

RECOMMENDATION ITU-R S.1554

**Methodology for determining the overall
accuracy of $epfd_{\downarrow}$ measurements**

(Question ITU-R 236/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000) adopted a combination of single-entry validation, single-entry operational and, for certain antenna sizes, single-entry additional operational equivalent power flux-density (downlink) ($epfd_{\downarrow}$) limits, contained in Article 22 of the Radio Regulations (RR), along with the aggregate limits in Resolution 76 (WRC-2000), which apply to non-geostationary fixed-satellite service (non-GSO FSS) systems, that protect GSO networks in parts of the frequency range 10.7-30 GHz;
- b) that compliance of a non-GSO FSS system with the single-entry operational $epfd_{\downarrow}$ limits is not subject to verification by the Radiocommunication Bureau;
- c) that administrations with assignments to GSO FSS and/or broadcasting-satellite service (BSS) networks that have been brought into use, as well as administrations with assignments to non-GSO FSS systems that have been brought into use, require reliable means of ascertaining that non-GSO FSS systems are in compliance with the single-entry operational limits referred to in *considering* a);
- d) that $epfd_{\downarrow}$ levels may have to be measured at operational GSO earth stations in order to determine if the operational limits are exceeded,

noting

- a) that Recommendation ITU-R S.1558 is being developed to provide a method for measuring $epfd_{\downarrow}$ levels,

recommends

- 1** that the methodology described in Annex 1 can be used to determine the accuracy of the measurement procedure.

ANNEX 1

Methodology for determining the overall accuracy of $\text{epfd}_{\downarrow}$ measurements**1 Introduction**

WRC-2000 adopted operational epfd limits to protect GSO FSS links from suffering loss of synchronization or degraded performance due to non-GSO systems and to protect GSO FSS systems employing adaptive coding in 30/20 GHz bands.

The non-GSO satellites, due to the geometry of their orbits with respect to the GSO ground antennas, may exceed the operational limits for only short periods of time (s). The operational limits could be measured at earth station locations that suffer loss of synchronization events or degraded performance at an unexpected time (e.g. not obviously caused by a very high rain fade, a sun outage event, or an event caused by equipment failure and/or associated with switch over).

The GSO satellite operator would determine whether the loss of synchronization or degraded performance was due to in-line interference from a non-GSO FSS system into the GSO network. If there is perceived to be a correlation between loss of synchronization or degraded performance and a non-GSO system in-line event, a measurement system would be used at the GSO receive earth station site incurring the losses of synchronization or degraded performance to measure the level of non-GSO interference being experienced by the GSO earth station.

The preferred embodiment of the measurement procedure requires a well-calibrated carrier system monitoring (CSM) earth station in the same beam as the affected earth station. The CSM station provides a calibrated reference level for the affected earth station. It allows the expertise required to perform calibration to be centralized. Additionally, it is desirable to set up an automated measurement system at the affected earth station to reduce the probability of human error affecting the results.

In this Annex the overall accuracy of operational measurements of non-GSO interference is calculated for the preferred measurement procedure.

Acronym list

AWG:	additive white Gaussian
B:	bandwidth
CSM:	carrier system monitoring
DSP:	digital signal processing
IOT:	in-orbit test
LNA:	low noise amplifier
RSS:	root squared sum
S/N :	signal-to-noise ratio
T :	time (s)

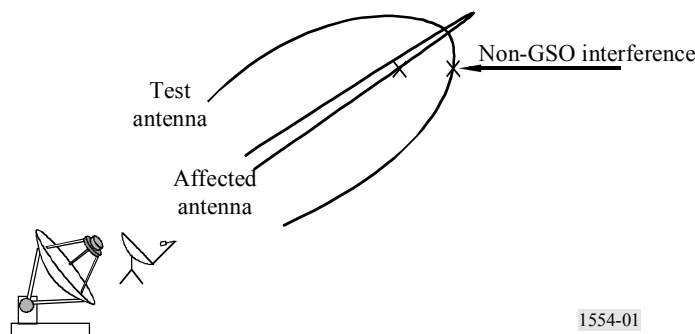
2 Measurement procedure realization using a DSP, spectrum analyser or power meter

The critical concern in accurately measuring the non-GSO interference is system calibration. The calibration equipment may be integrated into the earth station affected by non-GSO interference; calibration can be performed remotely from a CSM station, or a well-calibrated portable system can be brought to the affected earth station site. Additionally, the portable system could be implemented using a scanning antenna. Each system design involves its own set of trade-offs.

In order to measure $\text{epfd}_{\downarrow}$ accurately, one of the straightforward approaches could be to integrate the measurement and calibration equipment into the earth station receiving the interference. However, this approach will require disruption of the GSO service, while the system is integrated and calibrated. Service may be disrupted for several hours. Additionally, service would presumably be disrupted again if the measuring equipment is needed at another earth station site.

