FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 23569

ISO/TC **20**/SC **14**

Secretariat: ANSI

Voting begins on:
2021-09-02

Voting terminates on:
2021-10-28

Space systems — Spacecraft system level radio frequency (RF) performance test in compact range

Systèmes spatiaux — Essai de performance des radiofréquences (RF) dans une gamme compacte au niveau du système de l'engin spatial

Reference number
ISO/FDIS 23569:2021(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

System level test for RF performance of spacecraft, which is the test for spacecraft expected performance on orbit, includes test of EIRP, *G*/*T*, SPFD, AFR, group delay, PIM, etc. In some conditions, it also includes verification of the antenna pattern on two crossed planes (normally the antenna pattern is measured in unit level and subsystem level; if it is necessary to measure in system level, the antenna pattern on two crossed planes would be chosen for verification purpose). Compact range is suitable for spacecraft full-link RF performance test, which includes uplink and downlink.

Currently there are well-defined requirements for acceptance test of integrated spacecraft as final RF performance verification tests, especially for commercial communication spacecraft. RF performance test for the payload system (including the transponder and Tx/Rx antennas) is becoming more and more important and should be verified before launch. At present, the system level RF performance test has become one important step listed in the spacecraft production flow. It is carried out to verify whether there is unexpected variation during the assembling of the spacecraft and whether the RF performance in coverage area (footprint) can satisfy the specification.

According to ISO 15864, the system level RF performance test items have been identified as necessary functional performance parameters in acceptance tests, so they can be tailored to the test requirement for each kind of spacecraft or test plan.

Space systems — Spacecraft system level radio frequency (RF) performance test in compact range

1 Scope

This document specifies the verification test activities for assessing the RF performance of integrated spacecraft, including test items, test requirements, and typical test procedures, test facility and chamber environment, with respect to the testing using compact range. This document is applicable to the RF performance test for spacecraft at system level using compact range.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
nominal plane wave axis of compact range
NPA
axis of propagation of a single plane wave generated by the compact range reflector

3.2
effective free space distance in compact range
R
equivalent distance from the feed, where spherical attenuation exists

4 Abbreviated terms

AFR	amplitude-frequency response
AM	amplitude modulation
CR	compact range
DUT	device under test
EIRP	effective isotropically radiated power
EM	electrical model
FM	frequency modulation
G/*T*	ratio of gain-to-noise temperature (quality factor of spacecraft receiving system)
PIM	passive intermodulation

QZ quiet zone

RBW resolution bandwidth

RF radio frequency

Rx receive

SERAP serration radiation protection structure

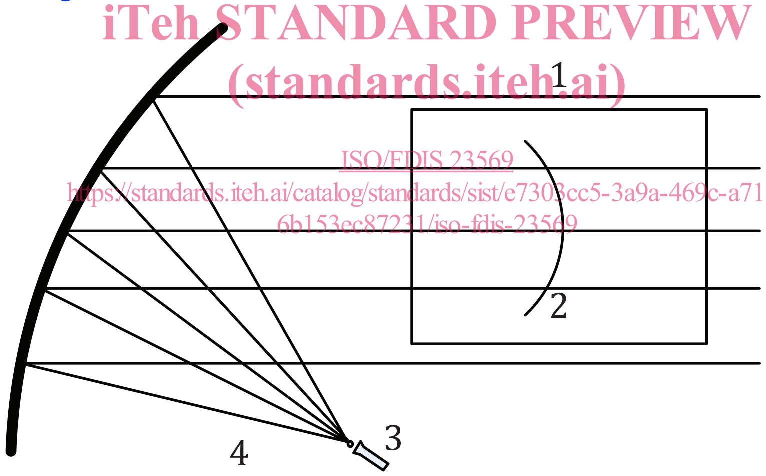
SPFD saturated power flux density

Tx transmit

CW continuous wave

5 Test facility

According to Reference [1], the compact range is one in which the test antenna is illuminated by the collimated energy in the aperture of a larger point or line focus antenna. For example, a precision paraboloidal antenna can be used to collimate the energy, as shown schematically in Figure 1, it is more suitable for test antenna; a precision dual reflector antenna can be used to collimate the energy also, like Cassegrain dual reflector antenna which is more suitable for the spacecraft system level test, as shown schematically in Figure 2.



