RA-4000e
Radar Altimeter System

Pilot Guide

And

Equipment Installation Manual

		DATE
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Table of Contents

1. Introduction

This manual contains installation data and specifications for the FreeFlight Systems Radar Altimeter RA-4000e (P/N 84560-01). The 4000e meets the requirements for a TSO-C87 Radar Altimeter with Precision Equipment output.

The 4000e is designed to provide AGL altitude directly to an integrated Flight Management System (FMS). Altitude is calculated by assessing the round trip delay of a signal reflected from the ground.

The system consists of three Line Replaceable Units (LRUs): the RA-4000e R/T Unit and two Antenna Units (Free Flight P/N 9-1203-115-00). Refer to Figure 1-1 for a system overview.

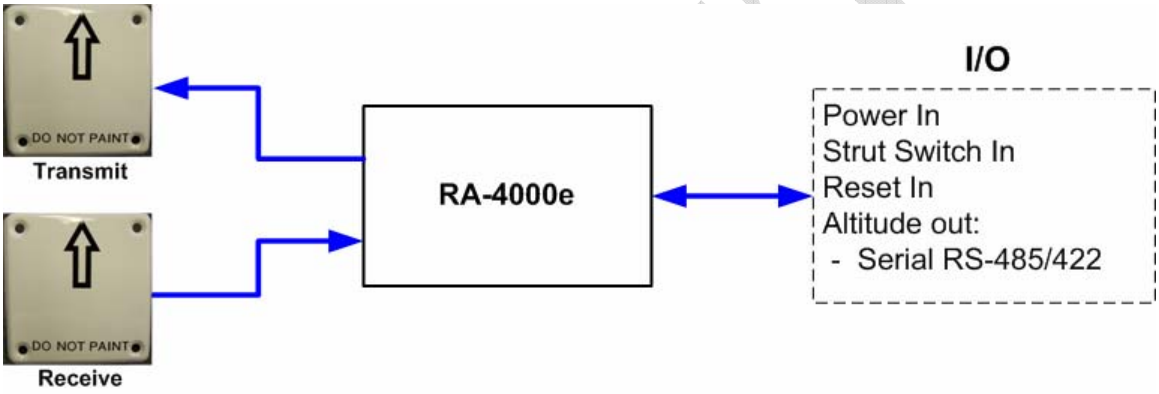

Figure 1-1: RA-4000e System Block Diagram

1.1. Reference Documents

Document Number	Title
RTCA/DO -160E	Environmental Conditions and Test Procedures for Airborne Equipment; 29-July-97 (incorporating Change 1 dated 14-Dec-00, Change 2 dated 12-June-01, and Change 3 dated 05-Dec-02).
RTCA/DO-178B	Software Considerations In Airborne Systems And Equipment Certification; 1-Dec-92.
TSO – C87	AIRBORNE, LOW-RANGE RADIO ALTIMETER ; 1-Feb-1966.
RTCA/DO-155	Minimum Performance Standards Airborne Low-Range Radar Altimeters; 1-Nov-1974.

1.2. Table of Acronyms & Abbreviations

The following acronyms and abbreviations are used throughout this document.

Abbreviation	Definition
AGL	Above Ground Level
CCA	Circuit Card Assembly
FAA	Federal Aviation Administration
FAQ	Frequently Asked Questions
FFS	FreeFlight Systems
FMCW	Frequency Modulated Continuous Wave
FMS	Flight Management System
LRU	Line Replaceable Unit
R/T	Receiver / Transmitter
TSO	Technical Standard Order

2. Description

A complete system consists of an RA-4000e receiver/transmitter unit and two antennas. The RA-4000e provides AGL altitude information from 0 feet up to 2000 feet maximum via computer interface.

The RA-4000e Radar Altimeter system utilizes a reliable solid-state voltage controlled oscillator (VCO) to drive its transmitter. Embedded processors precisely measure the signal delay, calculate the altitude, and provide a simple to use computer interface.

