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MOPS for GNSS Airborne Active Antenna Equipment for the L1/E1 and L5/E5a Frequency Bands

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FOREWORD

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- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and

- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

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EXECUTIVE SUMMARY

The purpose of this MOPS is to specify performance requirements for an active integrated dual frequency GNSS Aviation Antenna. This includes requirements that address reception of GNSS signals that support safety of life aviation applications in the L1/E1 (centered at 1575.42 MHz) and L5/E5a (centered at 1176.45 MHz) bands. The requirements developed in this antenna MOPS support a range of flight phases including enroute, terminal, approach, precision landing and surface operations. In comparison to RTCA/DO-301, this antenna MOPS specifies better needed performance in the L1/E1 band for parameters including (but not limited to) G/T, group delay differential, axial ratio and boresight frequency response.

Inclusion of details regarding antennas that receive GLONASS signals in Appendix B is for informational purposes alone. These are not part of the requirements basis in this MOPS and are not intended to be part of a TSO that may reference this MOPS.

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1 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards (MOPS) for GNSS airborne active antenna equipment designed to use GNSS signals centered at L1 (1575.42 MHz) and L5 (1176.45 MHz) frequencies with a double-sided bandwidth as indicated in Table 2-1. These signals may be augmented by other systems/equipment/techniques as appropriate to meet the performance requirements for enroute, terminal, non-precision, and precision approach phases of flight and surface operations. An active antenna is one integrated with a preamplifier.

Section 1.0 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals, and forms the basis for the standards stated in Sections 2.0 through 4.0.

Section 2.0 contains the minimum performance standards for the equipment. These standards define required performance under standard operating conditions and stressed physical environmental conditions. It also details the recommended bench test procedures necessary to demonstrate compliance.

Section 3.0 provides information regarding the performance required of the installed equipment.

Section 4.0 provides information on the operational performance evaluation for the GNSS Antenna

Compliance with these standards by manufacturers, installers, and users is recommended as one means of assuring that the equipment will satisfactorily perform its intended function(s) under conditions normally encountered in routine aeronautical operations.

The word "equipment" as used in this document includes all components or units necessary (as determined by the equipment manufacturer or installer) for the equipment to properly perform its intended function. It is recognized that any regulatory application of these standards is the responsibility of appropriate government agencies.

As the measured values of equipment performance characteristics may be a function of the measurement method, standard test conditions and methods of test are recommended in this document.

1.2 System Overview

The GNSS is a world-wide position, velocity, and time determination system that includes one or more satellite constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation. The GNSS includes ground control and monitoring stations, satellites, and avionics including antenna(s), and currently consists of the United States Global Positioning System (GPS), the European Galileo, the Russian Federation Global Orbiting Navigation Satellite System (GLONASS), the Chinese Beidou system and others. The GNSS also includes ICAO SARPS compliant Satellite Based Augmentation Systems (SBAS) and Ground Based Augmentation Systems (GBAS).

This antenna MOPS is applicable to the GPS L1 and L5 frequencies [RD2, RD3] as well as the Galileo E1 and E5a [RD1] frequencies. Details on multiband antennas that receive the GLONASS signals are listed in Appendix B. However, reception of signals from the GLONASS constellation is not covered by the requirements listed in this MOPS. Appendix B is included for informational purposes alone and is not intended to be invoked as part of any TSO that may reference this MOPS. Any references made to constellations other than GLONASS in Appendix B are superseded by the relevant sections in the main body of this antenna MOPS.

1.3 Operational Applications

The GNSS active antenna equipment is intended to be used in all phases of aircraft operation, including on the surface, approach and landing, departure, terminal, and enroute.

1.4 Intended Function

The airborne GNSS navigation system can be used as a means of navigation system in an aircraft when approved and an operational GNSS navigation satellite system is available. Incorporated within these standards are equipment characteristics that should be useful to users, designers, manufacturers, and installers of the equipment. This document defines the performance for antennas that will be used with GNSS receiver equipment in the L1 and L5 frequency bands. Throughout this document, the terms L1 and L5 frequencies are used to denote the GNSS signals with center frequencies and bandwidths as described in Table 2-1.

1.5 Operational Goals

The operational goal for the GNSS antenna is to provide adequate GNSS satellite signals under a wide range of environmental conditions and installations that will assure safe flight operations. The requirements of this document provide the minimum requirements for antennas designed for GNSS service and employing active designs at the L1 and L5 frequencies.

1.6 Assumptions

It is assumed that the GNSS active antenna will be used with GNSS receiver equipment defined in appropriate MOPS.

1.7 Test Procedures

The test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

The order of tests specified suggests that the antenna be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Section 2.0 need to be demonstrated as a precondition to satisfactory completion of the installed systems tests of Section 3.0.

Four types of test procedures are specified. These include:

a. Environmental Tests

Environmental test requirements are specified in Section 2.3. The procedures and their associated limit requirements are intended to provide a laboratory means of determining the electrical and mechanical performance of the antenna under environmental conditions expected to be encountered in actual operations.

Unless otherwise specified, the environmental conditions and test procedures contained in DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment, are used to demonstrate antenna compliance Bench Tests.

b. Bench Tests

Bench Test procedures are specified in Section 2.4. These tests provide a laboratory means of demonstrating compliance with the requirements of Section 2.2. Test results may be used by antenna manufacturers as design guidance, for monitoring compliance, and, in certain cases, for obtaining formal approval of antenna design.

c. Installed Equipment Tests

Although bench and environmental test procedures are not included in the installed antenna tests, their successful completion is a precondition to completion of the installed tests. In certain instances, however, installed antenna tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from, or to, other antenna installed on the aircraft, etc. Installed tests are normally performed under two conditions:

i. With the aircraft on the ground and using simulated or operational system inputs.

ii. With the aircraft in flight using operational system inputs appropriate to the antenna under test.

Test results may be used to demonstrate functional performance in the intended operational environment.

d. Operational Tests

The operational tests are specified in Section 2.4. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function(s).

1.8 Structure of the document

This document outlines the general antenna requirements for usage on an aircraft. Antenna performance requirements under standard conditions are presented. Performance requirements under environmental conditions are presented and test procedures for the antenna are specified.

1.9 Definition of Terms

1.9.1 Requirement Word Definitions

To ensure consistency of interpretation of performance requirements and test procedures contained in Section 2 of this MOPS, the following table of definitions is provided:

Table 1.1: Terms for use in Performance Requirements and Test Procedures

	Requirements	Good Industry Practice	Alternate Method
Word	Shall	Should	May
Meaning	Refers to a mandatory performance requirement or test procedure	Refers to a performance or test procedure recommendation that, although not mandatory, is considered good industry practice	With regard to performance requirements and test procedures, refers to an alternate approach for manufacturer consideration
Impact to Design	Could result in inability to meet intended function or interoperability with other equipment	Although not necessary to meet performance requirements, could result in a deficiency to the end user or installation problems if not followed	None. However, the alternate method should be followed in its entirety if the manufacturer chooses to use that method

Per RTCA MOPS style guide, in the text of performance requirements provided in Section 2.0, the use of the words "must" and "will" is discouraged.

1.9.2 Additional Relevant Terms

Active Sub-Assembly	Portion of the active antenna unit that includes all circuitry except for the passive radiating element and its associated passive feed network.
Axial Ratio	The ratio of the major axis to the minor axis of the polarization ellipse.
Boresight	Unless specified otherwise, this direction is parallel to the Z axis in Figure 2-2.
dBic	dB relative to an isotropic antenna with circular polarization.
dBm	dB relative to one milliwatt.
Elevation Angle	The angle between the axis of the measurement line and the installed antenna horizontal plane.
G/T Ratio	The ratio of the passive radiating element gain to the equivalent input noise temperature of the active subassembly (referred to the passive antenna terminals)
HIRF	High Intensity Radiated Fields (e.g., from an off-board high power radar transmitter)
Polarization	That property of a radiated electromagnetic wave describing the time-varying direction and amplitude of

	the electric field vector; specifically, the figure traced as a function of time by the extremity of the vector at a fixed location in space, as observed along the direction of propagation.
Total Transducer Gain	The product of the active antenna unit passive antenna element gain and the active subassembly gain.
VSWR	Voltage Standing Wave Ratio.

1.10 Aircraft Equipment Information Vulnerabilities

The DFMC Antenna is an active electronic device that is comprised of components such as a passive radiator, diplexer, filters, LNA's and other simple electronic hardware that are not exposed to information vulnerabilities (such as cybersecurity risks). In addition, it is typically devoid of any programmable software modules or components.

Aircraft equipment information vulnerabilities (such as cybersecurity risks) are not applicable to this antenna.

1.11 References

1.11.1 Applicable Documents

[AD1] Environmental Conditions and Test Procedures for Airborne Equipment, DO-160G, Dec 2010

1.11.2 Reference Documents

[RD1] Galileo Open Service, Signal In Space Interface Control Document, ESA European GNSS Authority, Issue 1.3, December 2016.

[RD2] Navstar GPS Space Segment/Navigation User Interfaces, IS-GPS-200, Revision H, Sep 2013

[RD3] Navstar GPS Space Segment - User Segment L5 Interfaces, IS-GPS-705D, Sept-2013

[RD4] ARINC CHARACTERISTIC 743A-5, May 29, 2009

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2 EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

Under no circumstance shall the installed and connected GNSS antenna impair the aircraft airworthiness.

2.1.2 Intended Function

The antenna shall perform its intended function(s), as defined by the manufacturer, and its proper use shall not create a hazard to other airspace users.

2.1.3 Communications Regulatory Compliance

All equipment shall comply with the applicable rules of the communications regulator. For the US the communications regulator is the FCC (Federal Communications Commission).

2.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (e.g., seals, grommets) that would not contribute significantly to the propagation of a fire.

Note: One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.

2.1.5 Effects of Test

The antenna shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

The laboratory testing methods in this MOPS require the antenna to be installed on a ground plane as described in Section 2.4.1.7. A ground plane of this or larger area is common on air carrier size aircraft but may not be possible on smaller platforms such as helicopters or unmanned aircraft. The Size of the ground plane used for test shall be specified in the installation instructions for the antenna.

2.2 GNSS Active Antenna Unit Performance – Standard Conditions

This section describes the RF performance of the GNSS antenna under Standard Conditions. The Standard Conditions are defined by the laboratory environment and related testing facility conditions. The GNSS active antenna unit is the complete unit consisting of all subsystems including the passive radiator, diplexers, LNAs, combiners and DC bias interface circuitry.

This MOPS defines key performance parameters for GNSS active antennas. This MOPS does not specify performance standards for a passive GNSS antenna.

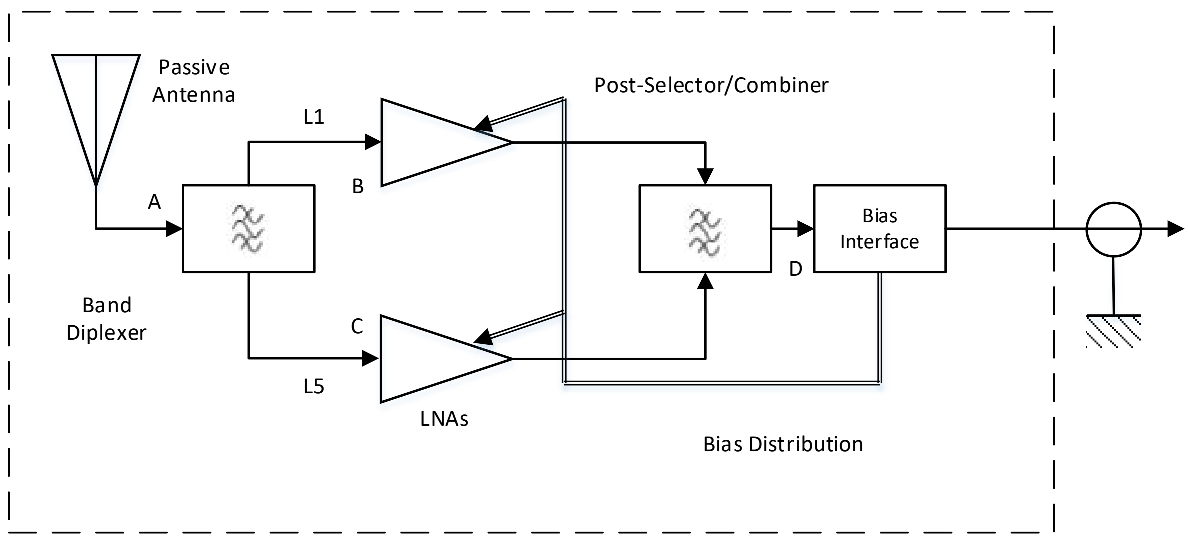

Figure 2-1: GNSS Integrated Active Antenna.

Figure 2-1 shows the architecture for one possible version of the active antenna. Separate Low Noise Amplifiers (LNAs) are shown for each frequency band. Stage A in the processing represents the input to the L1/L5 diplexer. Stages B and C are the inputs to first active stages in the antenna on the L1 and L5 paths. Stage D is the output of the L1/L5 combiner. There may be addition stages of filtering and/or amplification along either of the L1 (ABD) /L5 (ACD) signal flow paths as seen in Figure 2-1.

It is understood that the bulk of applications will require active antennas, especially those dealing with a significant separation distance between GNSS antenna and receiver. For those installations, an attenuation of 13 dB may be used to account for cabling losses. For active antennas the output port will be the applicable point of reference. It is assumed that the majority of the multi-band antennas will be of the active type. Therefore, this standard will address active antennas only.

Note: The GNSS Active antenna is intended to be an integrated active antenna that can support the A743A-5 [RD-4] footprint for the purposes of backwards compatibility on some existing air transport platforms.

2.2.1 Frequency of Operation

The antenna unit shall operate over the bands outlined in Table 2-1, unless otherwise specified for a particular parameter.

Table 2-1: GNSS Bands

Band	Central frequency (MHz)	Lower frequency limit (MHz)	Upper frequency limit (MHz)	Bandwidth (MHz)
E5a Galileo	1176.45	1166.22	1186.68	20.46
E1 Galileo	1575.42	1565.19	1585.65	20.46
L5 GPS	1176.45	1166.22	1186.68	20.46
L1 GPS	1575.42	1565.19	1585.65	20.46

Note:

1. *Although the specific GPS and Galileo signal bands are indicated in Table 2-1, the RF aperture of this antenna is expected to support any GNSS signal that is centered at L1/L5 with a signal bandwidth that is adequately addressed by the antenna bandwidth requirements in this MOPS.*
2. *The bandwidths indicated in Table 2-1 are the nominal values for this band. The minimum and maximum bandwidths for these bands are listed in Section 2.2.8.1.*
3. *The bandwidth requirements for this antenna is adequate to support the BOC(1,1) signal processing needs for Galileo E1b,c.*

2.2.2 Antenna Unit return loss and impedance

2.2.2.1 Antenna Unit Output Return Loss and Impedance

The Return Loss at the output port of the dry GNSS antenna shall be less than -14 dB (1.5:1 VSWR) referred to 50 Ohm impedance throughout the bandwidths of the GNSS bands specified in Table 2-1. The Return Loss at the output port of the GNSS antenna shall be less than -10 dB (2:1 VSWR) when 0.5 inches of ice is accumulated over the antenna throughout the bandwidths of the GNSS bands specified in Table 2-1

2.2.2.2 Active subassembly Input VSWR

The input VSWR as measured at the input of the active sub assembly shall be less than 1.8 over the operating frequency range.

Note: The manufacturer may choose the appropriate reference impedance for this VSWR measurement.

2.2.3 Antenna Unit Relative Radiation Pattern and Passive Element Gain

2.2.3.1 Antenna Unit Relative Radiation Pattern

The antenna radiation pattern refers to a coordinate system with zero-degree elevation measured at the horizon and 90-degree elevation at zenith. Zero-degree azimuth is referenced parallel to the X axis of the airframe as seen in Figure 2-2. The definition of azimuth and elevation angles is also denoted. The antenna is assumed to be placed at the origin of the coordinate system O (Figure 2-2). The GNSS antenna quantity defined is the relative radiation pattern (i.e.) the radiation pattern normalized to its peak value expressed in dB. The peak normalization reference value is the maximum value based on all available azimuthal cuts restricted within an elevation angle cone of 15° from zenith.

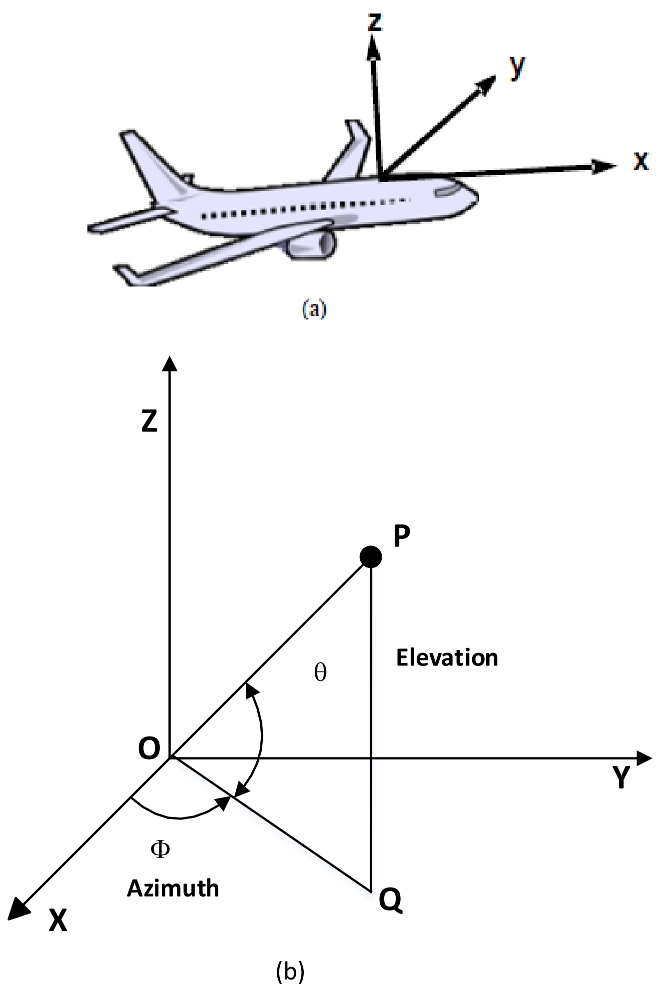

Figure 2-2: Coordinate systems for radiation patterns

The relative radiation pattern measured at the GNSS band centers (Table 2-1) shall comply with the maximum and minimum gain per the elevation angle templates specified in Table 2-2. These templates are assumed to form in a linear (in dB) piecewise fashion with break points defined by the values of Table 2-2.

Table 2-2: Relative Radiation Pattern template

Elevation Angle (degrees)	Minimum (dB)	Maximum (dB)
0	-11	-7
5	-8.5	-5
10	-7	-3
15	-5.5	-1
30	-3.5	-0.75
>= 75	-2.5	0

Note: Including the measurement system accuracy limitations, small deviations are acceptable provided that their magnitude does not exceed the 1 dB and the percentage of the angular regions of deviation do not exceed 5% of the total angular directions.

The relative antenna gains shall not vary by more than 1 dB taking into account the full operational temperature range.

2.2.3.2 Passive Element Gain

The passive radiating element gain for the active antenna unit is specified in terms of the absolute gain (dBic) for the passive element and any associated passive feed network and radome with respect to an ideal circular isotropic antenna. The passive radiating element gain at 1575.42 MHz and 1176.45 MHz at and above 5° elevation shall be at least -4.5 dBic over all azimuth angles. The maximum passive element gain above 75 degrees elevation shall be limited to +4 dBic.

Note: In their installation instructions, the antenna manufacturer should identify the minimum passive element gain at 5 degrees and the maximum passive element gain above 75 degrees elevation for their equipment. Receiver manufacturers can take advantage of performance better than the minimum requirement, and documenting improved performance facilitates the installation and integration of the antenna and receiver.

2.2.4 Polarization and Axial Ratio

The antenna radiation pattern polarization shall be nominally right-hand circularly polarized. The axial ratio shall be less than or equal to 3.0 dB over the operating frequency range as measured in a region extending from boresight down to 40 degrees of elevation off boresight across all azimuth angles.

2.2.5 Antenna Sensitivity: The G/T Ratio

The antenna, irrespective of its implementation, needs to ensure delivery of a minimum acceptable C/N_o GNSS signal to the receiver. The quantity for ensuring this (as used traditionally with other satellite communication systems) is the G/T.

In the L1/E1 band, the GNSS antenna's G/T value shall be >= 30.6 dB/K for all elevation angles θ (where: $5° <= \theta <= 90°$), across all azimuth angles and for all frequencies within $f_C \pm 8$MHz; with f_c set to 1575.42 MHz.

In the L5/E5a band, The GNSS antenna's G/T value shall be >= -32.5 dB/K for all elevation angles θ (where: 5° <= θ <= 90°), across all azimuth angles and for all frequencies within f_C±10.23 MHz; with f_c set to 1176.45 MHz.

The antenna gain-to-noise temperature ratio G/T is usually computed at the interface between the passive antenna and the input of the antenna front-end (low noise amplifier). This would be at stages B (L1) and C (L5) in Figure 2-1. However, the G/T value is the same at any interface in the antenna system.

The G/T is computed by dividing the antenna gain at the input of the antenna front-end (i.e. the gain of the passive antenna element) by the antenna system noise temperature at the input of the antenna front-end:

$$G/T = G_{\text{passive antenna}} / T_{\text{antenna system}} \qquad \text{(Equation 2-1)}$$

The antenna system noise temperature is the sum of the sky noise temperature and the equivalent noise temperature at the input of the antenna front-end electronics:

$$T_{\text{antenna system}} = T_{\text{sky}} + T_{\text{equivalent noise temperature}} \qquad \text{(Equation 2-2)}$$

T_{sky} is computed by evaluating the sky noise temperature taking into account the radiation pattern of the antenna. For an antenna with a hemispherical coverage in L-band this temperature (T_{sky}) is no more than 100 K.

The gain of the antenna decreases as the elevation angle decreases. Since the G/T requirement is also applicable down to 5º elevation angle, the maximum equivalent noise temperature can be determined by using the absolute gain at this elevation. A minimum figure for the absolute gain for this type of antenna at 5º elevation is -4.5 dBic. This implies a maximum antenna system noise temperature of 407 K. The max equivalent noise temperature of the front end is then 307 K. The noise figure of the front end of the total antenna system can be computed by using the relationship:

$$Te = [F-1]*To \qquad \text{(Equation 2-3)}$$

with To = 290 K. Therefore, the maximum noise figure of the antenna front end shall be Nfe = 3.14 dB and the maximum total antenna system noise figure (Nas = 3.8 dB) at L1/E1 frequency.

For the L5/E5a band, this implies a maximum antenna system noise temperature (Nas) of 631 K (5.02 dB) and a maximum noise temperature of the antenna front end (Nfe) of 531K (4.52 dB).

The minimum G/T requirement shall be met over the full operational temperature range. See Appendix A for further details.

2.2.6 Total Transducer Gain and Gain Compression

2.2.6.1 Minimum Boresight Total Transducer Gain

The transducer gain is a term containing both the passive antenna gain and the gain of the preamplifier. The specification here deals only with the active GNSS antennas. Its purpose is to ensure the quality of the delivered GNSS signal to the receiver when both are connected with a long length of cable. The peak value of the transducer gain assuming the peak angular response shall be no less than 29.5 dBic across 1575.42 MHz (L1/E1)) +/- 8 MHz and 1176.45 (L5/E5a) +/- 10.23 MHz over the full environmental temperature range.

2.2.6.2 Active Sub-Assembly Transducer Gain

The minimum active sub-assembly gain over the frequency ranges 1575.42 +/- 8 MHz and 1176.45 +/- 10.23 MHz shall not be less than 26.5 dB over the full temperature range.

Note:

1. *The active sub-assembly is assumed to contain the HIRF protection, pre- and post-selection RF filtering, preamplifier and DC bias circuitry and interface at a single input port to the passive radiating element.*
2. *The listed active sub-assembly minimum gain value is consistent with the total transducer gain in Section 2.2.6.1. For installations with higher cable attenuation, a higher active sub-assembly minimum gain (and therefore a higher total transducer gain) may be necessary. To avoid excessive receiver dynamic range impact, the active sub-assembly mid-band gain value should remain within a +/- 2 dB range about a nominal manufacturer-specified value.*
3. *The antenna manufacturer should identify the nominal amplifier gain and tolerance for their equipment in their installation instructions. Receiver manufacturers need this information to define installation instructions that integrate the antenna and receiver.*

The difference in overall gain across the L1/E1 and L5/E5a RF chains in the antenna shall be ≤ 6dB.

2.2.6.3 Boresight Transducer Gain Compression Point

Boresight transducer gain compression is a measure of the linearity of the active antenna. The active antenna unit shall have less than 1 dB gain reduction to a low-level signal (at central frequencies per Table 2-1) at boresight when a second test signal is present at the frequency and minimum power values shown in Table 2-3 or equivalently in Figure 2-3. Compression points for frequencies less than or equal to 1315 MHz shall be referenced to a low-level signal at 1176.45 MHz. Compression points for other frequencies in Table 2-3 shall be referenced to a low-level signal at 1575.42 MHz. The compression point values at other points in frequency (which are in-between any two points listed in table) may be inferred by linearly interpolating the values (in dB scale) between the two closest points in the table.

The 1 dB input compression power is referred to the input port of the associated preamplifier as shown in Figure 2-1.

Table 2-3: 1 dB Input Compression Point as a Function of Frequency

Frequency (MHz)	1dB Input Compression Point (dBm)
1000	23
1090.45	23
1130.45	23
1149.45	8
1162.45	-15
1190.45	-15
1200.45	10
1225.45	23

Frequency (MHz)	1dB Input Compression Point (dBm)
1250.45	23
1315	23
1400	20
1515.42	8
1531.42	0
1554.42	-12
1558.42	-15
1591.92	-15
1605.42	-8
1616.42	-4
1619.42	1
1625.42	8
2000	20

Note: The 1dB Input Compression Point for frequencies in-between those specified in the table are determined by linearly interpolating the compression point values (in dB) between frequency points specified in the Table.

