INTERNATIONAL STANDARD

ISO 23569

First edition
2021-11

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 23569:2021(E)

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Foreword

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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 terminology 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

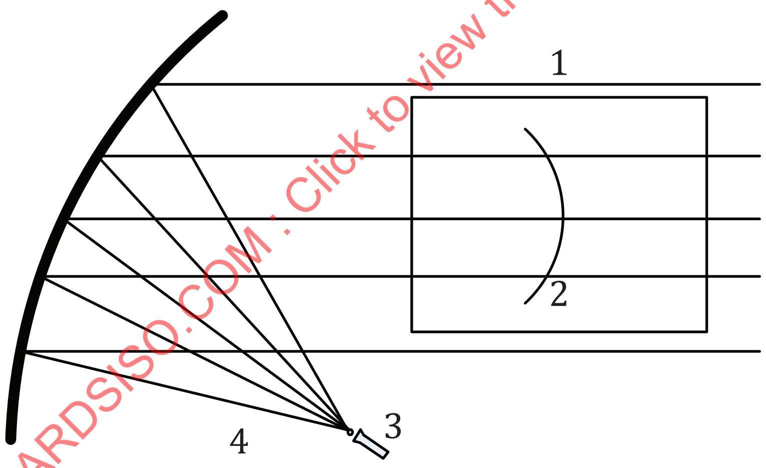
4 Abbreviated terms

AFR	amplitude-frequency response
AM	amplitude modulation
ALC	automatic level control
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

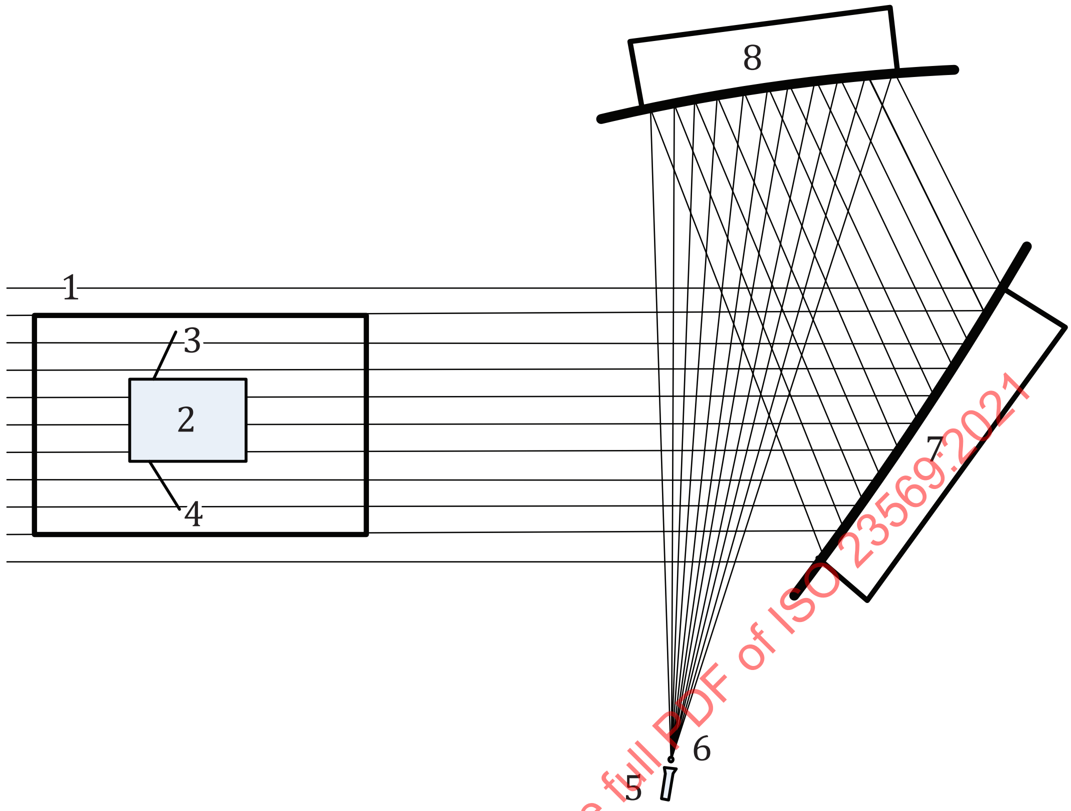
1 quiet zone (QZ)

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 quiet 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

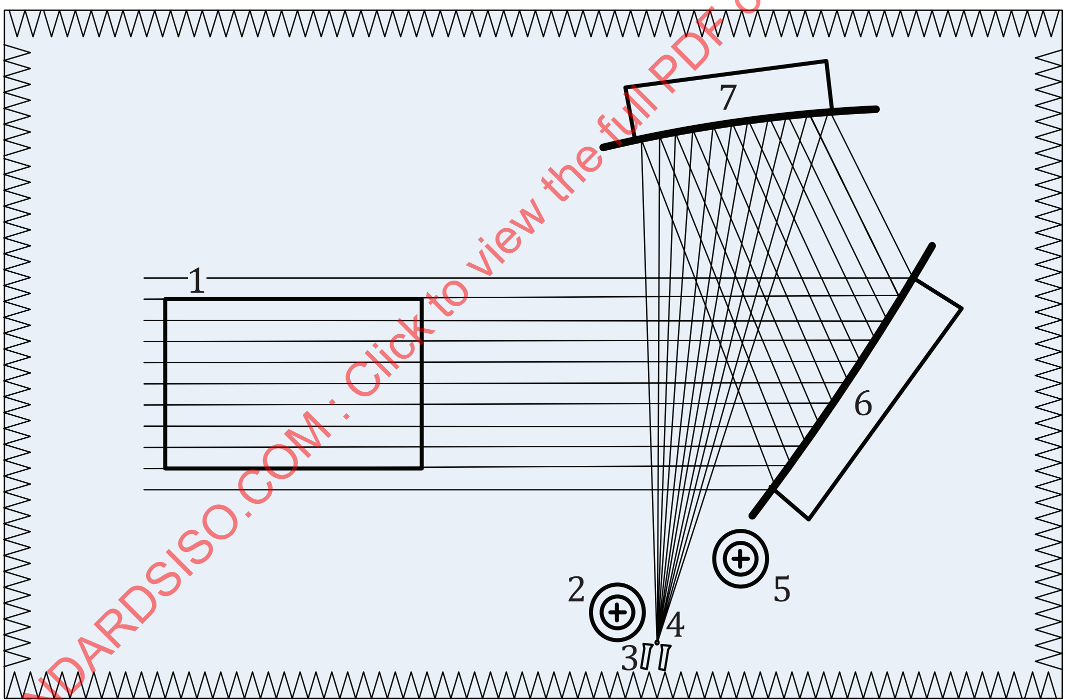
In order to verify whether the final RF performance can satisfy the specification, and to perform the RF tests, the compact range system should fulfil the following conditions for either facility or customer's equipment.

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 quiet 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).

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

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

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

where

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

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

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

$G_{\text{Rx,CR}}$ 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):

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

$$Y_1 = P_2 / P_1 \tag{5}$$

$$Y_2 = P_3 / P_2 \tag{6}$$

where

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

$$r_{G/T} = \frac{k \cdot B \cdot L_{p,up}}{P_d - P_b} \cdot \left[\frac{P_c - P_d}{Q_{EIRP,Tx,CR,2}} - \frac{P_a - P_b}{Q_{EIRP,Tx,CR,1}} \right] \quad (7)$$

where

k is the Boltzmann constant, J/K;

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

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

$Q_{EIRP,Tx,CR,1}$ 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.

The SPFD presents the received power density value at the spacecraft Rx antenna in a certain direction. Usually SPFD is measured with the output amplifier of the spacecraft in its saturated point. So SPFD can be calculated by Formula (8):

$$B_{\text{SPFD}} = P_{\text{Tx,CR}} \cdot G_{\text{Tx,CR}} \cdot \left(\frac{1}{4\pi R^2} \right) \tag{8}$$

where

$P_{\text{Tx,CR}}$ is the Tx power at Tx range feed, W;

$G_{\text{Tx,CR}}$ is the gain of Tx range feed;

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

$1/4\pi R^2$ is identical to space distribution factor, m^{-2}.

8.3.3 Illustrative test procedure

Two illustrative procedure examples for the SPFD test are provided in Annex C. The SPFD 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 the QZ can satisfy the full link setup.

8.4 AFR test

8.4.1 Test purpose

The purpose of amplitude-frequency response (AFR) test is to measure and to evaluate AFR curves near the beam peak of the spacecraft uplink or downlink coverage area. The test results show whether the AFR is flat enough to satisfy the specifications.

8.4.2 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.

Set the spacecraft's uplink and downlink to make it operate in linear state, and change the frequency of the range source with each specific step to get the amplitude-frequency performance curves.

8.4.3 Illustrative test procedure

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

8.5 Group delay test

8.5.1 Test purpose

The purpose of the group delay test is to measure and to evaluate group delay response curves near the beam peak of the spacecraft uplink or downlink coverage area. The test results show whether the group delay response curves can satisfy the specifications.

8.5.2 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.

Set the uplink and downlink of the spacecraft to make it operate in linear state, down convert and de-modulate the downlink signal with modulation. The absolute delay in test frequency point can be obtained by comparing the resulted signal with the original modulated signal. The group delay curve in test band is obtained by changing the test frequency of the range source with each specific step.

8.5.3 Illustrative test procedure

The illustrative procedure example for the group delay test is provided in Annex E. The group delay test only can be done in full link wireless setup, if the size of the QZ is not enough to support the full link wireless test, this group delay test item will be tailored.

