HGA-7001 Antenna
Product Specification

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DOCUMENT CHANGE HISTORY

ISSUE	DATE	ECP	DESCRIPTION OF CHANGE
1.0	12 Oct 07	07/356	Initial document
1.1	06 Nov 07	07/356	General update to reflect current build spec and qualification status.
1.2	12 Jun 08	08/056	Ch 3: Added antenna delivery package Ch. 4: RTCA/DO-160D changed to RTCA/DO-160E; Ch. 6: Added: Inmarsat approval, anti-static protection, Ch.7: 160D changed to 160E, update vibration categories, update RF Susceptibility categories, added DO-160E categorization string, added environmental considerations
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DOCUMENT APPROVAL AND VALIDATION

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1. SCOPE

This document outlines the technical details of the HGA-7001 High Gain Antenna. The aim of this document is to describe the product, its architecture, functional design and other specifications.

2. ABBREVIATIONS

ARINC	Aeronautical Radio Inc
BITE	Built-in Test Equipment
BGAN	Broadband Global Area Network (Inmarsat), also see SBB below
BSU	Beam Steering Unit
DLNA	Diplexer and Low Noise Amplifier
HGA	High Gain Antenna
HPA	High Power Amplifier
HSD	High Speed Data
IGA	Intermediate Gain Antenna
IP	Internet Protocol
IRS	Inertial Reference System
ISDN	Integrated Services Digital Network
LNA	Low Noise Amplifier
LRU	Line-Replaceable Unit
MCU	Modular Component Unit
MPDS	Mobile Packet Data Service
QMS	Quality Management System
RF	Radio frequency
Rx	Receive signal
S64	Swift64
SBB	SwiftBroadband = Aeronautical BGAN
SDM	System Definition Manual (Inmarsat Specification)
SDU	Satellite Data Unit (includes the HPA in the ARINC 781 definition)
Tx	Transmit signal

3. PRODUCT DESCRIPTION

3.1 General Description

The HGA-7001 is a High Gain Antenna (HGA) with integral beam steering unit (BSU) functionality, providing access to the Inmarsat Aero H, H+, Swift 64 and SwiftBroadband services.

The antenna complies with both the ARINC741 and the ARINC 781 Requirements for Aeronautical Satellite Communications equipment and with the Inmarsat System Definition Manual (SDM).

The antenna was adapted from the HGA-7000 that was launched in 2004. To date, more than 270 HGA-7000's have been installed on a variety of platforms, ranging from air transport aircraft (A319, B737 and B757) to bizjets (Embraer, Dassault and Gulfstream) and military platforms (Bombardier Dash-8, C-130 and C-160).

3.2 Equipment Features

The main features of the **HGA-7001 High Gain Antenna** are:

1. Inmarsat approved for SwiftBB, Swift64 and Classic with no restrictions
2. Low drag through ultra low profile (antenna height is less than 2 inches)
3. Superior Carrier/Multipath ratio improves low elevation performance.
4. ARINC 781 compliant
5. Weight of less than 10 kg
6. TSO C-132 approved

3.3 Description of the HGA-7001 Antenna

Figure 1: HGA-7001 High Gain Antenna

The HGA-7001 High Gain Antenna, shown in Figure 1, is a derivative of the proven HGA-7000 Antenna, specifically designed to reduce drag and meet the ARINC 781 specifications. Figure 1 shows the removable tail cover in place. Access to the RF and control connectors is by removal of the tail cap.

The primary differences between the HGA-7000 and the HGA-7001 are listed below:

- ARINC 429 compliant BSU functionality included
- ARINC 781 electrical interfaces
- DC or AC power (115VAC, 400Hz and variable frequency)
- Addition of input and output protection circuitry
- Drag reducing streamlining and external access to the connectors

3.4 Equipment Functional Description

The HGA-7001 High Gain Antenna consists of a multi-element phase steered array that is mounted on a base plate inside a radio transparent composite radome. The RF signal is distributed to the individual antenna elements via a low loss feeder network and a phase shifter. A control processor interprets the beam steering commands into phase delays that are applied to individual elements. This process allows the beam to be steerable over the full Inmarsat hemisphere whilst meeting the gain, discrimination and phase discontinuity requirements of the SDM.