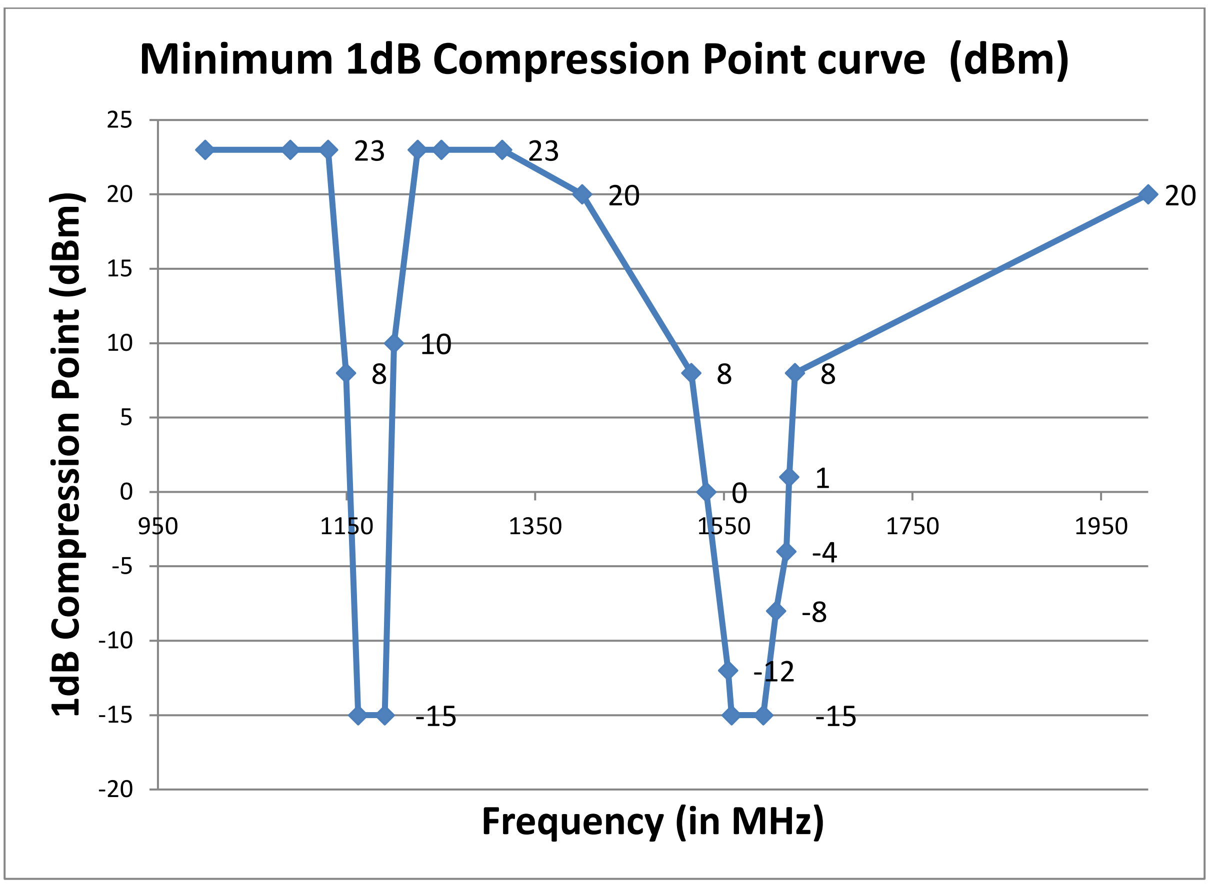

Figure 2-3: 1 dB compression point graph (in dBm).

Note: In case of an integrated antenna the input preamplifier port may not be easily accessible or when a test point cannot be easily inserted the 1 dB compression power points can be translated as an externally applied Electrical field (E) illuminating the full antenna assembly along a preselected direction. The formula for deriving the field strength of the applied electrical field producing the set power at the internal input of the preamplifier is:

$$E\ (dBV/m) = P_{in}\ (dBm) - G_p\ (dBi) + 20 \log (f_{GHz}) + 17.21 \qquad \text{(Equation 2-4)}$$

With G_P the reference total Gain of the embedded passive antenna used. Scaling at any other direction is possible and permissible using the above formula and the measured relative pattern.

2.2.7 Output Load Stability

The active antenna shall be unconditionally stable for any positive real output load impedance.

Note: This implies that the active sub assembly (which includes the amplifiers) does not suffer from issues such as oscillations when connected to a positive real output load impedance.

2.2.8 Boresight Gain Relative Frequency Response

The Relative Frequency Response (RFR) is defined as the Transducer Gain variation in dB at the boresight direction (Elevation angle θ= 90°) at any frequency normalized to the peak response at the same direction taking into account the Transducer Gain values across the GNSS frequencies at the frequency bands:

a) L5/E5a +/- 10.23 MHz

b) L1/E1 +/- 8 MHz

The normalization is done separately for (a) and (b). Frequencies equal to or below 1315 MHz are normalized to the L5/E5a band and frequencies above 1315 MHz are normalized to the L1/E1 band.

2.2.8.1 -3 dB Relative Response Frequencies

At the L1/E1 frequency band, the active antenna relative boresight gain lower frequency -3 dB point shall be lower than 1567.42 MHz and the upper frequency -3 dB point shall be higher than 1583.42 MHz. At the L5/E5a frequency band, the active antenna relative boresight gain lower frequency -3 dB point shall be lower than 1166.22 MHz and the upper frequency -3 dB point shall be higher than 1186.68 MHz.

2.2.8.2 Maximum Boresight Relative Frequency Response

The maximum relative boresight gain shall have the frequency response as specified in Table 2-4 and illustrated in Figure 2-4.

Table 2-4: Maximum Boresight Relative Frequency Response (MHz)

Frequency (MHz)	Relative Frequency Response (dB)
1000	-87
1090.45	-78
1130.45	-56
1149.45	-35
1162.45	0
1190.45	0
1200.45	-37
1225.45	-62
1250.45	-77
1315	-77
1400	-50
1515.42	-50
1531.42	-50
1535.42	-30
1554.42	-5
1558.42	0
1591.92	0
1605.42	-25.35
1616.42	-43
1619.42	-50
1625.42	-50
2000	-50

Note: The selectivity for frequencies in-between those specified in Table 2-4 are determined by linearly interpolating the selectivity mask values (in dB) between frequency points specified in this table.

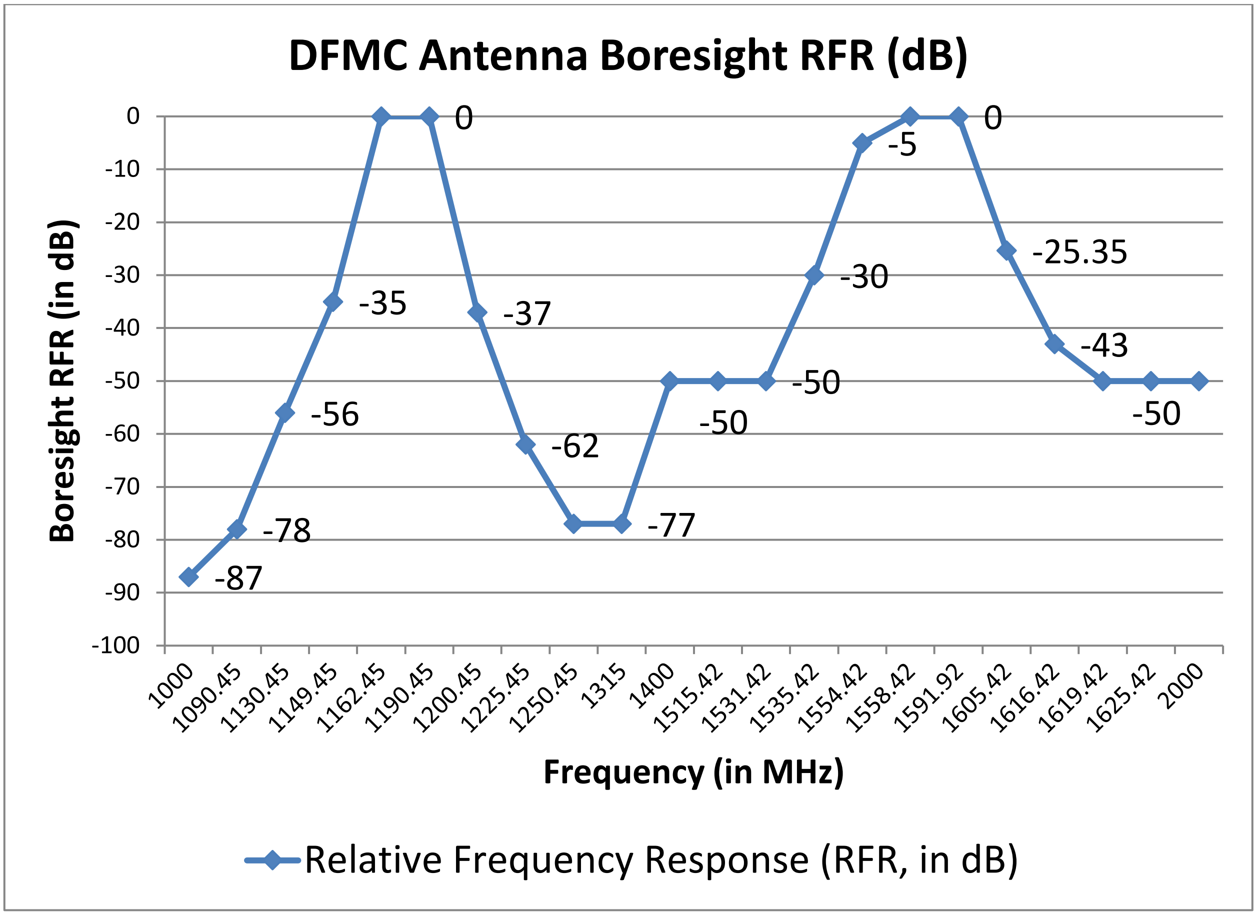

Figure 2-4: Boresight RFR –Antenna Selectivity

2.2.9 Burnout Limit

The antenna preamplifier shall withstand a CW input carrier up to +30 dBm without damage. Under these conditions the output of the preamplifier shall be limited to +20 dBm. The input carrier is referred to the notional or real output of the passive antenna radiator constituent of the antenna assembly. For those cases where the passive radiator and the preamplifier are closely integrated, an alternative requirement can be formulated by translating the input power and thus specifying the externally impressed electric field producing the above stated output. The details are entirely analogous to the methodology outlined in Note 1 of Section 2.2.6.3.

2.2.10 Pulse power Recovery Time

The pulse power recover time specifies the delay of resuming normal operation after a strong spurious pulse signal is applied to the active antenna. The specification takes into account the realistic scenarios for these strong signals sources and at points makes explicit reference to them. The power levels of the pulse are applicable at the output of the passive radiator component of the active antenna (at the input of the active subassembly). The method used to determine the excitation levels is similar to the methodology outlined in Note 1 of Section 2.2.6.3.

2.2.10.1 In band maximum pulse input at L1/E1 Band

The GNSS active antenna shall resume normal operation within 10 µs of the trailing edge of a pulse with a width of up to 1 ms and a peak power of 30 dBm and a duty cycle of 10%.

2.2.10.2 In band maximum pulse input at L5/E5a Band

The GNSS active antenna shall provide normal performance when a DME type pulse with peak power of no more than -45 dBm is received at the output of the embedded passive radiator. For higher peak power DME-like pulse signals of up to 30 dBm, the GNSS antenna shall resume normal operation within 10 µs. The main characteristics of airborne DME as applicable to GNSS in the L5/E5a band are provided in Appendix C.

2.2.10.3 Out of band maximum pulse input

For the GNSS L5 band, out of band frequencies are those that are outside of the range 1149 MHz to 1201 MHz for the L5 band. The GNSS active antenna shall provide normal performance when a DME type pulse with peak power of no more than --22 dBm is received in the out of band frequencies surrounding GNSS L5 at the output of the embedded passive radiator. For higher peak power pulses up to 30 dBm, the GNSS antenna shall resume normal operation within 1 µs.

2.2.11 Group Delay

2.2.11.1 Boresight Differential Group Delay (BDGD)

The Group delay deals with the behavior of the phase pattern of the Copolar (RHCP) Transducer pattern. If the transducer pattern (voltage or electric field terms) is denoted in complex form and is expressed as:

$$E(\theta,\varphi,f) = \| \ E(\theta,\varphi,f) \ \|. \angle E(\theta,\varphi,f) \qquad \text{(Equation 2-5)}$$

With

- θ: the elevation angle (degrees)
- φ: the azimuth angle (degrees)
- f: the frequency (Hz)

The phase pattern is the angular part of it:

$$\Phi(\theta,\phi,f) = \angle(E(\theta,\varphi,f) \qquad \text{(Equation 2-6)}$$

in degrees.

The Group Delay is defined as:

$$\delta\tau(\theta,\phi,f) = \frac{-1}{360}\frac{\delta\Phi(\theta,\varphi,f)}{\delta f} \qquad \text{(Equation 2-7)}$$

in seconds.

The Boresight Differential Group Delay (BDGD) is defined individually and separately for each of the frequency bands in Table 2-1 as:

$$\Delta T_B = max \ \| \ \delta\tau(\theta_B,\varphi_B,f_i) - \delta\tau(\theta_B,\varphi_B,f_j) \ \| \qquad \text{(Equation 2-8)}$$

Where:

- θ_B, φ_B denote the boresight direction
- and fi, fj are any and all frequency pairs within the individual bandwidth of the GNSS frequency bands as defined in Table 2-1with fj > fi.

The BDGD of the antenna shall be less than 25 ns.

Note: The BDGD represents the combined effects of both the passive radiator as well as the built-in preamplifier and embedded filtering functions.

2.2.11.2 Differential Group Delay versus Angle (DGA)

The DGA (for each frequency band) is defined as:

$$\Delta T_A = max \parallel \delta\tau(\theta, \varphi_C, f_G) - \overline{\delta\tau(85^o, \varphi_C, f_G)} \parallel \quad \text{(Equation 2-9)}$$

With f_G being the center of each of the GNSS Frequency bands (L1/E1 and L5/E5a, Table 2-1). The above expression for the DGA is calculated for every elevation angle θ (at or above 5 degrees) within an azimuthal pattern cut $\varphi = \varphi_C$ and for all azimuthal angle subsets. The DGA (ΔT_A) for the L1/E1 and L5/E5a frequency bands (measured independently) shall be:

$\leq (1.5 - 0.02125*(\theta - 5^o))$ nanoseconds, for $5^o <= \theta < 45^o$ and, (Equation 2-10)

≤ 0.65 nanoseconds, for $\theta \geq 45^o$.

Note:

1. *The DGA quantity is affected solely by the intrinsic properties of the passive radiator.*
2. *Based on previous measurements, it has been seen that the DGA may increase in a monotonic fashion as we go down in antenna elevation (towards the horizon).*

2.2.11.3 L1-L5 Group delay difference

The group delay difference between the L1 and L5 operating frequencies shall not exceed 15 nanoseconds over the operating temperature range. The L1-L5 group delay difference is defined as the difference between the group delay measured at the center of the L1 operating frequency and the group delay measured at the center of the L5 operating frequency as measured at boresight.

2.2.12 Power Interface

All antenna power shall be supplied on a DC power interface. DC power required shall be supplied directly through the coaxial RF output connector. The GNSS antenna shall operate with a DC input voltage anywhere within the range of 4.5 to14.4 V and it shall draw no more than 200 mA of current. The load capacitance of the central conductor of the RF coaxial output to any internal interfaces shall not exceed 0.75 uF.

Note: The current allocation exceeds the legacy 60 mA specification on existing GPS only antenna installation as this reflects the increased complexity due to multiple frequency bands and the demands for increased linearity.

2.3 Equipment Performance - Environmental Conditions

The environmental tests and performance requirements described in this subsection are intended to provide a laboratory means of determining the overall performance characteristics of the antenna under conditions representative of those that may be encountered in actual operations.

Some of the environmental tests contained in this subsection need not be performed unless the manufacturer wishes to qualify the equipment for that particular environmental condition. These tests are identified by the phrase "When Required." If the manufacturer wishes to qualify the equipment to these additional environmental conditions, then these "When Required" tests shall be performed.

Unless otherwise specified, the test procedures applicable to a determination of antenna performance under environmental test conditions are set forth in RTCA Document DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*. General information on the use of DO-160G is contained in Sections 1.0 through 3.0 of that document. In addition, a method of identifying which environmental tests are conducted and other amplifying information on conducting the tests is contained in Appendix A of DO-160G.

Some of the performance requirements in Section 2.2 are not required to be tested to all of the conditions contained in DO-160G. If judgment and experience indicate that these particular performance parameters are not susceptible to certain environmental conditions, and that the level of performance specified in Section 2.2 will not be measurably degraded by exposure to these particular environmental conditions, such tests may be omitted.

In addition to the exceptions above, certain environmental tests contained in this section are not required for minimum performance equipment unless the manufacturer wishes to qualify the antenna for additional environmental conditions. If the manufacturer wishes to qualify the antenna to these additional conditions, then these tests shall be performed.

The purpose of the tests are to ensure that both operational performance requirements and survivability requirements have been met per the procedures outlined in Section 2.3.1. According to DO-160G multiple test articles may be used, tests may be performed in any order, and separate test articles may be used for demonstrating compliance with the separate tests. It should be noted that the sand and dust test are not to be conducted prior to the salt fog or humidity tests. However, the DC interface requirement (Section 2.2.12) shall be performed on the antenna test article that was subjected to the Burnout Limit (Section 2.2.9) test requirement.

2.3.1 Specific Environmental Test Conditions

The equipment shall be subjected to the test conditions as specified in DO-160G as indicated below (Table 2-5). For some test conditions, the performance parameters must be met during the environmental stimulus, while for others, the performance parameters must be met after the stimulus. For the G/T ratio performance parameter, a “hot-cold” noise test at boresight is an acceptable alternative that can be performed before and after the environmental stimulus, to identify any relative performance change. Categories are for locations external to the aircraft.

Table 2-5. Environmental Test Conditions Summary – DO-160G Reference.
(ASA is Antenna's Active Sub-Assembly, AAU is Active Antenna Unit (the complete active antenna))

Section No	Section Title	Category	Operational test
4	Temperature & Altitude	F2	AAU: No ASA: Yes
5	Temperature Variation	A	AAU: No ASA: Yes
6	Humidity	B	Yes
7	Shock & Crash Safety	B	No
8	Vibration	C L Y	Yes
9	Explosion Proofness	N/A	N/A
10	Water-proof	S	No
11	Fluids	F [3)]	No
12	Sand & Dust	D	No
13	Fungus Resistance	N/A	N/A
14	Salt Spray	S	No
15	Magnetic Fields	A	Yes
16	Power Input	N/A	N/A
17	Voltage Spike	N/A	N/A
18	Audio Frequency Conducted Susceptibility – Power Inputs	N/A	N/A
19	Induced Signal Susceptibility	ZC	Yes
20	Radio Frequency Susceptibility	RR	Yes
21	Spurious Radio Frequencies	H	Yes
22	Lightning Induced Effects	A3J3L3 [1)]	No
23	Lightning Direct Effects	2A [2)]	No
24	Icing	C	Yes (by test or analysis)
25	ESD	A	Yes
26	Fire, Flammability	C	No

[1.] To protect the antenna for indirect lightning effects, the use of a lightning protection circuit at the output of the antenna is recommended in the design of the antenna. This protection circuit will protect the active parts of the antenna to the lightning induced voltages in the antenna cable. From an installation and safety point-of-view, this protection should be built-in in the antenna case.

[2.] To protect the antenna for direct lightning effects, the use of shorting pins to the antenna patch is recommended in the design of the antenna.

[3.] Fluid susceptibility for solvents, cleaning, and de-icing fluids.

2.3.2 Temperature and Altitude Tests (DO-160G, Section 4.0)

DO-160G contains several temperature and altitude test procedures that are specified according to the category specified in the preceding Section 2.3.1. The following Sections contain the applicable test conditions specified in Section 4.0 of DO-160G.

2.3.2.1 Operating Low Temperature Test

The equipment shall be subjected to the test conditions as specified in DO-160G, Section 4.5.2, and the following requirements of this standard shall be met:

1. Active Sub-Assembly (ASA) Input VSWR: The input VSWR shall be less than 1.8 over the operating frequency range.
2. Active Sub-Assembly (ASA) Input Noise Temperature:
   L1/E1: Section 2.2.5 - Input Noise Temperature ≤ 307 K over 1575.42 +/- 8 MHz
   L5/E5a: Section 2.2.5 - Input Noise Temperature ≤ 531 K over 1176.45 +/- 10.23 MHz
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain
4. L1/E1: Section 2.2.8.1 - -3 dB Relative Response Frequencies (ASA)
   L5/E5a: Section 2.2.8.1 - -3 dB Relative Response Frequencies (ASA)
5. L1/E1: Section 2.2.8.2 - Maximum Boresight Relative Frequency Response
   The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
   L5/E5a: Section 2.2.8.2 - Maximum Boresight Relative Frequency Response
   The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz)
6. Section 2.2.7 - Output Load Stability {this test may be met with an integrated active unit}
7. L1/E1: Section 2.2.9- Burnout Protection (ASA)
   L5/E5a: Section 2.2.9 – Burnout Protection (ASA)
8. L1/E1: Section 2.2.11.1 – Boresight Differential Group Delay (ASA)
   L5/E5a: Section 2.2.11.1 - Boresight Differential Group Delay (ASA)
9. L1 – L5 Section 2.2.11.3 - Group Delay Difference (ASA)
10. Section 2.2.12 – DC Power Interface

2.3.2.2 High Operating Temperature Test

The equipment shall be subjected to the test conditions as specified in DO-160G, Section 4.5.4, and the following requirements of this standard shall be met:

1. Active Sub-Assembly (ASA) Input VSWR: The input VSWR shall be less than 1.8 over the operating frequency range.
2. Active Sub-Assembly (ASA) Input Noise Temperature:
   L1/E1: Section 2.2.5 - Input Noise Temperature ≤ 307 K over 1575.42 +/- 8 MHz
   L5/E5a: Section 2.2.5 - Input Noise Temperature ≤ 531 K over 1176.45 +/- 10.23 MHz
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain
4. L1/E1: Section 2.2.8.1 - -3 dB Relative Response Frequencies (ASA)
   L5/E5a: Section 2.2.8.1 - -3 dB Relative Response Frequencies (ASA)
5. L1/E1: Section 2.2.8.2 - Maximum Boresight Relative Frequency Response

The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
L5/E5a: Section 2.2.8.2 - Maximum Boresight Relative Frequency Response
The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz)

6. L1/E1: Section 2.2.9- Burnout Protection (ASA)
   L5/E5a: Section 2.2.9– Burnout Protection (ASA)
7. L1/E1: Section 2.2.10.1 – In-band Pulse Power Saturation Recovery Time (ASA)
   L1/E1: Section 2.2.10.3 – Out of band Pulse Power Saturation Recovery Time (ASA)
   L5/E5a: Section 2.2.10.2 – In-band Pulse Power Saturation Recovery Time (ASA)
   L5/E5a: Section 2.2.10.3 – Out of band Pulse Power Saturation Recovery Time (ASA)
8. L1/E1: Section 2.2.11.1 – Boresight Differential Group Delay (ASA)
   L5/E5a: Section 2.2.11.1 - Boresight Differential Group Delay (ASA)
9. L1 – L5: Section 2.2.11.3 - Group Delay Difference (ASA)
10. Section 2.2.12 – DC Power Interface

2.3.2.3 Altitude Test

The equipment shall be subjected to the test conditions as specified in DO-160G, Section 4.6.1, and the following requirements of this standard shall be met during the test condition application except as noted:

1. L1/E1: Section 2.2.5 – G/T Ratio (AUT, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AUT, before and after test condition application)
   A radiated "hot-cold" noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.
2. Active Sub-Assembly (ASA) Input Noise Temperature:
   L1/E1: Section 2.2.5 - Input Noise Temperature ≤ 307 K over 1575.42 +/- 8 MHz
   L5/E5a: Section 2.2.5 - Input Noise Temperature ≤ 531 K over 1176.45 +/- 10.23 MHz
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain

2.3.3 Temperature Variation Test (DO-160G, Section 5.0)

The equipment shall be subjected to the test conditions as specified in DO-160G, Section 5.0, and the following requirements of this standard shall be met during the test condition application except as noted:

1. L1/E1: Section 2.2.5 – G/T Ratio (AUT, before and after test condition application)

L5/E5a: Section 2.2.5 – G/T Ratio (AUT, before and after test condition application)
A radiated "hot-cold" noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change in an integrated active antenna unit

2. Active Sub-Assembly (ASA) Input Noise Temperature:
   L1/E1: Section 2.2.5 - Input Noise Temperature ≤ 307 K over 1575.42 +/- 8 MHz
   L5/E5a: Section 2.2.5 - Input Noise Temperature ≤ 531 K over 1176.45 +/- 10.23 MHz
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain
4. Section 2.2.12 – DC Power Interface

2.3.4 Humidity Test (DO-160G, Section 6.0)

The active antenna unit equipment shall be subjected to the test conditions as specified in DO-160G, Section 6.0, and the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain
4. L1/E1 Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
   L5/E5a Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz)

2.3.5 Shock Tests (DO-160G, Section 7.0)

2.3.5.1 Operational Shocks

The active antenna unit equipment shall be subjected to the test conditions as specified in DO-160G, Section 7.2, and the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AUT Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, After)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, After)
3. L1/E1: Section 2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, After)
   L5/E5a: Section 2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, After)
4. L1/E1: Section 2.2.11.1 – Boresight Differential Group Delay (AAU, before, after)
   L5/E5a: Section 2.2.11.1 - Boresight Differential Group Delay (AAU, before, after)
5. L1 – L5 Group Delay Difference 2.2.11.3 (AAU, before, after)

2.3.5.2 Crash Safety Shocks

The application of Crash Safety Shock tests in DO-160G, Section 7.3 may result in damage to the antenna under test. Therefore, this test may be conducted after the other tests have been completed. In this case, Section 2.4 "Effects of Test" does not apply. The active antenna unit is considered to have passed this test if it stays attached to its mounting.

2.3.6 Vibration Test (DO-160G, Section 8.0)

The equipment shall be subjected to the test conditions as specified in DO-160G, Section 8.0, and the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)

2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
3. L1/E1 Section 2.2.6.2 – ASA Transducer Gain (during vibration)
   L5/E5a Section 2.2.6.2 – ASA Transducer Gain (during vibration)
4. Section 2.2.12 – DC Power Interface (active during vibration)
   The DC current shall not indicate intermittent behavior during vibration.

2.3.7 Explosion Test (DO-160G, Section 9.0)

Explosion testing is not required because the antenna is not normally installed in an explosive environment.

2.3.8 Waterproofness Tests (DO-160G, Section 10.0)

The integrated active antenna equipment shall be subjected to the continuous stream proof test conditions as specified in DO-160G, Section 10.3.4, and the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   A radiated "hot-cold" noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.

   Note: This test shall be conducted with the spray directed perpendicular to the most vulnerable area(s) as determined by the equipment manufacturer.

2.3.9 Fluids Susceptibility Tests (DO-160G, Section 11.0)

The following sections contain the applicable test conditions specified in Section 11.0 of DO-160G.

2.3.9.1 Spray Test

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 11.4.1, and the following requirements of this standard shall be met:

A. At the end of the 24-hour exposure period, the equipment shall operate at a level of performance that indicates that no significant failures of components or circuitry have occurred.

B. Following the 2-hour operational period at ambient temperature, after the 160-hour exposure period at elevated temperature, the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application
   A radiated "hot-cold" noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)

L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)

4. L1/E1 Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
   L5/E5a Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) Maximum Boresight Relative Frequency Response (after, radiated test)

2.3.9.2 Immersion Test

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 11.4.2, and the following requirements of this standard shall be met:

A. At the end of the 24-hour immersion period, the equipment shall operate at a level of performance that indicates that no significant failures of components or circuitry have occurred.

B. Following the 2-hour operational period at ambient temperature, after the 160-hour exposure period at elevated temperature, the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application
   A radiated "hot-cold" noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)
4. L1/E1 Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
   L5/E5a Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) Maximum Boresight Relative Frequency Response (after, radiated test)

2.3.10 Sand and Dust Test (DO-160G, Section 12.0)

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 12.0, and the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5– G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5– G/T Ratio (AAU, before and after test condition application

A radiated “hot-cold” noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.