8.6 PIM test

8.6.1 Test purpose

The purpose of passive intermodulation (PIM) test is to measure and to evaluate PIM values at the beam peak and/or typical point in the spacecraft uplink coverage area. The test results show whether the PIM values can satisfy the PIM specifications.

8.6.2 Test principle

As described in 8.1.2, the spacecraft is located in the QZ, and illuminated by the plane wave.

As known, PIM can be represented as: $f_{\mathrm{PIM}} = \pm m \cdot f_{11} \pm n \cdot f_{22}$, with two downlink signals, f_{11} and f_{22}, corresponding to two uplink carrier signals, f_1 and f_2. For spacecraft antenna system which shares Rx/Tx signals, if f_{PIM} falls in uplink frequency band, a relatively high level f_{PIM} interferes with the normal communication immediately.

To measure PIM in compact range is actually to measure the downlink signal harmonics, $f_{\mathrm{PIM,down}}$, that falls at spacecraft's uplink operational band, f_{PIM}. This is different from the unit level PIM test. Only $f_{\mathrm{PIM,down}}$ higher than the transponder's noise spectrum can be detected. Usually the PIM is measured with spacecraft's output amplifier at its saturation point.

8.6.3 Illustrative test procedure

Two illustrative procedure examples for the PIM test are provided in Annex F. The PIM values 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.

9 Test report

A test report should include:

a) purposes and requirements of the test;

b) a reference to this document, e.g. ISO 23569:2021;

c) test procedures;

d) photos during the test;

e) chamber environment description;

f) test items;

g) test facility and measurement instrumentation;

h) test results and analysis on test error.

Annex A
(informative)

Illustrative procedures for EIRP test

A.1 EIRP test method with full link wireless setup

A.1.1 Overview

The spacecraft is installed on the DUT positioner located in the QZ. The Rx range feed is located at the focus of the range reflector. The Tx range feed is near the Rx range feed.

The Tx range feed transmits uplink signal, via the range reflector to the QZ. The spacecraft Rx antenna can receive the uplink signal, while the spacecraft Tx antenna can transmit the downlink signal. Then the Rx range feed can receive the downlink signal. That is the full link wireless transmission route.

By using the value of received power measured by the Rx range feed in uplink saturation state, the EIRP can be calculated.

A.1.2 Test schematic diagram

The EIRP test schematic diagram of full link wireless transmission route is shown in Figure A.1.

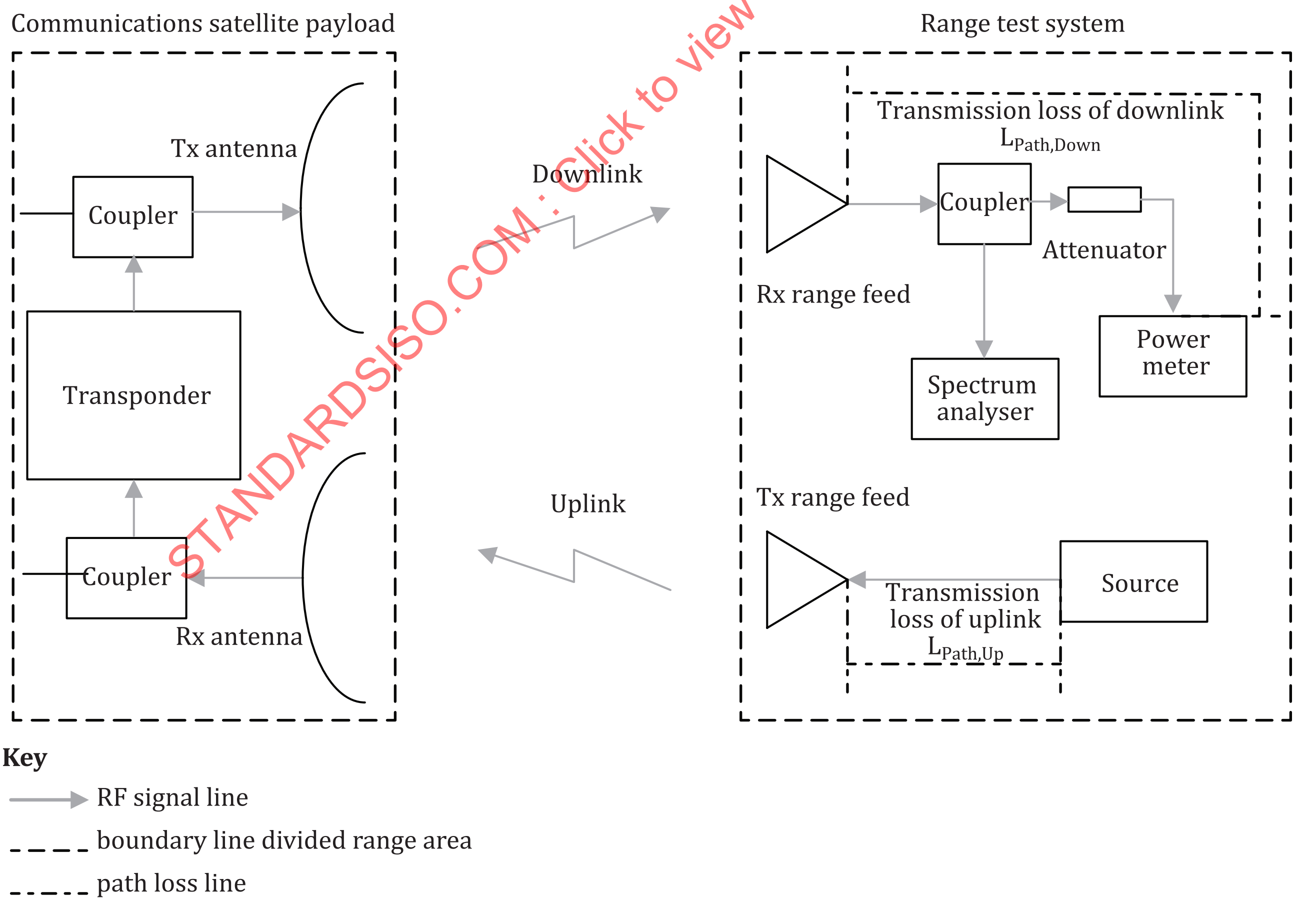


Figure A.1 — EIRP test schematic diagram of full link wireless transmission route

A.1.3 Test instruments and equipment

a) Source: with AM modulation.

b) Spectrum analyser.

c) Power meter.

d) Fixed attenuator: with suitable attenuation.

e) Coupler.

A.1.4 Preparation before test

a) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it work at fixed gain level.

b) Move the Rx range feed to the reflector's focus for receiving and move the Tx range feed near the Rx range feed for transmitting. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

c) Rotate the DUT positioner to make the spacecraft's transmitting orientation to be tested (peak point or typical point) coincide with NPA.

d) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

e) Calibrate the range's receiving path (from Rx range feed to power meter) and record the path loss, $L_{\text{path, down}}$.

A.1.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level (at least 20 dB lower than the budget value) to make the payload work in linear mode, and monitor the readings of the power meter.

b) Increase the source's RF output power step by step until the uplink saturation point is reached. Then record the readings of power meter.

A.1.6 Data processing

By calculating the EIRP according to Formulae (A.1) and (A.2), the EIRP for linear polarization in the test point can be obtained.

$$Q_{\text{EIRP}} = P_{\text{Rx,CR}} + L_{\text{p,path,down}} + L_{\text{p,down}} - G_{\text{Rx,CR}} - 30 \quad \text{(A.1)}$$

$$L_{\text{p,down}} = 20 \times \log \frac{4\pi R}{\lambda_{\text{down}}} \quad \text{(A.2)}$$

where

Q_{EIRP} is the equivalent isotropic radiation power, dBW;

$P_{\text{Rx,CR}}$ is the power meter's reading, dBm;

$L_{\text{p,path,down}}$ is the range receiving path loss (from Rx range feed to power meter), dB;

$L_{p,down}$ is the equivalent range free space loss, dB;

$G_{Rx,CR}$ is the gain of the Rx range feed, dBi;

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

λ_{down} is the wavelength of downlink signal, m.

If the polarization of spacecraft Tx antenna is circular, a 0 dB to 3 dB compensation shall be added to the EIRP since the range feed is in linear polarization. It is based on the antenna's polarization properties.

By combining the EIRP value at the beam peak and the antenna pattern measured in subsystem level EM/RM (radiation mock-up), the EIRP coverage pattern can be obtained.