3.5 System Architecture and Block Diagram

A typical system block diagram is given below:

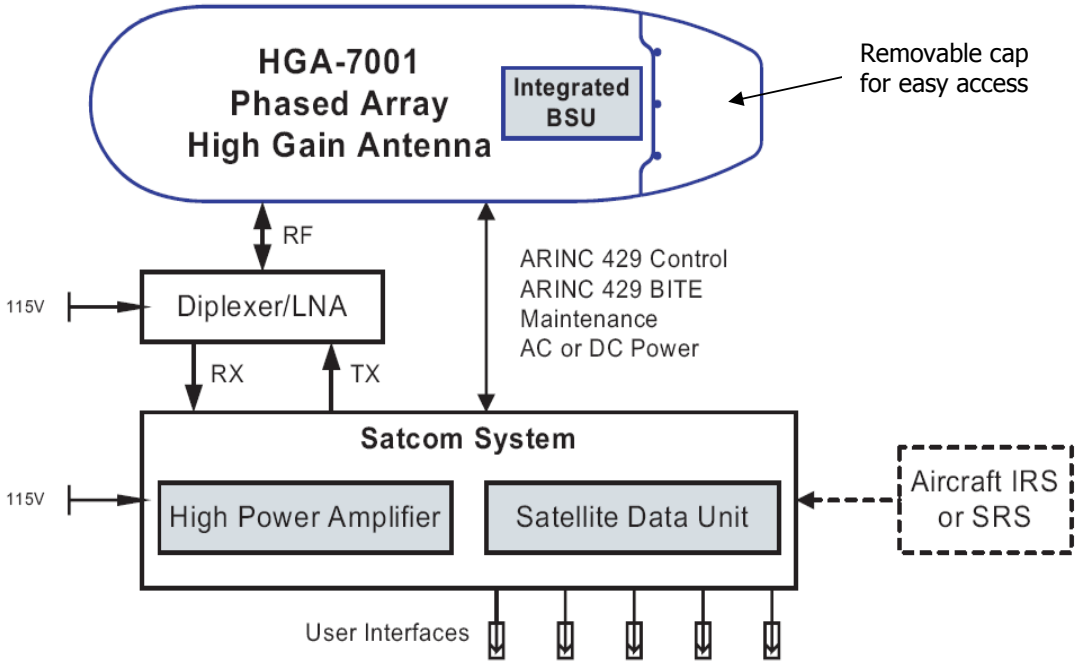

Figure 2: ARINC 781 Satcom System block diagram with HGA-7001 Antenna.

3.6 Antenna Delivery Package

The antenna is supplied with a Mounting Hole Sealing Kit consisting of 8 × Sealing Caps, 8 × Foam Plugs and 8 × "O"-rings. No mounting bolts are supplied.

The Antenna can be supplied with a mounting kit consisting typically of an adapter plate, 8 x Nut Plate Ø5, 8 x Nut Plate Ø4 and Installation Template. No mounting bolts are supplied.

4. PRODUCT SPECIFICATION: MAIN PARAMETERS

Specification	HGA-7001 Antenna
Length	1050 mm [41.34″]
Width	299 mm [11.77″]
Height	48.4 mm [1.91″]
Weight kg [lb]	typical 9.3 kg [20.5 lbs]
Operating Temperature range	-65°C to 70°C [-85°F to 158°F]
Altitude	Up to 21000 m [70000 ft]
Frequency	1525 MHz to 1660.5 MHz (L-band)
Power supply	115 VAC or 28 VDC; Nominal <35 W
Coverage	Seamless coverage compliant to Inmarsat SDM
Polarization	Right hand circular
Gain	12 dBi to 16 dBi over 90% of the Inmarsat Hemisphere
Qualification (Software)	RTCA/DO-178B, Level D
Qualification (Environmental)	RTCA/DO-160E
Certification	TSO-132 awarded

Table 1: The main component parameters of the HGA-7001 antenna

5. INTERFACES

The HGA-7001 electrical interfaces (RF and control) are ARINC 781 compliant and are found in the connector compartment at the rear of the antenna.