2.1. Operational Modes

Once the unit has completed a reset, it begins outputting data at a 10 hertz rate. Data consists of the altitude and a Status byte. Following is a description of different modes for the unit.

2.1.1. Power On Self-Test

At power on, or upon assertion of the Reset input, the system initializes operation and performs a self-test for approximately 20 seconds. In the self-test, the lock circuitry is tested and a test signal applied to the receive circuitry. During this time, the unit reports an altitude of 40 feet and asserts the "Self-Test" bit in the Status byte.

2.1.2. Altitude Zero Calibration

When the Altitude Zero Calibration mode is selected during installation, the unit automatically calibrates the zero altitude point. This automatically compensates for different cable lengths or installation factors that would otherwise bias the altitude reading.

2.1.3. On Ground Operation

While on the ground, the unit is susceptible to erroneous readings caused by signals returned from nearby buildings or personnel. Utilization of the Strut input allows the unit to ignore these erroneous signals and report zero feet. The "Strut" bit of the Status byte provides an indication of the input signal.

2.1.4. Normal Operation

When the unit detects a locked signal and does not have a Strut indication (i.e. – aircraft in the air), it reports altitude with the "Signal" bit indicating Locked. If conditions on the ground prevent a stable received signal, the "Signal" bit of the Status word indicates Unlocked. Note that if ground conditions provide a sufficient return signal, the unit may report a locked altitude as high as 2500 feet.

2.2. System Limitations

2.2.1. Terrain

At altitudes above 1500 feet, terrain with poor reflectivity may cause the unit to unlock. Examples of unfavorable terrain are dry, loose soil, (e.g. - tilled farmland), or sand.

2.2.2. Excessive Pitch/Roll

An excessive pitch or roll attitude may also cause the system to unlock. This sensitivity increases with altitude. In general, below 1500 feet a 30 degree bank is tolerated. Above 1500 feet, the aircraft should be maintained within a 20 degree bank for proper operation. If the unit unlocks due to marginal conditions, it will automatically relock when a signal sufficient for ranging is detected.

2.2.3. Rapid Descent

In cases of extremely rapid descent, both the response time of the system and pitch of the aircraft may prevent normal operation. At a descent rate of 500 feet/minute or less, the RA-4000e system provides normal operation below 2000 feet.

2.2.4. Response Time

When flying the RA-4000e system over rapidly changing terrain, e.g., a cliff or ravine, the system is limited by the 10 Hz response time of the unit.

2.2.5. Cold Start

When the unit is powered on at an ambient temperature of less than -30ºC a warm-up period is required. This period varies from 30 minutes from a cold start at -55ºC, to none at -30ºC. During this time, the unit will output altitude with the Invalid bit asserted. Once the unit has reached a reliable operating temperature, the Invalid bit is cleared.

NOTE:
The RA-4000e system surveys ground directly below the aircraft, and should not be relied on as either a forward looking or warning device.

2.3. Specifications

Specifications for the RA-4000e system are listed in Tables 2-1 through 2-3.

Parameter	Value
Type	Dual antenna, FMCW
Compatible Antennas	FreeFlight P/N 9-1203-115-00 EDO P/N DM PN19-2-1
Altitude Range	0 to 2000 feet
Altitude Accuracy	0 to 100 feet +/- 3 feet 100 to 500 feet +/- 3% 500 to 2000 feet +/- 5%
Frequency Range	100 MHz sweep 4.25 - 4.35 GHz
Sweep Frequency	100 Hz
Input Voltage	28 VDC +/- 10% (Internal fuse and reverse polarity protection)
Input Current	350 ma Max (steady-state)
Max. Inrush Current	5.5 amps for 10 uSec @ 28 VDC
Altitude Output, Rate	RS-485/422, 10 Hz
Altitude Latency	50 mSec
Self-Test / Reset	On ground or during flight
Environmental (Pending)	DO-160E
Certifications (Pending)	TSO-C87, DO-178B Level B, FCC Part 15