Key

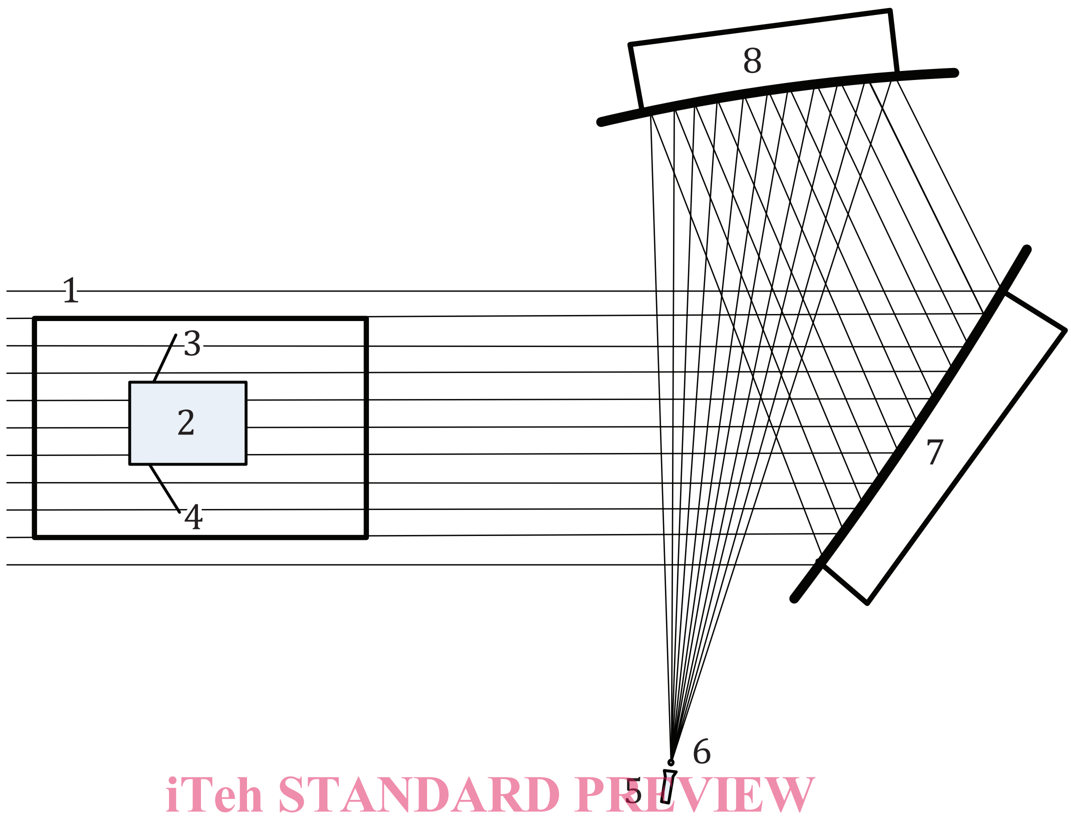
1 quite zone (QZ)

2 test antenna

3 range Tx/Rx feed

4 focal point

Figure 1 — Schematic representation of a compact range using a reflector and feed



Key

1 quite zone (QZ)
2 spacecraft
3 Tx/Rx antenna
4 Tx/Rx antenna
5 range Tx/Rx feed
6 focal point
7 main reflection
8 subreflector

Figure 2 — Schematic representation of a compact range using a dual reflector and feed

The test facility is mainly composed of a range illuminating subsystem, a positioner subsystem, an anechoic chamber and RF test instruments.

The range illuminating subsystem, which includes the range reflector and the range feeds, shall be able to provide the plane wave with flatter amplitude and phase distribution in the QZ. The alignment between the range reflector and the range feed can be done annually or biennially; the nominal plane wave axis of compact range (NPA) direction can be shown (by cubic mirror or others). The reflector shall have sufficient accuracy.

The positioner subsystem, which includes the DUT positioner and the range feed positioners, shall be able to rotate the DUT and range feeds with sufficient accuracy. Due to the heft of the DUT, the DUT positioner can be equipped with counter weight for balance.