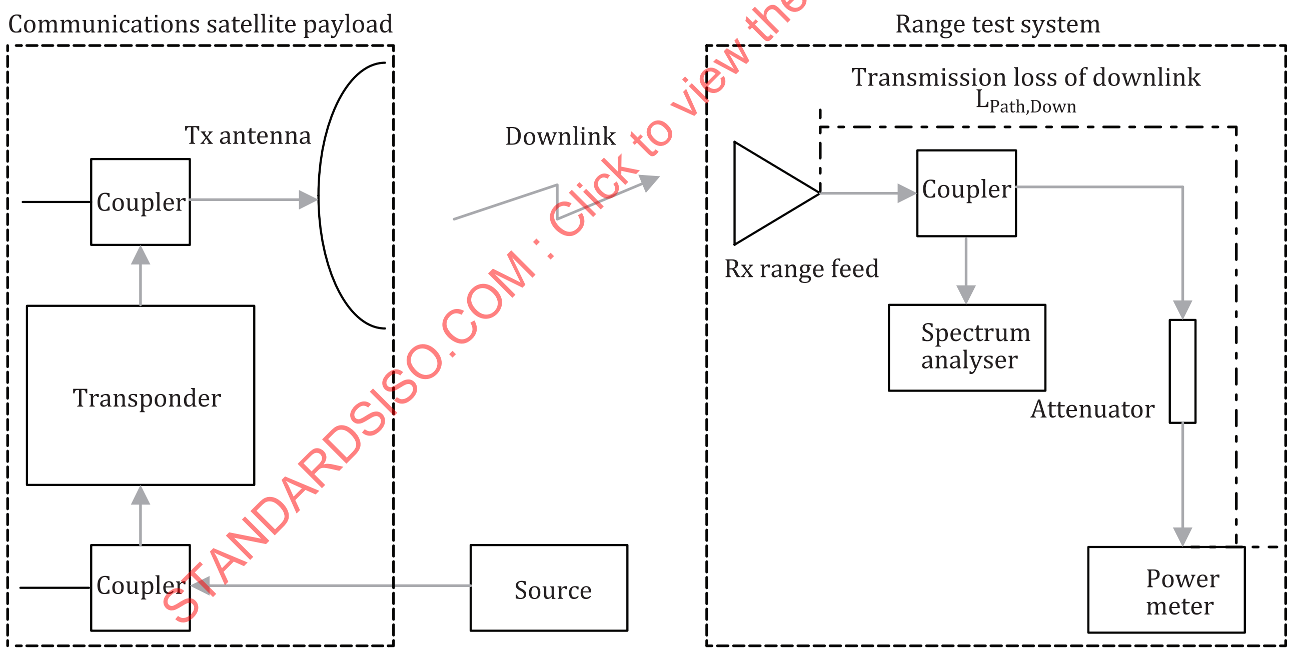
A.2 EIRP test method with downlink wireless setup

A.2.1 Overview

The wireless downlink transmission route for the EIRP test means the spacecraft uplink is input by cable directly. As done with full link wireless transmission route, the EIRP can be calculated using the value of received power measured by the Rx range feed with the spacecraft in uplink saturation state.

A.2.2 Test schematic diagram

The EIRP test schematic diagram of downlink wireless transmission route is shown in Figure A.2.



Key

RF signal line

boundary line divided range area

path loss line

Figure A.2 — EIRP test schematic diagram of downlink wireless transmission route

A.2.3 Test instruments and equipment

As defined in A.1.3.

A.2.4 Preparation before test

a) Move the RF source near the DUT positioner and input the uplink signal by cable directly to the spacecraft's receiver.

b) Spacecraft payload setup: correctly set the antenna beams, warm up the repeater's operating channels and make it normally work at fixed gain level.

c) Move the Rx range feed to the reflector's focus for receiving. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

d) Rotate the DUT positioner to make the spacecraft transmitting antenna's orientation to be tested (peak point or typical point) coincide with NPA.

e) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

f) Calibrate the range's receiving path (from Rx range feed to power meter), and record the path loss, $L_{\text{path, down}}$.

A.2.5 Test procedure

a) Based on link budget, set the RF source at operating frequency and output power level (at least 20 dB lower than the budget value) to make the payload work in linear mode, and monitor the readings of power meter.

b) Increase the RF source output power step by step until the uplink saturation point is reached. Then record the readings of power meter.

A.2.6 Data processing

By calculating the EIRP according to Formulae (A.1) and (A.2), the EIRP for linear polarization in the test point can be obtained.

If the polarization of spacecraft Tx antenna is circular, a 0 dB to 3 dB compensation shall be added to the EIRP since the range feed is in linear polarization. It is based on the antenna's polarization properties.

By combining the EIRP value at the beam peak and the antenna pattern, measured in subsystem level EM/RM (radiation mock-up), the EIRP coverage pattern can be obtained.

Annex B
(informative)

Illustrative procedures for *G*/*T*-test

B.1 *G*/*T*-test method in fixed gain mode with full link wireless setup

B.1.1 Overview

The spacecraft is installed on the DUT positioner located in the QZ, the Tx range feed for uplink transmitting is located at the focus of the range reflector, and the Rx range feed for downlink receiving is near the Rx range feed.

The Tx range feed transmits uplink signal, via the range reflector to the QZ. The spacecraft Rx antenna can receive the uplink signal, while the spacecraft Tx antenna can transmit the downlink signal. Then the Rx range feed can receive the downlink signal. That is the full link wireless transmission route.

The *G*/*T* can be calculated by the Y factor method.

B.1.2 Test schematic diagram

The *G*/*T*-test schematic diagram of full link wireless transmission route in fixed gain mode is shown in Figure B.1.

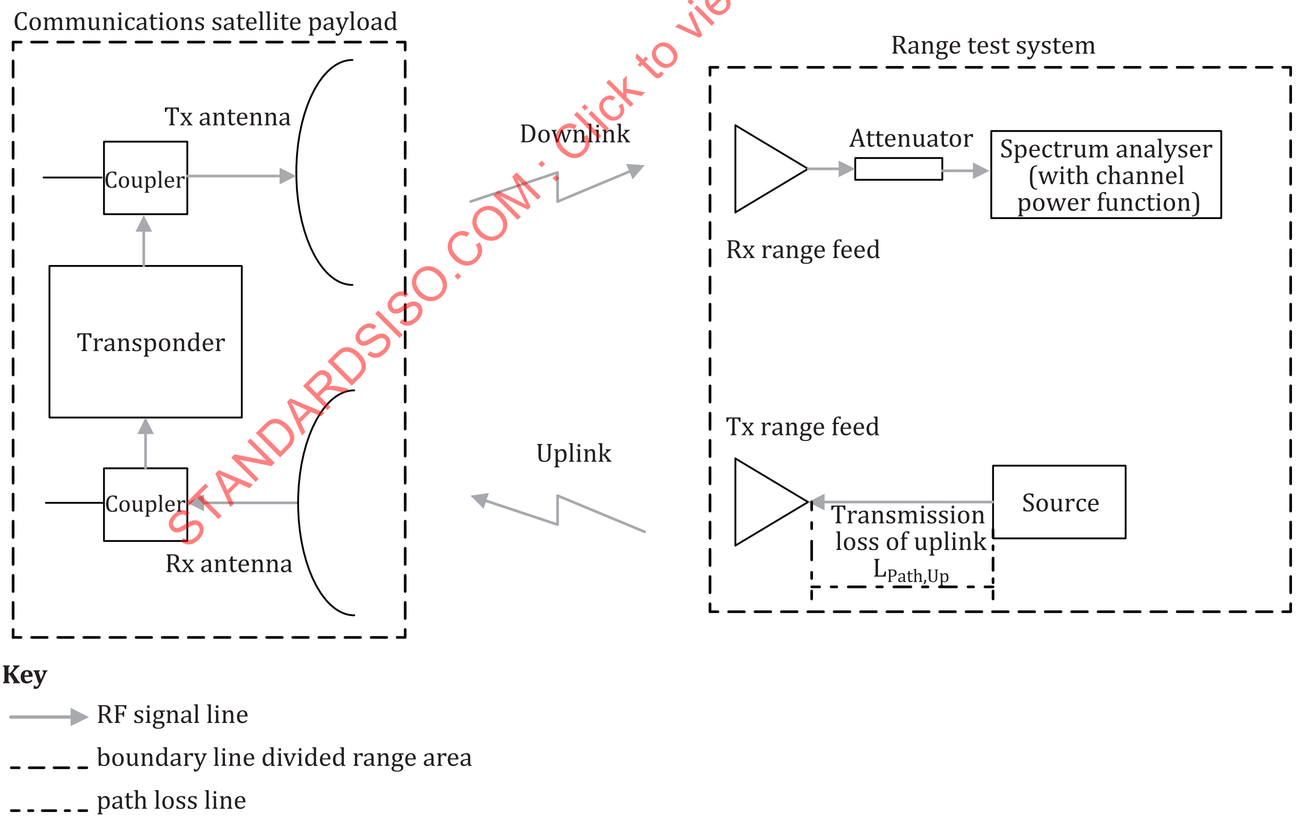


Figure B.1 — *G*/*T*-test schematic diagram of full link wireless transmission route in fixed gain mode

B.1.3 Test instruments and equipment

a) Source: with AM modulation.

b) Spectrum analyser: with the function of channel power measurement.

c) Fixed attenuator: with suitable attenuation.

B.1.4 Preparation before test

a) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

b) Move the Tx range feed to the reflector's focus for transmitting and move the Rx range feed near the Tx range feed for receiving. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

c) Rotate the DUT positioner to make the spacecraft receiving antenna's orientation to be tested (peak point or typical point) coincide with NPA.

d) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

e) Calibrate the range's transmitting path (from source to Tx range feed), and record the path loss, $L_{\text{path,up}}$.

B.1.5 Test procedures

a) Disconnect the Rx range feed, terminate the receiving range cable with matching load, set the working mode of spectrum analyser at "channel power" and select the frequency and span of spectrum analyser according to the test requirements, then record the received noise power P_1.

b) Reconnect the receiving range cable to the Rx range feed, make sure the transponder's working channel is in the corresponding state, keep the same setup at spectrum analyser and record the received noise power P_2. If the difference between P_2 and P_1 is less than 10 dB, then increase the transponder's gain level until it becomes higher than this value.

c) Turn on the range source RF output, adjust the transmitting power level to guarantee payload is operating in its linear range, and make the received power level P_3 of spectrum analyser at least 3 dB higher than P_2. If not, increase the range source output level until 3 dB higher than P_2 is reached. Record the received power P_3 and the range source output level P_{Tx}.