Table 2-1: System Technical Characteristics

Parameter	Value
Weight	1.8 lb
Height	3.06”
Length (Including mounting flange)	6.78”
Width	3.15”
Connectors	2 each TNC antenna connectors 1 each 22 pin circular connector

Table 2-2: RA-4000e Physical Characteristics

Parameter	Value
Quantity	2
Weight	0.3 lbs (0.6 lbs total)
Dimensions	3.5" W x 3.65" L x .15" H

Table 2-3: 9-1203-115-00 Antenna Physical Characteristics

2.4. Component and Accessory Part Numbers

Each 4000e unit is shipped individually, as indicated in Table 2-4. Two antennas and associated wiring are also required for installation. An Antenna Installation kit is available from FreeFlight, as indicated in Table 2-5. The items listed in Table 2-6 are required, but not supplied by FreeFlight.

ITEM	FREEFLIGHT P/N	QUANTITY
RA-4000e R/T Unit	**84560-01**	**1 required**

Table 2-4: RA-4000e Install Kit

ITEM	FREEFLIGHT P/N	QUANTITY
Optional Antenna Installation Kit	**1901-3501-00**	**2 required**
Coax Cable Assembly	1900-0432-12	1 per kit
Antenna	9-1203-115-00	1 per kit

Table 2-5: Optional FreeFlight Install Kit and Parts

ITEM	FREEFLIGHT P/N	QUANTITY
System Wiring	N/A	As required
Circuit Breaker – “Slow Blow” 3 Amp	N/A	1
System Indicator	N/A	1

Table 2-6: Other Required Accessories

2.5. License Requirements

As installed in the aircraft, the radar altimeter does not require an FCC operator’s license. For information, reference FCC 47 CFR Part 87.89 Minimum operator requirements.

3. Electrical Interfaces

Electrical interconnection to the RA-4000e is made via 22-pin connector. Refer to Table 3-1 for a description of the pinout.

Pin	Name	Function	Direction	Level
1	**Ground**	Ground	-	Ground
2	**Ground**	Ground	-	Ground
3	**Power In**	Aircraft voltage in	In	28 VDC +/- 10% Power In
4	**Power In**	Aircraft voltage in	In	28 VDC +/- 10% Power In
5	**Reset**	Reserved	In	NO CONNECT
6	Reserved			
7	Reserved			
8	**Strut**	/Strut (Active low)	In	Switched Ground
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	**Nav-TX**	Maint/Nav Port RS-232C Transmit	Out	RS-232C
14	**Nav-RX**	Maint/Nav Port RS-232C Receive	In	RS-232C
15	**PGM-EN**	Reserved	In	NO CONNECT
16	Reserved			
17	Reserved			
18	**Nav-Bias**	RS-485 100 ohm ground connection	-	RS-485 Ground
19	**Nav-Com**	Nav Port Ground	-	Ground
20	**Nav-Com**	Nav Port Ground	-	Ground
21	**Nav-TXA**	Navigation port Serial RS-485/422	Out	RS-485/422
22	**Nav-TXB**	Navigation port Serial RS-485/422	Out	RS-485/422

Table 3-1: RA-4000e Interface Pinout

3.1. Ground

Aircraft ground is connected on two pins.

3.2. Power In

Aircraft power of 28 VDC +/-10% is connected on two pins.

3.3. Reset

This circuit is reserved for factory test purposes only. Do not connect

3.4. Strut Input

The Strut signal is an active low input. That is, the input should be grounded when the aircraft is on the ground.

3.5. Maint/Nav TX/RX

The Maint/Nav-TX/RX lines use RS-232C signal levels. The Maint/Nav-TX output carries the same data as the Nav-TXA/TXB pair. The Maint/Nav-TX/RX lines are used to initiate the Altitude Zero Calibration function and to reprogram the unit via serial RS-232C protocol. Note that it may be advantageous to route

these lines to a point which facilitates shorting them for the Altitude Zero Calibration (see 6.4.1). If this is done, care should be taken that the lines do not accidentally short during normal flight. During normal operation after the Zero Calibration has been accomplished, these lines should not be connected.