The anechoic chamber, which is covered with several types of absorbing material, can provide test environment with low reflectivity.

As part of the test facility, related RF instruments shall be provided, to produce uplink RF signal and to measure downlink RF radiating signal of the DUT, the standard RF instruments are listed in Table 1. The frequency range, linearity and dynamic range of the RF measurement system shall satisfy the test requirements. Part of the measurement equipment that makes up the test facility can be calibrated periodically or in advance of the test by a national metrology institute.

Table 1 — Standard RF instruments

No.	Name of instrument	Function	Applicated test item
1	Source	Produce uplink transmitting signal.	EIRP, *G*/*T*, SPFD, AFR Group delay Two sources are needed for PIM test item.
2	Spectrum analyser	Monitor the downlink receiving signal and spectrum; Measure the power of downlink receiving signal.	EIRP, *G*/*T*, SPFD, AFR, PIM
3	Power meter	Measure the power of downlink receiving signal.	EIRP, SPFD
4	Fixed attenuator	Reduce the power of downlink signal or Reduce the power of uplink signal.	EIRP, *G*/*T*, SPFD, AFR, PIM
5	Coupler	Couple a part of power from path.	EIRP
6	Power hybrid	Combine the signals of two paths with different frequencies into one path.	PIM
7	AM or FM modulation signal generator	Produce the AM or FM modulation signal which will be carried by uplink and downlink signal.	Group delay
8	Down converter	Convert the downlink signal to lower frequency.	Group delay
9	Modem	Demodulate the downlink signal to get the AM or FM modulation signal.	Group delay
10	Modulation domain analyser	Compare the two AM or FM modulation signal, one is carried by uplink signal, another is carried by downlink signal, to get the related time delay.	Group delay
11	Data acquisition computer	Run automatically controlled by computer software to complete the data acquisition.	AFR

6 Test requirement

6.1 System level RF performance test

When the spacecraft system is very complex, system level RF performance test should be planned based on the specifications and listed in the spacecraft production flow. The following preparations should be considered:

a) DUT test scheme, such as which channel and how many channels will be tested;

b) goal budget of EIRP, *G*/*T*, SPFD for spacecraft system;

c) installation of the DUT self-alignment target which will be in accordance with the NPA;

d) installation of wind pipes for spacecraft heat dissipation, if necessary;

e) installation of additional humidifier/dehumidifier for special sensitive payload, if necessary;

f) provision of a suitable adapter as interface between spacecraft and the DUT positioner.

6.2 RF performance test in compact range

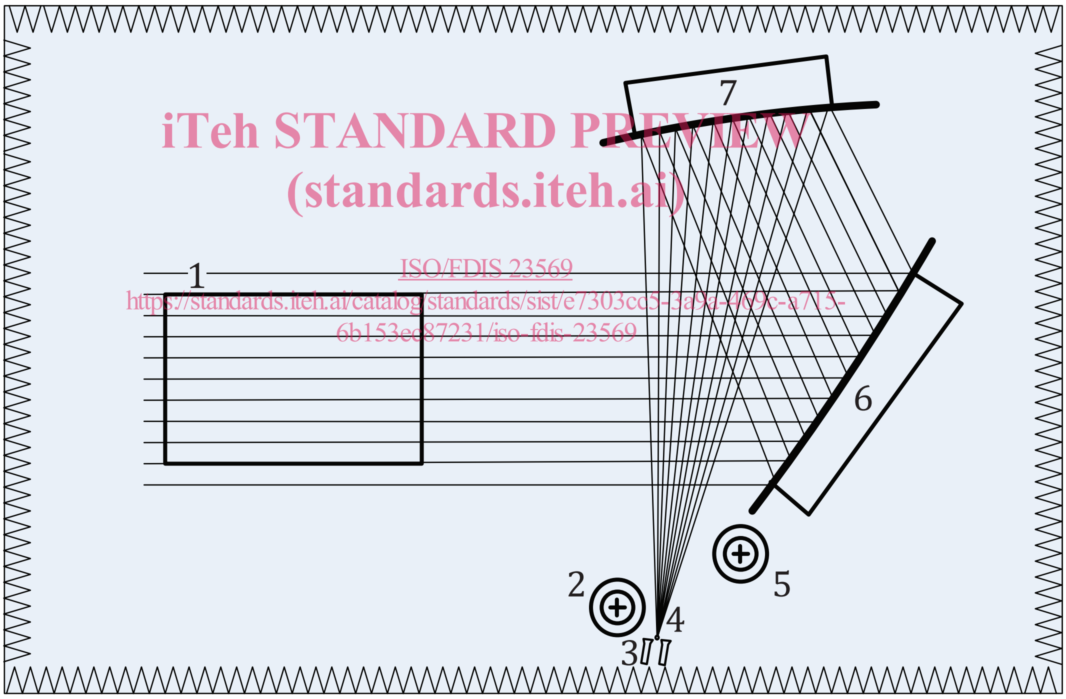
In order to verify whether the final RF performance can satisfy the specification, and to perform the RF tests, the compact range system should fulfil the following conditions for either facility or customer's equipment.