B.1.6 Data processing

Based on the Formulae (B.1) to (B.5), calculate the test point G/T value.

$$r_{G/T} = 10 \times \log \frac{k \times B \times (Y_2 - 1) \times Y_1}{Y_1 - 1} + L_{\text{p,up}} - Q_{\text{EIRP,CR}} \tag{B.1}$$

$$L_{\text{p,up}} = 20 \times \log \frac{4\pi R}{\lambda_{\text{up}}} \tag{B.2}$$

$$Q_{\text{EIRP,CR}} = P_{\text{Tx}} - L_{\text{p,path,up}} + G_{\text{Tx,CR}} \tag{B.3}$$

$$Y_1 = P_2 / P_1 \tag{B.4}$$

$$Y_2 = P_3 / P_2 \tag{B.5}$$

where

$r_{G/T}$	is the receiving system quality factor of the spacecraft, dB/K;
k	is the Boltzmann constant, J/K;
B	is the noise bandwidth (correspond to the test bandwidth), Hz;
$L_{\text{p,up}}$	is the uplink equivalent free space loss in compact range, dB;
$Q_{\text{EIRP,CR}}$	is the range equivalent isotropic radiation power, dBW;
P_{Tx}	is the range source output level, dBm;
$L_{\text{p,path,up}}$	is the transmission loss from the range source to Rx range feed, dB;
$G_{\text{Tx,CR}}$	is the gain of the Tx range feed, dBi;
P_1	is the noise power level of the receiving test equipment, W;
P_2	is the noise power level of the receiving test equipment, including the spacecraft noise level, W;
P_3	is the power level of the receiving test equipment, including the spacecraft noise level and carrier power, W;
Y_1	is the Y factor 1, P_2/P_1;
Y_2	is the Y factor 2, P_3 /P_2.

If the polarization of spacecraft Rx antenna is circular, since the range feed is in linear polarization, a 0 dB to 3 dB compensation shall be added to the G/T, depending on the antenna's polarization properties.

By combining the G/T value at the beam peak and the antenna pattern, measured in subsystem level EM/RM (radiation mock-up), the G/T coverage pattern can be obtained.

B.2 *G*/*T*-test method in automatic level control (ALC) mode with full link wireless setup

B.2.1 Overview

As described in the method in fixed gain mode, to build the full link wireless transmission route.

The G/T can be calculated by the test method in ALC mode.

B.2.2 Test schematic diagram

The G/T-test schematic diagram of full link wireless transmission route in ALC mode is the same as shown in Figure B.1.

B.2.3 Test instruments and equipment

As defined in B.1.3.

B.2.4 Preparation before test

As defined in B.1.4, except the transponder work at ALC mode.

B.2.5 Test procedure

a) Turn on the range source RF output, adjust the transmitting power level to guarantee payload is operating in its linear range, record the output level to P_{01}; set the working mode of the spectrum analyser at “Channel power” and select the frequency and span of the spectrum analyser according to the test requirements, then record the received power of spectrum analyser P_a.

b) Keep the same setup at spectrum analyser, make the frequency of spectrum analyser departure off the downlink carrier frequency (make sure the downlink carrier frequency is out of the specific bandwidth B), only noise power in transponder band can be received by spectrum analyser, and record the received power level P_b on spectrum analyser. P_a shall be at least 3 dB higher than P_b.

c) Set the RF output level of the range source to $P_{02} \neq P_{01}$, P_{02} at least 3 dB higher than P_{01}, and make the frequency of spectrum analyser back to the original test frequency, keep the same setup at spectrum analyser, then record the received power of spectrum analyser P_c.

d) Make the frequency of spectrum analyser departure off the downlink carrier frequency again (make sure the downlink carrier frequency is out of the specific bandwidth B), only noise power in transponder band can be received by spectrum analyser, and record the received power level P_d on spectrum analyser. P_c shall be at least 3 dB higher than P_d.

B.2.6 Data processing

Based on the Formula (B.6), calculate the test point G/T:

$$r_{G/T} = \frac{k \cdot B \cdot L_{\mathrm{p,up}}}{P_d - P_b} \cdot \left[\frac{P_c - P_d}{Q_{\mathrm{EIRP,Tx,CR,2}}} - \frac{P_a - P_b}{Q_{\mathrm{EIRP,Tx,CR,1}}} \right] \quad \text{(B.6)}$$

where

P_a	is the spacecraft’s downlink signal power level plus spacecraft’s channel noise power and range receiving system noise power in the state of the range source transmitting power P_{01}, W;
P_b	is the spacecraft’s channel noise power plus range receiving system noise power in the state of the range source transmitting power P_{01}, W;
P_c	is the spacecraft’s downlink signal power level plus spacecraft’s channel noise power and range receiving system noise power in the state of the range source transmitting power P_{02}, W;
P_d	is the spacecraft’s channel noise power plus range receiving system noise power in the state of the range source transmitting power P_{02}, W;
$Q_{\mathrm{EIRPTx,CR,1}}$	is the range EIRP in the state of the range source transmitting power P_{01}, W;
$Q_{EIRP\mathrm{Tx,CR,2}}$	is the range EIRP in the state of the range source transmitting power P_{02}, W;
B	is the noise bandwidth (correspond to the test bandwidth), Hz.

If the polarization of spacecraft Rx antenna is circular, a 0 dB to 3 dB compensation shall be added to the G/T since the range feed is in linear polarization. It is based on the antenna’s polarization properties.

By combining the G/T value at the beam peak and the antenna pattern, measured in subsystem level EM/RM (radiation mock-up), the G/T coverage pattern can be obtained.

B.3 *G*/*T*-test method in fixed gain mode with uplink wireless setup

B.3.1 Overview

The wireless uplink transmission route for *G*/*T*-test means the spacecraft downlink is output by cable directly to the Rx test equipment. As done with full link wireless transmission route, measure the received power P_1, P_2 and P_3 from the Rx test equipment, then by the Y factor method, *G*/*T* can be calculated.

B.3.2 Test schematic diagram

The *G*/*T*-test schematic diagram of uplink wireless transmission route is shown in Figure B.2.

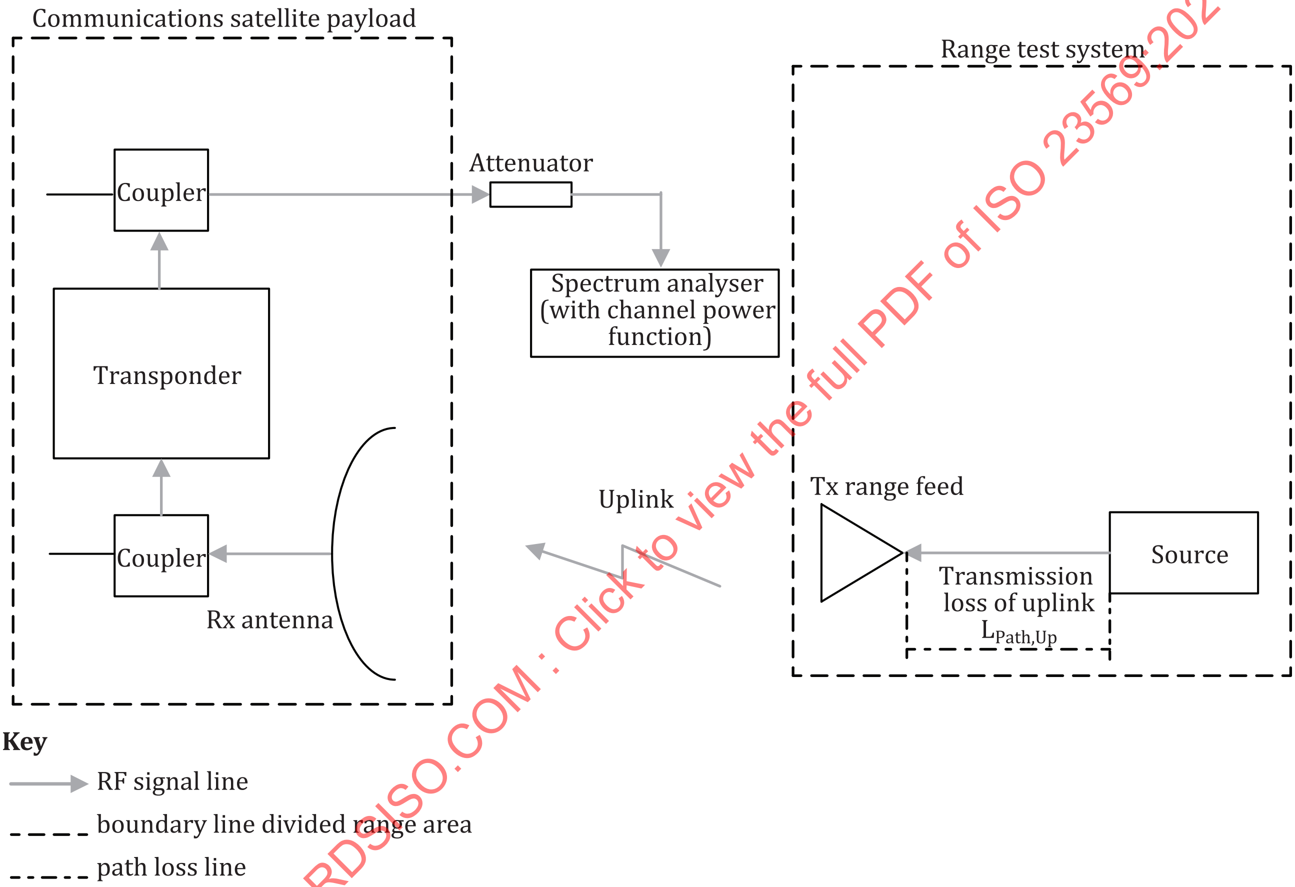


Figure B.2 — *G*/*T*-test schematic diagram of uplink wireless transmission route in fixed gain mode

B.3.3 Test instruments and equipment

As defined in B.1.3.