3.6. PGM-EN

The Program-Enable input is used to reprogram the unit. Do not connect in normal operation.

3.7. Nav-Bias

This common for RS-485 communications provides a 100 ohm resistive ground connection.

3.8. Nav-Com

These connections provide a direct ground reference, if desired.

3.9. Nav-TXA/TXB

As the primary data interconnect, these pins are driven by an LTC485 device.

4. Functional Interface

The Nav port provides radar altitude data via serial protocol via RS-485. The following sections describe the protocol used.

4.1. Data Rate

Data is transmitted in multi-byte packets with LSB first at 56,000 bps (8 data bits, one start, one stop, no parity). Packets are output at a rate of 10 Hz.

4.2. Protocol Definition

> **NOTE**:
> The information in this section is intended for engineering personnel and is not required for installation.

4.2.1. Packet Structure

Each packet conforms to the following structure:

Field	DLE	ID	LEN	DATA	CHECKSUM	DLE	ETX
Content	0x10	0xDF	0x03	3 bytes	1 byte	0x10	0x03

4.2.1.1. DLE (Data Link Escape Character)

Fixed byte = 0x10.

4.2.1.2. ID (Identification)

Fixed byte = 0xDF.

4.2.1.3. Len (Length)

Fixed byte = 0x03.

4.2.1.4. Data

Three data bytes are defined as follows:

Byte	Definition
1	Altitude High byte of a 2-byte binary field. (Units: Feet; Range: 0-2500)
2	Altitude Low byte of a 2-byte binary field.
3	Status Byte (See Table 4-2)

Table 4-1: Data Field Definition

Bit	High (1) Indication	Low (0) Indication
0 – Altitude	Ascending	Descending
1 – Self Test	Test in progress	Normal operation
2 – Status	Unit Failure	Normal operation
3 – Invalid	Unlocked / Invalid output	Locked / Valid output
4 – Strut	Asserted (On ground)	De-asserted (In air)
5 – Reserved		
6 – Reserved		
7 – Reserved		

Table 4-2: Status Byte Bit Definition

4.2.1.5. Checksum

This is the one-byte 2's complement of the sum of all the data bytes, including the packet ID and LEN bytes (i.e. 0xDF03). Refer to Table 4-3 for a sample packet with normal status (descending, locked, and good status) and an altitude of 1000 feet.

Byte	DLE	ID	LEN	Alt Hi	Alt Lo	Status	Chk	DLE	ETX
Value	0x10	0xDF	0x03	0x03	0xE8	0x00	0x33	0x10	0x03

Table 4-3: Sample Packet At 1000'

4.2.1.6. DLE (Data Link Escape Character)

Fixed byte = 0x10.

4.2.1.7. ETX (End Of Text Character)

Fixed data byte = 0x03.

4.2.2. DLE Stuffing

This protocol requires that an occurrence of the DLE (0x10) character in either the data or checksum must be followed by another DLE character. The receiver therefore, should remove, or "unstuff", the second DLE character when two are received in sequence. Note that the "unstuffing" should occur prior to calculation of the Checksum.

5. Mechanical

5.1. RA-4000e Mounting

The mounting requirements for the RA-4000e are illustrated below in Figure 5-1.

5.2. Connectors

Interfaces to the 4000e are provided through three connectors as described below in Table 5-1.