3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test).
4. L1/E1 Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
   L5/E5a Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)
   The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) Maximum Boresight Relative Frequency Response (after, radiated test).

2.3.11 Fungus Resistance Test (DO-160G, Section 13.0)

Fungus testing is not required because the antenna is not normally installed in a location that is conducive to growth of fungus.

However, if the manufacturer wishes to qualify the equipment for this particular condition due to specific circumstances, then the Antenna Under Test equipment shall be subjected to the test conditions as specified in DO-160G, Section 13.0, and the following requirements of this standard shall be met:

1. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   A radiated “hot-cold” noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.
2. L1/E1: Section 2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, before and after)
   L5/E5a: Section 2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, before and after.

2.3.12 Salt Spray Test (DO-160G, Section 14.0)

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 14.0, and the following requirements of this standard shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (After)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (After)
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, before and after test condition application)
   A radiated “hot-cold” noise test at boresight (Sect. 2.4.3.2) is an acceptable alternative to identify any relative change.
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (after, radiated test)
4. L1/E1 Section 2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA shall meet the relative gain response requirement over the frequency range 1531.42 - 1605.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz)
L5/E5a Section 2.2.8.2 - Maximum Boresight Relative Frequency Response
(After)
The ASA shall meet the relative gain response requirement over the frequency range 1150 - 1200 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) Maximum Boresight Relative Frequency Response (after, radiated test).

2.3.13 Magnetic Effect Test (DO-160G, Section 15.0)

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 15.0, and the equipment shall meet the requirements of the appropriate instrument or equipment class specified therein.

2.3.14 Power Input Tests (DO-160G, Section 16.0)

This test is not applicable since the aircraft power bus does not directly apply DC power to the active antenna.

2.3.15 Voltage Spike Conducted Test (DO-160G, Section 17.0)

This test is not applicable since the aircraft power bus does not directly apply DC power to the active antenna.

2.3.16 Audio Frequency Conducted Susceptibility Test (DO-160G, Section 18.0)

This test is not applicable since the aircraft power bus does not directly apply DC power to the active antenna.

2.3.17 Induced Signal Susceptibility Test (DO-160G, Section 19.0)

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 19.0.as described in Sub-sections 19.3.1 through 19.3.5. For conditions in Sub-sections 19.3.1 and 19.3.2, the magnetic and electric fields need only be applied under the antenna unit-under-test. The induced signals in Sub-sections 19.3.3 through 19.3.5 are applied to the RF coaxial output cable from the unit. The following requirements shall be met during application of the environmental condition:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (radiated test)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (radiated test)
2. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (radiated test)

2.3.18 Radio Frequency Susceptibility Test (Radiated & Conducted) (DO-160G, Section 20.0)

The equipment shall be subjected to the test conditions as specified in DO-160G, Section 20. Radiated susceptibility test levels for frequencies between 1.0 and 2.0 GHz shall follow the frequency response shape of Section 3.7 (where the listed power limits are converted to equivalent field strength values). The following requirements of this standard shall be met during application of the environmental test stimulus:

2.3.19 Conducted Susceptibility Performance

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance (radiated test)
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance (radiated test)
2. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (radiated test)

2.3.19.1 Radiated Susceptibility Performance

1. L1/E1: Section 2.2.6.3 - Boresight Transducer Gain Compression Point (determined by radiating at the AAU a second, low-level, CW signal at 1575.42 MHz together with the test stimulus and monitoring for less than 1 dB peak decrease in CW signal level. See Section 2.4.2.6 for 1-2 GHz test levels, and modulation, and other details.)
   L5/E5a: Section 2.2.6. - Boresight Transducer Gain Compression Point (determined by radiating at the AAU a second, low-level, CW signal at 1176.45 MHz together with the test stimulus and monitoring for less than 1 dB peak decrease in CW signal level. See Section 2.4.2.6 for 1-2 GHz test levels, and modulation, and other details.)
2. L1/E1/L5/E5a: Section 2.2.9 – Burnout Protection (saturated output power only). For high-level signal test frequencies between 1.0 and 2.0 GHz the AAU (peak) output power at the test frequency from the 150 V/m peak incident field shall not exceed the +20 dBm output limit.
3. L1/E1: Section 2.2.10.1 – Pulse Saturation Recovery Time: (See Section 2.4.2.6 for test procedure details.)
   L5/E5a: Section 2.2.10.2 – Pulse Saturation Recovery Time: (See Section 2.4.2.6 for test procedure details.)

2.3.20 Emission of Radio Frequency Energy Test (DO-160G, Section 21.0)

When the AAU equipment is subjected to the test conditions as specified in DO-160G, Section 21.0, it shall meet the requirements specified therein.

2.3.21 Lightning Induced Transient Susceptibility (DO-160G, Section 22.0)

The AAU equipment shall be subjected to the test conditions as specified in DO-160G, Section 22.0, and the following requirements of this standard shall be met before and after the environmental condition is applied:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, optional measurement at boresight)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, optional measurement at boresight)
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (radiated test)

Note: The intent of these tests is to check for performance degradation after the lightning induced transients have been applied to the integrated antenna unit.

2.3.22 Lightning Direct Effects (DO-160G, Section 23.0)

The integrated active antenna equipment shall be subjected to the test conditions as specified in DO-160G, Section 23.0, and the following requirements of this standard shall be met before and after the environmental condition is applied.

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance
2. L1/E1: Section 2.2.5 – G/T Ratio (AAU, optional measurement at boresight)
   L5/E5a: Section 2.2.5 – G/T Ratio (AAU, optional measurement at boresight).
3. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (radiated test)
4. Lightning-induced signals on the RF coaxial cable shall not exceed the levels associated with DO-160G Section 22, Category A3J3L3 when measured at the 50 Ohm cable termination.

Note: The intent of these tests is to check for performance degradation after the lightning direct transients have been applied to the integrated antenna unit. The induced output transient signals on the coax cable become the receiver indirect test condition.

2.3.23 Icing (DO-160G, Section 24.0)

The AAU equipment shall be subjected to the test conditions as specified in DO-160G, Section 24.0, and the following requirements shall be met:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance
   L1/E1: The output VSWR for an antenna unit exposed to an ice accumulation of 0.5 inches shall not exceed 2.0.
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance
   L5/E5a: The output VSWR for an antenna unit exposed to an ice accumulation of 0.5 inches shall not exceed 2.0.
2. Antenna Unit Relative Radiation Pattern Section 2.2.3.1:
   L1/E1: The antenna unit relative pattern gain shall not degrade more than 4.5 dB at 30º elevation from the dry condition value at the same ambient temperature.
   L5/E5a: The antenna unit relative pattern gain shall not degrade more than 4.5 dB at 30º elevation from the dry condition value at the same ambient temperature.

2.3.24 Electrostatic Discharge (DO-160G, Section 25.0)

The AAU equipment shall be subjected to the test conditions as specified in DO-160G, Section 25.0, and the following requirements shall be met following the test:

1. L1/E1 Section 2.2.2 – AAU Output VSWR and Impedance
   L5/E5a Section 2.2.2 – AAU Output VSWR and Impedance
2. L1/E1: Section 2.2.6.2 – ASA Transducer Gain (radiated test)
   L5/E5a: Section 2.2.6.2 – ASA Transducer Gain (radiated test)

2.3.25 Fire, Flammability (DO-160G, Section 26.0)

The AAU equipment shall be subjected to the test conditions as specified in DO-160G, Section 26.0, and the pass/fail requirements met therein. The purpose of this test is to ensure the non-propagation of the flame in the case where ignition would appear inside or outside of the equipment, while the equipment is in a non-operating mode. There are no electrical performance parameters that need to be conducted following this test.

2.4 Equipment Test Procedures

The test procedures in this section constitute a satisfactory method of determining that the GNSS antenna meets the required performance stated in Section 2.2. Although specific test procedures are cited, it is recognized that other methods may be preferred. Such alternative methods may be used if the manufacturer can demonstrate equivalent test procedures. In this case, the test procedures cited herein must be used as one set of criteria in evaluating the acceptability of the alternate procedures.

Table 2-6 indicates the correspondence between the equipment performance requirements in Section 3 and the tests in this section.

Table 2-6: Test Cross Reference

Requirement	Subject	Tests
2.2.1	Frequency of Operation	2.4.2.1
2.2.2	Antenna Unit Output Return Loss and Impedance	2.4.2.1
2.2.3	Antenna Unit Radiation Patterns	2.4.2.2
2.2.4	Polarization and Axial Ratio	2.4.2.3
2.2.5	Antenna Sensitivity: The G/T Ratio	2.4.2.2, 2.4.2.4
2.2.6.1	Transducer Gain	2.4.2.2
2.2.6.2	Antenna Sub-Assembly (ASA) Gain	2.4.3.1
2.2.3.2	Passive Element Gain	2.4.2.2.2
2.2.6.3	Linearity: Boresight Transducer Gain Compression Point	2.4.2.6.1
2.2.7	Load Stability	2.4.2.5
2.2.8.2	Maximum Boresight frequency response limits	2.4.2.2, 2.4.3.1, 2.4.3.2
2.2.8.1	-3 dB Relative response Frequencies	2.4.2.2, 2.4.3.1
2.2.11.1	Boresight Differential Group Delay versus Frequency	2.4.2.2
2.2.11.2	Differential Group Delay Versus Aspect Angle	2.4.2.2
2.2.11.3	L1 – L5 Group Delay Difference	2.4.2.2
2.2.9	Burnout Limit	2.4.3.3
2.2.10.1	Recovery Time: In band maximum pulse input at L1/E1 Band	2.4.2.6.2
2.2.10.2	Recovery Time: In band maximum pulse input at L5/E5a Band	2.4.2.6.2
2.2.10.3	Recovery Time: Out of band maximum pulse input	2.4.2.6.2
2.2.12	DC Power Interface	2.4.3.3

2.4.1 Test Conditions

The following tests conditions are applicable to the tests specified in this document:

2.4.1.1 Power Input Voltage

Unless otherwise specified, all tests shall be conducted with the input voltage adjusted to design voltage ± 2%.

2.4.1.2 Power Frequency

In the case of equipment designed for operation from an AC power source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency ± 2%.

2.4.1.3 Antenna Installation

The antenna test installation shall include any adapter plates, where used, or other hardware used to interface the antenna to the fuselage. The Antenna Subsystem under test shall include any electronics considered part of the installed Antenna Subsystem. If a radome forms part of the antenna, this shall also be installed during the measurements.

2.4.1.4 Ambient Conditions

Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure, and humidity.

2.4.1.5 Warm-Up Period

Unless otherwise specified, all tests shall be conducted after the manufacturer's specified warm-up period.

2.4.1.6 Connected Loads

Unless otherwise specified, all tests shall be performed with the equipment connected to loads having the impedance values for which it was designed.

2.4.1.7 Antenna Ground Plane

An antenna ground plane shall be used to simulate the conductive mounting surface on the intended aircraft. The metallic ground plane shall have at least a 2-foot radius flat section extending from the center of the antenna unit mounting area. In addition, beyond the minimum 2-foot radius flat section, the ground plane shall incorporate a minimum 90-degree arc as a means of reducing the edge diffraction effects. One example is a minimum 2-inch radius-of-curvature cylindrical metallic section attached below and approximately tangent to the flat section around the entire flat section circumference.

2.4.1.8 Antenna Measurement Range

Testing shall be performed in accordance with the Institute of Electrical and Electronic Engineers (IEEE) Standard Test Procedures for Antennas, IEEE-STD-149-1979. A suitable test range shall be used having a reflectivity level less than -25 dB within a quiet zone containing the antenna under test and the ground plane, and meet the $2D^2/\lambda$ criterion. Figure 2-4 shows a representative test configuration for the test range. "Compact ranges" and/or near-field probing techniques may also be employed if analysis shows that an equivalent accuracy may be obtained.

Other items of standard test equipment are:

Range instrumentation including a 2-axis (minimum) positioner, positioner controller, tunable L-Band RF signal source, receiver, pattern recorder, and polarization measurement instrumentation.

Reference RHCP or linearly-polarized, standard-gain antenna, with gain calibration traceable to National Institute for Standards and Technology (NIST), or other national standards.

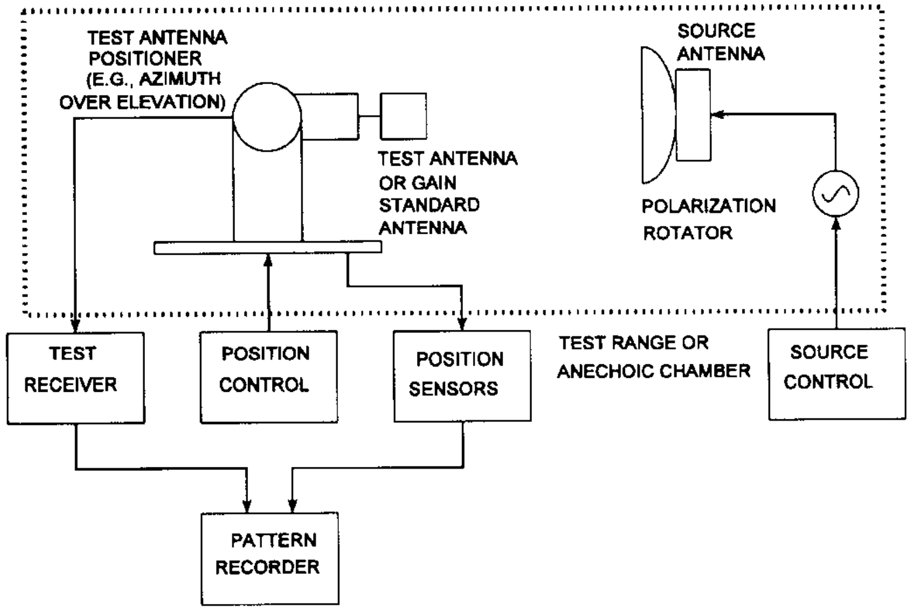

Figure 2-5: Antenna Measurement Range

2.4.1.9 Test Frequencies

Antenna unit measurements for relative pattern and aspect angle group delay tests shall be performed at a minimum of 17 uniformly spaced frequencies for the L1/E1 band and 17 uniformly spaced frequencies for the L5/E5a band to include:

L1/E1 Test Frequency Point	Frequency Value
Lower Band-edge	1559.42 MHz
GPS Mid-Band	1575.42 MHz
Upper Band-edge	1591.42 MHz
L5/E5a Test Frequency Point	Frequency Value
Lower Band-edge	1160.45 MHz
GPS Mid-Band	1176.45 MHz
Upper Band-edge	1192.45 MHz

For boresight relative frequency response, antenna unit measurements shall be performed over a wide frequency range to include at least the -50 dB breakpoints in the frequency response requirement for L1 and the -87 dB breakpoints in the frequency response requirement for L5 and with frequency steps small enough to resolve gain breakpoints.

For boresight differential group delay tests, measurements may be limited to the -20 dB breakpoint in the frequency response with frequency steps small enough to enable time delay computations. These will be performed for both L1 and L5 bands.

Unless otherwise indicated, all other measurements shall be performed over the minimum L1/E1 operating frequency range of 1575.42 ± 10.23 MHz, and the minimum L5/E5a operating frequency range of 1176.45 ± 10.23 MHz.

Note: Frequency accuracy shall be within ± 0.002 MHz.

2.4.2 GNSS Antenna Unit Tests

2.4.2.1 Frequency of Operation and Antenna Unit Output VSWR and Impedance Test (Sections 2.2.1, 2.2.2)

Equipment Required:

Ground Plane - refer to Section 2.4.1.7.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

RF Bias Tee and DC Supply.

Measurement Requirements:

Connect the equipment as shown in Figure 2-6 with the vector network analyzer as the measurement instrument. Measure the output VSWR over the operating frequency ranges 1565.42 – 1585.42 MHz and 1166.22 – 1186.68 MHz at the RF port of the active antenna unit in an anechoic chamber or reflection-less environment. Verify that the results comply with the requirements in Section 2.2.2.

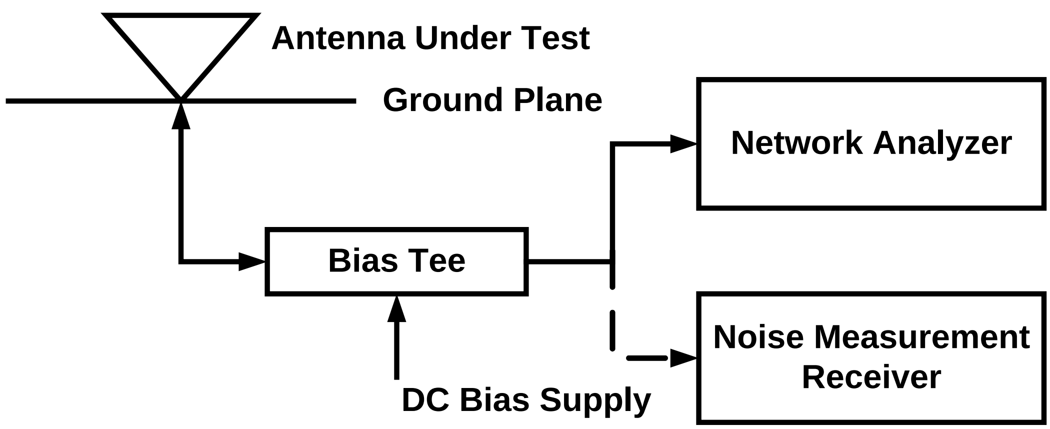

Figure 2-6: Output VSWR and Total Output Noise Test Set-Up

2.4.2.2 Radiation Pattern Gain and Transfer Phase Test (Sections 3.3, 3.5, 3.6, 3.7, 3.9, 3.10)

Equipment Required:

Antenna Measurement Range - refer to Section 2.4.1.8.

Ground Plane - refer to Section 2.4.1.7.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

RF Bias Tee and DC Supply

Gain Standard Antenna, RHCP source antenna.

Measurement Requirements:

Connect the equipment as shown in Figure 2-6. Measure the antenna unit total gain and transfer phase, per IEEE Standard 149-1979, for azimuth angles of at least 0, 45, 90, 135, 180, 225, 270, and 315 degrees, and elevation angles of at least 0, 5, 10, 20, 30, 45, 60, 75 and 90 degrees and at the frequencies defined in Section 2.4.1.9.

2.4.2.2.1 Relative Radiation Gain Pattern (Section 3.3)

At the L1 center frequency, 1575.42 MHz, form the relative pattern gain by dividing the pattern total gain at every elevation and azimuth measurement point by the maximum gain value that occurs within 15 degrees elevation of the zenith point (elevation = 90º). Verify the relative gain falls within the limits of Table 2-2 at all the upper hemisphere pattern points.

At the L5/E5a center frequency, 1176.45 MHz, form the relative pattern gain by dividing the pattern total gain at every elevation and azimuth measurement point by the maximum gain value that occurs within 15 degrees elevation of the zenith point (elevation = 90º). Verify the relative gain falls within the limits of Table 2-2 at all the upper hemisphere pattern points.

2.4.2.2.2 Passive Element Gain (Section 2.2.3.2)

At the L1 center frequency, 1575.42 MHz, measure the absolute gain at 5 degrees elevation and all azimuth angles. Verify that the gain equals or exceeds the limit of Section 2.2.3.2 over all azimuth angles.

At the L5/E5a center frequency, 1176.45 MHz, measure the absolute gain at 5 degrees elevation and all azimuth angles. Verify that the gain equals or exceeds the limit of Section 2.2.3.2 over all azimuth angles.

2.4.2.2.3 Total Transducer Gain Factor for G/T Ratio (Section 2.2.5)

Combine the total gain measurements at 5º elevation and frequencies 1575.42 ± 8 MHz with the total output noise measurements as indicated in Section 2.4.2.4.

Combine the total gain measurements at 5º elevation and frequencies 1176.45 ± 10.23 MHz with the total output noise measurements as indicated in Section 2.4.2.4.

2.4.2.2.4 Minimum Boresight Total Transducer Gain (Section 2.2.6)

L1/E1: Verify that the total transducer gain at 90º elevation meets the limit of Section 2.2.6.

L5/E5a: Verify that the total transducer gain at 90º elevation meets the limit of Section 2.2.6.

2.4.2.2.5 Boresight Relative Gain Frequency Response (Sections 2.2.8.1 and 2.2.8.2)

Normalize the wide swept frequency boresight total gain measurements (indicated in 2.4.1.9) by the maximum gain value within 1575.42 ± 8 MHz and 1176.45 ± 10.23 MHz respectively. Verify that the maximum relative response requirements and -3dB relative response of Sections 2.2.8.1 and 2.2.8.2 are met.

2.4.2.2.6 Differential Group Delay Requirements (Section 2.2.11)

Calculate the group delay, $\tau(f)$, at frequency, f, from transfer phase measurements, $\Phi(f_i)$, at successive test frequencies, f_1 and f_2 with $f_1 \le f < f_2$ by the discrete approximation formula:

$$\tau(f) = -\frac{[\Phi(f_2) - \Phi(f_1)]}{360[f_2 - f_1]} \qquad \text{(Equation 2-11)}$$

($\Phi(f_i)$ is in degrees, f_i is in Hz and time delay is in seconds.) Insert the delay values in the appropriate limit formula in Section 2.2.11 and verify that the requirements of Sub-sections 2.2.11.1, 2.2.11.2, and 2.2.11.3 are met.

Note: Normally for test frequency steps more than about 2 MHz, the assigned frequency for the delay, $f = 0.5(f_2 + f_1)$. For small steps ($\le$ 0.5 MHz), $f = f_1$ is acceptable.

2.4.2.3 Polarization and Boresight Axial Ratio Test (Section 2.2.4)

Equipment Required:

Antenna Measurement Range - refer to Section 2.4.1.8.

Antenna Ground Plane - refer to Section 2.4.1.7.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

RF Bias Tee and DC Power Supply.

LHCP gain standard antenna.

Measurement Requirements:

Connect the equipment as shown in Figure 2-5. Measure the unit-under-test total transducer gain relative to the LHCP gain standard per IEEE Standard 149-1979, for one set of principal plane points defined in Section 2.4.2.2. Calculate the ratio of RHCP gain to LHCP gain (i.e.; the cross-polarization ratio) for the same set of principal plane points. The requirements of Section 2.2.4 are satisfied if the cross-polarization ratio is greater than 15 dB at 1575.42 MHz and 1176.45 MHz over the range of 50 – 90 degrees elevation.

2.4.2.4 Total Output Noise Test (Section 2.2.5)

Equipment Required:

Antenna Ground Plane - refer to Section 2.4.1.7.

Noise Measurement Receiver or Spectrum Analyzer (Agilent N8973A, HP-8970B, or equivalent)

Noise Diode or noise calibration source (HP 346B or equivalent)

RF Bias Tee

DC Power Supply

Measurement Requirements:

1. Mount the ground plane in a horizontal orientation at a suitable outdoor location and attach the active antenna unit-under-test.
2. Connect the equipment as shown in Figure 2-6 with the noise measurement receiver as the measuring instrument.

3. Calibrate the noise measurement receiver set-up with the noise diode connected to the set-up at the interface to the antenna unit RF output connector (no bias applied through the bias tee).
4. Measure the antenna unit output noise power ratio (NPRout in dB with respect to kT_0B_{MEAS}) at each RF frequency, f, for which the 5 degree elevation, total transducer gain, $G_{TTG}(\phi,85^o,f)$ was measured (Section 2.4.2.2).
5. Calculate the G/T ratio (in dB/K) at 5 degrees elevation angle (85º from zenith) per Equation 2-11 and verify that the requirement of Section 2.2.5 is satisfied.

$$\left(\frac{G_A\left(\phi,85^o,f\right)}{T_{SYS}\left(f\right)}\right)=G_{TTG}\left(\phi,85^o,f\right)-10\log_{10}\left(290\right)-NPR_{OUT}\left(f\right) \qquad \text{(Equation 2-12)}$$

where G_{TTG} and NPR_{OUT} are in dB.

Note:

1. *If the test is performed at or near room ambient temperature, sufficient margin must be allowed to account for degradation over the full temperature range.*
2. *The output noise temperature measurement at the L1 and L5 center frequencies (1575.42 MHz, 1176.45 MHz) will likely contain a contribution from the GPS L1 C/A and L5 aggregate satellite power visible at the test location. To correct the measurement for this component, the noise power ratio value used in Equation 2-4 at 1575.42 MHz and 1176.45 MHz should be the average of the readings at the two adjacent frequencies, one on either side of 1575.42 MHz and 1176.45 MHz (2 MHz nominal frequency spacing).*

2.4.2.5 Active Antenna Unit Output Load Stability Test (Section 2.2.7)

Equipment Required:

Spectrum Analyzer (Hewlett-Packard 8568B, or equivalent).

Antenna Test Set.

Antenna Test Set (to provide power as required by the manufacturer to the preamplifier).

50 Ohm RF Terminator.

Bridge-T.

Measurement Requirements:

The stability of the amplifier shall be tested in 4 steps:

1. Mount the unit-under-test in a shielded anechoic chamber and connect the antenna unit output through an RF bias tee, cable, and coupler to the spectrum analyzer. Set the spectrum analyzer to measure signals at least as low as -110 dBm, and with as wide a frequency range as practical.

2. Apply power to the antenna unit and verify that the antenna unit does not generate any detectable signals.

3. Connect an adjustable-length, short-circuited transmission line to the straight-through path of the couplet to which the spectrum analyzer is attached and adjust the line length through at least 1 wavelength (1575.42 MHz and 1176.45 MHz).

4. Verify that the active antenna unit does not generate any signals at its output under different positions of the variable length shorted line.

2.4.2.6 High Radiated Power Performance Tests

The following tests are intended to be used in conjunction with standard DO-160G Section 20 radiated susceptibility environmental test. Specific test frequencies, levels, and modulation are given for the 1-2 GHz frequency range. Outside that range, DO-160G levels apply.

Equipment Required:

Bias Tee and DC Power Supply

Two Synthesized RF Signal Generators (Hewlett-Packard 8662A or equivalent)

Spectrum Analyzer (Hewlett-Packard 8568B, or equivalent)

Modulator (Hewlett-Packard 11665B, or equivalent)

Pulse Generator (Fluke 5712, or equivalent)

Linear RF Power Amplifier (500 W peak, minimum)

30 dB Directional Coupler

Variable Attenuator (0-40 dB) (optional)

Two. 6 dB Power Splitters (for recovery time test)

Adjustable Phase Delay Line (for recovery time test)

Phase Detector (for recovery time test)

Oscilloscope

2.4.2.6.1 Boresight Gain Compression Point and Test (Section 2.2.6.3)

Measurement Requirements:

1. Mount the antenna unit-under-test on the ground plane and connect the equipment as shown in Figure 2-7.
2. Set the RF Signal Generator #1 for frequency to 1575.42 MHz and set the CW signal level such that the antenna unit-under-test is in its linear operating range (~ -40 dBm from a 0 dBic antenna).
3. Tune the spectrum analyzer to the 1575.42 MHz low level probe signal and set the analyzer to the “zero-span” mode.
4. Set the RF Signal Generator #2 frequency to the test #1 setting from Table 2-7, set the level to produce the associated test field strength for that frequency, set the pulse modulator to produce the desired waveform, and synchronize the spectrum analyzer sweep to the pulse PRF.
5. Verify that any compression of the probe signal level is within the 1 dB limit of Section 2.2.6.3 during the test frequency pulse duration.
6. Repeat Steps 4-5 for all the test settings in Table 2-7.
7. Repeat Steps 2-6, except this time set RF Signal Generator #1 for a frequency of 1176.45 MHz for Step 2 and tune the spectrum analyzer to 1176.45 MHz for Step 3.