B.3.4 Preparation before test

a) Move the Rx test equipment (spectrum analyser) near the DUT positioner. The spacecraft downlink signal goes through cable directly to the spectrum analyser.

b) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

c) Move the Tx range feed to the reflector's focus for transmitting. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft Rx antenna. If the polarization of spacecraft Rx antenna is linear polarization, the polarization of range Tx feed will coincide with the spacecraft Rx antenna's polarization; if the polarization of spacecraft Rx antenna is circular polarization, make the polarization of range Tx feed horizontal.

d) Rotate the DUT positioner to make the spacecraft receiving antenna's orientation to be tested (peak point or typical point) coincide with NPA.

e) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

f) Calibrate the range's transmitting path (from source to Tx range feed), and record the path loss, $L_{\text{path,up}}$.

B.3.5 Test procedures

As defined in B.1.5.

B.3.6 Data processing

As described in B.1.6, based on the Formulae (B.1) to (B.5), calculate the test point G/T value.

If the polarization of spacecraft Rx antenna is circular, a 0 dB to 3 dB compensation shall be added to the G/T since the range feed is in linear polarization. It is based on the antenna's polarization properties.

By combining the G/T value at the beam peak and the antenna pattern, measured in subsystem level EM/RM (radiation mock-up), the G/T coverage pattern can be obtained.

B.4 *G*/*T*-test method in automatic level control (ALC) mode with uplink wireless setup

B.4.1 Overview

As described in B.3.1 to build the uplink wireless transmission route, as described in B2, the G/T can be calculated by the test method in ALC mode.

B.4.2 Test schematic diagram

The G/T-test schematic diagram of uplink wireless transmission route in ALC mode is shown in Figure B.2.

B.4.3 Test instruments and equipment

As defined in B.1.3.

B.4.4 Preparation before test

As defined in B.3.4.

B.4.5 Test procedure

As defined in B.2.5.

B.4.6 Data processing

As described in B.2.6, based on the Formula (B.6), calculate the test point G/T.

If the polarization of spacecraft Rx antenna is circular, a 0 dB to 3 dB compensation shall be added to the G/T since the range feed is in linear polarization. It is based on the antenna's polarization properties.

By combining the G/T value at the beam peak and the antenna pattern, measured in subsystem level EM/RM (radiation mock-up), the G/T coverage pattern can be obtained.

Annex C
(informative)

Illustrative procedures for SPFD test

C.1 SPFD test method with full link wireless setup

C.1.1 Overview

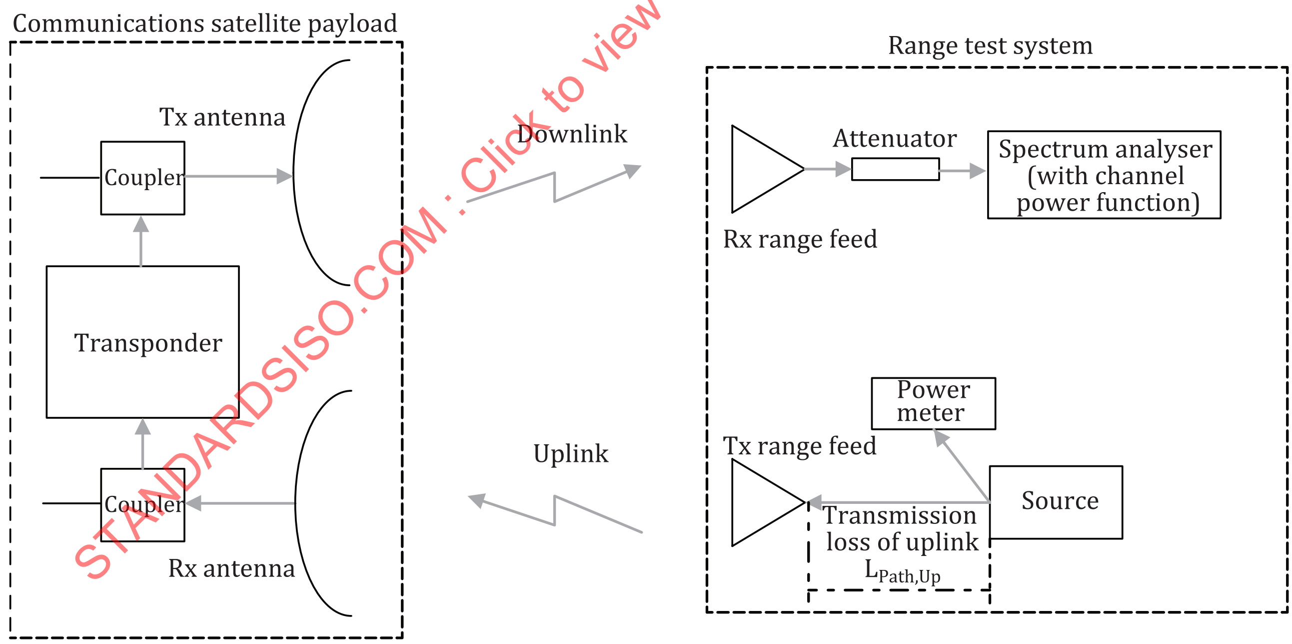
The spacecraft is installed on the DUT positioner located in the QZ, the Tx range feed for uplink transmitting is located at the range reflector's focus, and the Rx range feed for downlink receiving is near the Tx range feed.

The Tx range feed transmits uplink signal, via the range reflector to the QZ. The spacecraft Rx antenna can receive the uplink signal, while the spacecraft Tx antenna can transmit the downlink signal. Then the Rx range feed can receive the downlink signal. That is the full link wireless transmission route.

By testing the transmitting power of Tx range feed in uplink saturation state, the SPFD can be calculated.

C.1.2 Test schematic diagram

The SPFD test schematic diagram of full link wireless transmission route is shown in Figure C.1.



Key

RF signal line

boundary line divided range area

path loss line

Figure C.1 — SPFD test schematic diagram of full link wireless transmission route

C.1.3 Test instruments and equipment

a) Source: with AM modulation.

b) Spectrum analyser.

c) Power meter.

d) Fixed attenuator: with suitable attenuation.

C.1.4 Preparation before test

a) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

b) Move the Tx range feed to the reflector's focus for transmitting and move the Rx range feed near Tx range feed for receiving. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

c) Rotate the DUT positioner to make the spacecraft Rx antenna's orientation to be tested (peak point or typical point) coincide with NPA.

d) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

e) Calibrate the range's transmitting path (from Tx source to Tx range feed), and record the path loss, $L_{\text{path,up}}$.

C.1.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level (at least 20 dB lower than the budget value) to make the payload work in linear mode, and monitor the readings of the power meter.

b) Increase the source's RF output power step by step, until the uplink saturation point is reached.

c) Record the source's RF output power value readings by the power meter, P_{Tx}.

C.1.6 Data processing

By calculating the SPFD according to Formula (C.1), the SPFD level for linear polarization in the test point can be obtained.

$$\begin{aligned} B_{\text{SPFD}} &= P_{\text{Tx}} - L_{\text{path,up}} + G_{\text{Tx,CR}} - 10\times\log 4\pi R^2 - 30 \\ &= P_{\text{Tx}}' + G_{\text{Tx,CR}} - 10\times\log 4\pi R^2 - 30 \end{aligned} \tag{C.1}$$

where

B_{SPFD}	is the saturated power flux density of spacecraft, dBW/m^2;
P_{Tx}	is the range source RF output power level, dBm;
P_{Tx}'	is the RF input power level to the Tx range feed, dBm;
$G_{\text{Tx,CR}}$	is the gain of Tx range feed, dBi;

$L_{path,up}$ is the transmission loss from the range source to the range feed, dB.

If the polarization of spacecraft Rx antenna is circular, since the range feed is in linear polarization, a 0 dB to 3 dB compensation shall be subtracted from the SPFD. It is based on the antenna's polarization properties.

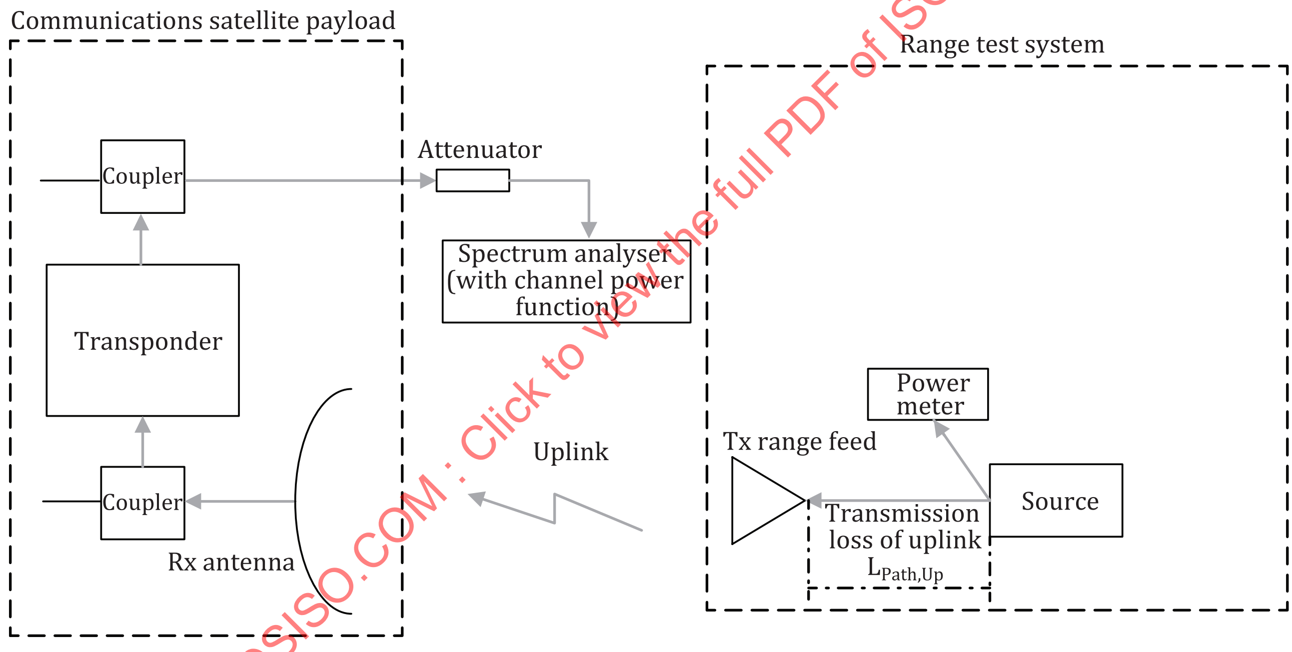
C.2 SPFD test method with uplink wireless setup