5.1 Power supply

The antenna will operate with 115V single phase variable frequency supply (360 to 800 Hz) or 28 Vdc. Although no damage will be caused if 115Vac and 28 Vdc power supplies are connected simultaneously, it is not recommended

5.2 Antenna Connectors

The power/data connector is a MIL-C-38999 Series III or equivalent. The RF connector is a TNC Jack (female) from Suhner, and the external material is branded "Sucoplate". This connector tested PIM free when used with a mating connector of the same material. The use of connectors containing Nickel is discouraged.

5.3 Antenna Adapter / Mounting Plate

An adapter or mounting plate is required to adapt the flat antenna base to a curved airframe. Omnipless offers two options:

1. An **adapter plate** with clearance holes that match the mounting holes of the antenna. This adapter plate does not carry any structural load (considered to be a shim), as the antenna is mounted to the fuselage through the adapter plate.

2. A **mounting plate** that is fixed to the aircraft and that is structurally designed to carry the antenna load, with captive inserts that match the mounting holes of the antenna, to allow the fixing of the antenna to the mounting plate.

See Figure 3 below for a drawing of a typical installation using an adapter plate.

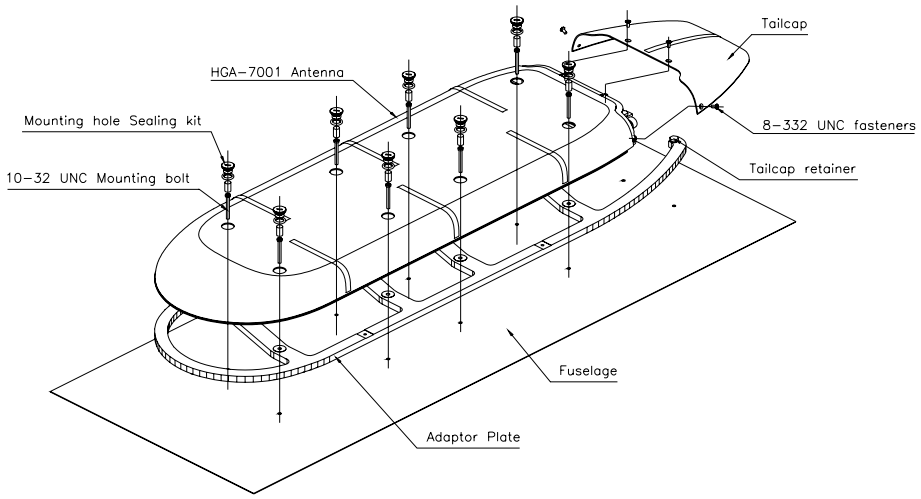

Figure 3: An illustration of how the HGA-7001 is mounted on an adapter plate.

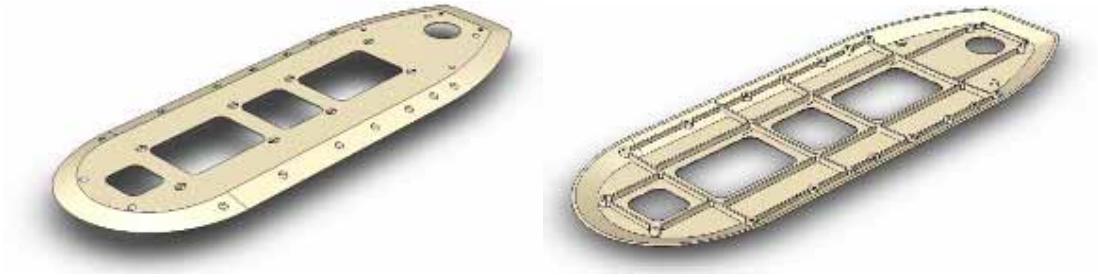

Figure 4: Top and bottom views of a rigid mounting plate for the HGA-7001.