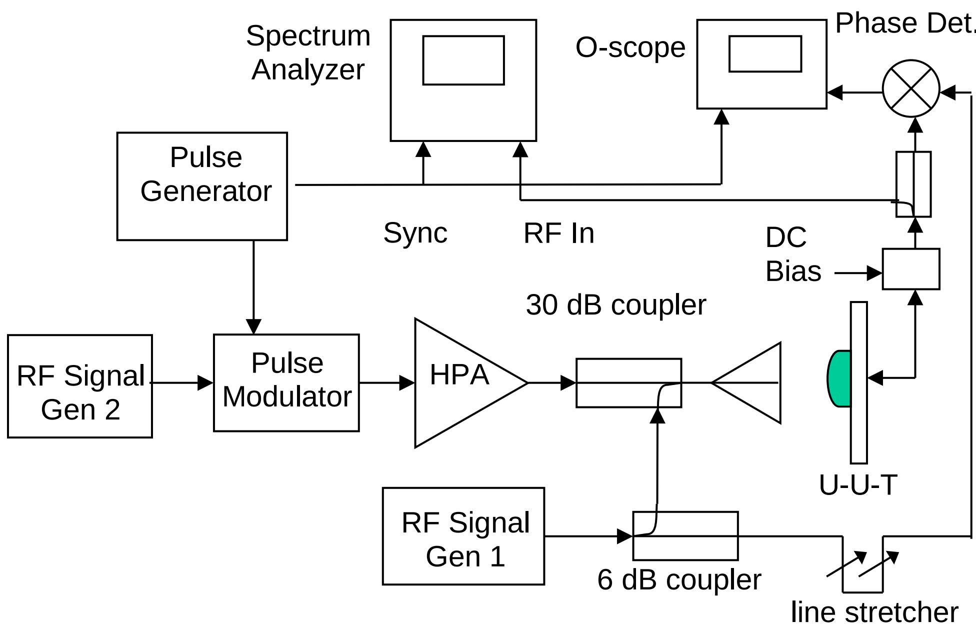

Figure 2-7: Boresight 1 dB Gain Compression and Recovery Time Test Set-up

2.4.2.6.2 Pulse Saturation Recovery Time Test (Sections 2.2.10.1, 2.2.10.2, 2.2.10.3)

Measurement Requirements:

1. Connect the equipment as shown in Figure 2-7.
2. Temporarily disable the pulse power signal from RF Signal Generator #2. Set the RF Signal Generator #1 frequency of 1575.42 MHz and adjust its signal level to produce an input power of about 10 dB below the 1 dB input compression point of the active antenna unit-under-test. Verify that the RF Signal Generator #1 power input to the phase detector is in the range for proper operation.
3. Apply DC bias to the active antenna unit-under-test and adjust the phase delay line (line stretcher) such that the oscilloscope shows a 90-degree phase difference between the active antenna unit output and the delayed generator #1 signal (0 Volts on scope display). Note also the phase detector peak output voltage (0 or 180-degree path phase difference).
4. Set the Pulse Generator and RF Signal Generator #2 to produce the pulsed signal required for test #8 in Table 2-7. The level should be set to produce 115 V/m at the unit-under-test.
5. Verify that the preamplifier meets all criteria set forth in Section 2.2.10.1. The recovery time shall be measured as the time needed by the preamplifier to return to a peak phase difference between its output signal and the delayed RF Signal Generator #1 signal of less than 30 degrees (half the peak amplitude), as shown by the oscilloscope.
6. Repeat Steps 4 and 5 for tests 7 and 10 using the appropriate settings shown in Table 2-7 for each test, except verify that the preamplifier meets all criteria set forth in Section 2.2.10.3.

7. Repeat Step 2 using 1176.45 MHz.
8. Repeat Step 3.
9. Repeat Step 4, except using test #3 in Table 2-7 at 87 V/m.
10. Repeat Step 5, except using the criteria set forth in Section 2.2.10.2.
11. Repeat Step 4, except using tests #2 and #5 from Table 2-7 at 87 V/m.
12. Repeat Step 5, except using the criteria set forth in Section 2.2.10.3.

Table 2-7: Gain Compression and Recovery Time* Test Settings

Test	RF Frequency (MHz)	Pulse Width	PRF (pps)	RF Peak Field (V/m)
1	1000.00	1 ms	22	102.5
2	1149.45	1 ms	22	21**
3	1166.45	1 ms	22	1.5**
4	1186.45	1 ms	22	1.5
5	1200.45	1 ms	22	27.5**
6	1315.00	1 ms	22	135
7	1531.42	1 ms	100	11.1*
8	1565.42	1 ms	100	2*
9	1585.42	1 ms	100	2
10	1616.42	1 ms	100	7.4*
11	1660.00	1 ms	56	34
12	2000.00	1 ms	56	145

** The Pulse Power Saturation Recovery Time test uses the settings from lines 7, 8, and 10 except that the field strength value in each case is 115 V/m.*

*** The Pulse Power Saturation Recovery Time test uses the settings from lines 2, 3, and 5 except that the field strength value in each case is 87 V/m.*

2.4.3 Active Antenna Sub-Assembly Tests

The tests in the following subsections address requirements which are impractical to perform on the entire active antenna unit. Examples of the requirements include mainly the environmental requirements of Section 2.3.1. Proper care shall be taken so that the performance of the active subassembly and, if necessary, the passive radiating element used in these tests remain unchanged from the complete integrated assembly.

2.4.3.1 Active Sub-Assembly RF Gain Response and Noise Temperature Test

This test is intended for use in the applicable environmental tests of Section 2.3.1 for measuring unit performance while the environmental test conditions are applied.

Equipment Required:

RF Bias Tee and DC Supply.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

Automatic Noise Figure Meter (Hewlett-Packard 8970A or equivalent).

Measurement Requirements:

Any loss in the RF cables connecting the antenna and the test equipment shall be properly taken into account.

2.4.3.1.1 RF Gain and Frequency Response Test

1. Connect the RF output of the vector network analyzer to the active sub-assembly input, as shown in Figure 2-8. Connect the active sub-assembly output through the bias tee and output cabling to the vector network analyzer input.
2. Set the vector network analyzer to sweep from 1559.42 MHz to 1591.42 MHz for the L1/E1 test and 1168.45 MHz to 1184.45 MHz for the L5/E5a test and set the output level to -40 dBm.
3. Verify that the active sub-assembly transducer gain meets the requirement of Section 2.2.6.1, and the -3 dB gain normalized response requirement of Section 2.2.8.1 over the specified frequency ranges.
4. Verify that the active sub-assembly differential group delay meets the requirement of Section 2.2.11.
5. Set the vector network analyzer to sweep from 1000 MHz to 2000 MHz at -40 dBm and verify that the normalized frequency response meets the requirements of Section 2.2.8.2. Frequencies equal to or below 1315 MHz are normalized to the L5/E5a band and frequencies above 1315 MHz are normalized to the L1/E1 band.

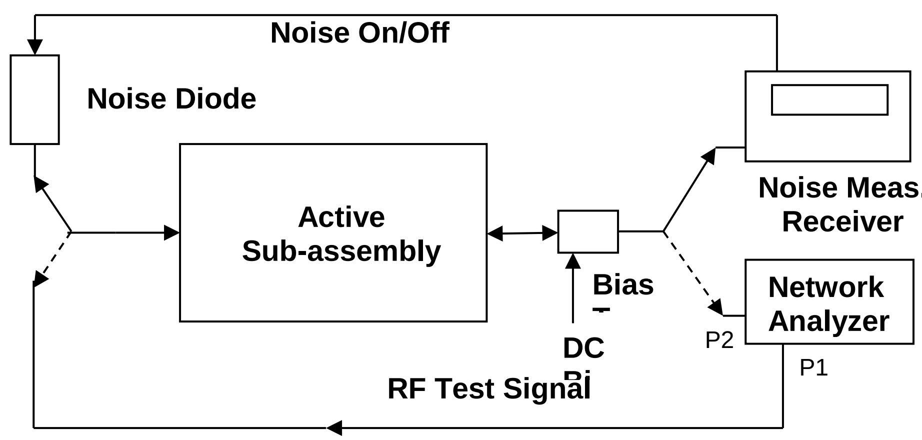

Figure 2-8: Active Sub-Assembly Gain and Noise Temperature Test Set-up

2.4.3.1.2 Noise Temperature Test:

1. Connect the noise diode voltage input to the noise measurement receiver drive voltage port and the noise diode output port to the test set-up at the point where the RF bias tee and output cabling would connect to the active sub-assembly output (Figure 2-8). Calibrate the noise measurement receiver over the frequency range 1575.42 ± 16 MHz for the L1/E1 test or 1176.45 ± 16 MHz for the L5/E5a test.
2. Connect the noise diode to the active sub-assembly input and active sub-assembly output to the noise measurement receiver RF input through the RF bias tee and output cabling.
3. Verify that the noise figure is no more than 3.14 dB over the frequency band of 1567.42 MHz to 1583.42 MHz for the L1/E1 test and that the noise figure is no more than 4.5 dB over the frequency band of 1168.45 MHz to 1184.45 MHz for the L5/E5a test.

2.4.3.2 Active Unit Radiated Hot-Cold Noise and Boresight Signal Performance Test

Equipment Required:

1. Small, shielded, anechoic material-lined test chamber
2. Circularly-polarized source antenna
3. Noise Generator
4. Antenna ground plane and mounting plate (sufficient to cover one end of the chamber)
5. Reference Passive Antenna (identical in design and packaged in the identical manner as the passive radiating element in the active antenna unit)
6. Noise Measurement Receiver or Spectrum Analyzer (Agilent N8973A, HP-8970B, or equivalent)
7. Vector Network Analyzer
8. RF Bias Tee
9. DC-Power Supply

2.4.3.2.1 Radiated Hot-Cold Test for Active Sub-Assembly Gain and Noise Temperature

Measurement Requirements:

1. Mount the ground plane with the reference passive antenna attached to the small anechoic test chamber.
2. Connect the equipment for noise measurements as shown in Figure 2-9.
3. Calibrate the noise measurement receiver set-up at each RF frequency, f, at which the performance is to be verified with the noise diode connected to the set-up at the interface to the antenna unit RF output connector (no bias applied through the bias tee).
4. Measure the reference passive antenna unit output noise power ratio (dB with respect to kT_0B_{MEAS}) at each RF frequency, f, at which the performance is to be verified for both the "hot" and "cold" settings of the radiating noise source. (measurements designated $PR_{HOT}(f)$ and $PR_{COLD}(f)$)
5. Replace the reference passive antenna with the active antenna unit-under-test and measure active antenna unit output noise power ratio (dB with respect to kT_0B_{MEAS}) at each RF frequency, f, at which the performance is to be verified for both the "hot" and "cold" settings of the radiating noise source (measurements designated $PA_{HOT}(f)$ and $PA_{COLD}(f)$)
6. Calculate the antenna unit active sub-assembly input noise temperature, $\tilde{\overset{\frown}{\mathrm{T}}}_{\mathrm{R}}$ (f)and gain, $\tilde{\overset{\frown}{\mathrm{G}}}_{\mathrm{R,dB}}$ (f) , by:

$$\tilde{\overset{\frown}{\mathrm{T}}}_{\mathrm{R}}\,(\mathrm{f}) = \left(\frac{T_{HOT}(f)*\Delta G_A(f)-Y_{UUT}(f)*T_{COLD}(f)}{Y_{UUT}(f)-1}\right) \qquad \text{(Equation 2-13)}$$

and:

$$\tilde{\overset{\frown}{G}}_{R,dB}\,(f) = 10 * log\left(\frac{(Y_{UUT}(f)-1)*T'_{COLD}(f)}{T_{HOT}(f)*\Delta G_A(f)-T_{COLD}(f)}\right) \qquad \text{(Equation 2-14)}$$

Where,

$$Y_{UUT}(f) = 10^{0.1*(PA_{HOT}(f) - PA_{COLD}(f))} \quad \text{(Equation 2-15)},$$

$$T_{HOT}(f) = 290 * 10^{0.1*(PR_{HOT}(f))} \quad \text{(Equation 2-16)},$$

$$T_{COLD}(f) = 290 * 10^{0.1*(PR_{COLD}(f))} \quad \text{(Equation 2-17)},$$

$$T'_{COLD}(f) = 290 * 10^{0.1*(PA_{COLD}(f))} \quad \text{(Equation 2-18)}.$$

7. Set $\Delta G_A = 1$ and verify that $\overset{\frown\frown}{T}_R$ (f) is less than 307 K and $\overset{\frown\frown}{G}_{R,dB}(f)$ is greater than 26.5 dB for the range 1575.42 ± 8 MHz. Set $\Delta G_A = 1$ and verify that $\overset{\frown\frown}{T}_R$ (f) is less than 531 K and $\overset{\frown\frown}{G}_{R,dB}(f)$ is greater than 26.5 dB for the range 1176.45 ± 10.23 MHz. The measured values shall be within the limits by at least the associated measurement procedure uncertainty as described in Appendix A.2. If the measurement is made at or near room ambient temperature, an additional temperature variation margin shall be used.

Note:

1. *The parameter $\Delta G_A(f)$ is the ratio of the passive radiator element gain of the unit under test to the reference passive element gain. As such, it represents a first-order uncertainty in the measurement procedure. Setting the baseline ratio at unity for the test result enables the use of the measurement uncertainty computation described in Appendix A.2.*
2. *The noise generator used in the test should have sufficient output noise density to produce a ratio $PR_{HOT}/PR_{COLD} \cong 10$ dB with the reference passive antenna.*

2.4.3.2.2 Boresight Radiated Active Sub-Assembly Gain Response Test

Measurement Requirements:

1. Connect the equipment for vector network analyzer measurements as shown in Figure 2-9.
2. Calibrate the analyzer with appropriate reflection and transmission standards.
3. Mount the reference passive antenna and measure the boresight transmission gain and phase of the path though the chamber and the passive reference antenna over the frequency range 1575.42 ± 16 MHz for the L1/E1 test or 1176.45 ± 16 MHz for the L5/E5a test. (This measurement serves as the chamber calibration to be de-embedded from the active antenna unit-under-test measurement)
4. Mount the active antenna unit-under-test and measure the boresight transmission gain and phase of the path though the chamber and the unit-under-test over the frequency range 1575.42 ± 16 MHz for the L1/E1 test or 1176.45 ± 16 MHz for the L5/E5a test. Correct the measurement with the chamber/passive reference calibration from Step 3.
5. Verify that the active sub-assembly transducer gain meets the requirement of Section 2.2.6.2 and the -3 dB gain normalized response requirement of Section 2.2.8.1 over the specified frequency ranges.

6. Verify that the (active sub-assembly) boresight differential group delay meets the requirement of Section 2.2.11.

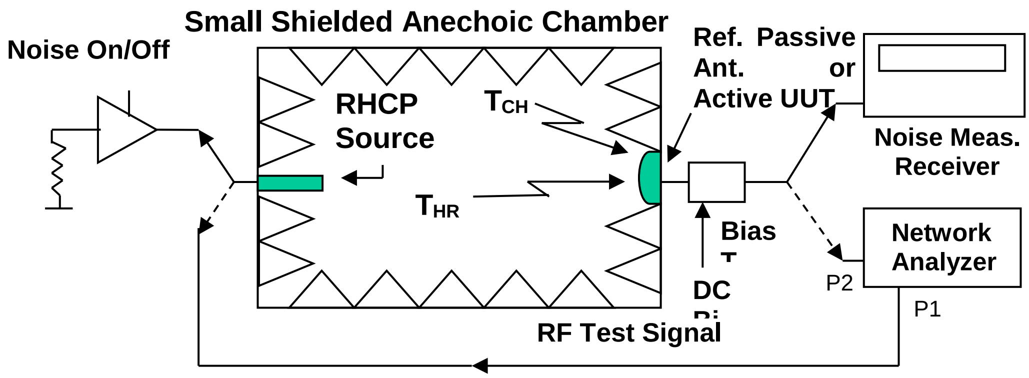

Figure 2-9: Radiated Hot-Cold Noise and Boresight Signal Test Setup

2.4.3.3 Active Sub-Assembly Burnout Protection Test (Section 2.2.9)

Equipment Required:

RF Bias Tee and DC Power Supply

Synthesized Signal Generator (Hewlett-Packard 8662A or equivalent).

Spectrum Analyzer (Hewlett-Packard 8568B, or equivalent).

RF Amplifier (Hewlett-Packard 8347A, or equivalent).

Measurement Requirements:

1. Connect the equipment as shown in Figure 2-10.
2. Set RF Signal Generator #1 to a frequency of 1575.42 MHz and adjust the level to obtain a low-level input signal of -35 dBm at the active subassembly input, apply DC power to the active sub-assembly and determine the transducer linear power gain using the spectrum analyzer.
3. Set RF Signal Generator #2 to a frequency of 1565.42 MHz with a peak pulse power of +30 dBm for a 1 ms pulse at 100 Hz PRF (10% duty factor, +20 dBm ave. power)
4. Subject the active sub-assembly input to the +30 dBm peak test signal at 1565.42 MHz for 5 minutes while monitoring the gain of the low level 1575.42 MHz probe signal. Then change the RF Signal Generator #2 frequency to 1585.42 MHz and dwell for 5 minutes while monitoring the probe signal gain. Verify for each test signal frequency that the peak pulse output from the active antenna unit remains below +20 dBm.
5. Repeat the tests described in Section 2.4.3.1 to verify that the active sub-assembly still meets the gain, delay and noise temperature requirements therein.
6. Re-connect the equipment as stated in step 1.

7. With no RF Signal Generator #1 probe signal and DC power removed from the active sub-assembly, subject the input to a RF Signal Generator #2 test signal of +30 dBm at 1575.42 MHz for 5 minutes.
8. Repeat the tests described in Section 2.4.3.1 to verify that the preamplifier still meets the gain, delay, and noise temperature requirements therein.
9. Repeat Step 2, except use a frequency of 1176.45 MHz.
10. Repeat Step 3, except use a frequency of 1166.45 MHz.
11. Repeat Step 4, except monitor the gain of the 1176.45 MHz signal, while the RF Signal Generator #2 frequency is set to first 1166.45 MHz and then 1186.45 MHz.
12. Repeat Steps 5 and 6.
13. Repeat Step 7, except use a frequency of 1176.45 MHz.
14. Repeat Step 8, except use a frequency of 1176.45 MHz.
15. Insert a DC ammeter in series with the Bias T's DC port, and verify that the DC current draw is within specification over its full operating voltage range.

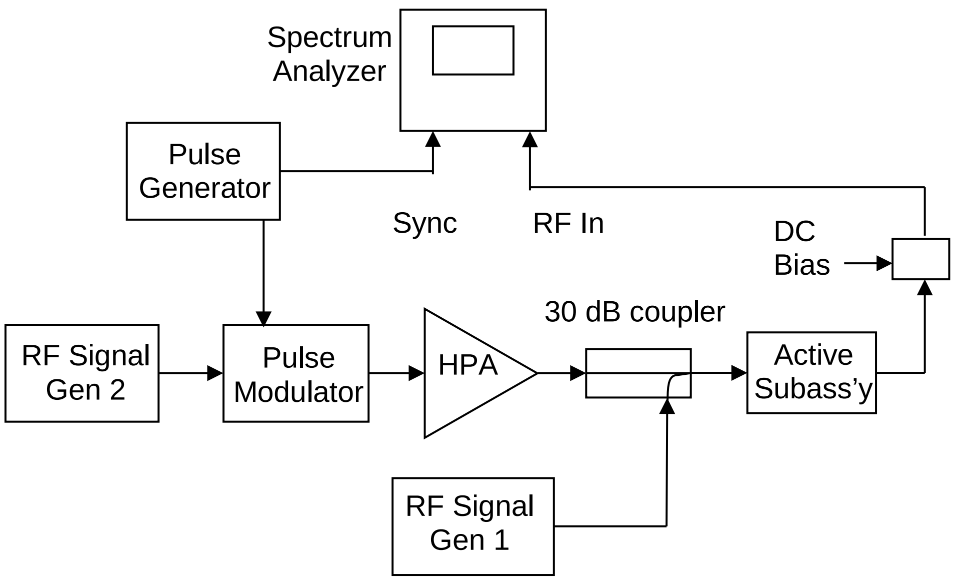

Figure 2-10: Active Sub-Assembly Burnout Protection Test Set-up

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3 INSTALLED ANTENNA PERFORMANCE

The installed performance of the GNSS antenna shall be evaluated in conjunction with the installed GNSS receiver equipment to ensure that GNSS performance is met in accordance with the appropriate MOPS.

Note: For an L1 only GPS receiver to be compatible with this antenna, it needs to provide adequate current to power this antenna (200 mA per the requirements in this MOPS) and demonstrate adequate frequency selectivity in and around the L5 band as dictated by the relevant receiver MOPS.

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4 EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS

The operational performance of the GNSS antenna shall be evaluated in conjunction with the operational tests of the GNSS receiver equipment to ensure that GNSS performance is met in accordance with the appropriate MOPS. Operational tests of GNSS antennas may be conducted as part of normal preflight tests.

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APPENDIX A: G/T RATIO MEASUREMENT THEORY AND APPLICATION TO RECEIVER SYSTEM ANALYSIS AND TEST

GNSS airborne antennas with integral RF amplifiers and preselector filters pose difficulties for testing gain and noise performance of the amplifier and filter section and the gain of the passive antenna radiator element independently. Production units typically have only one connector interface, an RF coaxial connector which outputs the amplified GNSS satellite signals. DC power is also fed through the cable and connector center conductor to the antenna active circuitry. No external access is available to the junction between the passive radiator terminals and the active circuit section. One practical way to overcome the lack of direct access to the passive antenna radiator terminals is to measure the active antenna unit radiation pattern in terms total transducer gain (see Sect. 2.4.2.2) and the noise performance in terms of output noise power (see Sect. 2.4.2.4). Overall antenna unit performance, specified (Sect. 2.2.5) in terms of gain-to-noise temperature (G/T) ratio, is then determined from the ratio of the measured total transducer gain to the measured output noise power.

Other methods for measuring active antenna performance could be used (such as passive element gain and noise figure). However, performance parameters measured with these other methods must be converted to G/T ratio and uncertainties must be accounted for in the test results and the conversion. In all cases, some parameter estimation is required. The goal is to minimize the effect of parameter estimation.

Section A.1 gives the theoretical background for the G/T requirements and measurement approach taken in the active antenna unit MOPS. The total transducer gain and output noise power ratio parameters are defined and the antenna unit G/T ratio is derived from them. Relative pattern gain and selectivity performance responses are shown to be derived from total transducer gain data. The importance of G/T ratio in determining receiver system signal-to-thermal noise ratio density is demonstrated.

Section A.2 describes some other measurement approaches and how their results can be related to the G/T requirements along with corresponding measurement and relational uncertainties.

Section A.3 describes how the active antenna performance parameters are used to calculate input signal, thermal noise, and interference levels at the input to the GNSS receiver for receiver performance testing.

A.1 GNSS Active Antenna G/T Ratio Measurement Theory

A.1.1 Antenna Unit Total Transducer Gain

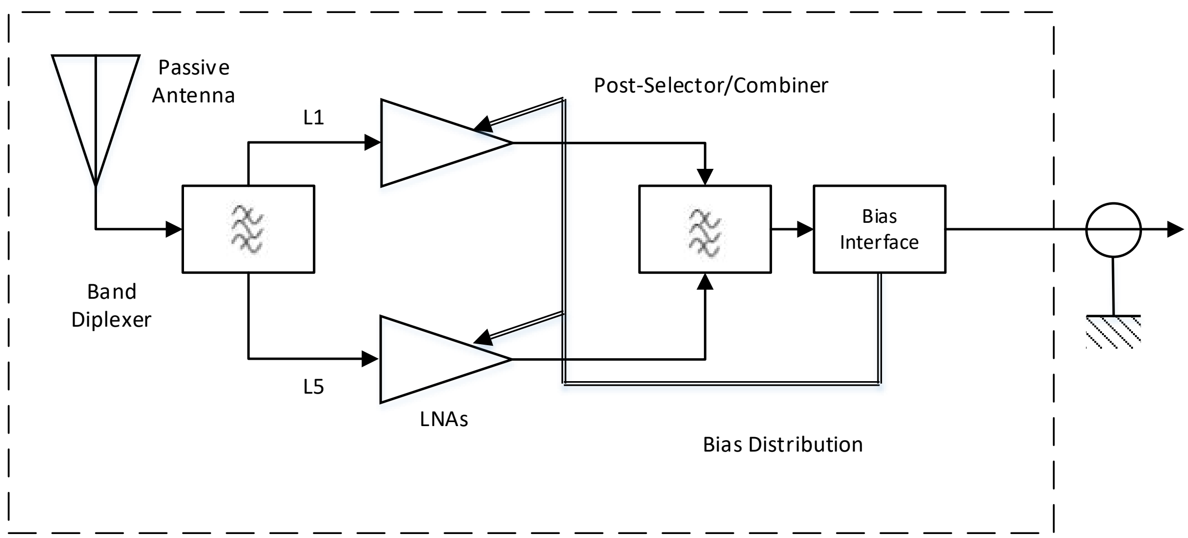

Figure A-1: Simplified GNSS Active Antenna Unit Block Diagram

The first of two measurements needed to determine the antenna unit G/T ratio is the total transducer gain. From the simplified antenna unit block diagram (Figure A-1) define the total transducer power gain as

$$G_{TTG}(\varphi, \gamma, f) = G_A(\varphi, \gamma, f) * G_R(f) \quad \text{(Equation A-1)}$$

where $G_A(\varphi, \gamma, f)$ is the passive radiator element gain as a function of the pattern polar coordinate angles φ, θ and frequency f and $G_R(f)$ is the active sub-assembly net power gain as a function of frequency. The total transducer power gain, $G_{TTG}(\varphi, \gamma, f)$, is the measured gain value of the integrated active antenna unit from a conventional antenna pattern measurement. For maximum usefulness in GNSS airborne receive system applications, the transducer gain is referenced to a unity-gain, isotropic, right-hand circular polarized antenna and measured over a sufficient frequency range to determine its passband shape and out-of-band rejection.

In addition to its role in the G/T ratio, the total transducer gain, $G_{TTG}(\varphi, \gamma, f)$, can also be normalized to a convenient value, for example at the L1 (or L5) center frequency as applicable and boresight orientation (γ = 0). Relative gain patterns versus pattern orientation can then be plotted and compared with requirements. Boresight total transducer gain, normalized to the maximum passband value, can also be used for passband bandwidth and skirt selectivity requirements.