C.2.1 Overview

The wireless uplink transmission route for the SPFD test means the spacecraft downlink is output by cable directly to the Rx test equipment. As done with full link wireless transmission route, by measuring the Tx power of the Tx range feed in uplink saturation state, the SPFD can be calculated.

C.2.2 Test schematic diagram

The SPFD test schematic diagram of uplink wireless transmission route is shown in Figure C.2.



Key

RF signal line
boundary line divided range area
path loss line

Figure C.2 — SPFD test schematic diagram of uplink wireless transmission route

C.2.3 Test instruments and equipment

As defined in C.1.3.

C.2.4 Preparation before test

a) Move the Rx test equipment (spectrum analyser) near the DUT positioner. The spacecraft downlink signal is output through cable directly to spectrum analyser.

b) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

c) Move the Tx range feed to the reflector's focus for transmitting. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

d) Rotate the DUT positioner to make the spacecraft Rx antenna's orientation to be tested (peak point or typical point) coincide with NPA.

e) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

f) Calibrate the range's transmitting path (from Tx source to Tx range feed), and record the path loss, $L_{path,up}$.

C.2.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level (at least 20 dB lower than the budget value) to make the payload work in linear mode, and monitor the readings of the power meter.

b) Increase the source output power step by step, until the uplink saturation point is reached. For the SPFD test, it is really related only to the uplink, if the saturation point can be achieved by monitoring the telemetry parameters of spacecraft's amplifier, the downlink test equipment is not necessary, only uplink wireless transmission route is enough for the SPFD test.

c) Record the source's RF output power value readings by the power meter, P_{Tx}.

C.2.6 Data processing

By calculating the SPFD according to Formula (C.1), the SPFD level for linear polarization in the test point can be obtained.

If the polarization of spacecraft Rx antenna is circular, since the range feed is in linear polarization, a 0 dB to 3 dB compensation shall be subtracted from the SPFD. It is based on the antenna's polarization properties.

Annex D
(informative)

Illustrative procedures for AFR test

D.1 AFR test method with full link wireless setup

D.1.1 Overview

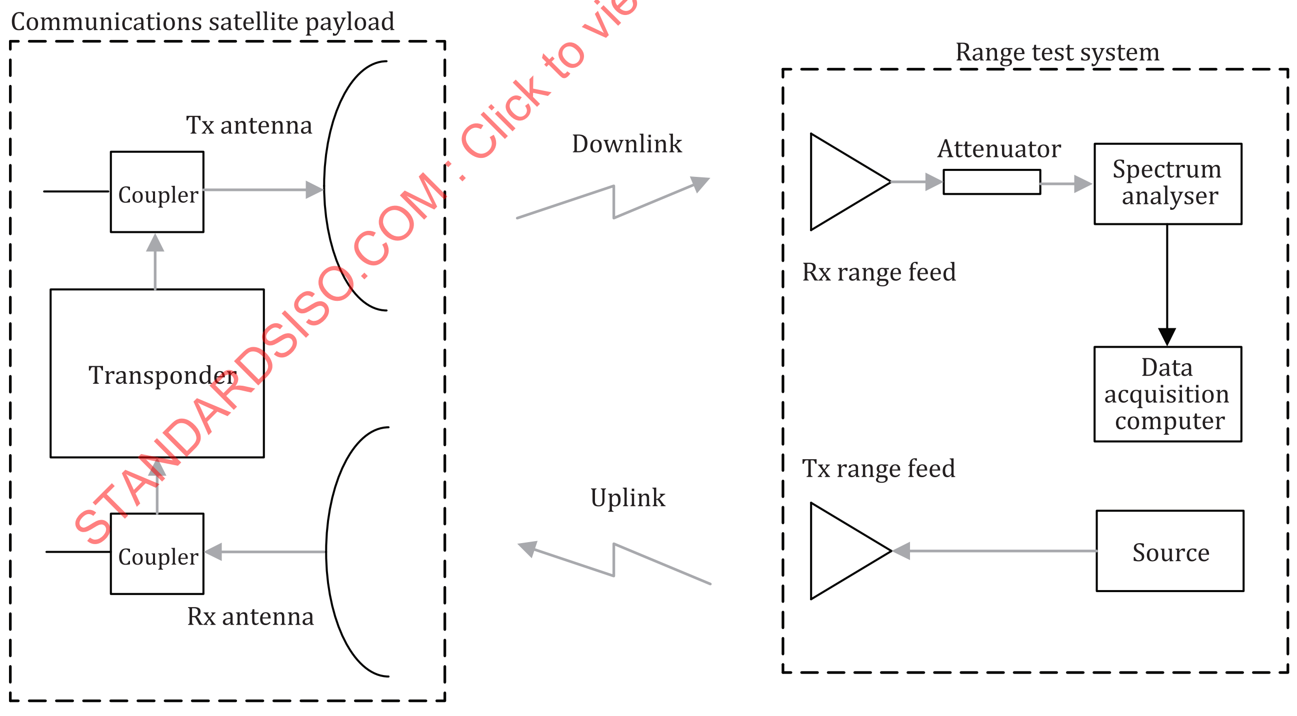
The spacecraft is installed on the DUT positioner located in the QZ. For the output AFR test, move the Rx range feed to the reflector's focus for receiving and move the Tx range feed near the Rx range feed for transmitting; for the input AFR test, move the Tx range feed to the reflector's focus for transmitting and move the Rx range feed near the Rx range feed for receiving.

The Tx range feed transmits uplink signal, via the range reflector to the QZ. The spacecraft Rx antenna can receive the uplink signal, while the spacecraft Tx antenna can transmit the downlink signal. Then the Rx range feed can receive the downlink signal. That is the full link wireless transmission route.

Change the frequency of the range source with each specific step, so as to get the AFR curves.

D.1.2 Test schematic diagram

The AFR test schematic diagram of full link wireless setup is shown in Figure D.1.



Key

RF signal line

boundary line divided range area

Figure D.1 — AFR test schematic diagram of full link wireless setup

D.1.3 Test instruments and equipment

a) Source: with AM modulation

b) Spectrum analyser

c) Data acquisition computer

d) Fixed attenuator: with suitable attenuation

D.1.4 Preparation before test

a) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

b) Move the Tx range feed to the reflector's focus for transmitting and move the Rx range feed near Tx range feed for receiving, or move the Rx range feed to the reflector's focus for receiving and move the Tx range feed near the Rx range feed for transmitting, depending on which AFR will be test, input or output. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

c) For the output AFR test, rotate the DUT positioner to make the spacecraft Tx antenna's orientation to be tested (peak point) coincide with NPA; for the input AFR test, rotate the DUT positioner to make the spacecraft Rx antenna's orientation to be tested (peak point) coincide with NPA.

d) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

D.1.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level to make the transponder operate in linear fixed signal level (e.g. 15 dB below the saturation point).

b) Change the frequency of the range source with each specific step and record the reading out of spectrum analyser corresponding to each frequency point.

   Spectrum analyser span frequency range shall cover the test frequency range.

D.1.6 Data processing

The AFR curve is obtained by plotting the received power level for each frequency set, Y-axis by X-axis respectively.