Mounting plates are designed to add minimum weight and height to the installation. The edges of the mounting plate are also designed to have minimum impact on the RF performance, specifically at low elevation angles. The examples above are for illustrative purposes only as mounting plates are unique to aircraft type and mounting position.

6. PERFORMANCE OF THE HGA-7001 ANTENNA

6.1 Measurement Reference Ground Plane

A standard ARINC 781 compliant ground plane (L=2.4m; W=1.6m; R=3.05m) is used for comparative antenna measurements. A photograph of an HGA-7001 mounted on the ground plane is shown below.

Figure 5: An HGA-7001 on the ARINC 781 ground plane

6.2 Coverage

The antenna aims to achieve a desired performance over an ideal coverage volume (relative to the aircraft's horizontal line of flight) defined by an elevation range of 5° to 90° and an azimuth range of 360°. The HGA-7001 antenna has usable gain below 5° elevation and the actual coverage performance will largely depend on the final installation parameters and the flight path or route travelled.

6.3 Gain

HGA-7001 RHCP Gain (dBiC) at 1542MHz										
		Azimuth (degrees)								
		90	75	60	45	30	15	10	5	0
Elevation (degrees)	0	15.8	15.7	15.6	15.1	13.1	13.7	13.0	11.4	9.0
	45	15.8	15.6	15.6	15.2	14.3	14.4	13.1	10.7	7.9
	90	15.8	15.6	15.3	15.3	14.7	13.2	12.4	10.5	8.2
	135	15.8	15.7	15.3	14.8	14.0	13.4	12.6	11.2	8.8
	180	15.8	15.7	15.7	15.0	13.4	13.6	12.8	11.0	9.0
	225	15.8	15.8	15.6	15.1	14.2	14.0	12.9	10.3	7.6
	270	15.8	16.0	15.6	15.3	14.2	12.9	11.7	10.0	7.7
	315	15.8	15.7	15.7	15.2	14.1	13.2	12.5	11.0	8.7

HGA-7001 RHCP Gain (dBiC) at 1644MHz										
		Azimuth (degrees)								
		90	75	60	45	30	15	10	5	0
Elevation (degrees)	0	15.5	15.4	15.1	14.8	13.5	12.6	11.8	9.7	7.1
	45	15.5	15.2	15.0	15.1	14.4	14.6	13.6	11.6	8.9
	90	15.5	15.3	15.0	15.4	14.7	13.8	12.5	10.1	7.4
	135	15.5	15.6	15.6	15.2	14.1	12.5	10.5	8.3	5.1
	180	15.5	15.5	15.2	15.2	13.4	12.9	11.9	9.9	7.4
	225	15.5	15.4	15.3	14.9	14.3	14.7	13.3	11.6	8.9
	270	15.5	15.5	15.3	15.3	14.6	13.7	12.2	10.0	7.2
	315	15.5	15.6	15.5	15.3	13.9	12.3	10.1	7.9	4.8