a) The QZ quality needs to consider the customer’s requirement.

b) The DUT positioner’s maximum bending moment shall be strong enough for spacecraft holding. Based on the DUT’s weight and centre of gravity, the positioner’s counter weight can be calculated. Both of the positioner’s elevation and azimuth axes should be balanced with counter weight, so as to maintain the rotated angle accuracy.

c) The range reflection sources should be reduced. High-performance absorbing material should be placed between the feed and the DUT to further reduce the effects of the diffraction from the feed structure. It also helps to suppress any direct radiation from the feed antenna to the test region.

If the compact range has baffle or SERAP, position the baffle in the line-of-sight between the feed and the QZ to reduce stray radiation directed to the QZ; and position the SERAP in an appropriate place to prevent the feed from illuminating the main reflector serrations. The position of baffle or SERAP in compact range is shown in Figure 3.



Key

1 quite zone (QZ)
2 baffle
3 range Tx/Rx feed
4 focal point
5 SERAP
6 main reflector
7 subreflector

Figure 3 — Schematic of baffle and SERAP’s position

d) The spacecraft’s support structure shall be covered with absorbing material, so as to reduce additional reflection as far as possible.

e) In the anechoic chamber, the range feed local area shall be covered with high power absorbing material, because the spacecraft downlink is high power transmitting state, this area shall withstand high power, if necessary. The temperature of this area shall be monitored during the test.

Also, the range reflector local area shall be maintained in stable temperature state by running the air-condition system continually if necessary, depending on manufacturer's requirement, so as to maintain stable QZ performance.

f) The capability of crane and hook need to consider the requirement of spacecraft lifting.

g) The electrical isolation / grounding should be available.

Normally, three grounding terminals isolated from each other can be prepared, and separately connected to spacecraft surface, test instrument, and any other test equipment temporarily used in the chamber.

h) The earth resistances need to consider the customer's requirement.

i) Because of the high-power level in spacecraft system level test, the hazard areas should be identified with warning plates and / or warning lamps at any personnel gate.

j) Calculate the RF link budget.

k) Do self-calibration for the RF equipment before each absolute value test if necessary, e.g. using a power meter for absolute power test.

l) Do RF-cable loss calibration, if necessary.

m) Prepare the gain calibration data of the range feeds.

n) Prepare the antenna pattern data measured in subsystem level EM/RM (radiation mock-up).

7 Test item

RF performance test items described in this document refer to tests of EIRP, *G*/*T*, SPFD, AFR, group delay and PIM.

RF performance test items are tailored to the test requirement for each kind of spacecraft or test plan. The channels selected to be tested depend on the test requirement.

To verify the spacecraft's uplink performance, *G*/*T* and SPFD shall be tested. The spacecraft body together with the Rx antennas shall be located in the QZ, while the Tx range feed shall be located at the focus of the range reflector.

To verify the spacecraft's downlink performance, EIRP shall be tested. The spacecraft body together with the Tx antennas shall be located in the QZ, while the Rx range feed shall be located at the focus of the range reflector.

