|  |
| --- |
| U.S. Radiocommunications SectorFact Sheet |
| **Working Party:** ITU-R WP 5D | **Document No:** USWP5C33-03 |
| **Ref:** Recs. ITU-R F.1108-4, F.758-8 | **Date:** September 22, 2025 |
| **Document Title:** Calculation of fractional degradation of performance (FDP) over smooth earth and over random terrain |
| **Author(s)/Contributors(s):**Kathryn Martin, DoD CIOJennifer Seiler, RKF Engineering for DoD CIOTed Kaplan, RKF Engineering for DoD CIOChristine DiLapi, HII for DoD CIOTanin Izadi, HII for DoD CIOFranz Zichy, HII for DoD CIO | **Email Address:**[kathryn.a.martin23.civ@mail.mil](file:///C%3A%5CUsers%5Cdilapch%5CAppData%5CLocal%5CTemp%5CMicrosoftEdgeDownloads%5C06d6f6d2-3c4e-4fc4-928d-43a0b14fbc1a%5Ckathryn.a.martin23.civ%40mail.mil)[jseiler@rkf-eng.com](file:///C%3A%5CUsers%5Cdilapch%5CAppData%5CLocal%5CTemp%5CMicrosoftEdgeDownloads%5C06d6f6d2-3c4e-4fc4-928d-43a0b14fbc1a%5Cjseiler%40rkf-eng.com) tkaplan@rkf-eng.comchristine.dilapi@hii.comtanin.izadi@hii.comfranz.zichy@hii.com |
| **Purpose/Objective:** Provide equations and a methodology for calculating the FDP over smooth earth and over random terrain, for facilitating the completion of sharing between the fixed service and other services. |
| **Abstract:** This contribution outlines an approach and derives equations for calculating the FDP. FS links are engineered to achieve extremely high availability targets—typically between 99.9% and 99.999%—requiring substantial fade margins (often exceeding 20 dB). Because of these high margins, a long-term criterion that reflects only a small performance degradation does not adequately capture the impact on service availability. In contrast, the FDP directly measures the effect of both short-term and long-term interference on link availability. This paper does not consider the effects of power control or ACM. |

|  |  |
| --- | --- |
| **Radiocommunication Study Groups** | Logo  Description automatically generated |
|  |  |
|  |  |
| Received: Xx Yyyy 2025Subject: Recs. ITU-R F.1108, F.758 | **Document US5C-03** |
| **11 July 2025** |
| **English only** |
| United States of America |
| Calculation of fractional degradation of performance (FDP) over smooth earth and over random terrain |

Introduction

Recommendation ITU-R F.758-8 defines error performance and availability objectives for FS links. For interference from co-primary sources, the total degradation in these objectives — considering both short-term and long-term interference — should be limited to 10% of the performance and availability criteria of the FS system. For interference from **non-co-primary sources** F.758-8 allows the total degradation to be **no more than 1%** of the FS system’s performance objectives.

FS links are designed to meet very high availability targets typically between 99.9% (unavailability=0.1%) and 99.999% (unavailability=0.001%). For a link with availability of 99.999% for example, F.758-8, allows a co-primary user to increase the link unavailability by up to 10 to 0.0011% reducing the availability to 99.9989%.

Recommendation ITU-R F.758-8 references Recommendation ITU-R F.1108-4 for the calculation of the Fractional Degradation of Performance (FDP), which defines the change in unavailability (limited to 10% for co-primary operation). A detailed derivation of FDP can be found in Attachment A.

This derivation applies to frequencies below 10 GHz, where FS system degradation is primarily driven by multipath fading, which can be treated as independent of environmental interference. At higher frequencies where rain fade dominates the interference and rain fade are correlated. This derivation does not consider the use of power control or adaptive coding and modulation in FS systems.

The purpose of this contribution is to invite further discussion of the derivation of FDP, with a longer term view of potentially revising the above-mentioned F-Series Recommendations or initiating the development of a draft new Report or Recommendation on this topic.

## Simulations to assess the FDP criterion

The FDP is a critical metric as it measures FS service degradation. When designing systems, FS operators assess the clear-sky link budget and determine the link margin needed to achieve their availability targets. Antennas and amplifiers are then selected to meet these targets, and customers expect those targets to be consistently maintained.

### 1.1 Smooth earth assumption

This section outlines the procedure for calculating the FDP under the assumption of smooth-earth terrain. The method requires estimating the probability density functions (pdfs) of both the environmental fade degradation and the aggregate interference at the FS receiver. The fade degradation pdf can be derived from ITU-R Recommendation P.530, taking into account the FS link parameters such as antenna heights and the transmitter–receiver separation. The corresponding cumulative distribution function (CDF) indicates the fade margin required to achieve a target link availability, or conversely, allows estimation of the availability for a given fade margin.