Table 2: Typical gain values at center of Receive (above) and Transmit bands

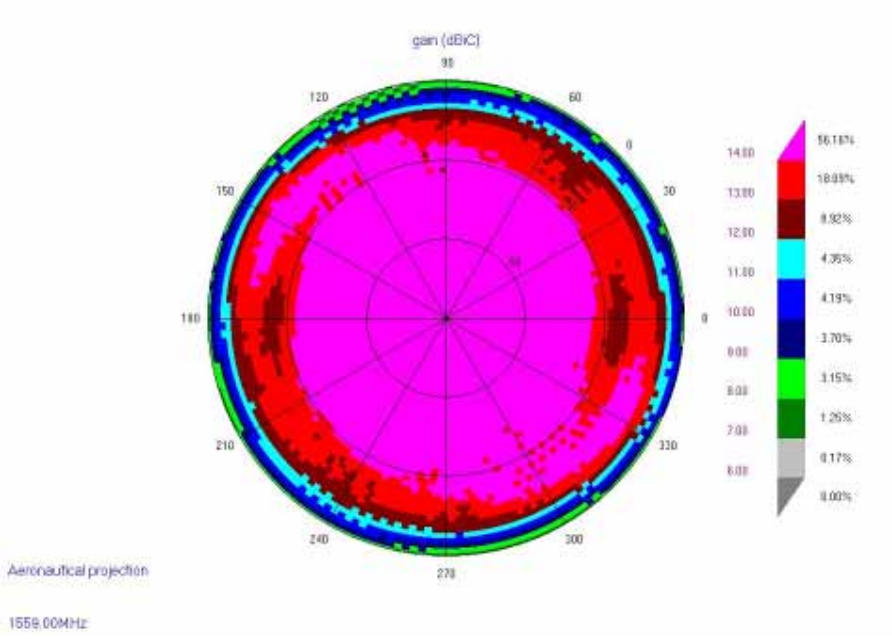

Figure 6: A typical gain map of the HGA-7001 antenna.

6.4 G/T performance

The G/T result is measured with the Omnipless DAU-7060 DLNA. This DLNA has a maximum noise figure of 1.3 dB. The resulting G/T is calculated (using the gain data presented in the previous section) and the following receive system parameters:

Antenna to DLNA loss	0.3dB
DLNA noise figure	1.25dB(1525MHz), 1.1dB(1542MHz), 1.18dB(1559MHz)
DLNA gain	57dB
DLNA to SDU loss	25dB
SDU noise figure	10dB

Table 3 Receive system parameters

		G/T					
		> -11 dB/K	**> -12 dB/K**	**> -13 dB/K**	**> -14 dB/K**	**> -15 dB/K**	**> -16 dB/K**
Elevation sector	**5° -10°**	2%	15%	55%	89%	100%	100%
	10° -15°	17%	73%	98%	100%	100%	100%
	15° -20°	52%	100%	100%	100%	100%	100%
	20° -25°	53%	100%	100%	100%	100%	100%
	25° -30°	76%	100%	100%	100%	100%	100%
	30° -35°	95%	100%	100%	100%	100%	100%
	35° -40°	100%	100%	100%	100%	100%	100%
	40° -45°	100%	100%	100%	100%	100%	100%
	45° -50°	100%	100%	100%	100%	100%	100%
	50° -55°	100%	100%	100%	100%	100%	100%
	55° -60°	100%	100%	100%	100%	100%	100%
	60° -65°	100%	100%	100%	100%	100%	100%
	65° -70°	100%	100%	100%	100%	100%	100%
	70° -75°	100%	100%	100%	100%	100%	100%
	75° -80°	100%	100%	100%	100%	100%	100%
	80° -85°	100%	100%	100%	100%	100%	100%
	85° -90°	100%	100%	100%	100%	100%	100%

Table 4: Detailed G/T performance map for 5 degrees elevation angle sectors

6.5 Multipath rejection, C/M discrimination.

The HGA-7001 C/M performance is 10-14dB higher than the Inmarsat specification. The tables below indicate the C/M performance (in dB) at 5 and 20 degrees elevation. It is clear that the minimum C/M performance (10 and 12 dB respectively) is exceeded by a wide margin. The results in the tables below are calculated for median sea conditions ($C/M_{median} = 0.3C/M_{smooth} + 0.7C/M_{rough}$).