Function	Description
Aircraft interconnections	This 22-pin circular connector mates with AMPHENOL P/N 10-565995-231N.
TX Antenna	This TNC connector mates with AMPHENOL P/N 225554-6
RX Antenna	This TNC connector mates with AMPHENOL P/N 225554-6

Table 5-1: Connector Descriptions

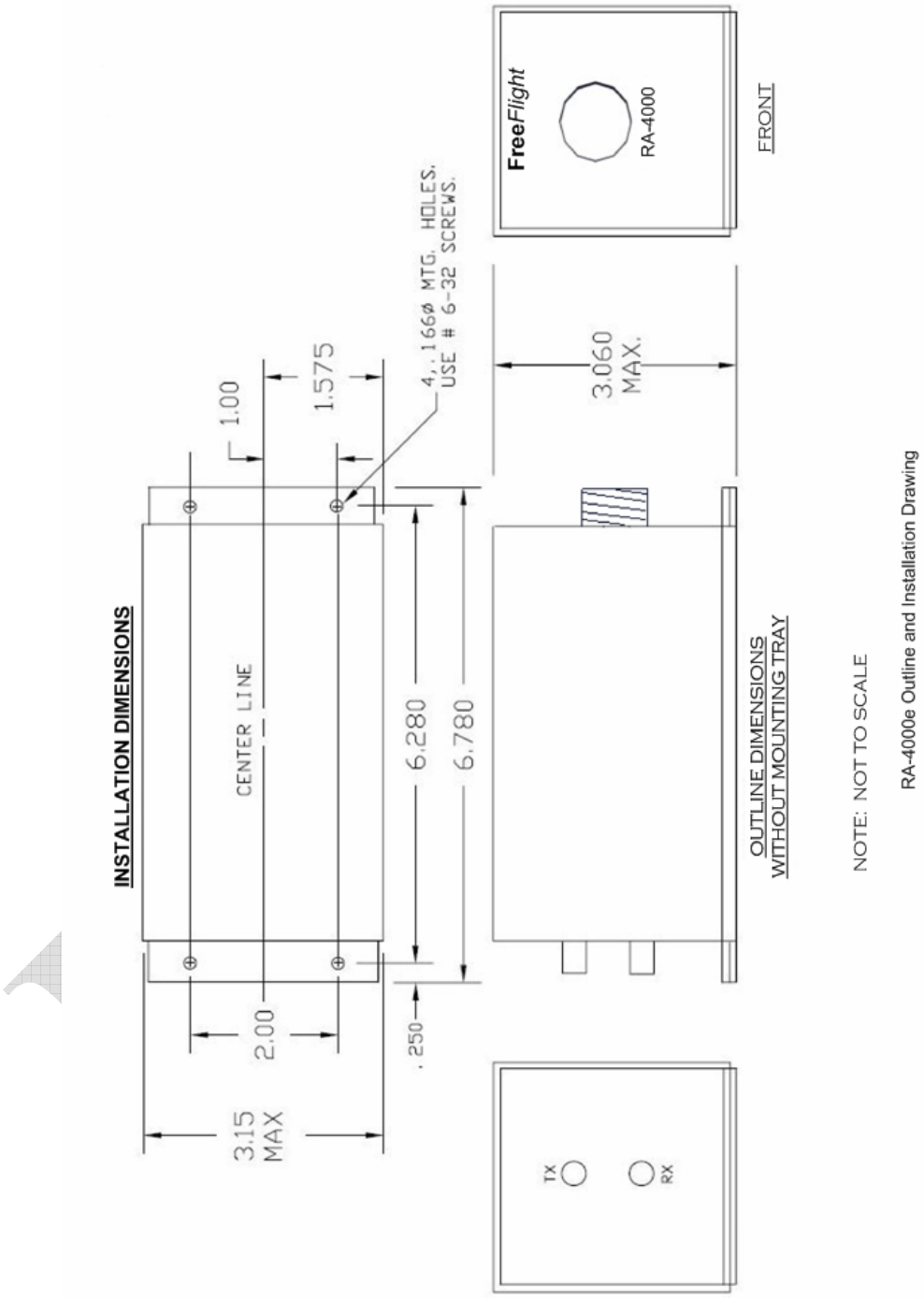

Figure 5-1: Mounting Illustration

5.3. Antenna Mounting

Refer to Figures 5-2 and 5-3 for mounting information for antenna P/N 9-1203-115-00.