A.1.2 Antenna Unit Output Noise Power Density

The second measurement needed for the antenna unit G/T ratio is the output noise power density as a function of frequency, $PSD_{OUT}(f)$, over the same frequency range as in the transducer gain measurement. A noise analysis of the antenna unit diagram (Figure A-1) yields the following result for the output noise power density:

$$PSD_{OUT}(f) = k * \left(T_A(f) + T_R(f)\right) * G_R(f) \qquad \text{(Equation A-2)}$$

where k is Boltzmann's Constant (1.38065 x 10^{-23} W/Hz/K); $T_R(f)$ is the effective input noise temperature (K) of the active circuit section terminals; $G_R(f)$ is the active sub-assembly net power gain; and $T_A(f)$ is the effective antenna temperature. All three parameters are referenced to the passive antenna radiator element port. Note that the active section net power gain term, $G_R(f)$, in (Equation A-2) is the same term as in the transducer gain (Equation A-1).

The active section input noise temperature; $T_R(f)$, (in K) is related to its input noise factor, $F_R(f)$, given in ratio, by

$$T_R(f) = (F_R(f) - 1) * 290 \qquad \text{(Equation A-3)}$$

The effective antenna temperature, $T_A(f)$, a less well-known parameter, is essentially the average over the antenna pattern of the received black-body radiation at frequency, f [Ref. A-1]. A common range of T_A values observed for GNSS airborne antennas is 75 to 100 K when mounted outdoors with the pattern main lobe pointing upward. The antenna noise temperature is about 300 K when measured in an indoor anechoic chamber whose absorber material is at normal room temperature (23 C). Since the antenna temperature is a significant component in the sum with T_R, the output noise power density measurement should be taken outdoors with the antenna mounted on the same ground plane used in the transducer pattern tests. This outdoor measurement will then reasonably replicate actual aircraft-installed conditions. Correction of anechoic chamber measurements of output noise power density and the associated uncertainties are discussed in a later section.

A.1.3 G/T Ratio Calculation

The G/T ratio for the GNSS antenna is determined by the scaling the measured transducer gain (Equation A-1) by Boltzmann's Constant and dividing by the measured output noise power density (Equation A-2) as shown below:

$$\frac{k * G_{TTG}(\varphi, \gamma, f)}{PSD_{OUT}(f)} = \frac{k * G_A(\varphi, \gamma, f) * G_R(f)}{k * \left(T_A(f) + T_R(f)\right) * G_R(f)}$$

$$= \frac{G_A(\varphi,\gamma,f)}{\left(T_A(f) + T_R(f)\right)} \qquad \text{(Equation A-4)}$$

Substituting the definition of the integrated active antenna unit input noise temperature,

$$T_{IN}(f) = T_A(f) + T_R(f) \qquad \text{(Equation A-5)}$$

into the interim result in Equation A-4 yields the final G/T ratio result:

$$\frac{k * G_{TTG}(\varphi,\gamma,f)}{PSD_{OUT}(f)} = \frac{G_A(\varphi,\gamma,f)}{\left(T_{IN}(f)\right)} \qquad \text{(Equation A-6)}$$

The principal G_A/T_{IN} pattern angle range of interest is the constant 5º elevation contour (γ = 85º, ϕ= -180º to + 180º). The associated frequency ranges of interest are 1575.42 ±8 MHz and 1176.45 +/- 10.23 MHz. These correspond to the elevation angle for the minimum GPS satellite signal-in-space power and frequency range of the principal lobe and one or more adjacent sidelobes of the GPS L1 C/A, Galileo E1b,c, GPS L5 and Galileo

E5a signal spectra. The minimum limit (Sect. 2.2.5) for G_A/T_{IN} for the respective frequency band is applied over these angles and frequency ranges.

A.1.4 Relationship of G/T Ratio to Receiver System Input Signal-to-Noise Density Ratio

The receiver system equivalent input carrier-to-thermal noise density ratio, S/N_0, can be written as

$$\frac{S}{N_o}(f) = \frac{S}{k} * \left(\frac{G_S}{T_{SYS}}(f)\right) \qquad \text{(Equation A-7)}$$

where S is the desired GPS satellite signal power (into a 0 dBic antenna), G_S is the antenna unit equivalent passive gain toward the GPS satellite, T_{SYS} is the receiver system input temperature and k is Boltzmann's Constant. Note, that in general, this carrier-to-noise density ratio is a function of frequency, f. A representative GPS receiver system consists of an active antenna unit connected to a receiver through a coaxial cable. Neglecting the frequency dependency, the system input noise temperature, in that case is

$$T_{SYS} = T_A + T_R + \frac{T_{Rcvr} * L_{Cab}}{G_R} + \frac{T_{Cab} * (L_{cab} - 1)}{G_R} \qquad \text{(Equation A-8)}$$

where G_R is the antenna unit active sub-assembly net gain, L_{Cab} is the coax cable loss factor (> 1), T_{Cab} is the cable ambient temperature (~300K), and T_{Rcvr} is the receiver input noise temperature. Note the sum of the first two terms in Equation A-8 equals the antenna unit effective input temperature, T_{IN}. In a well-designed system, G_R will be sufficiently large to make third and fourth terms in Equation A-8 insignificant compared to T_{IN}. Thus, Equation A-8 reduces to $T_{SYS} \cong T_{IN}$. With this approximation for T_{SYS} applied for the case of minimum signal conditions, Equation A-6 becomes:

$$\left(\frac{S}{N_o}\right)_{MIN} = \frac{S_{MIN}}{k} * \left(\frac{G_S}{T_{SYS}}\right)_{MIN} \cong \frac{S_{MIN}}{k} * \left(\frac{G_A}{T_{IN}}\right) \qquad \text{(Equation A-9)}$$

Equation A-9 demonstrates how the minimum G/T ratio, defined in Section A.1.3 above, essentially determines the minimum input S/N_0 ratio (a key system sensitivity parameter) resulting from the minimum satellite signal limit.

Note, that in general, this carrier-to-noise density ratio is a function of frequency, f. The minimum G/T ratio, as specified in Section 2.2.5, and thus the minimum S/N_0, can be at some frequency other than at the center of the respective frequency bands (L1/E1 or L5/E5a). However, due to the receiver's correlation spreading process, this dependency on frequency will change.

A.2 Other Measurement Approaches and Associated Uncertainties in Conversion to G/T

A.2.1 Anechoic Chamber Measurement of Antenna Unit Output Noise Power Density

A variation on the G/T measurement approach described in Section A.1 is to perform the same total transducer gain measurements and then make the output noise power density measurements in the same anechoic chamber in which the gain measurements are performed. The measured output noise density, $PSD_{OUT,M}$, must be corrected for the estimated difference between the anechoic chamber temperature and an assumed antenna/sky temperature (between 75K and 100K). For this approach, Equation A-4 becomes

$$\frac{k*G_{TTG}(\varphi,\gamma,f)}{PSD_{OUT,C}\,(f)} = \frac{k*G_{TTG}(\varphi,\gamma,f)}{PSD_{OUT,M}\,(f) - k*\Delta T_A * G_R(f)} \qquad \text{(Equation A-10)}$$

where $PSD_{OUT,M}(f)$ is the anechoic chamber measured PSD and ΔT_A is the estimated temperature difference (smallest if T_A = 100K). The description following Equation A-4 is then the same except that the final result must account for an additional error source – the error in the estimate of the temperature difference, multiplied by an estimate of the active section net power gain. This would result in a requirement for a higher G/T than specified in Section 2.2.5 of the MOPS.

In terms of Equation A-4 and including temperature and gain estimation error terms, Equation A-10 becomes

$$\frac{k*G_{TTG}(\varphi,\gamma,f)}{PSD_{OUT,C}\,(f)} = \frac{k*G_A(\varphi,\gamma,f)*G_R(f)}{k*\left(T_{AC}(f)+\ T_R(f)\right)*\ G_R(f) - k*\Delta T_A*\widehat{G_R(f)}}$$

$$= \frac{G_A(\varphi,\gamma,f)}{T_{IN}(f) - \delta T_A*\left(1+\ \frac{\delta G_R(f)}{G_R(f)}\right) - \Delta T_A*\frac{\delta G_R(f)}{G_R(f)}}$$

$$= \frac{G_A(\varphi,\gamma,f)}{T_{IN}(f)}\left(\frac{1}{1-\frac{\delta\Delta T_A}{T_{IN}(f)}*\left(1+\ \frac{\delta G_R(f)}{G_R(f)}\right) - \frac{\Delta T_A}{T_{IN}(f)}*\frac{\delta G_R(f)}{G_R(f)}}\right) \qquad \text{(Equation A-11)}$$

where the errors are $\delta\Delta T_A$, the error in the temperature difference estimate, and $\delta G_R(f)$, the error in the estimate of the active section net power gain. $\delta\Delta T_A$ is constrained at the limits of ΔT_A – this error can only be negative when T_A is assumed to be 100K and only positive when T_A is assumed to be 75K. Neglecting products of error terms and linearizing, Equation A-11 becomes

$$\frac{k*G_{TTG}(\varphi,\gamma,f)}{PSD_{OUT,C}\,(f)} \approx \frac{G_A(\varphi,\gamma,f)}{T_{IN}(f)}\left(\frac{1}{1-\ \frac{\Delta T_A}{T_{IN}(f)}*\left(\frac{\delta G_R(f)}{G_R(f)}\right) - \frac{\delta\Delta T_A}{T_{IN}(f)}}\right)$$

$$\approx \frac{G_A(\varphi,\gamma,f)}{T_{IN}(f)}\left(1+\ \frac{\Delta T_A}{T_{IN}(f)}*\left(\frac{\delta G_R(f)}{G_R(f)}\right) + \frac{\delta\Delta T_A}{T_{IN}(f)}\right) \qquad \text{(Equation A-12)}$$

Note that the first term of the multiplication term includes the gain estimation error. This error can easily dominate since it multiplies the gain error times the entire temperature correction.

Once compensation is applied to account for the estimation errors, the procedure to verify specification compliance is the same as described in Section A.1.3. If T_A is assumed to be 100K, $\delta\Delta T_A$ can be set to zero. Likewise, if the active gain estimation is set to its minimum limit, the gain estimation error can also be set to zero. These two conditions set $T_{IN}(f)$ to its maximum possible value.

A.2.2 Radiated Hot-Cold Chamber Measurement of Active Sub-Assembly Performance

This method uses a small anechoic chamber to measure total boresight gain and the combined noise temperature of the active antenna/anechoic chamber relative to a representative reference patch antenna (Figure A-2). First the noise measurement receiver is calibrated with a standard noise diode. Next the "hot" and "cold" chamber noise temperatures are measured with representative passive antenna in the place of the active antenna. Finally, the gain and input noise temperature of the active antenna unit-under-test (UUT) are measured in a conventional Y-factor test [Ref. A-2].

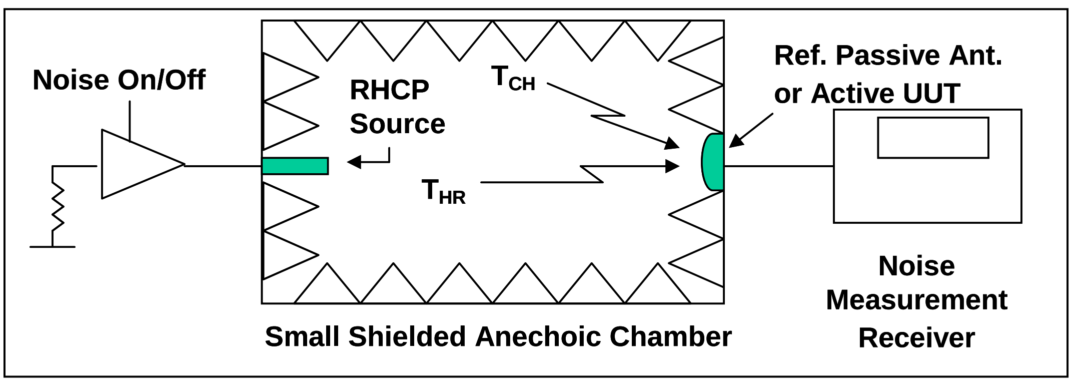

Figure A-2: Radiated Hot-Cold Active Sub-Assembly Noise /Gain Test Set-up

Noise temperature and active sub-assembly gain are determined from the basic Y-factor and chamber calibration measurements by the following method. From the chamber calibration step, define the measured "hot" temperature at the output of the reference passive patch as T_{HOT} and the corresponding "cold" output temperature as T_{COLD}. These result from the RHCP radiating noise source in the "on" and "off" (un-powered state), respectively. Since black-body radiation from the chamber walls (at ambient temperature T_{CH}) is always present, $T_{HOT} = T_{HR} + T_{CH}$ and $T_{COLD} = T_{CH}$. Next, define the noise temperature outputs for the active unit-under-test in the chamber radiating noise source "on" and "off" states as

$$T'_{HOT} = (T_{HOT} * \Delta G_A + T_R) * G_R \quad \text{(Equation A-13)}$$

and

$$T'_{COLD} = (T_{COLD} + T_R) * G_R \quad \text{(Equation A-14)}$$

In these equations

$$\Delta G_A = \frac{G_{A,UUT}}{G_{A,REF}} \quad \text{(Equation A-15)}$$

is the ratio of the boresight passive element gains and represents a principal uncertainty in the measurement? Then, define the active antenna measured Y-factor as

$$Y_{UUT} = \frac{T'_{HOT}}{T'_{COLD}} \quad \text{(Equation A-16)}$$

This set of measurements yields estimates of the test unit active sub-assembly input noise temperature and the gain as

$$\widehat{T_R} = \left(\frac{T_{HOT} * \Delta G_A - Y_{UUT} * T_{COLD}}{Y_{UUT} - 1}\right) \quad \text{(Equation A-17)}$$

And

$$\widehat{G_R} = \left(\frac{(Y_{UUT} - 1) * \dot{T}_{COLD}}{T_{HOT} * \Delta G_A - T_{COLD}}\right) \quad \text{(Equation A-18)}$$

Note how the passive element gain uncertainty affects both input noise temperature and active gain.

Since this simple anechoic chamber is assumed to lack an antenna positioner, total transducer gain versus roll and pitch angles, needed for the G/T ratio, must be made on the active unit-under-test in a full-featured anechoic chamber. Once the total transducer gain at 5^o elevation has been measured, the G/T ratio estimate for the active antenna is computed as follows

$$\left(\frac{G_A(85^0,f)}{T_{IN}(f)}\right)_{EST} = \frac{G_{TTG}(85^0,f)}{T_A + T_R(f) * G_R(f)} \quad \text{(Equation A-19)}$$

where $G_{TTG}(85^o,f)$ is the minimum total transducer gain at frequency, f, over all azimuth angles at 5 degrees elevation.

The parameters measured using this method are essentially the same as those described in A.2.3 except that the signal path is not broken and test points are not used. However, the passive antenna used as a reference must be representative of that of the active antenna under test, and, of course, mismatch errors relative to that passive antenna still apply. Antenna/sky temperature, T_A, must still be estimated to convert the measurements to the G/T specification.

The method is also useful in checking G/T before and after certain environmental tests described in this MOPS. In those cases, the G_{TTG} factor at boresight can be approximated by multiplying the boresight reference patch gain, $G_{A,REF}$ times the active element gain estimate shown in the denominator of Equation A-19. The formula in that equation (computed at boresight) can be used with the small-chamber noise measurements before and after the environmental condition to check for excessive change.

A.2.3 Separate Measurements Passive Antenna Element and Active Sub-Assembly

In this approach G/T is not measured directly, but rather computed from separate passive antenna gain and active sub-assembly gain and noise temperature measurements. One possible means to accomplish the separate measurements is to break the signal path and insert RF test points between the passive antenna and the active sub-assembly. Another means is to construct identical packaged units – one with only an antenna, the other with only an active sub-assembly and an additional input RF connector. The parameters measured are the passive antenna gain, $G_A(\phi,\theta,f)$, the active sub-assembly net power gain, $G_R(f)$, and noise temperature T_R, all with potential errors because of impedance mismatch and other losses associated with breaking the signal path.

The S/N_0 used in GNSS receiver performance analyses using inserted test point measurements is given by (neglecting implementation losses):

$$\frac{S}{N_o}(\gamma, f) = \frac{S(\gamma)}{k} * \left(\frac{G_A(\gamma,f)}{T_A + T_R(f)}\right) \qquad \text{(Equation A-20)}$$

where, in this case, $G_A(\gamma_s,f)$ is the minimum measured $G_A(\phi,\gamma,f)$ at a particular elevation angle (90-θ) over all azimuth angles, ϕ; T_A is the assumed antenna/sky noise temperature; and $T_R(f)$ is the measured noise temperature of the active sub-assembly (Figure A-1). The denominator of the bracketed quantity represents an estimate of the integrated antenna unit input noise temperature, $T_{IN}(f)$ (see Sect. A.1.4). Thus, the bracketed quantity in Equation A-20 can be compared to the specified G/T requirements, accounting for uncertainties in the measurements and the conversion to G/T ratio.

The uncertainties include the uncertainty in the measured passive antenna gain (due to mismatches as a result of breaking the connection), the antenna/sky temperature assumption error, and the uncertainty in the measured noise temperature (due to mismatches as result of breaking the connection). Neglecting products of error terms and linearizing, Equation A-20 becomes:

$$\left(\frac{G}{T}(\gamma, f)\right)_{ITP} = \left(\frac{G_A(\gamma, f) + \delta G_A}{T_A - \delta T_A + T_R(f) + \delta T_R}\right)$$

$$= \left(\frac{G_A(\gamma, f) + \delta G_A}{T_{IN}(f) - \delta T_A + \delta T_R}\right)$$

$$= \frac{G_A(\gamma, f)}{T_{IN}(f)} * \left(\frac{1 + \frac{\delta G_A}{G_A(\gamma, f)}}{1 + \frac{\delta T_R - \delta T_A}{T_{IN}(f)}}\right)$$

$$= \frac{G_A(\gamma,f)}{T_{IN}(f)} * \left(1 + \frac{\delta T_A}{T_{IN}(f)} - \frac{\delta T_R}{T_{IN}(f)} + \frac{\delta G_A}{G_A(\theta,f)}\right) \qquad \text{(Equation A-21)}$$

Once compensation is applied to account for the estimation errors, the procedure to verify specification compliance is the same as described in Section A.1.3. If T_A is assumed to be 100K, $\delta\Delta T_A$ can be set to zero. However, the other errors are due to breaking the signal path and cannot be set to zero. One source for a description of those error sources is Agilent Application Note 57-2 [Ref. A-2].

A.3 Receiver System Test Application of Total Transducer Gain and G/T Ratio

The following sections describe how the total transducer gain parameter (Sec. A.1.1) and the minimum G_A/T_{IN} ratio parameter (Sec. A.1.2) enable the calculation of receiver input GNSS signal level, thermal noise and interference densities when an active antenna unit is used.

A.3.1 General GNSS Receiver System Test Set-up Considerations

The general receiver system installed configuration can be diagramed as shown below (Figure A-3). The active antenna is connected through an RF coaxial cable to the GNSS receiver. The receiver supplies DC bias for the active antenna through the cable and processes the GNSS signals output from the active antenna.

Signal, noise, and RFI levels in the GNSS receiver MOPS are all defined relative to Point A. For better control and repeatability, GNSS receiver performance tests are typically run by simulating effect of the active antenna on the signal, noise and RF interference conditions at Point C. The key parameters in this active antenna MOPS give relative antenna pattern gain ratio (equivalent to passive antenna gain) and G/T ratio (essentially the signal-to-thermal noise ratio) all referenced to Point A. In addition the active antenna MOPS specifies a minimum passive antenna element gain (5° elevation), $G_{A,min}$ for the unit and a minimum active sub-assembly gain, G_R.

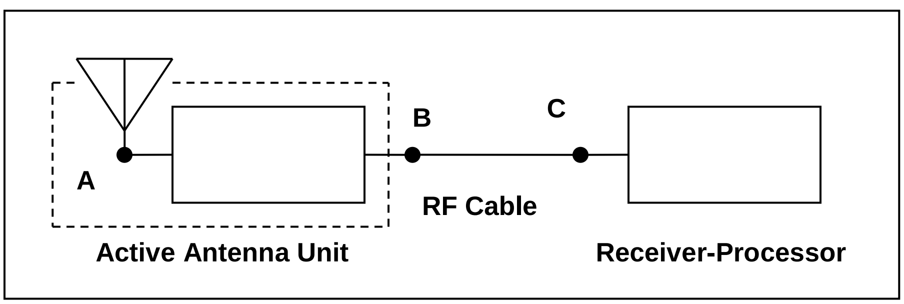

Figure A-3: GNSS Receiver System Installation Diagram

The only additional parameters needed to complete the necessary transformation of the Receiver MOPS requirements referenced to Point A to test values at Point C is the RF cable insertion loss. Antenna-to-receiver cable insertion loss is actually dependent on aircraft installation details. However, guidance on the cable loss from ARINC Characteristic 743A [Ref. A-3] suggests that 13 dB loss is appropriate assumption.

A.3.2 Transformation of Antenna Input Signal and Noise Levels to Receiver Input Values

The minimum passive element gain at 5° elevation is used as follows to find the antenna input noise temperature at center frequency (f_C) from the minimum mid-band G/T ratio. Since the minimum passive element gain at 5° elevation, $G_A(\phi,85°,f_c)$ is -4.5 dBic, the 5° elevation minimum G/T ratio, $[G_A(\phi,85°,f_c)/ T_{IN}(f_c)]$, is -30.6 dB/K (for the L1/E1 band) and

$$T_{IN}(f_c) = G_A(\emptyset, 85^0, f_c) * \left(\frac{T_{IN}(f_c)}{G_A(\emptyset, 85^0, f_c)}\right) \quad \text{(Equation A-22)}$$

then $T_{IN}(f_c)$=26.1 dB-K (=407 K) for the L1/E1 band. The input thermal noise density at Point A, $N_{IN}(f_C) = kT_{IN}(f_C)$ = -172.5 dBm/Hz (also known as $N_{sky,antenna}$ in DO-229E)

The minimum Earth-surface GPS L1 C/A signal level at 5 degrees elevation is specified to be -128.5 dBm (from a 0 dBic antenna). At Point A the minimum received signal, S_{MIN}, is -128.5 dBm – 4.5 dBic = -133.0 dBm. For Galileo E1b,c (combined power level) the minimum signal level S_{MIN} at point A is (-127.25 – 4.5) = -131.75 dBm. Similarly, the minimum signal levels at point A for GPS L5 and Galileo E5a are -129.4 dBm and -129.5 dBm.

When translated to Point C, the minimum satellite signal is: -128.5 dBm + $G_A(\phi,85^o,f_c)$ (in dBic) + $G_R(f_c)$ (in dB) – 13 dB (cable loss). Thus, the GPS L1 C/A signal is -119.5 dBm (= -133 +26.5-13). The RFI densities are already referenced to Point A so they are just increased by the net active amplifier gain and cable loss (= 13.5 dB). For Galileo E1b,c the signal level at point C is -118.25 dBm. Similarly, the signal level values for L5 at point C is -115.9 dBm and for E5a at point C is -116 dBm.

The input thermal noise temperature, $T_{IN}(f_c)$ is translated to the cable output Point C by

$$T_{OUT}(f_c) = \frac{T_{IN}(f_c) * G_R(f_c)}{L_{cab}(f_c)} + T_{Cab} * \left(1 - \frac{1}{L_{cab}(f_c)}\right) \quad \text{(Equation A-23)}$$

where T_{Cab} is the cable temperature (~300 K) and L_{Cab} is the assumed cable loss factor ($10^{13/10}$). Using the parameter determined above, the equivalent thermal noise temperature at Point C, T_{OUT} becomes 9397 K and the thermal noise density (kT_{OUT}) is -158.87 dBm/Hz. This value does not include the receiver unit input noise temperature which the receiver unit-under-test contributes. This value applies for GPS L1 C/A and E1 b,c. The equivalent value for GPS L5 and E5a at point C is -157.04 dB/Hz.

A.4 References

[A-1] Janda, R., *et al*, “Linking Microwave Remote Sensing Measurements to Fundamental Noise Standards” (antenna temperature theory and measurement) <https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=31938>

[A-2] “Noise Figure Measurement Accuracy – the Y-Factor Method,” Agilent Application Note 57-2, Agilent Technologies, Inc., Literature # 5952-3706 (see also AN 57-1 and AN 57-3)

[A-3] ARINC CHARACTERISTIC 743A-5, May 29, 2009

APPENDIX B: COMBINED GLONASS/GPS/GALILEO ACTIVE ANTENNA STANDARD AND ENVIROMENTAL CONDITIONS

B.1 Introduction

The Appendix is for informational purposes. It addresses multi-frequency aircraft antennas for a combination of constellations (including GLONASS) desirable for the potential user. This makes it possible for the manufacturers of avionics to produce unified options of equipment, taking into account regional user needs. This makes it possible for the manufacturers of avionics to produce unified options of equipment, taking into account regional requirements of users.

In the context of this Appendix, it is assumed that GNSS will consist of civil GPS elements (L1 and L5), the planned civil Galileo element (E1 and E5a), and the operating civil GLONASS elements (L1 and L3).

The increase in the number of additional constellations increases the GNSS stability reducing the interference vulnerability, improving the integrity, reliability and accuracy of the navigation support performance. At the same time, combining the needs for the reception and use of GPS, Galileo and GLONASS signals also makes it possible to provide any set of constellations used.

B.2 Equipment Performance Requirements and Test Procedures

B.2.1 General Requirements

Corresponds to MOPS Section 2.1.

B.2.2 GNSS Active Antenna Unit Performance – Standard Conditions

Corresponds to MOPS Section 2.2.

B.2.2.1 Frequency of Operation

The antenna unit should operate over the frequency bands outlined in Table B-1. The frequency of operation is defined in terms of the 3 dB points of the total antenna response.

Table B-1: GNSS Bands

Band	Central frequency (MHz)	Lower frequency limit (MHz)	Upper frequency limit (MHz)	Bandwidth (MHz)
E5a Galileo	1176.45	1166.22	1186.68	20.46
E1 Galileo	1575.42	1565.19	1585.65	20.46
L5 GPS	1176.45	1166.22	1186.68	20.46
L1 GPS	1575.42	1565.19	1585.65	20.46
L3 GLONASS	1202.025	1191.795	1212.255	20.46
L1 GLONASS	1602	1592.9525	1609.36	16,4

B.2.2.2 Antenna Unit Output Return Loss and Impedance

The Return Loss at the output port of the GNSS antenna should be no more than -14 dB (1.5:1 VSWR) referred to 50 Ohm impedance throughout the bandwidths of the GNSS bands outlined in Table B-1. This cannot degrade to more than -10 dB (2:1 VSWR) when 0.5 inches of ice is accumulated over the antenna.

B.2.2.3 Antenna Unit Relative Radiation Pattern and Passive Element Gain

B.2.2.3.1 Antenna Unit Relative Radiation Pattern

The antenna radiation patterns should refer to a coordinate system with zero-degree elevation measured at the horizon and 90-degree elevation is at zenith. Zero-degree azimuth is referenced parallel to the X axis of the airframe as seen in Figure B-1 a-b. The definition of azimuth and elevation angles is also denoted. The antenna is assumed to be placed at the origin of the coordinate system O (Figure B-1 b). The GNSS antenna quantity defined is the relative radiation pattern (i.e.) the radiation pattern normalized to its peak value expressed in dB. The peak normalization reference value is the maximum value based on all available of azimuthal cuts restricted within an elevation angle cone of 15° from zenith.