	Frequency (MHz)					
AZIMUTH (°)	**1525**	**1542**	**1559**	**1626**	**1644**	**1661**
0	23	23	23	22	21	20
22.5	20	21	21	21	21	21
45	18	18	18	19	19	19
67.5	18	17	17	18	18	18
90	18	18	17	17	17	18
112.5	20	19	19	17	17	18
135	21	21	20	18	18	19
157.5	23	22	21	20	19	19
180	22	22	22	21	20	19
Specification	10	10	10	10	10	10
Average	20	20	20	19	19	19
Minimum	18	17	17	17	17	18
Angle of minimum	67.5	67.5	67.5	90	112.5	112.5

Table 5: Detailed Carrier to Multipath Map for 5º elevation angle

	Frequency (MHz)					
AZIMUTH (°)	**1525**	**1542**	**1559**	**1626**	**1644**	**1661**
0	24	24	24	27	27	29
22.5	24	24	24	25	25	25
45	24	24	24	24	23	24
67.5	24	24	24	23	23	23
90	24	24	25	25	24	24
112.5	23	24	24	27	27	27
135	24	24	25	28	29	29
157.5	25	25	25	29	29	30
180	24	24	24	26	27	28
Specification	12	12	12	12	12	12
Average	24	24	24	26	26	27
Minimum	23	24	24	23	23	23
Angle of minimum	112.5	22.5	22.5	67.5	67.5	67.5

Table 6: Detailed Carrier to Multipath Map for 20º elevation angle

6.6 Axial ratio

The HGA-7001 axial ratio is generally less than 6.0 dB for all steering angles and at all frequencies of operation. Axial Ratio values greater than 6 dB are compensated by additional gain margin. A value of 2.5 dB is assumed for the Satellite antenna axial ratio, with the polarization ellipse major axes orthogonal.

6.7 Power handling

The antenna supports the transmission of a continuous single carrier of up to 60 W (i.e., 17.8 dBW) at the HGA input connector. Peak Envelope Power (PEP) for multiple carriers may exceed 150 watts.

6.8 VSWR

The antenna VSWR measured at the antenna input/output port is less than 1.5:1 (with respect to 50 ohm characteristic impedance) over at least 98% of all antenna beam pointing angles at all frequencies of operation. The antenna does not need to be powered to meet this VSWR.

6.9 Passive Intermodulation

The HGA-7001 complies with the highest level PIM requirements defined by ARINC 781 and the Inmarsat SBB SDM. This allows the antenna to be used without any restriction for any combination of SwiftBroadband, Swift64 and Classic Aero services.

6.10 Beam steering performance

The antenna points to the desired direction within less than 30 milliseconds from any initial condition. When switching beams, the signal is interrupted for less than 20 microseconds.

6.11 Lightning Protection

In addition to the protection provided by the 3mm thick composite radome, the antenna is further protected by segmented lightning diverter strips. The antenna is qualified to RTCA-DO-160E cat 2A lightning strike and is designed to be fully operational after such a lightning strike. Refer to the antenna installation manual for grounding requirements.

6.12 Aerodynamic Loading

The aerodynamic loading caused by the HGA-7001 depends on the flight level, the speed and a few other factors. See Table 7 for examples of drag calculated.

Height(m)	P(Pa)	Mach	Cd	Drag (N)	Aref (m^2)
10650	23517	0.85	0.2	42.4	0.017825
6650	42505	0.97	0.5	249.5	0.017825
12192	18671	0.72	0.2	21.4	0.015806
2284	76726	0.68	0.2	78.5	0.015806
2255	77002	0.72	0.2	88.3	0.015806

Table 7: HGA-7001 drag at different flight levels and speed.

6.13 Paint

The antenna is to be painted with an aircraft grade polyurethane outer coating (white) or equivalent (CA40000) and an antistatic sub layer (DeSoto® Antistatic Coating 528x306). The standard color is white, but other options are available on request.

6.14 Grounding

Antenna grounding is achieved through the 8 mounting bolts and their surrounding contact areas (shown below). These areas are protected from the environment by silicon "O" rings and are raised by 0.5mm from the surrounding surfaces to ensure ground contact.