To verify the spacecraft's full link performance, AFR and group delay shall be tested. For the AFR test, the spacecraft body together with the Tx antennas or the spacecraft body together with the Rx antennas shall be located in the QZ, while the Rx or the Tx range feed shall be located at the focus of the range reflector, depending on whether output AFR or input AFR will be tested. For the group delay test, the spacecraft body together with the Tx antennas and Rx antennas shall be located in the QZ, if the size of the QZ is not enough to support the full link wireless test, this group delay test item will be tailored.

For a spacecraft antenna system which shares Rx/Tx signals, the PIM components of the spacecraft's downlink transmitting signal may go directly to the uplink channels. If PIM frequencies are within the spacecraft's uplink receiving frequency band, PIM shall be tested. The spacecraft body together with the Tx antennas shall be located in the QZ, while the Rx range feed shall be located at the focus of the range reflector.

The EIRP, SPFD and PIM test need to be done in saturation state, which means spacecraft's uplink is saturated. The saturation point can be determined by several methods, such as power/gain method, AM number method, and by monitoring the telemetry parameters of spacecraft's amplifier.

8 RF performance test methods

8.1 EIRP test

8.1.1 Test purpose

The purpose of the EIRP test is to measure and to evaluate EIRP values at the beam peak and/or at a typical point in the spacecraft downlink coverage area (footprint), and to verify whether the EIRP values can satisfy the goal budget and specifications. By combining the antenna pattern measured in subsystem level EM/RM (radiation mock-up) and the system level measured EIRP values at the beam peak and/or at a typical point, the EIRP coverage pattern can be obtained.

If necessary, a verification of the spacecraft's Tx or Tx/Rx antenna radiation pattern can also be done on two crossed planes in coverage area by using the downlink EIRP setup.

8.1.2 Test principle

In compact range, the spherical wave from the range feed is reflected by the reflector, as a plane wave, to the QZ, wherein the spacecraft is located, then the equivalent spacecraft to earth RF link can be used for system level RF performance test. The distance from the range feed to the reflector and then to the QZ, is the effective free space distance in compact range, R; this value depends on the design of compact range.

Based on the reciprocity of compact range, spacecraft's downlink signal, Tx, is reflected by the range reflector and goes back to the range feed, wherein R is the same. The EIRP can be obtained by measuring the Rx signal received by the range feed. The EIRP can be calculated by Formulae (1), (2) and (3).

$$Q_{\mathrm{EIRP}} = G_{\mathrm{Tx,sat}} \cdot P_{\mathrm{Tx,sat}} \quad (1)$$

$$Q_{\mathrm{EIRP}} = \frac{P_{\mathrm{Rx,CR}} \cdot L_{\mathrm{p,down}}}{G_{\mathrm{Rx,CR}}} \quad (2)$$

$$L_{\mathrm{p,down}} = \left(\frac{4\pi R}{\lambda_{\mathrm{down}}} \right)^2 \quad (3)$$

where

$L_{\mathrm{p,down}}$ is the free space loss for the downlink signal;

R is the effective free space distance in compact range, m;

$P_{\mathrm{Rx,CR}}$ is the received power measured at the output port of the range feed, W;

$G_{\mathrm{Rx,CR}}$ is the gain of Rx range feed.

8.1.3 Illustrative test procedure

Two illustrative procedure examples for the EIRP test are provided in Annex A. The EIRP can be measured by two methods: with full wireless link setup or with wireless downlink setup. The procedure to be used depends on the test requirement and whether the size of QZ can satisfy the full link setup.

8.2 *G*/*T* -test

8.2.1 Test purpose

The purpose of the gain-to-noise temperature ratio, G/T, test is to measure and to evaluate G/T values at the beam peak and/or at a typical point in the spacecraft's uplink coverage area (footprint). The test results show whether the G/T values can satisfy the goal budget and specifications. The G/T coverage pattern can be obtained by combining the antenna pattern measured in subsystem level EM/RM (radiation mock-up) and the system level measured G/T values at the beam peak and/or at a typical point.

8.2.2 Test principle

As described in 8.1.2, the spacecraft is located in the QZ and illuminated by the plane wave. R is known and depends on the design of the compact range.

