 29.5-30.0 GHz

Earth stations operating while in motion employ relatively high gain directional antennas with multiple-axis stabilization that allows the signal quality of the link between the earth station antenna and the wanted GSO FSS satellite (and vice versa) to be high. To maintain the signal quality it is also necessary for these earth stations to maintain high pointing accuracy towards the wanted GSO FSS satellite. This Annex describes algorithms that may be employed by earth stations that operate in motion for tracking of the wanted satellite as well as techniques that reduce the possibility of capturing and tracking an adjacent satellite.

#### 1 Tracking techniques

There are well-known techniques for antenna tracking of a GSO FSS satellite which can be classified into two categories: those that make use of *open-loop* algorithms and those that make use of *RF closed-loop* algorithms. The following subsections provide a brief description of each of the two types.

##### 1.1 Open-loop pointing technique

An *open-loop* pointing technique employs a process of calculating the azimuth  $A$  and elevation  $E$  based upon the position of the earth station antenna on the earth (i.e., its latitude and longitude, acquired, for example, through a GPS signal) and the nominal longitude of the wanted satellite. The following equations show the relationship between the variables mentioned above:

$$A = \arctan\left(\frac{\tan L}{\sin l}\right) \quad (1)$$

$$\varepsilon = \arctan\left(\frac{\cos \varphi - \frac{R_E}{R_E + R_0}}{\sin \varphi}\right) \quad (2)$$

where:

$l$  : earth station latitude;

$L$  : earth station relative longitude<sup>4</sup>;

$\cos \varphi = \cos l \cos L$ ;

$R_E$ : earth radius;

$R_0$ : altitude of the satellite.

Due to the movement (relative to the earth station) of the GSO FSS satellite within its *station-keeping box*, depending on the width of the main beam of the earth station antenna the azimuth and elevation angles of that antenna might need to be adjusted at consecutive instants in order for the link between the earth station and the satellite not to be deteriorated or – eventually – lost. By employing an *open-loop* pointing strategy, the angles are calculated in advance for each instant by taking into account

---

<sup>4</sup> The relative longitude is defined as the absolute value of the difference from the longitude of the earth station to that of the satellite.

the predicted apparent movement of the satellite. ESOMPs typically operate as part of a network and under control of a network management system. One method employed by network operators is to broadcast satellite ephemeris data as part of a system bulletin board message that is repeated regularly. Earth stations operating in motion may download this updated ephemeris information and use it as part of the pointing solution to maintain accurate pointing toward the satellite over time. This information is then used by the Antenna Control Unit (ACU), as well as information about the orientation of the antenna platform from an inertial reference unit (IRU) to calculate the antenna pointing angles to the satellite.

## 1.2 RF closed-loop tracking technique

The second technique – RF closed-loop tracking – employs an algorithm that minimizes the pointing error by analysis of a pre-determined signal received from the wanted satellite. Since ESOMPs can change their position on the earth continuously and FSS spacecraft move about within their orbital station keeping limits, this technique may be more accurate than the open-loop method. The *RF closed-loop* automatic tracking technique consists in adjusting, at successive steps, the antenna pointing by maximising the strength of a reference signal or a carrier transmitted by the wanted space station. In addition to an accuracy that can be very high (up to  $0.05 \cdot \theta_{3\text{dB}}^5$ ), an advantage of this procedure is its autonomy, since the information used for tracking does not rely on the accuracy of the orbital data of the wanted satellite.

Furthermore, the precision with which the ESOMP points at the wanted satellite can be increased and maintained by an *inertial platform* in which the antenna is installed. Such platforms are equipped with angular rate gyroscopes that can accurately measure the angular speed in pitch, yaw and roll to allow the servo-loops of the ACU to account for the platform's motion.

Figure 2a and Fig. 2b provide example block diagrams for earth station antenna systems using *open-loop* pointing and using *RF closed-loop* tracking, respectively. The figures illustrate the relationships between the different elements composing the typical antenna system used by an ESOMP to perform the pointing and tracking of the wanted satellite network.