D.2 AFR test method with uplink or downlink wireless setup

D.2.1 Overview

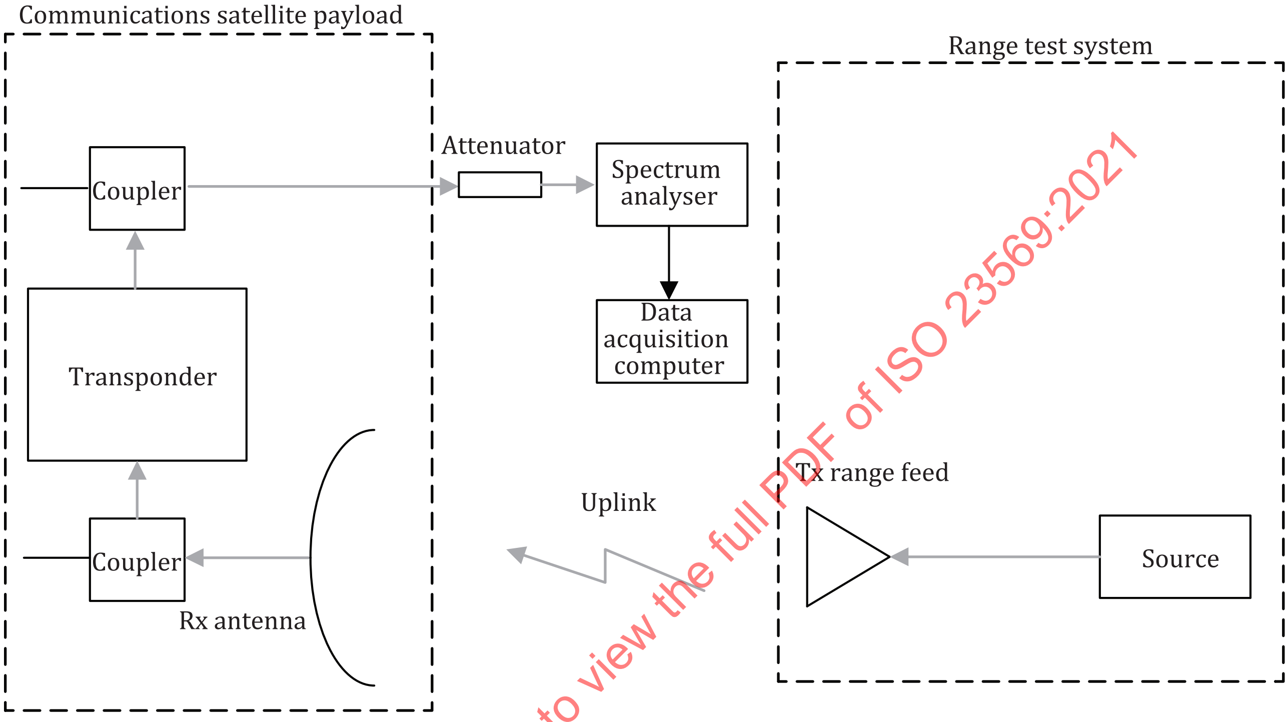
The wireless uplink transmission route for the AFR test means the spacecraft downlink is output by cable directly to the Rx test equipment. The wireless downlink transmission route for the AFR test means the spacecraft uplink is input by cable directly.

As done with full link wireless transmission route, the spacecraft is installed on the DUT positioner located in QZ, the Tx range feed for uplink transmitting is located at the focus of the range reflector for input AFR test; the Rx range feed for downlink receiving is located at the focus of the range reflector for output AFR test.

Change the frequency of the range source with each specific step, in order to get the input or output AFR curves.

D.2.2 Test schematic diagram

The input AFR test schematic diagram of uplink wireless setup is shown in Figure D.2; the output AFR test schematic diagram of downlink wireless setup is shown in Figure D.3.



Key

RF signal line

boundary line divided range area

Figure D.2 — Input AFR test schematic diagram of uplink wireless setup

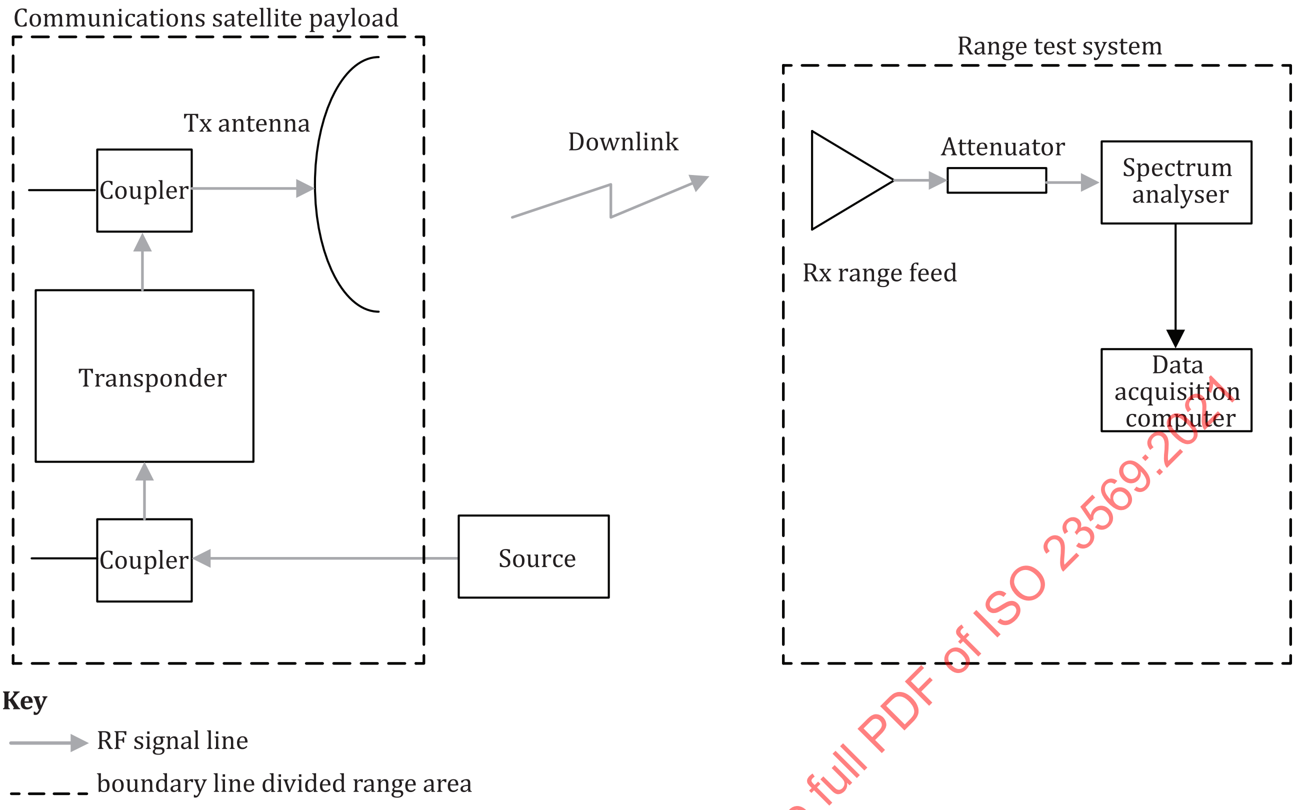


Figure D.3 — Output AFR test schematic diagram of downlink wireless setup

D.2.3 Test instruments and equipment

As described in D.1.3.

D.2.4 Preparation before test

a) For the input AFR test, the range Rx test equipment is located near the DUT positioner, and the spacecraft downlink signal is output by cable directly to the range Rx test equipment; for the output AFR test, the RF source is located near the DUT positioner, and the uplink signal is input by cable directly to the spacecraft's receiver.

b) Spacecraft payload setup: correctly set the Tx antenna beams for input AFR test or Rx antenna beams for output AFR test, warm up the transponder's operating channels and make it normally work at stated gain level.

c) For the input AFR test, move the Tx range feed to the reflector's focus for transmitting; or for the output AFR test, move the Rx range feed to the reflector's focus for receiving. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

d) To test the output AFR, rotate the DUT positioner to make the spacecraft Tx antenna's orientation to be tested (peak point) coincide with NPA; to test the input AFR, rotate the DUT positioner to make the spacecraft Rx antenna's orientation to be tested (peak point) coincide with NPA.

e) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

D.2.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level to make the transponder operate in linear fixed signal level (e.g. 15 dB lower than the saturation point).

b) Change the frequency of the range source with each specific step and record the reading out of spectrum analyser corresponding to each frequency point.

   Spectrum analyser span frequency range shall cover the test frequency range.

D.2.6 Data processing

The AFR curve is obtained by plotting the received power level for each frequency set, Y-axis by X-axis respectively.

Annex E
(informative)

Illustrative procedures for group delay test

E.1 Group delay characteristics test method with full link wireless setup

E.1.1 Overview

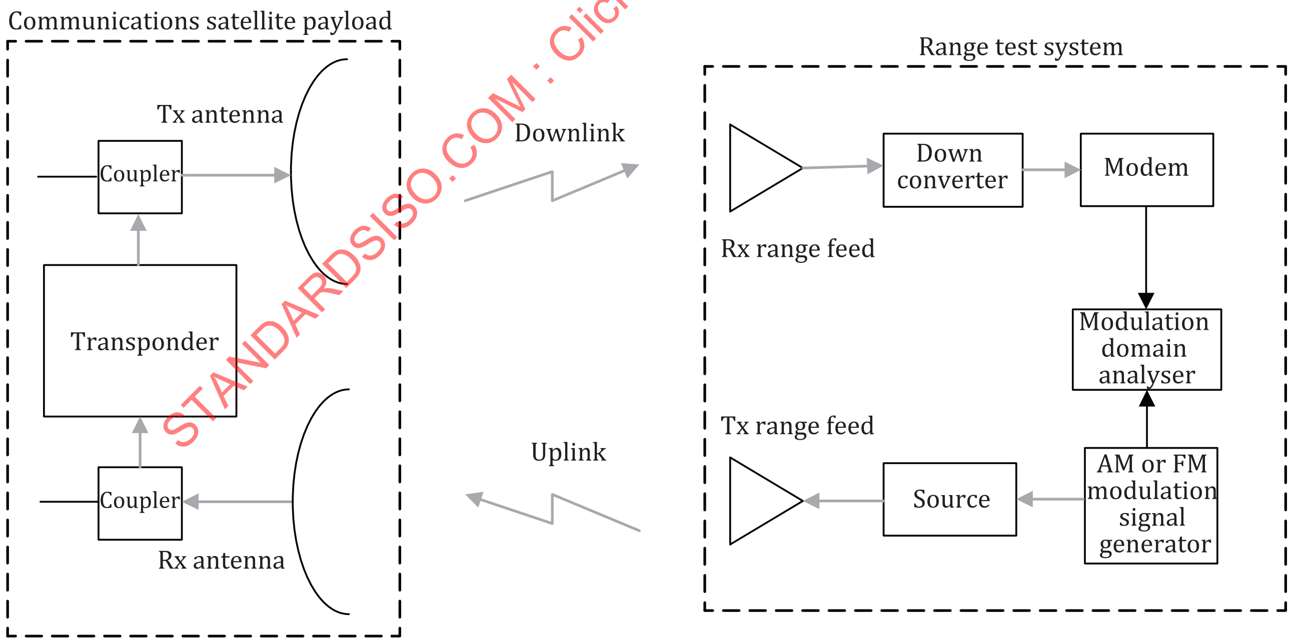
The spacecraft is installed on the DUT positioner located in the QZ. For two range feeds, make one of them located at the focus of the range reflector as Rx range feed for downlink receiving, and the other one near the Rx range feed, as Tx range feed for uplink transmitting.