The G/T can be measured in two different modes: the fixed gain mode and the automatic level control (ALC) mode. The ALC mode requires one more step in the data acquisition compared with the fixed gain mode. The major difference between these two modes is that the output power level varies with the input power level in the fixed gain mode, whereas the output power level is constant in the ALC mode.

a) G/T in the fixed gain mode is obtained from three sequential power level measurements:

1) noise power level, P_1, of the receiving test equipment, while the spacecraft transponder is turning off, the RF output of range source is turning off also;

2) noise power level, P_2, of the receiving test equipment, including the spacecraft noise level, while the spacecraft transponder is turning on, the RF output of range source is turning off;

3) power level, P_3, of the receiving test equipment, including the spacecraft noise level and carrier power level, while the spacecraft transponder is turning on, the RF output of range source is turning on also.

Then G/T can be calculated by Formulae (4), (5) and (6):

$$r_{G/T} = \frac{k \cdot B \cdot L_{\mathrm{p,up}} \cdot (Y_2 - 1) \cdot Y_1}{Q_{\mathrm{EIRP,Tx,CR}} \cdot (Y_1 - 1)} \quad (4)$$

$$Y_1 = P_2 / P_1 \quad (5)$$

$$Y_2 = P_3 / P_2 \quad (6)$$

where

k	is the Boltzmann constant, J/K;
B	is the noise bandwidth corresponding to the test bandwidth, Hz;
$L_{\mathrm{p,up}}$	is the free space loss for the uplink signal;
$Q_{\mathrm{EIRP,Tx,CR}}$	is the EIRP of the Tx range feed, W.

The detailed derivation for Formulae (4) and (7) can be found in Annex G.

b) The G/T in the ALC mode is obtained from four sequential power level measurements:

1) power level, P_a, of the receiving test equipment, including the spacecraft noise level and carrier power, while the spacecraft transponder is turning on, the RF output of range source is turning on also;

2) noise power level, P_b, of the receiving test equipment, including the spacecraft noise level (same setup as, P_a, measurement), while the spacecraft transponder is turning on, the RF output of range source is turning off;

3) power level, P_c, of the receiving test equipment, including the spacecraft noise level and carrier power (same setup as P_a measurement, but EIRP at Tx range station is different);

4) noise power level, P_d, of the receiving test equipment, including the spacecraft noise level (same setup as P_c measurement), while the spacecraft transponder is turning on, the RF output of range source is turning off;

Then G/T can be calculated by Formula (7).

$$r_{G/T} = \frac{k \cdot B \cdot L_{\mathrm{p,up}}}{P_{\mathrm{d}} - P_{\mathrm{b}}} \cdot \left[\frac{P_{\mathrm{c}} - P_{\mathrm{d}}}{Q_{\mathrm{EIRP,Tx,CR,2}}} - \frac{P_{\mathrm{a}} - P_{\mathrm{b}}}{Q_{\mathrm{EIRP,Tx,CR,1}}} \right] \tag{7}$$

where

k is the Boltzmann constant, J/K;

B is the noise bandwidth corresponding to the test bandwidth, Hz;

$L_{\mathrm{p,up}}$ is the free space loss for the uplink signal;

$Q_{\mathrm{EIRP,Tx,CR,1}}$ is the EIRP at Tx range station, when P_a and P_b are measured, W;

The detailed derivation for G/T formulae can be found in Annex G.

8.2.3 Illustrative test procedure

Two illustrative procedure examples for the G/T-test are provided in Annex B. Both the G/T-test with fixed gain mode and G/T-test with ALC mode can be measured by two methods: with full wireless link setup or with wireless uplink setup. The procedure to be used depends on the test requirement and whether the size of QZ can satisfy the full link setup.

8.3 SPFD test

8.3.1 Test purpose

The purpose of the saturated power flux density (SPFD) test is to measure and to evaluate SPFD values at the beam peak and/or at a typical point in the spacecraft uplink coverage area. The test results show whether the SPFD values can satisfy the goal budget and specifications.

If necessary, a verification of the spacecraft's Rx antenna radiation pattern should be performed on two crossed planes in coverage area with uplink SPFD setup.

8.3.2 Test principle

As described in 8.1.2, the spacecraft is located in the QZ, and illuminated by the plane wave. R is known and depends on the design of compact range.