Figure 7: The conductive contact area around the mounting hole

In addition, a grounding stud is provided under the removable tail-cap of the antenna.

Figure 8: The additional grounding stud on the HGA-7001

Features of grounding stud:

- 10/32 x ½ external shaft
- Made from stainless steel
- < 1mΩ contact resistance
- Thread locked in place
- Can be replaced if damaged

6.15 Antenna Anti-static Protection

The radome of the antenna is to be painted with an anti-static primer. As described above, there are 8 conductive bonding points at the base of the mounting holes to provide grounding to the airframe via the mounting or adapter plate. Refer to the antenna installation manual for grounding requirements.

6.16 Aerodynamic Noise

The antenna has a height of only 48 mm and due to its sleek shape and resulting low drag, will cause negligible aerodynamic noise.

6.17 Connector Sealing

No special precautions are required for connector sealing. The MIL and TNC connectors are environmentally sealed once mated.

6.18 Maintainability

The antenna does not contain any user adjustable or maintainable parts. Maintenance consists of routine inspection for radome damage and general corrosion preventative measures. Both these activities can be scheduled during routine aircraft maintenance periods. Refer to the installation manual for more details.

6.19 Flammability

The antenna contains standard small electronic components, none of which are manufactured of flammable materials. The antenna passed the RTCA/DO-160E cat E explosion proof test.

7. ENVIRONMENTAL QUALIFICATION

7.1 Environmental Protection

To ensure that the environmental exposure of the antenna installation does not adversely affect the antenna performance, the following instructions are provided in the antenna installation manual and application notes

- Being a breathing antenna with the vent hole located inside the tail-cap (rear of the antenna,) the installation must ensure that airflow is available to at least the tail-cap area and that water entering the area below the antenna is able to drain out.
- Grounding areas are provided around each antenna mounting bolt hole. The area is raised above the rest of the surface and is large enough to provide a sealing surface for the O-ring on the antenna base plate.
- Eight small recesses are provided around the edge to help separate the antenna from the adapter or mounting plate. These are positioned opposite each mounting hole for ease of locating when hidden by sealant.
- Two areas are provided for ground straps to connect the adapter or mounting plate to the fuselage as required.
- Drainage channels are provided along the edges to prevent water from collecting (damming up) between the Antenna and the fuselage.
- The adapter or mounting plate is typically supplied attached to a keeper plate to prevent bending during transport and to retain mounting integrity by keeping it flat.
- It is recommended to create a fillet of sealant around the lower metal edge of the Adaptor Plate in order to reduce the amount of water that can enter the cavity between the antenna and the fuselage.

7.2 Environmental Qualification

The antenna is qualified to RTCA/DO-160 E as specified below.

DO-160E Section	Description	Category
4	Temperature and Altitude	E1
4.5.4	Loss of Cooling	X
5	Temperature Variation	A
6	Humidity	B
7	Shock	E
8	Vibration	U(G), R(C,C1),R(E,E1), H(R), S(L,M,Y)
9	Explosion	E
10	Waterproofness	RS
11	Fluids Susceptibility	F
12	Sand and Dust	S
13	Fungus Resistance	F
14	Salt Spray	S
15	Magnetic Effect	Z
16	Power Input	A(WF)X
17	Voltage Spike	A
18	Audio Frequency Conducted Susceptibility	K(WF)
19	Induced Signal Susceptibility	CW
20	Radiated Frequency Susceptibility (HIRF)	(RW)(RY)
21	Emission of Radio Frequency Energy	H
22	Lightning Induced Transient	A3J44
23	Lightning Direct Effects	1A2A
24	Icing	AC
25	Electrostatic Discharge	A
26	Fire, Flammability	X

This relates to the following DO-160E categorization string:

[E1]XABE[U(G),R(C,C1),R(E,E1),H(R),S(LMY)]E[RS]FSFSZ[A(WF)X]A[K(WF)][CW][(RW)(RY)]H[A3J44][1A2A][AC]AX