The interference distribution is obtained through a Monte Carlo simulation. The simulation may incorporate random factors influencing aggregate interference, including emitter deployment strategy, deployment density, antenna orientation, transmit power variability, propagation loss variations, and nearby clutter. To capture the extreme tails of the distribution, the simulation must be run with sufficient iterations. For example, assessing a link with 99.999% availability (0.001% unavailability) requires more than one million iterations.

The resulting aggregate interference pdf is mapped to link degradation using:
 **Link degradation = 10·log₁₀((I + N)/N)**,
where *N* is the receiver noise power.

The combined effect of fading and interference is obtained by convolving (in dB) the fade margin pdf with the interference degradation pdf. Since fading and interference are statistically independent, their convolution yields the joint pdf of total degradation. This distribution is then used to determine the FDP.

Attachment A separates this convolution into two components:

* **Short-term component** – the probability that interference degradation alone exceeds the fade margin, even without fading.
* **Long-term component** – the conditional probability that interference is below the margin, but the combined effect of multipath fading and interference still exceeds the fade margin.

Detailed equations are provided in Attachment B.

## FDP Analysis Over Random Terrain

Evaluating FDP across random terrain introduces additional complexity beyond the smooth-earth case. Both aggregate interference and multipath fading pdfs are impacted by changes in terrain profile. The multipath fading pdf varies with the terrain height where the FS stations are located, and aggregate interference varies due to terrain interactions. Assuming the path profiles are uncorrelated, the calculation proceeds as follows:

1. Per-Profile Analysis
	* For each terrain path the aggregate interference degradation pdf and the multipath fade pdf are calculated as described above.
	* For each path profile, the FS link geometry (antenna heights, pointing direction, and link distance) is held constant; only terrain heights vary.
2. Fade Margin Ensemble
	* Generate the fade ensemble pdf over all terrain paths by numerically convolving the individual multipath fade pdfs.
	* Convert the resulting pdf to dB and apply a shift of –10 × log(number of paths).
	* This yields the pdf of the ensemble-average of the multipath fade across all terrain profiles, from which the fade margin required to achieve the link availability can be determined.
3. Interference Ensemble
	* Generate the interference ensemble pdf over all terrain paths by numerically convolving the individual aggregate interference degradation pdfs.
	* Convert the result to dB and shift by –10 × log(number of paths).
	* This yields the pdf of the ensemble-average of the aggregate interference across all terrain profiles.
4. Final FDP Calculation
	* Convolve the ensemble fade margin pdf with the ensemble interference degradation pdf (both in dB).
	* Compare the resulting pdf to the ensemble fade margin pdf from Step 2 to determine the increase in link unavailability.

attachment A

Derivation of Fractional degradation in performance (FDP)

In this derivation no account is taken of Automatic Power Control (ATPC) or Adaptive Coding and Modulation (ACM). The FS link design is based on a reference modulation and the FDP is calculated relative to this reference modulation. ATPC isn’t accounted for as it can be turned off and there is no information as to whether IMT interference does or does not trigger the ATPC mechanism.

Figure B-1 shows a plot of the received signal-to-noise ratio (SNR) for an FS, without ATPC. The SNR\_RMC (reference measurement channel) is defined as the SNR which results in severely errored seconds (SES) at the target link modulation. This is the design modulation of the link and defines the availability objectives for that link. The fade margin (FM) is the clear sky margin required to achieve the target link availability.



Figure B-1: ATPC Threshold and ATPC Range 1

The full interference probability distribution shall be considered in the total degradation. The total apportionment of error performance objectives (EPOs) derived from the fractional degradation of performance (FDP) from long and short-term interference should not exceed 10%; (co-primary services).

The following derivations assume that fading and interference events are statistically independent. However, in a rain dominated environment (>10 GHz) the fading on the desired and interfering paths could be correlated. The correlation will depend on the lengths of interfering and desired paths.

As described in ITU-R Rec. F.1108 the FDP is given by

 = (1)

Where:

* Po,0= is the probability of outage due to fading only.
* =
* is the fade in dB
* = the fade probability density function calculated using ITU-R P.530, defined from to .
* FM is the Fading Margin in dB estimated based on Rec. P.530 according to the Performance Objectives (EPO) parameters.
* Po,i =The probability of outage from fading and interference and is given by the joint probability in equation 2. This is written in a format that was derived in F.1108.

 (2)

Where:

* , and is the numerical interference to noise ratio in linear scale,
* is the probability density function of the interference to noise ratio distribution and its support is from to
* FDP >0

The FDP equation can be divided into two components, a short-term and long-term:

*FDP= FDPLT +FDPST*  (3)

Where,

* FDPST = The short-term fractional degradation in performance occurs when the interference degradation exceeds the FM. This is referred to as short-term degradation because high levels of interference occur with low probability.
* FDPST = (4)
* FDPLT = The long-term fractional degradation in performance occurs when the interference degradation is less than the FM, but the combination of fading and interference exceed the FM. It is referred to as long-term because low levels of interference occur with higher probability.
* FDPLT = (5)
* is the joint probability of outage from fading and interference when the interference degradation is greater than or equal to the FM (or and  and is given by:

(6)