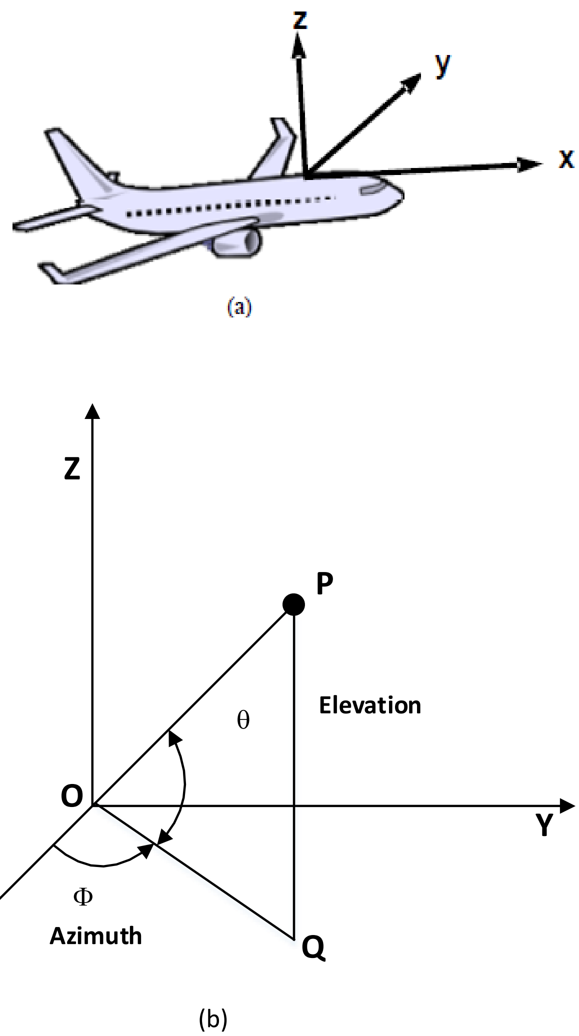

Figure B-1: Coordinate Systems for Radiation Patterns

The relative radiation pattern measured at the GNSS band centers (Table B-2) should comply with the maximum and minimum gain templates described in Table B-2. These templates are assumed to form in a linear piecewise fashion with break points defined by the values of Table B-2.

Table B-2: Relative Radiation Pattern Template.

Elevation Angle (degrees)	Minimum (dB)	Maximum (dB)
0	-11	-7
5	-8.5	-5
10	-7	-3
15	-5.5	-1
30	-3.5	-0.75
>=75	-2.5	0

Note:

1. *Small deviations may still be considered acceptable provided that their magnitude does not exceed the 1 dB and the percentage of the angular regions of deviation do not exceed the 5% of total angular directions measured taking into account the above guidance for the elevation-azimuth grid of points.*
2. *The relative antenna gains should not vary by more than 1 dB taking into account the full operational temperature range.*

B.2.2.3.2 Passive Element Gain

The passive radiating element gain for the active antenna unit is specified in terms of the absolute gain (dBic) for the passive element and any associated passive feed network and radome with respect to an ideal circular isotropic antenna. The passive radiating element gain at 1602 MHz, 1575.42 MHz, 1202.025 MHz and 1176.45 MHz and 5° elevation should be at least -4.5 dBic over all azimuth angles.

Note:

1. *In their installation instructions, the manufacturer should identify the minimum passive element gain at 5 degrees and the maximum passive element gain above 75 degrees elevation for their equipment. Receiver manufacturers can take advantage of performance better than the minimum requirement, and documenting improved performance facilitates the installation and integration of the antenna and receiver.*
2. *The maximum passive element gain above 75 degrees elevation is expected to be not more than +4 dBic.*

B.2.2.4 Polarization and Axial Ratio

The antenna radiation pattern polarization should be nominally right-hand circularly polarized, and its axial ratio should not exceed 3.0 dB over the operating frequency range as measured in a region extending from boresight down to 40 degrees of elevation off boresight across all azimuth.

B.2.2.5 Antenna Sensitivity: The G/T Ratio

The antenna, irrespective of its implementation, should ensure delivery of a minimum acceptable C/N_o GNSS signal to the receiver. The quantity for ensuring this (as used traditionally with other satellite communication systems) is the G/T.

The GNSS antenna has to demonstrate that its G/T value is >= -30.6 dB/K for all elevation angles Θ when: $5° < \theta < 90°$ and for all frequencies:

within f_C±5MHz with f_c set to 1602 MHz;

within f_C±8MHz with f_c set to 1575.42 MHz.

The GNSS antenna has to demonstrate that its G/T value is >= -32.5 dB/K for all elevation angles Θ when: $5° <= \theta <= 90°$ and for all frequencies within f_C±10.23 MHz with f_c set to 1202.025 MHz and

1176.45 MHz.

Note: Compliance to the minimum G/T figure quoted has to be unequivocal including all operational temperatures.

B.2.2.6 Total Transducer Gain and Gain Compression

B.2.2.6.1 Minimum Boresight Total Transducer Gain

The transducer gain is a term containing both and inseparably the passive antenna gain and the gain of the preamplifier. The specification here deals only with the active GNSS antennas. Its purpose is to ensure the quality of the delivered GNSS signal to the receiver when both are connected with a long length of cable. The quantity specified here refers to the peak value of the transducer gain over the bandwidth of the respective GNSS bands defined in Table B-1 and assuming the peak angular response. This value should be no less than 29.5 dBic over the frequency range of:

f_C±5MHz with f_c set to 1602 MHz;

f_C±8MHz with f_c set to 1575.42 MHz;

f_C±10.23 MHz with f_c set to 1202.025 MHz and f_c set to 1176.45 MHz.

B.2.2.6.2 Active Sub-Assembly Transducer Gain

The minimum active sub-assembly gain over the frequency ranges 1602±5MHz, 1575.42±8 MHz, 1202.025±10.23 MHz and 1176.45±10.23 MHz should not be less than 26.5 dB over the full temperature range.

Note:

1. *The active sub-assembly is assumed to contain the HIRF protection, pre- and post-selection RF filtering, preamplifier and DC bias circuitry and interface at a single input port to the passive radiating element.*
2. *The listed active sub-assembly minimum gain value is consistent with the total transducer gain in Section 2.2.6. For installations with higher cable attenuation, a higher active sub-assembly minimum gain (and therefore a higher total transducer gain) may be necessary. To avoid excessive receiver dynamic range impact, the active sub-assembly mid-band gain value should remain within a +/- 2 dB range about a nominal manufacturer-specified value.*
3. *The manufacturer should identify the nominal amplifier gain and tolerance for their equipment in their installation instructions. Receiver manufacturers need this information to define installation instructions that integrate the antenna and receiver.*

B.2.2.6.3 Boresight Transducer Gain Compression Point

This refers to active antenna configurations. This is a measure of the linearity of the active antenna performance and the definition is based on the input port 1 dB compression point traditionally defined in amplifier and receiver circuitry. The 1 dB input compression power is referred to the input port of the associated preamplifier. The limits of acceptable performance are given in Table B-3 or equivalently in Figure B-2.

Table B-3: 1 dB Input Compression Point

Frequency (MHz)	1dB Input Compression Point (dBm)
1000	23
1090.45	23
1130.45	23
1149.45	8
1162.45	-15
1213	-15
1278	23
1315	23
1400	20
1515.42	8
1531.42	0
1558.42	-11
1562.2	-12
1563	-15
1610	-15
1613.7	-13
1616.42	-7
1619.42	1
1625.42	8
2000	20

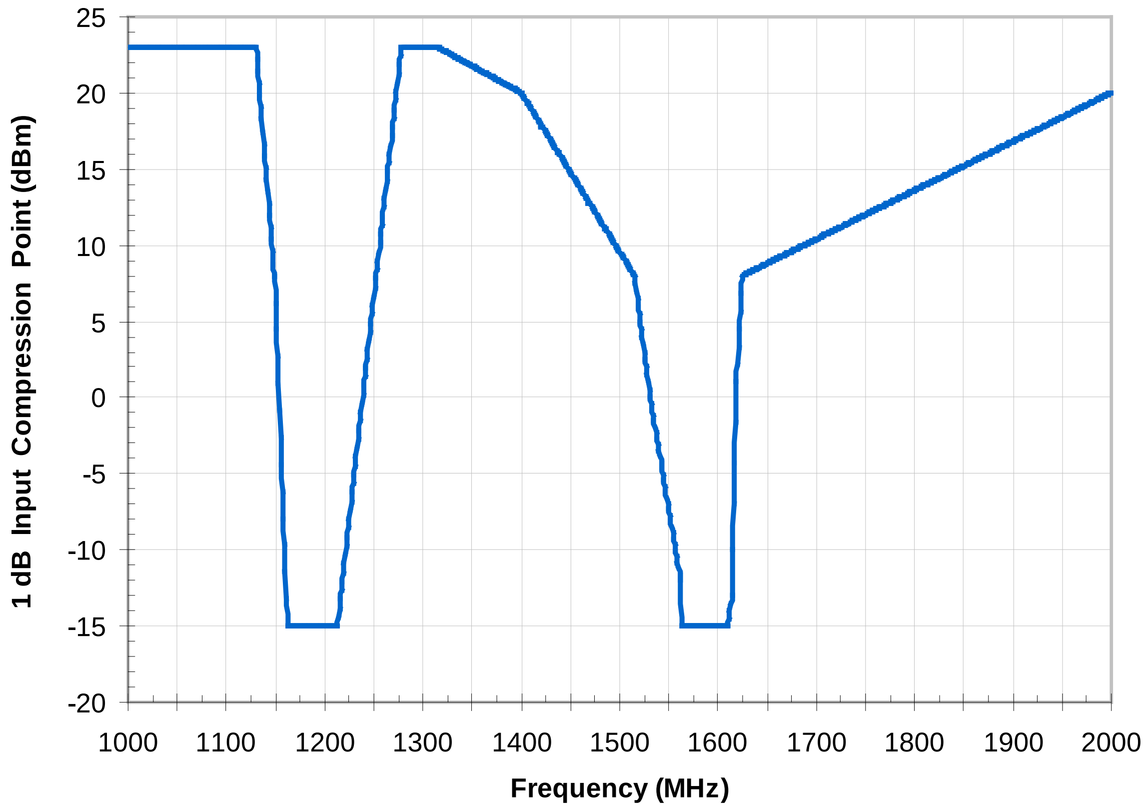

Figure B-2: 1 dB Compression Point Graph (in dBm).

Note: In case of an integrated antenna the input preamplifier port may not be easily accessible or when a test point cannot be easily inserted the 1 dB compression power points can be translated as an externally applied Electrical field (E) illuminating the full antenna assembly along a preselected direction.

The formula for deriving the field strength of the applied electrical field producing the set power at the internal input of the preamplifier is:

$E\ (\mathrm{dBV/m}) = P_{in}\ (\mathrm{dBm}) - G_p\ (\mathrm{dBi}) + 20 \log (f_{GHz}) + 17.21$ (Equation B-1)

With G_P the reference total Gain of the embedded passive antenna used. Scaling at any other direction is possible and permissible using the above formula and the measured relative pattern.

B.2.2.7 Load Stability

The active antenna should be unconditionally stable for any passive output load impedance with a positive real component.

B.2.2.8 Boresight Gain Relative Frequency Response

The Relative Frequency Response (RFR) is defined as the Transducer Gain variation in dB at the boresight direction (Elevation angle Θ=90°) normalized to the peak response at the same direction taking into account the Transducer Gain values across the GNSS frequencies at the combined bands:

a) L5/E5a +/- 10.23 MHz ;

b) L1 GPS /E1 +/- 8 MHz ;

c) L3 +/- 10.23 MHz;

d) L1 GLONASS +/- 5 MHz.

The normalization is done separately for (a) and (b) and (c) and (d).

B.2.2.8.1 -3 dB Relative Response Frequencies

The active antenna relative boresight gain lower frequency -3 dB point should not be higher than:

1597 MHz at L1 GLONASS frequency;

1567.42 MHz at L1 GPS /E1 frequency;

1191.795 MHz at L3 frequency;

1166.22 MHz at L5/E5a frequency.

The active antenna relative boresight gain upper frequency -3 dB point should not be lower than:

1607 MHz at L1 GLONASS frequency;

1583.42 MHz at L1 GPS /E1 frequency;

1212.255 MHz at L3 frequency;

1186.68 MHz at L5/E5a frequency.

B.2.2.8.2 Maximum Boresight Frequency Response Limits

The maximum RFR limits for the GNSS antenna are defined in Table B-4_and illustrated equivalently in Figure B-3.

Table B-4: Maximum Boresight Relative Frequency Response

Frequency (MHz)	Selectivity (dB)
1000	-87
1090.45	-78
1130.45	-56
1149.45	-35
1162.45	0
1213	0
1278	-50
1315	-77
1400	-50
1515.42	-50
1531.42	-35
1554.42	-5
1558.42	0
1609.36	0
1615	-5
1625.42	-50
2000	-70

Figure B-3: Boresight RFR –Antenna Selectivity

B.2.2.9 Burnout Limit

This specification deals with the maximum CW carrier that the preamplifier can withstand. The antenna preamplifier should withstand a CW input carrier upto + 30 dBm without damage. Under these conditions the output of the preamplifier should be limited to +20 dBm. The input carrier is referred to the notional or real output of the passive antenna radiator constituent of the antenna assembly. For those cases where the passive radiator and the preamplifier are closely integrated, an alternative requirement can be formulated by translating the input power and thus specifying the externally impressed electric field producing the above stated output. The details are entirely analogous to the methodology outlined in Note 1 of Section B.2.2.6.3.

Note: This requirement is applicable to in-band signals and transition band signals. Out-of-band performance is warranted to comply by virtue of the compression point specifications (see Section B.2.2.6.3).

B.2.2.10 Pulse power Recovery Time

This specification deals with the delay of resuming normal operation after a strong spurious pulse signal is applied to the active antenna. The specification takes into account the realistic scenarios for these strong signals sources and at points makes explicit reference to them. This refers to excitation powers at the output of the passive radiator component of the active antenna (at the input of the active subassembly). The details are entirely analogous to the methodology outlined in Note 1 of Section B.2.2.6.3.

B.2.2.10.1 In Band Maximum Pulse Input at L1/E1 Band

The GNSS active antenna should resume normal operation within 10 µs of the trailing edge of a pulse with a width of up to 1 ms and a peak power of 30 dBm and a duty cycle of 10%.

B.2.2.10.2 In Band Maximum Pulse Input at L5/E5a/L3 Band

The GNSS active antenna should provide normal and unobstructed performance when a DME type pulse with peak power of no more than -60 dBm is received at the output of the embedded passive radiator. For higher peak power DME-like pulse signals of up to 30 dBm, the GNSS antenna should resume normal operation within 10 µs. The main characteristics of ground and airborne DME are provided in Appendix C.

B.2.2.10.3 Out of Band Maximum Pulse Input

For higher peak power pulses than the one defined in Appendix C and up to 30 dBm, the GNSS antenna should resume normal operation within 1 µs.

B.2.2.11 Group Delay

B.2.2.11.1 Boresight Differential Group Delay (BDGD)

The Group delay in the present context deals with the behavior of the phase pattern of the Copolar (RHCP) Transducer pattern. If the transducer pattern (voltage or electric field terms) is denoted in complex form and is expressed as:

$$E(\theta,\varphi,f) = \| E(\theta,\varphi,f) \| . \angle E(\theta,\varphi,f) \qquad \text{(Equation B-2)}$$

With

- θ: the elevation angle
- φ: the azimuth angle

- f: the frequency (Hz)

The phase pattern is the angular part of it:

$$\Phi(\theta,\phi,f) = \angle(E(\theta,\varphi,f) \quad \text{(Equation B-3)}$$

The Group Delay is defined as:

$$\delta\tau(\theta,\phi,f) = \frac{-1}{360}\frac{\delta\Phi(\theta,\varphi,f)}{\delta f} \quad \text{(Equation B-4)}$$

in seconds

The Boresight Differential Group Delay (BDGD) is defined individually and separately for each of the bands in Table B-1 as:

$$\Delta T_B = max \parallel \delta\tau(\theta_B,\varphi_B,f_i) - \delta\tau(\theta_B,\varphi_B,f_j) \parallel \quad \text{(Equation B-5)}$$

Where:

- θ_B, φ_B denote the boresight direction
- and f_i, f_j any frequency within the individual bandwidth of the GNSS bands as defined in Table B-1.

The BDGD of the antenna should satisfy the following requirement:

- The BDGD in any of the GNSS bands in consideration should be less than 25 ns

Note: The BDGD represents the combined effects of both the passive radiator as well as the built-in preamplifier and embedded filtering functions.

B.2.2.11.2 Differential Group Delay Versus Angle (DGA)

This is defined as:

$$\Delta T_A = max \parallel \delta\tau(\theta,\varphi_C,f_G) - \delta\tau(5^o,\varphi_C,f_G) \parallel \quad \text{(Equation B-6)}$$

With f_G the center of each of the GNSS Bands (Table B.2-1) individually addressed.

The above expression for the DGA is further calculated for every elevation angle θ within an azimuthal pattern cut $\varphi = \varphi_C$ and for all the azimuthal angle subsets individually. It is assumed that the phase pattern is retrieved within an angular grid complying with the requirements outlined in the Relative Pattern Section B.2.2.3.

The requirements are that the DGA calculated for each GNSS band separately should not exceed the limit:

$\Delta T_A \leq 2$ ns

This limit is applicable to all values calculated individually from the azimuth cuts per GNSS band.

Note:

1. *The DGA quantity is affected solely by the intrinsic properties of the passive radiator.*
2. *Based on previous measurements, it has been seen that the DGA may increase in a monotonic fashion as we go down in antenna elevation (towards the horizon).*

B.2.2.11.3 L1 GPS - L5 Group Delay Difference and L1 GLONASS – L3 Group Delay Difference

The group delay difference between the L1 GPS and L5 operating frequencies should not exceed 15 nanoseconds over the operating temperature range. The L1 GPS - L5 group delay difference is defined as the difference between the group delay measured at the center of the L1 GPS operating frequency and the group delay measured at the center of the L5 operating frequency.

The group delay difference between the L1 GLONASS and L3 operating frequencies should not exceed 15 nanoseconds over the operating temperature range. The L1 GLONASS - L3 group delay difference is defined as the difference between the group delay measured at the center of the L1 GLONASS operating frequency and the group delay measured at the center of the L3 operating frequency.

B.2.2.12 DC Power Interface

Any DC power that may be required should be supplied directly through the coaxial RF output connector. The GNSS antenna should operate with a DC input voltage anywhere within the range 4.5 -14.4 V and it should draw no more than 200 mA of current. The load capacitance of the central conductor of the RF coaxial output to any internal interfaces should not exceed the 0.75 uF.

Note:

1. *The current allocation exceeds the legacy 60 mA specification on existing GPS only antenna installation as this reflects the increased complexity due to multiple bands and the demands for increased linearity.*
2. *It is of interest for aircraft OEMs, antenna and receiver manufacturers to support development of a dual frequency GNSS antenna that is backwards compatible with currently certified GNSS L1 antennas. Potential solutions comprise the use of voltage/current levels to switch L5, L3 reception on or off.*
3. *The GNSS Active antenna is intended to be an integrated active antenna that meets the A743-A4 footprint. The total height of the antenna should not exceed 1.25 inches.*

B.2.3 Equipment Performance – Environmental Conditions

Corresponds to MOPS Section 2.3.

B.2.3.1 Specific Environmental Test Conditions

Corresponds to MOPS Section 2.3.1.

B.2.3.2 Temperature and Altitude Tests (DO-160G, Section 4.0)

Corresponds to MOPS Section 2.3.1.

B.2.3.2.1 Operating Low Temperature Test

The equipment should be subjected to the test conditions as specified in DO-160G, Section 4.5.2, and the following requirements of this standard should be met:

1. Active Sub-Assembly (ASA) Input VSWR: The input VSWR should be less than 1.8 over the operating frequency range.

2. Active Sub-Assembly (ASA) Input Noise Temperature:

   L1/E1: Section B.2.2.5 - Input Noise Temperature $\leq$ 307 K over 1575.42 +/- 8 MHz and 1602 +/- 5 MHz

   L5/E5a/L3: Section B.2.2.5 - Input Noise Temperature $\leq$ 531 K over 1176.45 +/- 10.23 MHz and 1202.025 +/- 8 MHz

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain

4. L1/E1: Section B.2.2.8.1 - -3 dB Relative Response Frequencies (ASA)

   L5/E5a/L3: Section B.2.2.8.1 - -3 dB Relative Response Frequencies (ASA)

5. L1/E1: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response

   The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

   L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response

   The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz

6 Section B.2.2.7 - Output Load Stability {this test may be met with an integrated active unit}

7. L1/E1: Section B.2.2.9- Burnout Protection (ASA)

   L5/E5a/L3: Section B.2.2.9 – Burnout Protection (ASA)

8 L1/E1: Section B.2.2.11.1 – Boresight Differential Group Delay (ASA)

   L5/E5a/L3: Section B.2.2.11.1 - Boresight Differential Group Delay (ASA)

9. L1 GPS – L5 and L1 GLONASS – L3 Section B.2.2.11.3 - Group Delay Difference (ASA)

10. Section B.2.2.14 – DC Power Interface

B.2.3.2.2 High Operating Temperature Test

The equipment should be subjected to the test conditions as specified in DO-160G, Section 4.5.2, and the following requirements of this standard should be met:

1. Active Sub-Assembly (ASA) Input VSWR: The input VSWR should be less than 1.8 over the operating frequency range.

2. Active Sub-Assembly (ASA) Input Noise Temperature:

   L1/E1: Section B.2.2.5 - Input Noise Temperature ≤ 307 K over 1575.42 +/- 8 MHz and 1602 +/- 5 MHz

   L5/E5a/L3: Section B.2.2.5 - Input Noise Temperature ≤ 531 K over 1176.45 +/- 10.23 MHz and 1202.025 +/- 8 MHz

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain

4. L1/E1: Section B.2.2.8.1 - -3 dB Relative Response Frequencies (ASA)

   L5/E5a/L3: Section B.2.2.8.1 - -3 dB Relative Response Frequencies (ASA)

5. L1/E1: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response

   The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

   L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response

   The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz

6. L1/E1: Section B.2.2.9- Burnout Protection (ASA)

   L5/E5a/L3: Section B.2.2.9 – Burnout Protection (ASA)

7 L1/E1: Section B.2.2.10.1 – In-band Pulse Power Saturation Recovery Time (ASA)

   L1/E1: Section B.2.2.10.3 – Out of band Pulse Power Saturation Recovery Time (ASA)

   L5/E5a/L3: Section B.2.2.10.2 – In-band Pulse Power Saturation Recovery Time (ASA)

   L5/E5a/L3: Section B.2.2.10.3 – Out of band Pulse Power Saturation Recovery Time

   (ASA)

8 L1/E1: Section B.2.2.11.1 – Boresight Differential Group Delay (ASA)

   L5/E5a/L3: Section B.2.2.11.1 - Boresight Differential Group Delay (ASA)

9. L1 GPS – L5 and L1 GLONASS – L3 Section B.2.2.11.3 - Group Delay Difference (ASA)

10. Section B.2.2.14 – DC Power Interface

B.2.3.2.3 Altitude Test

The equipment should be subjected to the test conditions as specified in DO-160G, Section 4.6.1, and the following requirements of this standard should be met during the test condition application except as noted:

1. L1/E1: Section B.2.2.5 – G/T Ratio (AUT, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AUT, before and after test condition application)

   A radiated "hot-cold" noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change.

2. Active Sub-Assembly (ASA) Input Noise Temperature:

   L1/E1: Section B.2.2.5 - Input Noise Temperature < 307 K over 1575.42 +/- 8 MHz and 1602 +/- 5 MHz

   L5/E5a/L3: Section B.2.2.5 - Input Noise Temperature < 531 K over 1176.45 +/- 10.23 MHz and 1202.025 +/- 8 MHz

   L1/E1: Section B.2.2.6.2 – ASA Transducer Gain

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain

B.2.3.3 Temperature Variation Test (DO-160G, Section 5.0)

The equipment should be subjected to the test conditions as specified in DO-160G, Section 5.0, and the following requirements of this standard should be met during the test condition application except as noted:

1. L1/E1: Section B.2.2.5 – G/T Ratio (AUT, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AUT, before and after test condition application)

   A radiated "hot-cold" noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change in an integrated active antenna unit

2. Active Sub-Assembly (ASA) Input Noise Temperature:

   L1/E1: Section B.2.2.5 - Input Noise Temperature < 307 K over 1575.42 +/- 8 MHz and 1602 +/- 5 MHz

   L5/E5a/L3: Section B.2.2.5 - Input Noise Temperature < 531 K over 1176.45 +/- 10.23 MHz and 1202.025 +/- 8 MHz

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain

4. Section B.2.2.14 – DC Power Interface

B.2.3.4 Humidity Test (DO-160G, Section 6.0)

The active antenna unit equipment should be subjected to the test conditions as specified in DO-160G, Section 6.0, and the following requirements of this standard should be met:

1 L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain

4. L1/E1: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz

B.2.3.5 Shock Tests (DO-160G, Section 7.0)

B.2.3.5.1 Operational Shocks

The active antenna unit equipment should be subjected to the test conditions as specified in DO-160G, Section 7.2, and the following requirements of this standard should be met:

L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

L5/E5a/L3 Section B.2.2.2 – AUT Output VSWR and Impedance (After)

2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, After)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, After)

3. L1/E1: Section B.2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, After)

   L5/E5a/L3: Section B.2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, After)

4. L1/E1: Section B.2.2.11.1 – Boresight Differential Group Delay (AAU, before, after)

   L5/E5a/L3: Section B.2.2.11.1 - Boresight Differential Group Delay (AAU, before, after)

5. L1 GPS – L5 and L1 GLONASS – L3 Section B.2.2.11.3 (AAU, before, after)

B.2.3.5.2 Crash Safety Shocks

The application of Crash Safety Shock tests in DO-160G, Section 7.3 may result in damage to the antenna under test. Therefore, this test may be conducted after the other tests have been completed. In this case, Section B.2.4 "Effects of Test" does not apply. The active antenna unit is considered to have passed this test if it stays attached to its mounting.

B.2.3.6 Vibration Test (DO-160G, Section 8.0)

The equipment should be subjected to the test conditions as specified in DO-160G, Section 8.0, and the following requirements of this standard should be met:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AUT Output VSWR and Impedance (After)
2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)
3. L1/E1 Section B.2.2.6.2 – ASA Transducer Gain (during vibration)

   L5/E5a/L3 Section B.2.2.6.2 – ASA Transducer Gain (during vibration)
4. Section B.2.2.14 – DC Power Interface (active during vibration)

   The DC current should not indicate intermittent behavior during vibration.

B.2.3.7 Explosion Test (DO-160G, Section 9.0)

Explosion testing is not required because the antenna is not normally installed in an explosive environment.

B.2.3.8 Waterproofness Tests (DO-160G, Section 10.0)

The integrated active antenna equipment should be subjected to the continuous stream proof test conditions as specified in DO-160G, Section 10.3.4, and the following requirements of this standard should be met:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AUT Output VSWR and Impedance (After)
2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

A radiated "hot-cold" noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change.