---

<sup>5</sup>  $\theta_{3\text{dB}}$  is the 3 dB angular width of the earth station on mobile platform antenna and can be approximated by the following:

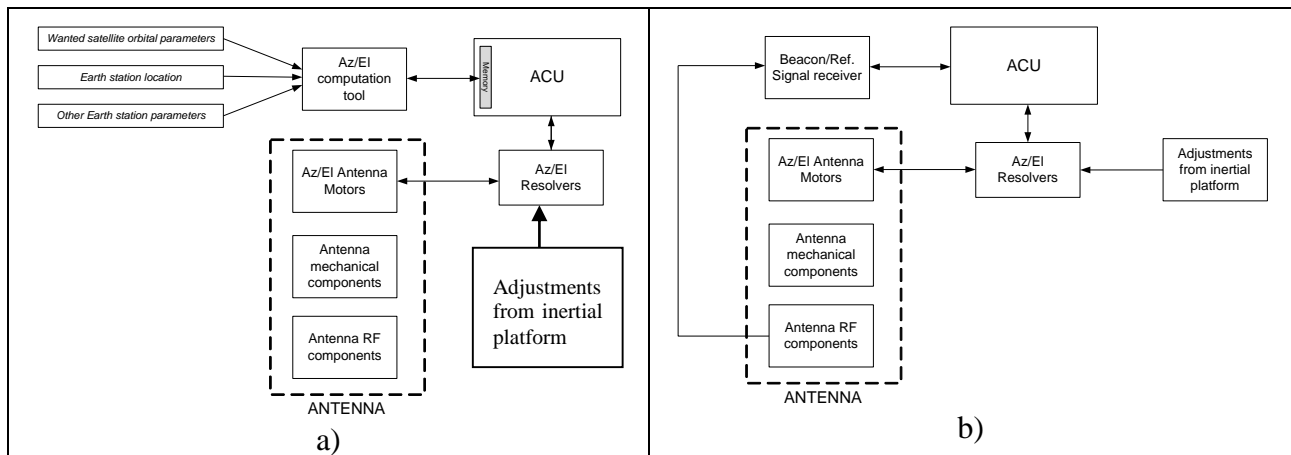
$$\theta_{3\text{dB}} = 70 \frac{\lambda}{D}$$

where:

$\lambda$  : transmission wavelength (m); and

$D$  : is the antenna diameter (m).

FIGURE 2



## 2 Measures to avoid potential harmful interference due to mis-pointing of earth stations on mobile platforms

Meeting the limits specified in Annex 1 of this Report helps to minimize potential harmful interference from mis-pointing experienced by ESOMPs.

Taking into account the pointing accuracy and tracking capabilities of ESOMPs, it is important to develop measures to ensure that GSO FSS satellite networks located near the wanted GSO FSS satellite do not receive harmful interference from these earth stations. This section provides two example measures that can be applied to ensure that ESOMPs comply with the e.i.r.p. density limits specified above.

In the case of the open-loop pointing technique, the maximum mis-pointing of the earth station is determined by design and operational knowledge of wanted GSO satellite station keeping manoeuvres. Satellite ephemeris updates may be communicated to the earth station as necessary and the maximum transmitted e.i.r.p. of the earth station is set accordingly to ensure that the applicable limits are met.

In the case of the *RF closed-loop* tracking technique, the antenna pointing is continuously adjusted by maximising a pre-determined signal received from the wanted satellite. The choice of the signal is up to the satellite operator – some employ a separate carrier, such as a satellite beacon, while others use the same wide band carrier as that used for the forward link. The technical parameters of the signal employed by the RF closed-loop algorithm are important and should be agreed between GSO FSS satellite network operators. This is to ensure that the pointing error to the wanted GSO satellite can be determined instantaneously, so that continuous adjustments to the transmitted e.i.r.p. can be applied, as needed.

In the case of both open and closed loop systems, the terminal ceases transmission if it loses its wanted satellite acquisition.