The Tx range feed transmits uplink signal with modulation, via the range reflector to the QZ. The spacecraft Rx antenna can receive the uplink signal with modulation, while the spacecraft Tx antenna can transmit the downlink signal also with modulation. Then the Rx range feed can receive the downlink signal with modulation. That is the full link wireless transmission route.

Downlink signal with modulation should first be down converted, then arrive to modem and be de-modulated by it. By comparing this signal with the uplink original modulated signal, the absolute delay in test frequency point is achieved. By changing the test frequency of the range source with each specific step, group delay in test band is obtained.

E.1.2 Test schematic diagram

The group delay test schematic diagram is shown in Figure E.1.



Key

RF signal line

boundary line divided range area

Figure E.1 — Group delay test schematic diagram

E.1.3 Test instruments and equipment

a) AM or FM modulation signal generator

b) Source

c) Down converter

d) Modem

e) Modulation domain analyser

E.1.4 Preparation before test

a) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

b) Move the Tx range feed to the reflector's focus for transmitting and move the Rx range feed near the Tx range feed for receiving; or move the Rx range feed to the reflector's focus for receiving and move the Tx range feed near the Rx range feed for transmitting. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

c) If the Tx range feed is located at the reflector's focus, rotate the DUT positioner to make the spacecraft Rx antenna's orientation to be tested (peak point) coincident with NPA; if the Rx range feed is located at the reflector's focus, rotate the DUT positioner to make the spacecraft Tx antenna's orientation to be tested (peak point) coincide with NPA.

d) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

E.1.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level to make the transponder operate in linear fixed signal level (e.g. 15 dB lower than the saturation point).

b) Change the frequency of the range source with each specific step; for each frequency point, test with the modulation domain analyser, and record the absolute delay, so as to get the group delay in test band.

   Modulation domain analyser span frequency range shall cover the test frequency range.

E.1.6 Data processing

The group delay curve is obtained by plotting the absolute time delay for each frequency set, Y-axis by X-axis respectively.

Annex F
(informative)

Illustrative procedures for PIM test

F.1 PIM test method with full link wireless setup

F.1.1 Overview

The spacecraft is installed on the DUT positioner located in the QZ, the Rx range feed for downlink receiving is located at the range reflector's focus, and the Tx range feed for uplink transmitting is near the Rx range feed.

The Tx range feed transmits two pre-calculated uplink hybrid signals via the range reflector to the QZ; the spacecraft Rx antenna receives the uplink signal, while the spacecraft Tx antenna transmits the downlink signal, then the Rx range feed receives the downlink signal. That is the full link wireless transmission route.

The PIM value is the difference between the levels of downlink signal and the PIM component $f_{\mathrm{PIM,down}}$.

F.1.2 Test schematic diagram

The PIM test schematic diagram of full link wireless setup is shown in Figure F.1.

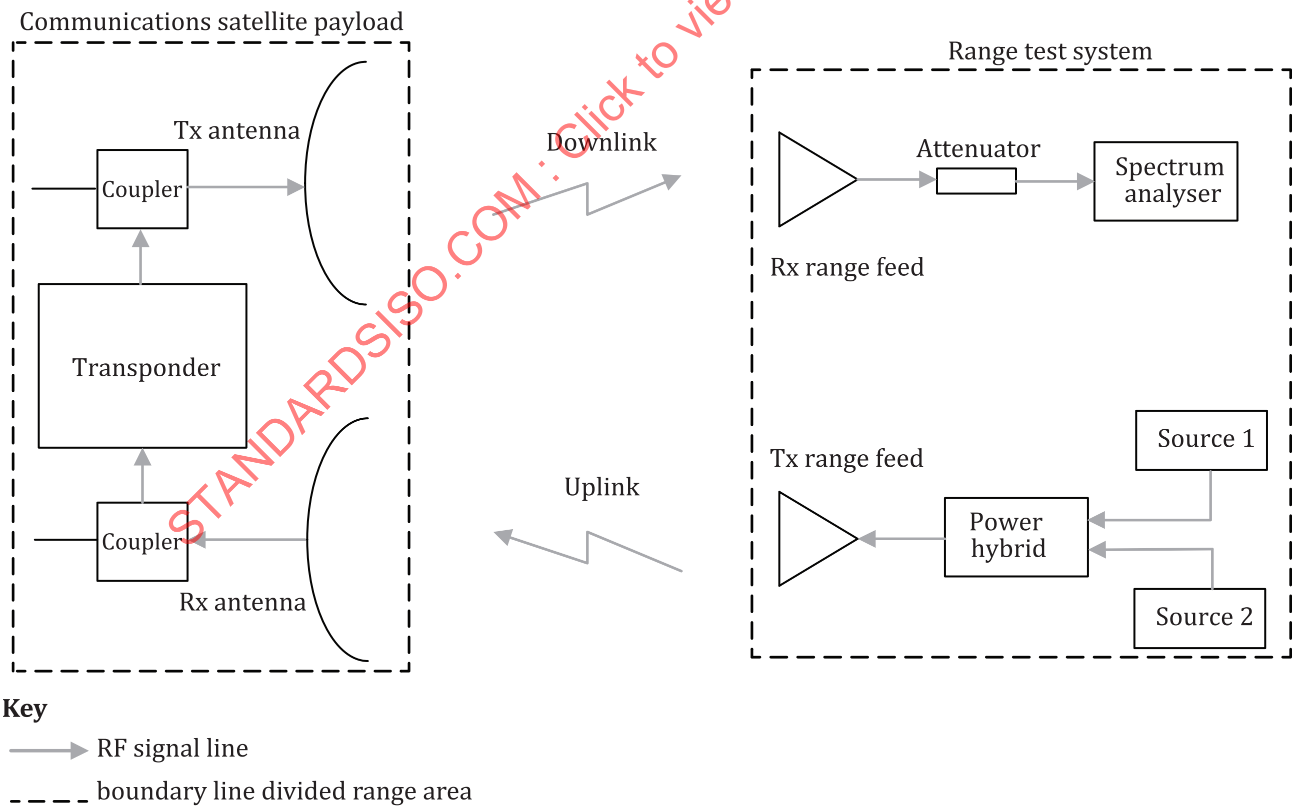


Figure F.1 — PIM test schematic diagram of full link wireless setup

F.1.3 Test instruments and equipment

a) Two sources: maximum stable output level should be higher than 10 dBm.

b) Power hybrid.

c) Spectrum analyser.

F.1.4 Preparation before test

a) Spacecraft payload setup: correctly set the antenna beams, warm up the transponder's operating channels and make it normally work at stated gain level.

b) Move the Rx range feed to the reflector's focus for receiving and move the Tx range feed near the Rx range feed for transmitting. Make the polarization of range feeds horizontal or vertical, depending on the polarization of spacecraft antennas. If the polarization of spacecraft antennas are linear polarization, the polarization of range feeds will coincide with the corresponding spacecraft antenna's polarization; if the polarization of spacecraft antennas are circular polarization, make the polarization of range feeds horizontal.

c) Rotate the DUT positioner to make the spacecraft Tx antenna's orientation to be tested (peak point) coincide with NPA.

d) If the compact range has baffle or SERAP, move them to the correct positions, so that there is no blockage of range feed beams, RF leakage to QZ, or illuminating at the nearby rim of the main reflector.

F.1.5 Test procedure

a) Based on link budget, set the RF source's frequency and output power level to make the transponder operate in linear fixed signal level (e.g. 15 dB lower than the saturation point).

b) Set two uplink carrier signals, f_1 and f_2, corresponding to the downlink signals, f_{11} and f_{22}.

c) Increase the output power of the two range sources step by step, until the saturation point of their respective uplink channels is reached.

d) Monitor the $f_{\text{PIM,down}}$ on spectrum analyser. If the PIM components $f_{\text{PIM,down}}$ are larger than the noise spectrum level of spacecraft in test band, then compare the PIM components with downlink major signal level; the PIM value is the difference between those levels.

   Spectrum analyser span frequency range shall cover the test frequency range.

F.2 PIM test method with downlink wireless setup

F.2.1 Overview

The wireless downlink transmission route for the PIM test means the spacecraft uplink is input by cable directly. As described in full link wireless transmission route, the spacecraft is installed on the DUT positioner located in the QZ, the two range sources are located near the DUT positioner, and the Rx range feed is located at the range reflector's focus for downlink receiving.

The range sources produce two pre-calculated uplink signals; the signals are combined through a hybrid and input by cable directly to the spacecraft, the downlink signal is transmitted by the Tx antenna, and then the Rx range feed can receive the downlink signal. That is the downlink wireless transmission route.

The PIM value is the difference between the levels of downlink signal and the PIM component $f_{\text{PIM,down}}$.