Note: This test should be conducted with the spray directed perpendicular to the most vulnerable area(s) as determined by the equipment manufacturer.

B.2.3.9 Fluids Susceptibility Tests (DO-160G, Section 11.0)

The following sections contain the applicable test conditions specified in Section 11.0 of DO-160G.

B.2.3.9.1 SPRAY TEST

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 11.4.1, and the following requirements of this standard should be met:

At the end of the 24-hour exposure period, the equipment should operate at a level of performance that indicates that no significant failures of components or circuitry have occurred.

Following the 2-hour operational period at ambient temperature, after the 160-hour exposure period at elevated temperature, the following requirements of this standard should be met:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AUT Output VSWR and Impedance (After)

2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition

   application

A radiated “hot-cold” noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change.

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

4. L1/E1 Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz Maximum Boresight Relative Frequency Response (after, radiated test)

B.2.3.9.2 Immersion Test

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 11.4.2, and the following requirements of this standard should be met:

A. At the end of the 24-hour immersion period, the equipment should operate at a level of performance that indicates that no significant failures of components or circuitry have occurred.

Following the 2-hour operational period at ambient temperature, after the 160-hour exposure period at elevated temperature, the following requirements of this standard should be met:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AUT Output VSWR and Impedance (After)

2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition

   application

   A radiated “hot-cold” noise test at boresight (Sect. B.2.4.3.2) is an acceptable

   alternative to identify any relative change.

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

4. L1/E1 Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz Maximum Boresight Relative Frequency Response (after, radiated test)

B.2.3.10 Sand and Dust Test (DO-160G, Section 12.0)

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 12.0, and the following requirements of this standard should be met:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AUT Output VSWR and Impedance (After)

2. L1/E1: Section B.2.2.5– G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5– G/T Ratio (AAU, before and after test condition application

   A radiated “hot-cold” noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change.

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test).

4. L1/E1 Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz Maximum Boresight Relative Frequency Response (after, radiated test)

B.2.3.11 Fungus Resistance Test (DO-160G, Section 13.0)

Fungus testing is not required because the antenna is not normally installed in a location that is conducive to growth of fungus.

However, if the manufacturer wishes to qualify the equipment for this particular condition due to specific circumstances, then the Antenna Under Test equipment should be subjected to the test conditions as specified in DO-160G, Section 13.0, and the following requirements of this standard should be met:

L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

A radiated "hot-cold" noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change.

2. L1/E1: Section B.2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, before and after)

L5/E5a/L3: Section B.2.2.6.1 – Minimum Boresight Total Transducer Gain (AAU, before and after.

B.2.3.12 Salt Spray Test (DO-160G, Section 14.0)

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 14.0, and the following requirements of this standard should be met:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

   L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance (After)

2. L1/E1: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition application)

   L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, before and after test condition

   application)

A radiated "hot-cold" noise test at boresight (Sect. B.2.4.3.2) is an acceptable alternative to identify any relative change.

3. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (after, radiated test)

4. L1/E1 Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1531.42 - 1625.42MHz (normalized to the maximum sub-assembly gain within 1575.42 ± 8 MHz) and 1602 +/- 5 MHz

L5/E5a/L3: Section B.2.2.8.2 - Maximum Boresight Relative Frequency Response (After)

The ASA should meet the relative gain response requirement over the frequency range 1150 - 1278 MHz (normalized to the maximum sub-assembly gain within 1176.45 ± 10.23 MHz) and 1202.025 +/- 8 MHz Maximum Boresight Relative Frequency Response (after, radiated test)

B.2.3.13 Magnetic Effect Test (DO-160G, Section 15.0)

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 15.0, and the equipment should meet the requirements of the appropriate instrument or equipment class specified therein.

B.2.3.14 Power Input Tests (DO-160G, Section 16.0)

This test is not applicable since the aircraft power bus does not directly apply DC power to the active antenna.

B.2.3.15 Voltage Spike Conducted Test (DO-160G, Section 17.0)

This test is not applicable since the aircraft power bus does not directly apply DC power to the active antenna.

B.2.3.16 Audio Frequency Conducted Susceptibility Test (DO-160G, Section 18.0)

This test is not applicable since the aircraft power bus does not directly apply DC power to the active antenna.

B.2.3.17 Induced Signal Susceptibility Test (DO-160G, Section 19.0)

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 19.0.as described in Sub-sections 19.3.1 through 19.3.5. For conditions in Sub-sections 19.3.1 and 19.3.2, the magnetic and electric fields need only be applied under the antenna unit-under-test. The induced signals in Sub-sections 19.3.3 through 19.3.5 are applied to the RF coaxial output cable from the unit. The following requirements should be met during application of the environmental condition:

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (radiated test)

   L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance (radiated test)

2. L1/E1: SectionB.2.2.6.2 – ASA Transducer Gain (radiated test)

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

B.2.3.18 Radio Frequency Susceptibility Test (Radiated & Conducted) (DO-160G, Section 20.0)

The equipment should be subjected to the test conditions as specified in DO-160G, Section 20. Radiated susceptibility test levels for frequencies between 1.0 and 2.0 GHz should follow the frequency response shape of Section 3.7 (where the listed power limits are converted to equivalent field strength values). The following requirements of this standard should be met during application of the environmental test stimulus:

B.2.3.18.1 Conducted Susceptibility Performance

1. L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance (radiated test)

   L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance (radiated test)

2. L1/E1: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

   L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

B.2.3.18.2 Radiated Susceptibility Performance

1. L1/E1: Section B.2.2.6.3 - Boresight Transducer Gain Compression Point (determined by radiating at the AAU a second, low-level, CW signal at 1575.42 MHz and 1602 MHz together with the test stimulus and monitoring for less than 1 dB peak decrease in CW signal level. See Section B.2.4.2.6 for 1-2 GHz test levels, and modulation, and other details.)

2. L5/E5a/L3: Section B.2.2.6.3 - Boresight Transducer Gain Compression Point (determined by radiating at the AAU a second, low-level, CW signal at 1176.45 MHz and

1202.025 MHz together with the test stimulus and monitoring for less than 1 dB peak decrease in CW signal level. See Section B.2.4.2.6 for 1-2 GHz test levels, and modulation, and other details.)

3. L1/E1/L5/E5a/L3: Section B.2.2.9 – Burnout Protection (saturated output power only). For high level signal test frequencies between 1.0 and 2.0 GHz the AAU (peak) output power at the test frequency from the 150 V/m peak incident field should not exceed the +20 dBm output limit.

4. L1/E1: Section B.2.2.10.1 – Pulse Saturation Recovery Time: (See Section B.2.4.2.6 for test procedure details.)

5. L5/E5a/L3: Section B.2.2.10.2 – Pulse Saturation Recovery Time: (See Section B.2.4.2.6 for test procedure details.)

B.2.3.19 Emission of Radio Frequency Energy Test (DO-160G, Section 21.0)

When the AAU equipment is subjected to the test conditions as specified in DO-160G, Section 21.0, it should meet the requirements specified therein.

B.2.3.20 Lightning Induced Transient Susceptibility (DO-160G, Section 22.0)

The AAU equipment should be subjected to the test conditions as specified in DO-160G, Section 22.0, and the following requirements of this standard should be met before and after the environmental condition is applied:

L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance

L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance

L1/E1: Section B.2.2.5 – G/T Ratio (AAU, optional measurement at boresight)

L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, optional measurement at boresight)

L1/E1: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

Note: The intent of these tests is to check for performance degradation after the lightning induced transients have been applied to the integrated antenna unit.

B.2.3.21 Lightning Direct Effects (DO-160G, Section 23.0)

The integrated active antenna equipment should be subjected to the test conditions as specified in DO-160G, Section 23.0, and the following requirements of this standard should be met before and after the environmental condition is applied.

L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance

L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance

L1/E1: Section B.2.2.5 – G/T Ratio (AAU, optional measurement at boresight)

L5/E5a/L3: Section B.2.2.5 – G/T Ratio (AAU, optional measurement at boresight).

L1/E1: Section B/2.2.6.2 – ASA Transducer Gain (radiated test)

L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

Lightning-induced signals on the RF coaxial cable should not exceed the levels associated with DO-160G Section 22, Category A3J3L3 when measured at the 50 Ohm cable termination.

Note: The intent of these tests is to check for performance degradation after the lightning direct transients have been applied to the integrated antenna unit. The induced output transient signals on the coax cable become the receiver indirect test condition.

B.2.3.22 Icing (DO-160G, Section 24.0)

The AAU equipment should be subjected to the test conditions as specified in DO-160G, Section 24.0, and the following requirements should be met:

L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance

L1/E1: The output VSWR for an antenna unit exposed to an ice accumulation of 0.5 inches should not exceed 2.0.

L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance

L5/E5a/L3: The output VSWR for an antenna unit exposed to an ice accumulation of 0.5 inches should not exceed 2.0.

Antenna Unit Relative Radiation Pattern Section B.2.2.3.1:

L1/E1: The antenna unit relative pattern gain should not degrade more than 4.5 dB at 30º elevation from the dry condition value at the same ambient temperature.

L5/E5a/L3: The antenna unit relative pattern gain should not degrade more than 4.5 dB at 30º elevation from the dry condition value at the same ambient temperature.

B.2.3.23 Electrostatic Discharge (DO-160G, Section 25.0)

The AAU equipment should be subjected to the test conditions as specified in DO-160G, Section 25.0, and the following requirements should be met following the test:

L1/E1 Section B.2.2.2 – AAU Output VSWR and Impedance

L5/E5a/L3 Section B.2.2.2 – AAU Output VSWR and Impedance

L1/E1: Section B/2.2.6.2 – ASA Transducer Gain (radiated test)

L5/E5a/L3: Section B.2.2.6.2 – ASA Transducer Gain (radiated test)

B.2.3.24 Fire, Flammability (DO-160G, Section 26.0)

The AAU equipment should be subjected to the test conditions as specified in DO-160G, Section 26.0, and the pass/fail requirements met therein. The purpose of this test is to ensure the non-propagation of the flame in the case where ignition would appear inside or outside of the equipment, while the equipment is in a non-operating mode. There are no electrical performance parameters that need to be conducted following this test.

B.2.4 Equipment Test Procedures

The test procedures in this section constitute a satisfactory method of determining that the GNSS antenna meets the required performance stated in Section 3. Although specific test procedures are cited, it is recognized that other methods may be preferred. Such alternative methods may be used if the manufacturer can demonstrate equivalent test procedures. In this case, the test procedures cited herein must be used as one set of criteria in evaluating the acceptability of the alternate procedures.

Table B.2-5 indicates the correspondence between the equipment performance requirements in Section 3 and the tests in this section.

Table B-5: Test Cross Reference

Requirement	Subject	Tests
B.2.2.1	Frequency of Operation	B.2.4.2.1
B.2.2.2	Antenna Unit Output Return Loss and Impedance	B.2.4.2.1
B.2.2.3	Antenna Unit Radiation Patterns	B.2.4.2.2
B.2.2.4	Polarization and Axial Ratio	B.2.4.2.3
B.2.2.5	Antenna Sensitivity: The G/T Ratio	B.2.4.2.2, B.2.4.2.4
B.2.2.6.1	Transducer Gain	B.2.4.2.2
B.2.2.6.2	Antenna Sub-Assembly (ASA) Gain	B.2.4.3.1
B.2.2.3.2	Passive Element Gain	B.2.4.2.2.2
B.2.2.6.3	Linearity: Boresight Transducer Gain Compression Point	B.2.4.2.6.1
B.2.2.7	Load Stability	B.2.4.2.5
B.2.2.8.2	Maximum Boresight frequency response limits	B.2.4.2.2, B.2.4.3.1, B.2.4.3.2
B.2.2.8.1	-3 dB Relative response Frequencies	B.2.4.2.2, B.2.4.3.1
B.2.2.11.1	Boresight Differential Group Delay versus Frequency	B.2.4.2.2
B.2.2.11.2	Differential Group Delay Versus Aspect Angle	B.2.4.2.2
B.2.2.11.3	L1 GPS – L5 and L1 GLONASS – L3 Group Delay Difference	B.2.4.2.2
B.2.2.9	Burnout Limit	B.2.4.3.3
B.2.2.10.1	Recovery Time: In band maximum pulse input at L1/E1 Band	B.2.4.2.6.2
B.2.2.10.2	Recovery Time: In band maximum pulse input at L5/E5a Band	B.2.4.2.6.2
B.2.2.10.3	Recovery Time: Out of band maximum pulse input	B.2.4.2.6.2
B.2.2.14	DC Power Interface	B.2.4.3.3

B.2.4.1 Test Conditions

The following tests conditions are applicable to the tests specified in this document:

B.2.4.1.1 Power Input Voltage

Corresponds to MOPS Section 2.4.1.1

B.2.4.1.2 Power Frequency

Corresponds to MOPS Section 2.4.1.2

B.2.4.1.3 Antenna Installation

Corresponds to MOPS Section 2.4.1.3

B.2.4.1.4 Ambient Conditions

Corresponds to MOPS Section 2.4.1.4

B.2.4.1.5 Warm-Up Period

Corresponds to MOPS Section 2.4.1.5

B.2.4.1.6 Connected Loads

Corresponds to MOPS Section 2.4.1.6

B.2.4.1.7 Antenna Ground Plane

Corresponds to MOPS Section 2.4.1.7

B.2.4.1.8 Antenna Measurement Range

Corresponds to MOPS Section 2.4.1.8

B.2.4.1.9 Test Frequencies

Antenna unit measurements for relative pattern and aspect angle group delay tests should be performed at a minimum of 17 frequencies for the L1 GLONASS band, L1 GPS /E1 band, L3 band, and the L5/E5a band to include:

L1 GLONASS Test Frequency Point	Frequency Value
Lower Band-edge	1593 MHz
GLONASS Mid-Band	1602 MHz
Upper Band-edge	1611 MHz
L1 GPS /E1 Test Frequency Point	Frequency Value
Lower Band-edge	1559.42 MHz
GPS Mid-Band	1575.42 MHz
Upper Band-edge	1591.42 MHz
L3 Test Frequency Point	Frequency Value
Lower Band-edge	1186.025 MHz
GLONASS Mid-Band	1202.025 MHz
Upper Band-edge	1218.025 MHz
L5/E5a Test Frequency Point	Frequency Value
Lower Band-edge	1160.45 MHz
GPS Mid-Band	1176.45 MHz
Upper Band-edge	1192.45 MHz

For boresight relative frequency response and boresight differential group delay tests, antenna unit measurements should be performed over a wide frequency range to include at least the -50 dB breakpoints in the frequency response requirement and with frequency steps small enough to enable time delay computation and resolve gain breakpoints.

Unless otherwise indicated, all other measurements should be performed over the minimum L1 GLONASS operating frequency range from 1592.9525 to 1609.36 MHz, the minimum L1 GPS /E1 operating frequency range of 1575.42 ± 10.23 MHz, the minimum

L3 operating frequency range of 1202.025±10.23 MHz and the minimum L5/E5a operating frequency range of 1176.45 ± 10.23 MHz.

Note: Frequency accuracy should be within ± 0.002 MHz.

B.2.4.2 GNSS Antenna Unit Tests

B.2.4.2.1 Frequency of Operation and Antenna Unit Output VSWR and Impedance Test (Sections B.2.2.1, B.2.2.2)

Equipment Required:

Ground Plane - refer to Section B.2.4.1.7.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

RF Bias Tee and DC Supply.

Measurement Requirements:

Connect the equipment as shown in Figure B.2-4 with the vector network analyzer as the measurement instrument. Measure the output VSWR over the operating frequency ranges 1592.9525 – 1609.36 MHz, 1565.42 – 1585.42 MHz, 1191.795 – 1212.255 MHz and 1166.22 – 1186.68 MHz at the RF port of the active antenna unit in an anechoic chamber or reflection-less environment. Verify that the results comply with the requirements in Section B.2.2.2.

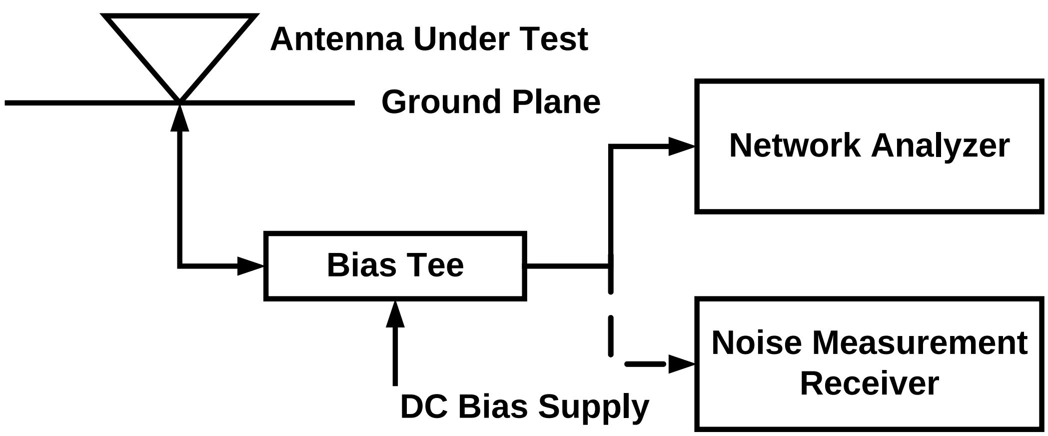

Figure B.4: Output VSWR and Total Output Noise Test Set-Up

B.2.4.2.2 Radiation Pattern Gain and Transfer Phase Test (Sections B.2.2.3, B.2.2.5, B.2.2.6.1, B.2.2.8.1, B.2.2.8.2, B.2.2.11.1, B.2.2.11.2, B.2.2.11.3)

Equipment Required:

Antenna Measurement Range - refer to Section B.2.4.1.8.

Ground Plane - refer to Section B.2.4.1.7.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

RF Bias Tee and DC Supply

Gain Standard Antenna, RHCP source antenna.

Measurement Requirements:

Connect the equipment as shown in Figure 2-6 MOPS. Measure the antenna unit total gain and transfer phase, per IEEE Standard 149-1979, for azimuth angles of at least 0, 45, 90, 135, 180, 225, 270, and 315 degrees, and elevation angles of at least 0, 5, 10, 20, 30, 45, 60, 75 and 90 degrees and at the frequencies defined in Section B.2.4.1.9.

B.2.4.2.2.1 Relative Radiation Gain Pattern (Section B.2.2.3)

At the L1 center frequencies, 1575.42 MHz and 1602 MHz, form the relative pattern gain by dividing the pattern total gain at every elevation and azimuth measurement point by the maximum gain value within 15 degrees elevation of the zenith point (elevation = 90º). Verify the relative gain falls within the limits of Table B.2-2 at all the upper hemisphere pattern points.

At the L5/E5a/L3 center frequencies, 1176.45 MHz and 1202.025 MHz, form the relative pattern gain by dividing the pattern total gain at every elevation and azimuth measurement point by the maximum gain value within 15 degrees elevation of the zenith point (elevation = 90º). Verify the relative gain falls within the limits of Table B.2-2 at all the upper hemisphere pattern points.

B.2.4.2.2.2 Passive Element Gain (Section B.2.2.3.2)

At the L1 center frequencies, 1575.42 MHz and 1602 MHz, measure the absolute gain at 5 degrees elevation and all azimuth angles. Verify that the gain equals or exceeds the limit of Section B.2.2.3.2 over all azimuth angles.

At the L5/E5a/L3 center frequencies, 1176.45 MHz and 1202.025 MHz, measure the absolute gain at 5 degrees elevation and all azimuth angles. Verify that the gain equals or exceeds the limit of Section B.2.2.3.2 over all azimuth angles.

B.2.4.2.2.3 Total Transducer Gain Factor for G/T Ratio (Section B.2.2.5)

Combine the total gain measurements at 5º elevation and frequencies 1575.42 ± 8 MHz and 1602±5MHz with the total output noise measurements as indicated in Section B.2.4.2.4.

Combine the total gain measurements at 5º elevation and frequencies 1176.45 ± 10.23 MHz and 1202.025±8 MHz with the total output noise measurements as indicated in Section B.2.4.2.4.

B.2.4.2.2.4 Minimum Boresight Total Transducer Gain (Section B.2.2.6)

L1/E1: Verify that the total transducer gain at 90º elevation meets the limit of Section B.2.2.6.

L5/E5a/L3: Verify that the total transducer gain at 90º elevation meets the limit of Section B.2.2.6.

B.2.4.2.2.5 Boresight Relative Gain Frequency Response (Sections B.2.2.8.1 and B.2.2.8.2)

Normalize the wide swept frequency boresight total gain measurements (indicated in B.2.4.1.9) by the maximum gain value within 1602±5MHz, 1575.42±8 MHz, 1202.025±10.23 MHz and 1176.45±10.23 MHz. Verify that the maximum relative response requirements and -3dB relative response of Sections B.2.2.8.1 and B.2.2.8.2 are met.

B.2.4.2.2.6 Differential Group Delay Requirements (Section B.2.2.11)

Calculate the group delay, $\tau(f)$, at frequency, f, from transfer phase measurements, $\Phi(f_i)$, at successive test frequencies, f_1 and f_2 with $f_1 \le f < f_2$ by the discrete approximation formula:

$$\tau(f) = -\frac{\left[\Phi(f_2) - \Phi(f_1)\right]}{360\left[f_2 - f_1\right]} \qquad \text{(Equation B-7)}$$

($\Phi(f_i)$ is in degrees, f_i is in Hz and time delay is in seconds.) Insert the delay values in the appropriate limit formula in Section B.2.2.11 and verify that the requirements of sub-sections B.2.2.11.1, B.2.2.11.2, and B.2.2.11.3 are met.

Note: Normally for test frequency steps more than about 2 MHz, the assigned frequency for the delay, $f = 0.5(f_2 + f_1)$. For small steps ($\le$0.5 MHz), $f = f_1$ is acceptable.

B.2.4.2.3 Polarization and Boresight Axial Ratio Test (Section B.2.2.4)

Equipment Required:

Antenna Measurement Range - refer to Section B.2.4.1.8.

Antenna Ground Plane - refer to Section B.2.4.1.7.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

RF Bias Tee and DC Power Supply.

LHCP gain standard antenna.

Measurement Requirements:

Connect the equipment as shown in Figure 2-6. Measure the unit-under-test total transducer gain relative to the LHCP gain standard per IEEE Standard 149-1979, for one set of principal plane points defined in Section B.2.4.2.2. Calculate the ratio of RHCP gain to LHCP gain (i.e.; the cross-polarization ratio) for the same set of principal plane points. The requirements of Section B.2.2.4 are satisfied if the cross-polarization ratio is greater than 15 dB at 1602 MHz, 1575.42 MHz, 1202.025 MHz and 1176.45 MHz over the range of 50 – 90 degrees elevation.

B.2.4.2.4 Total Output Noise Test (Section B.2.2.5)

Equipment Required:

Antenna Ground Plane - refer to Section B.2.4.1.7.

Noise Measurement Receiver or Spectrum Analyzer (Agilent N8973A, HP-8970B, or equivalent)

Noise Diode or noise calibration source (HP 346B or equivalent)

RF Bias Tee

DC Power Supply

Measurement Requirements:

1. Mount the ground plane in a horizontal orientation at a suitable outdoor location and attach the active antenna unit-under-test.
2. Connect the equipment as shown in Figure B.2-4 with the noise measurement receiver as the measuring instrument.
3. Calibrate the noise measurement receiver set-up with the noise diode connected to the set-up at the interface to the antenna unit RF output connector (no bias applied through the bias tee).
4. Measure the antenna unit output noise power ratio (NPRout in dB with respect to kT_0B_{MEAS}) at each RF frequency, f, for which the 5 degree elevation, total transducer gain, $G_{TTG}(\phi,85^o,f)$ was measured (Section B.2.4.2.2).
5. Calculate the G/T ratio (in dB/K) at 5 degrees elevation angle (85º from zenith) per Equation 2-11 and verify that the requirement of Section B.2.2.5 is satisfied.

$$\left(\frac{G_A\left(\phi,85^o,f\right)}{T_{SYS}\left(f\right)}\right)=G_{TTG}\left(\phi,85^o,f\right)-10\log_{10}\left(290\right)-NPR_{OUT}\left(f\right) \quad \text{(Equation B-8)}$$

where G_{TTG} and NPR_{OUT} are in dB.

Note:

1. *If the test is performed at or near room ambient temperature, sufficient margin must be allowed to account for degradation over the full temperature range.*
2. *The output noise temperature measurement at the L1 GLONASS, L1 GPS /E1, L3 and L5 center frequencies (1602 MHz, 1575.42 MHz, 1202.025 MHz, 1176.45 MHz) will likely contain a contribution from the GPS L1 C/A and L5 aggregate satellite power visible at the test location. To correct the measurement for this component, the noise power ratio value used in Equation 2-11 at 1602 MHz, 1575.42 MHz, 1202.025 MHz and 1176.45 MHz should be the average of the readings at the two adjacent frequencies, one on either side of 1602 MHz, 1575.42 MHz, 1202.025 MHz and 1176.45 MHz (2 MHz nominal frequency spacing).*

B.2.4.2.5 Active Antenna Unit Output Load Stability Test (Section B.2.2.7)

Equipment Required:

Spectrum Analyzer (Hewlett-Packard 8568B, or equivalent).

Antenna Test Set.

Antenna Test Set (to provide power as required by the manufacturer to the preamplifier).

50 Ohm RF Terminator.

Bridge-T.

Measurement Requirements:

The stability of the amplifier should be tested in 4 steps:

1. Mount the unit-under-test in a shielded anechoic chamber and connect the antenna unit output through an RF bias tee, cable, and coupler to the spectrum analyzer. Set the spectrum analyzer to measure signals at least as low as -110 dBm, and with as wide a frequency range as practical.
2. Apply power to the antenna unit and verify that the antenna unit does not generate any detectable signals.
3. Connect an adjustable-length, short-circuited transmission line to the straight-through path of the couplet to which the spectrum analyzer is attached and adjust the line length through at least 1 wavelength (1602 MHz, 1575.42 MHz, 1202.025 MHz and 1176.45 MHz).
4. Verify that the active antenna unit does not generate any signals at its output under different positions of the variable length shorted line.

B.2.4.2.6 High Radiated Power Performance Tests

The following tests are intended to be used in conjunction with standard DO-160G Section 20 radiated susceptibility environmental test. Specific test frequencies, levels, and modulation are given for the 1-2 GHz frequency range. Outside that range, DO-160G levels apply.

Equipment Required:

Bias Tee and DC Power Supply

Two Synthesized RF Signal Generators (Hewlett-Packard 8662A or equivalent)

Spectrum Analyzer (Hewlett-Packard 8568B, or equivalent)

Modulator (Hewlett-Packard 11665B, or equivalent)

Pulse Generator (Fluke 5712, or equivalent)

Linear RF Power Amplifier (500 W peak, minimum)

30 dB Directional Coupler

Variable Attenuator (0-40 dB) (optional)

Two. 6 dB Power Splitters (for recovery time test)

Adjustable Phase Delay Line (for recovery time test)

Phase Detector (for recovery time test)

Oscilloscope

B.2.4.2.6.1 Boresight Gain Compression Point and Test (Section B.2.2.6.3)

Measurement Requirements:

1. Mount the antenna unit-under-test on the ground plane and connect the equipment as shown in Figure B.2-5.
2. Set the RF Signal Generator #1 for frequency to 1575.42 MHz and set the CW signal level such that the antenna unit-under-test is in its linear operating range (~-40 dBm from a 0 dBic antenna)
3. Tune the spectrum analyzer to the 1575.42 MHz low level probe signal and set the analyzer to the “zero-span” mode.