A self-contained, portable, test set-up may be the most cost-effective approach. The system would not disrupt GSO operations and calibration measurements could be performed ahead of time. The portable test set-up may require a smaller antenna than the earth station affected by the interference. In this case the wider beamwidth test antenna could receive higher epfd levels from the non-GSO system compared to the affected antenna at small off-axis angles, as shown in Fig. 1.

FIGURE 1
Measurements with a small test antenna and a large earth station antenna



There are two solutions to the problem in Fig. 1. If the direction of the non-GSO interference is known, then the gain difference between the test antenna and affected earth station antenna can be accounted for if the respective antenna patterns are accurately known. Alternatively, the test antenna could track the non-GSO satellite. Additionally, if a large enough tracking antenna is used it will provide discrimination between the GSO signal and the non-GSO interference under test until the non-GSO is in the main lobe of the GSO antenna.

Using a smaller test antenna will yield a lower S/N relative to a larger antenna that is receiving the same signal strength. The lower the received S/N the longer the measurement time required to get the same level of accuracy. Table 1 shows the half power beamwidths and S/N (assuming a

receiver temperature of 200 K), for several different antenna sizes. The S/N correspond to signal levels equal to the operational limit values for a 3 m ($-161.25 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))}$) and 10 m ($-166 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))}$) antenna, respectively.

TABLE 1

Measurement characteristics for different size earth station antennas

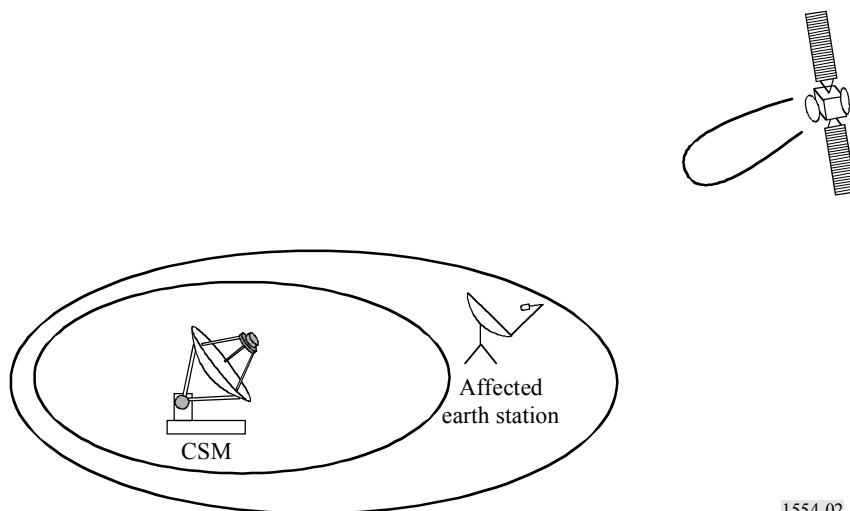
Antenna diameter (m)	Half power beamwidth (degrees)	(Signal level = $-161.25 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))}$) $S/N \text{ (dB)}$	(Signal level = $-166 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))}$) $S/N \text{ (dB)}$
2	1.75	1.4	-3.3
3	0.58	4.5	-0.2
10	0.175	15	10.3

Finally, if a calibrated CSM earth station is available in the same beam as the affected earth station then it can perform the calibration for the affected earth station. The CSM station is very accurately calibrated and can be used to determine the received signal level at the affected earth station.

Figure 2 shows the CSM station and the affected earth station. Notice that the CSM receives the same signal from the satellite as the affected earth station but with a different satellite gain. Since the relative satellite antenna gains in the direction of both earth stations are known (IOT measurements) the CSM station can calibrate the affected earth station receive signal level. This reference level can then be used by the affected earth station to determine its noise and interference levels.

FIGURE 2

CSM configuration providing calibration to an affected earth station



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This Annex focuses on the accuracy of the approach where a CSM station is used to calibrate the affected earth station receive signal level. The measurement procedure is as follows:

- Both the CSM and affected earth station could measure the satellite beacon. The beacon measurement provides a stable well-known signal level that can be used for calibration at the CSM station. It also provides an estimate of the differential between the atmospheric losses at the affected earth station compared to the CSM station.

If the variations in the beacon level due to stability and measurement error are greater than the variation due to atmospheric changes then the beacon measurement may not be valuable. The rest of this Annex assumes that interference measurements are performed in clear sky and the beacon measurements are not factored into the overall accuracy estimate.

It should be noted, however, that in the case of a low Earth orbit (LEO) system where the significant interference occurs near an in-line event the fading on the non-GSO signal can be assumed to be close to that of the GSO system. This implies that the carrier-to-interference level for the link is approximately the same in clear sky and during rain. Thus the true non-GSO interference level should take into account the fade level.

- At the CSM station measure a reference signal. Two sources for the reference signal have been investigated:
 - the reference signal is the earth station carrier affected by interference,
 - the reference signal is a pilot signal transmitted in the guardband adjacent to the affected signal.

Fig. 3 shows the affected signal under test. The guardband shows the pilot that can be used as the CSM reference signal.