4. Set the RF Signal Generator #2 frequency to the test #1 setting from Table B.2-6, set the level to produce the associated test field strength for that frequency, set the pulse modulator to produce the desired waveform, and synchronize the spectrum analyzer sweep to the pulse PRF.
5. Verify that any compression of the probe signal level is within the 1 dB limit of Section B.2.2.6.3 during the test frequency pulse duration.
6. Repeat Steps 4-5 for all the test settings in Table B.2-6
7. Repeat Steps 2-6, except this time set RF Signal Generator #1 for a frequency of 1176.45 MHz for Step 2, and tune the spectrum analyzer to 1176.45 MHz for Step 3.
8. Repeat Steps 2-6, except this time set RF Signal Generator #1 for a frequency of 1602 MHz for Step 2, and tune the spectrum analyzer to 1602 MHz for Step 3.
9. Repeat Steps 2-6, except this time set RF Signal Generator #1 for a frequency of 1202.025 MHz for Step 2, and tune the spectrum analyzer to 1202.025 MHz for Step 3.

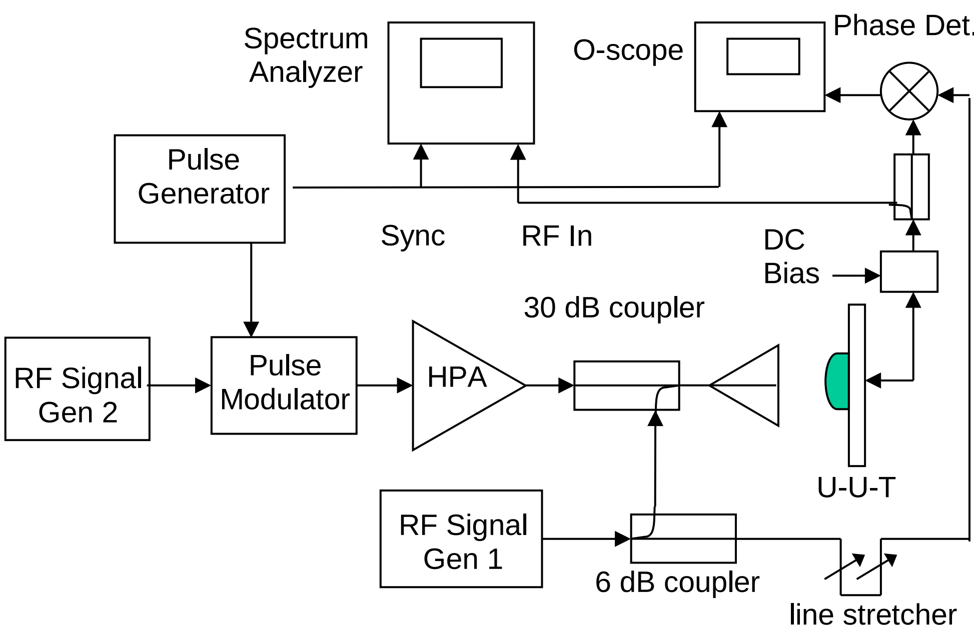

Figure B-5: Boresight 1 dB Gain Compression and Recovery Time Test Set-up

B.2.4.2.6.2 Pulse Saturation Recovery Time Test (Sections B.2.2.10.1, B.2.2.10.2, B.2.2.10.3)

Measurement Requirements:

1. Connect the equipment as shown in Figure B.2-5.
2. Temporarily disable the pulse power signal from RF Signal Generator #2. Set the RF Signal Generator #1 frequency of 1575.42 MHz and adjust its signal level to produce an input power of about 10 dB below the 1 dB input compression point of the active antenna unit-under-test. Verify that the RF Signal Generator #1 power input to the phase detector is in the range for proper operation.

3. Apply DC bias to the active antenna unit-under-test and adjust the phase delay line (line stretcher) such that the oscilloscope shows a 90-degree phase difference between the active antenna unit output and the delayed generator #1 signal (0 Volts on scope display). Note also the phase detector peak output voltage (0 or 180-degree path phase difference).
4. Set the Pulse Generator and RF Signal Generator #2 to produce the pulsed signal required for test #8 in Table B.2-6. The level should be set to produce 115 V/m at the unit-under-test.
5. Verify that the preamplifier meets all criteria set forth in Section B.2.2.10.1. The recovery time should be measured as the time needed by the preamplifier to return to a peak phase difference between its output signal and the delayed RF Signal Generator #1 signal of less than 30 degrees (half the peak amplitude), as shown by the oscilloscope.
6. Repeat Steps 4 and 5 for tests #7 and #10 using the appropriate settings shown in Table 2-6 for each test, except verify that the preamplifier meets all criteria set forth in Section B.2.2.10.3
7. Repeat Step 2 using 1602 MHz.
8. Repeat Step 3.
9. Repeat Step 4, except using test #8 in Table B.2-6 at 115 V/m.
10. Repeat Step 5.
11. Repeat Step 4, except using tests #7 and #10 from Table B.2-6 at 115 V/m.
12. Repeat Step 5, except using the criteria set forth in Section B.2.2.10.3.
13. Repeat Step 2 using 1176.45 MHz.
14. Repeat Step 3.
15. Repeat Step 4, except using test #3 in Table B.2-6 at 87 V/m.
16. Repeat Step 5, except using the criteria set forth in Section B.2.2.10.2.
17. Repeat Step 4, except using tests #2 and #5 from Table B.2-6 at 87 V/m.
18. Repeat Step 5, except using the criteria set forth in Section B.2.2.10.3.
19. Repeat Step 2 using 1202.025 MHz.
20. Repeat Step 3.
21. Repeat Step 4, except using test #3 in Table B.2-6 at 87 V/m.
22. Repeat Step 5, except using the criteria set forth in Section B.2.2.10.2.
23. Repeat Step 4, except using tests #2 and #5 from Table B.2-6 at 87 V/m.
24. Repeat Step 5, except using the criteria set forth in Section B.2.2.10.3.

Table B-6: Gain Compression and Recovery Time* Test Settings

Test	RF Frequency (MHz)	Pulse Width	PRF (pps)	RF Peak Field (V/m)
1	1000.00	1 ms	22	102.5
2	1149.45	1 ms	22	21**
3	1162.45	1 ms	22	1.5**
4	1213	1 ms	22	1.5
5	1278	1 ms	22	102.5**
6	1315.00	1 ms	22	135
7	1531.42	1 ms	100	11.1*
8	1558.42	1 ms	100	2.2*
9	1610	1 ms	100	2
10	1619.42	1 ms	100	12.7*
11	1625.42	1 ms	56	30
12	2000.00	1 ms	56	145

** The Pulse Power Saturation Recovery Time test uses the settings from lines 7, 8, and 10 except that the field strength value in each case is 115 V/m.*

*** The Pulse Power Saturation Recovery Time test uses the settings from lines 2, 3, and 5 except that the field strength value in each case is 87 V/m.*

B.2.4.3 Active Antenna Sub-Assembly Tests

The tests in the following subsections address requirements which are impractical to perform on the entire active antenna unit. Examples of the requirements include mainly the environmental requirements of Section B.2.3.1. Proper care should be taken so that the performance of the active subassembly and, if necessary, the passive radiating element used in these tests remain unchanged from the complete integrated assembly.

B.2.4.3.1 Active Sub-assembly RF Gain Response and Noise Temperature Test

This test is intended for use in the applicable environmental tests of Section B.2.3.1 for measuring unit performance while the environmental test conditions are applied.

Equipment Required:

RF Bias Tee and DC Supply.

Automatic Vector Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).

Automatic Noise Figure Meter (Hewlett-Packard 8970A or equivalent)

Measurement Requirements:

Any loss in the RF cables connecting the antenna and the test equipment should be properly taken into account.

B.2.4.3.1.1 RF Gain and Frequency Response Test

1. Connect the RF output of the vector network analyzer to the active sub-assembly input, as shown in Figure B.2-6. Connect the active sub-assembly output through the bias tee and output cabling to the vector network analyzer input.
2. Set the vector network analyzer to sweep from 1559.42 MHz to 1591.42 MHz for the L1 GPS /E1 test, 1592 MHz to 1611 MHz for the L1 GLONASS test, 1168.45

MHz to 1184.45 MHz for the L5/E5a test and 1186.025 MHz to 1218.025 MHz for the L3 test, and set the output level to -40 dBm.

3. Verify that the active sub-assembly transducer gain meets the requirement of Section B.2.2.6.1, and the -3 dB gain normalized response requirement of Section B.2.2.8.1 over the specified frequency ranges.
4. Verify that the active sub-assembly differential group delay meets the requirement of Section B.2.2.11.
5. Set the vector network analyzer to sweep from 1000 MHz to 2000 MHz at -40 dBm and verify that the normalized frequency response meets the requirements of Section B.2.2.8.2

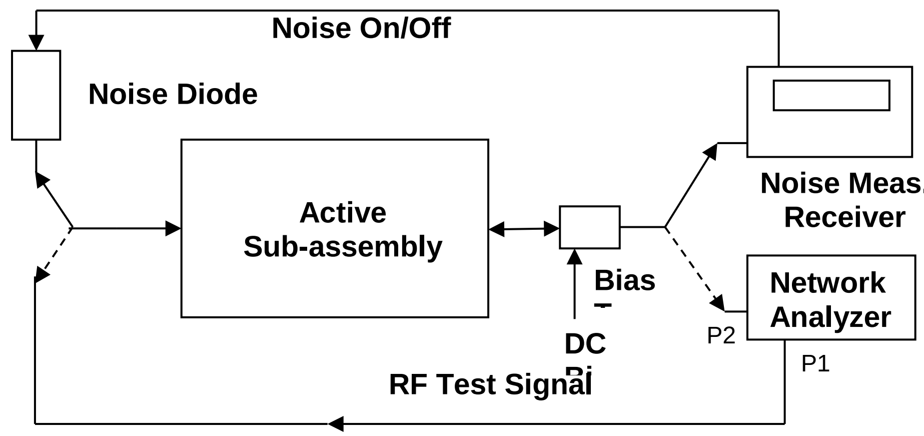

Figure B-6: Active Sub-Assembly Gain and Noise Temperature Test Set-up

B.2.4.3.1.2 Noise Temperature Test

1. Connect the noise diode voltage input to the noise measurement receiver drive voltage port and the noise diode output port to the test set-up at the point where the RF bias tee and output cabling would connect to the active sub-assembly output (Figure B.2-6). Calibrate the noise measurement receiver over the frequency range 1575.42 ± 16 MHz for the L1 GPS /E1 test or 1602 ± 10 MHz for the L1 GLONASS test or 1176.45 ± 16 MHz for the L5/E5a test or 1202.025 ± 16 MHz for the L3 test.
2. Connect the noise diode to the active sub-assembly input and active sub-assembly output to the noise measurement receiver RF input through the RF bias tee and output cabling.
3. Verify that the noise figure is no more than 3.14 dB over the frequency band of 1567.42 MHz to 1583.42 MHz for the L1 GPS /E1 test and 1597 MHz to 1607 MHz for the L1 GLONASS and that the noise figure is no more than 4.5 dB over the frequency band of 1168.45 MHz to 1184.45 MHz for the L5/E5a test and 1194.025 MHz to 1210.025 MHz for the L3.

B.2.4.3.2 Active Unit Radiated Hot-Cold Noise and Boresight Signal Performance Test

Equipment Required:

1. Small, shielded, anechoic material-lined test chamber

2. Circularly-polarized source antenna
3. Noise Generator
4. Antenna ground plane and mounting plate (sufficient to cover one end of the chamber)
5. Reference Passive Antenna (identical in design and packaged in the identical manner as the passive radiating element in the active antenna unit)
6. Noise Measurement Receiver or Spectrum Analyzer (Agilent N8973A, HP-8970B, or equivalent)
7. Vector Network Analyzer
8. RF Bias Tee
9. DC-Power Supply

B.2.4.3.2.1 Radiated Hot-Cold Test for Active Sub-Assembly Gain and Noise Temperature

Measurement Requirements:

1. Mount the ground plane with the reference passive antenna attached to the small anechoic test chamber.
2. Connect the equipment for noise measurements as shown in Figure B.2-7.
3. Calibrate the noise measurement receiver set-up at each RF frequency, f, at which the performance is to be verified with the noise diode connected to the set-up at the interface to the antenna unit RF output connector (no bias applied through the bias tee).
4. Measure the reference passive antenna unit output noise power ratio (dB with respect to kT_0B_{MEAS}) at each RF frequency, f, at which the performance is to be verified for both the "hot" and "cold" settings of the radiating noise source. (measurements designated $PR_{HOT}(f)$ and $PR_{COLD}(f)$)
5. Replace the reference passive antenna with the active antenna unit-under-test and measure active antenna unit output noise power ratio (dB with respect to kT_0B_{MEAS}) at each RF frequency, f, at which the performance is to be verified for both the "hot" and "cold" settings of the radiating noise source (measurements designated $PA_{HOT}(f)$ and $PA_{COLD}(f)$)
6. Calculate the antenna unit active sub-assembly input noise temperature, $\tilde{\tilde{T}}_R\ (f)$and gain, $\tilde{\tilde{G}}_{R,dB}\ (f)$, by:

$$\tilde{\tilde{T}}_R\ (f) = \left(\frac{T_{HOT}(f)*\Delta G_A(f) - Y_{UUT}(f)*T_{COLD}(f)}{Y_{UUT}(f)-1}\right) \qquad \text{(Equation B-9)}$$

and:

$$\tilde{\tilde{G}}_{R,dB}\ (f) = 10 * log\left(\frac{(Y_{UUT}(f)-1)*T'_{COLD}(f)}{T_{HOT}(f)*\Delta G_A(f) - T_{COLD}(f)}\right) \qquad \text{(Equation B-10)}$$

Where,

$$Y_{UUT}(f) = 10^{0.1*(PA_{HOT}(f) - PA_{COLD}(f))}, \qquad \text{(Equation B-11)}$$

$$T_{HOT}(f) = 290 * 10^{0.1*(PR_{HOT}(f))}, \quad \text{(Equation B-12)}$$

$$T_{COLD}(f) = 290 * 10^{0.1*(PR_{COLD}(f))}, \quad \text{(Equation B-13)}$$

$$T'_{COLD}(f) = 290 * 10^{0.1*(PA_{COLD}(f))}. \quad \text{(Equation B-14)}$$

Set ΔG_A =1 and verify that $\widetilde{T}_R$ (f) is less than 307 K and $\widetilde{G}_{R,dB}\ (f)$ is greater than 26.5 dB for the range 1575.42 ± 8 MHz and 1602 ± 5 MHz. Set ΔG_A =1 and verify that $\widetilde{T}_R$ (f) is less than 531 K and $\widetilde{G}_{R,dB}\ (f)$ is greater than 26.5 dB for the range 1176.45 ± 10.23 MHz and 1202.025 ± 8 MHz. The measured values should be within the limits by at least the associated measurement procedure uncertainty as described in Appendix A.2. If the measurement is made at or near room ambient temperature, an additional temperature variation margin should be used.

Note:

1. *The parameter $\Delta G_A(f)$ is the ratio of the passive radiator element gain of the unit under test to the reference passive element gain. As such, it represents a first-order uncertainty in the measurement procedure. Setting the baseline ratio at unity for the test result enables the use of the measurement uncertainty computation described in Appendix A.2.*
2. *The noise generator used in the test should have sufficient output noise density to produce a ratio $PR_{HOT}/PR_{COLD} \cong 10$ dB with the reference passive antenna.*

B.2.4.3.2.2 Boresight Radiated Active Sub-Assembly Gain Response Test

Measurement Requirements:

1. Connect the equipment for vector network analyzer measurements as shown in Figure B.2-7.

2. Calibrate the analyzer with appropriate reflection and transmission standards.

3. Mount the reference passive antenna and measure the boresight transmission gain and phase of the path though the chamber and the passive reference antenna over the frequency range 1575.42 ± 16 MHz for the L1 GPS /E1 test or 1602 ± 10 MHz for the L1 GLONASS test or 1176.45 ± 16 MHz for the L5/E5a test or 1202.025 ± 16 MHz for the L3 test. (This measurement serves as the chamber calibration to be de-embedded from the active antenna unit-under-test measurement)

4 Mount the active antenna unit-under-test and measure the boresight transmission gain and phase of the path though the chamber and the unit-under-test over the frequency range 1575.42 ± 16 MHz for the L1 GPS /E1 test or 1602 ± 10 MHz for the L1 GLONASS test or 1176.45 ± 16 MHz for the L5/E5a test or 1202.025 ± 16 MHz for the L3 test. Correct the measurement with the chamber/passive reference calibration from Step 3.

5. Verify that the active sub-assembly transducer gain meets the requirement of Section B.2.2.6.2 and the -3 dB gain normalized response requirement of Section B.2.2.8.1 over the specified frequency ranges.

6. Verify that the (active sub-assembly) boresight differential group delay meets the requirement of Section B.2.2.11.

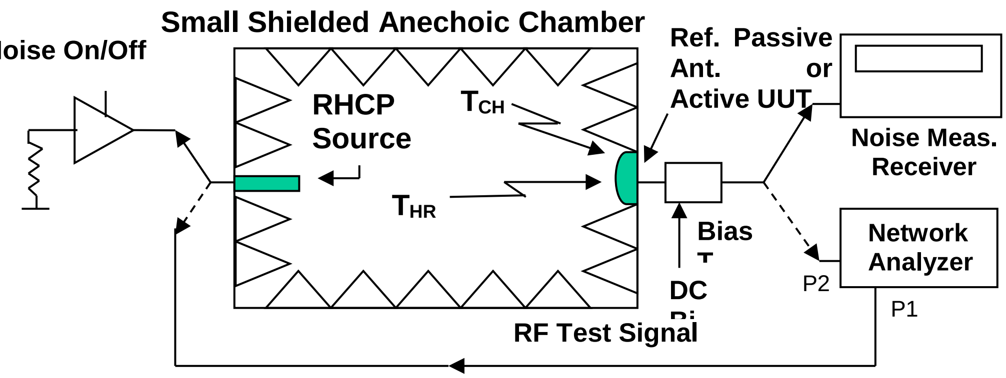

Figure B-7: Radiated Hot-Cold Noise and Boresight Signal Test Setup

B.2.4.3.3 Active Sub-Assembly Burnout Protection Test (Section B.2.2.9)

Equipment Required:

RF Bias Tee and DC Power Supply

Synthesized Signal Generator (Hewlett-Packard 8662A or equivalent).

Spectrum Analyzer (Hewlett-Packard 8568B, or equivalent).

RF Amplifier (Hewlett-Packard 8347A, or equivalent).

Measurement Requirements:

1. Connect the equipment as shown in Figure B.2-8.

2. Set RF Signal Generator #1 to a frequency of 1575.42 MHz and adjust the level to obtain a low-level input signal of -35 dBm at the active subassembly input, apply DC power to the active sub-assembly and determine the transducer linear power gain using the spectrum analyzer.

3. Set RF Signal Generator #2 to a frequency of 1565.42 MHz with a peak pulse power of +30 dBm for a 1 ms pulse at 100 Hz PRF (10% duty factor, +20 dBm ave. power)

4. Subject the active sub-assembly input to the +30 dBm peak test signal at 1565.42 MHz for 5 minutes while monitoring the gain of the low level 1575.42 MHz probe signal. Then change the RF Signal Generator #2 frequency to 1585.42 MHz and dwell for 5 minutes while monitoring the probe signal gain. Verify for each test signal frequency that the peak pulse output from the active antenna unit remains below +20 dBm.

5. Repeat the tests described in Section B.2.4.3.1 to verify that the active sub-assembly still meets the gain, delay and noise temperature requirements therein.

6. Re-connect the equipment as stated in step 1.

7. With no RF Signal Generator #1 probe signal and DC power removed from the active sub-assembly, subject the input to a RF Signal Generator #2 test signal of +30 dBm at 1575.42 MHz for 5 minutes.

8. Repeat the tests described in Section B.2.4.3.1 to verify that the preamplifier still meets the gain, delay, and noise temperature requirements therein.

9. Repeat Step 2, except use a frequency of 1602 MHz.

10. Repeat Step 3, except use a frequency of 1597 MHz.

11. Repeat Step 4, except monitor the gain of the 1602 MHz signal, while the RF Signal Generator #2 frequency is set to first 1597 MHz and then 1607 MHz.

12. Repeat Steps 5 and 6.

13. Repeat Step 7, except use a frequency of 1602 MHz.

14. Repeat Step 8, except use a frequency of 1602 MHz.

15. Repeat the tests described in Section B.2.4.3.1 to verify that the preamplifier still meets the gain, delay, and noise temperature requirements therein.

16. Repeat Step 2, except use a frequency of 1176.45 MHz.

17. Repeat Step 3, except use a frequency of 1166.45 MHz.

18. Repeat Step 4, except monitor the gain of the 1176.45 MHz signal, while the RF Signal Generator #2 frequency is set to first 1166.45 MHz and then 1186.45 MHz.

19. Repeat Steps 5 and 6.

20. Repeat Step 7, except use a frequency of 1176.45 MHz.

21. Repeat Step 8, except use a frequency of 1176.45 MHz.

22. Repeat the tests described in Section B.2.4.3.1 to verify that the preamplifier still meets the gain, delay, and noise temperature requirements therein.

23. Repeat Step 2, except use a frequency of 1202.025 MHz.

24. Repeat Step 3, except use a frequency of 1192.025 MHz.

25. Repeat Step 4, except monitor the gain of the 1202.025 MHz signal, while the RF Signal Generator #2 frequency is set to first 1192.025 MHz and then 1202.025 MHz.

26. Repeat Steps 5 and 6.

27. Repeat Step 7, except use a frequency of 1202.025 MHz.

28. Repeat Step 8, except use a frequency of 1202.025 MHz.

29. Insert a DC ammeter in series with the Bias T's DC port and verify that the DC current draw is within specification over its full operating voltage range.

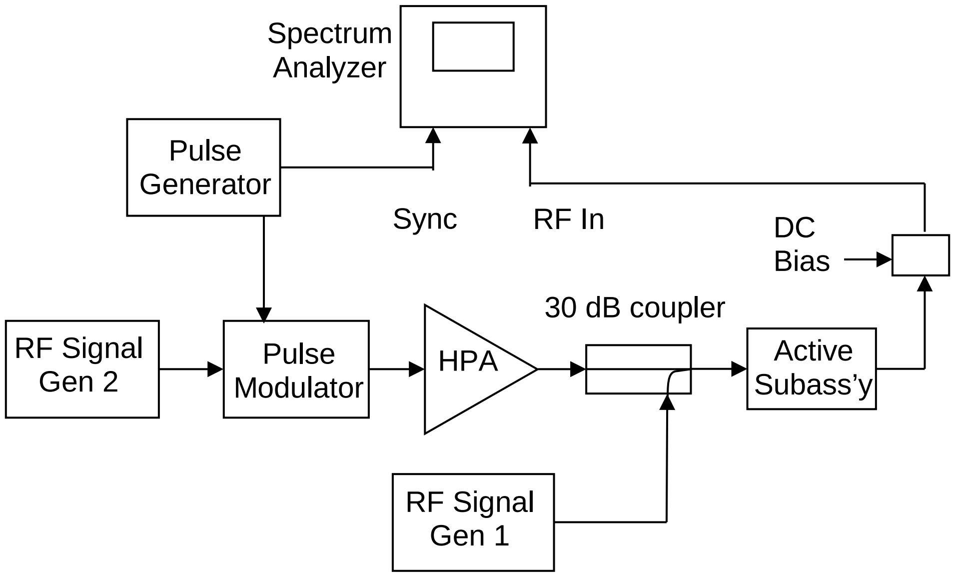

Figure B-8: Active Sub-Assembly Burnout Protection Test Set-up

B.3 Installed Antenna Performance

Corresponds to MOPS Section 3.

B.4 Equipment Operational Performance Characteristics

Corresponds to MOPS Section 4.

APPENDIX C: POTENTIAL INTERFERENCE FROM DME SIGNALS

C.1 C.1 DME ground station

According to the FAA, Service and Equipment Profile (FSEP) data of inventory of NAS Operational Infrastructure, there are 908 DME facilities in the CONUS, 51 in Alaska and 9 in Hawaii. In addition, there are a total of 668 Tactical Air Navigation (TACAN) systems of which 31 in Alaska, and 10 in Hawaii. TACAN operates in the frequency band of 960-1215 MHz. While the FSEP database is not accessible for public use, anyone can obtain information on specific navigation aid facility through AirNav.com. The FAA anticipates installing about 180 additional DME's to improve DME/DME RNAV coverage.

C.2 C.2 On board DME interrogator

The closest on-board DME channel to the E5/L5 band is 126X/Y, which has a center frequency of 1150 MHz. This channel has a distance of 16 MHz to the band edge of the E5/L5 band at 1166 MHz, and a distance of 26.45 MHz to the carrier frequency of E5A/L5 of 1176.45 MHz. Except during acquisition, the maximum rate at which an airborne DME interrogator can generate pulse pairs is assumed to be 48 pulse pairs per second. During acquisition, DME interrogators employ higher transmission rates, as high as 150 pulse pairs per second, for brief intervals.

The performance specifications for interrogators EUROCAE ED-54 and RTCA DO-189 limit their peak power to 2 kW (63 dBm). The peak power in any 0.5 MHz bandwidth channel more than 2 MHz from the channel on which the airborne interrogator is transmitting is required to be at least 38 dB below that (63 dBm – 38 dB = 25 dBm). This results in a peak level of -15 dBm for an assumed isolation between antenna ports of E5/L5 and DME antennas of 40 dB.

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APPENDIX D: ABBREVIATIONS

AAU	Active Antenna Unit
ABAS	Aircraft Based Augmentation System
AD	Applicable Document
AFE	Antenna Front-End
AR	Axial Ratio
ASA	Active Sub-Assembly
AUT	Antenna under Test
BDGD	Boresight Differential Group Delay
BT	Bias Tee
CW	Continuous wave
dB	decibel
DC	Direct Current
DFMC	Dual-Frequency Multi-Constellation
DGA	Differential Group Delay versus Angle
DME	Distance Measuring Equipment
EC	European Commission
EMC	Electromagnetic Compatibility
ESA	European Space Agency
ESD	Electrostatic Discharge
EUROCAE	European Organization for Civil Aviation Equipment
GBAS	Ground Based Augmentation System
GLONASS	GLobal Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
K	Kelvin
LNA	Low Noise Amplifier
MOPS	Minimum Operational Performance Standard
PS	Power Supply
RD	Reference Document
RF	Radio Frequency
RFR	Relative Frequency Response
RHCP	Right Hand Circular Polarization
RTCA	Radio Technical Commission for Aeronautics

SBAS	Space Based Augmentation System
SC	Sub Committee
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Ratio
WG	Working Group

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