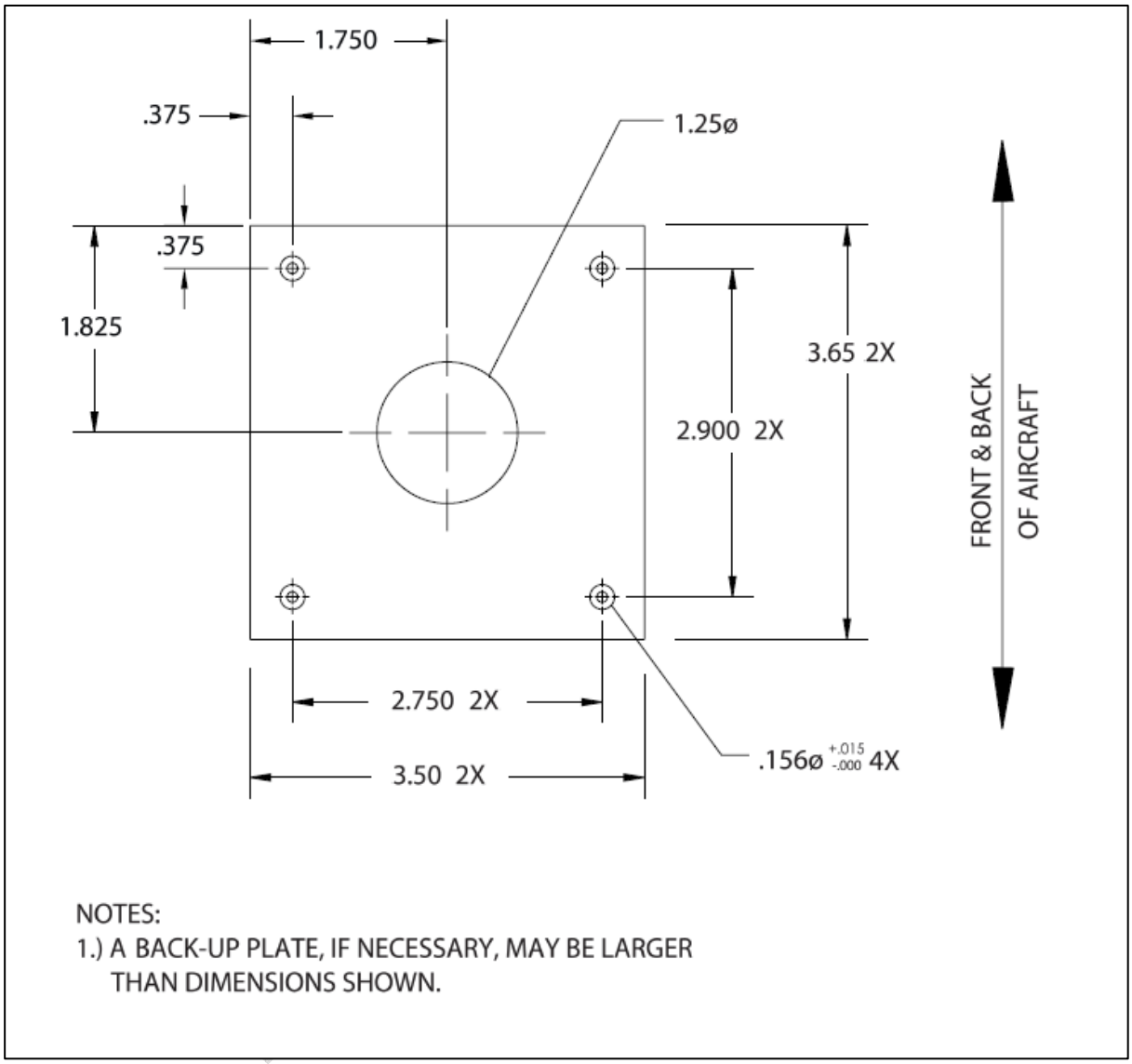

Figure 5-2: Antenna P/N 9-1203-115-00 Mounting Illustration #1

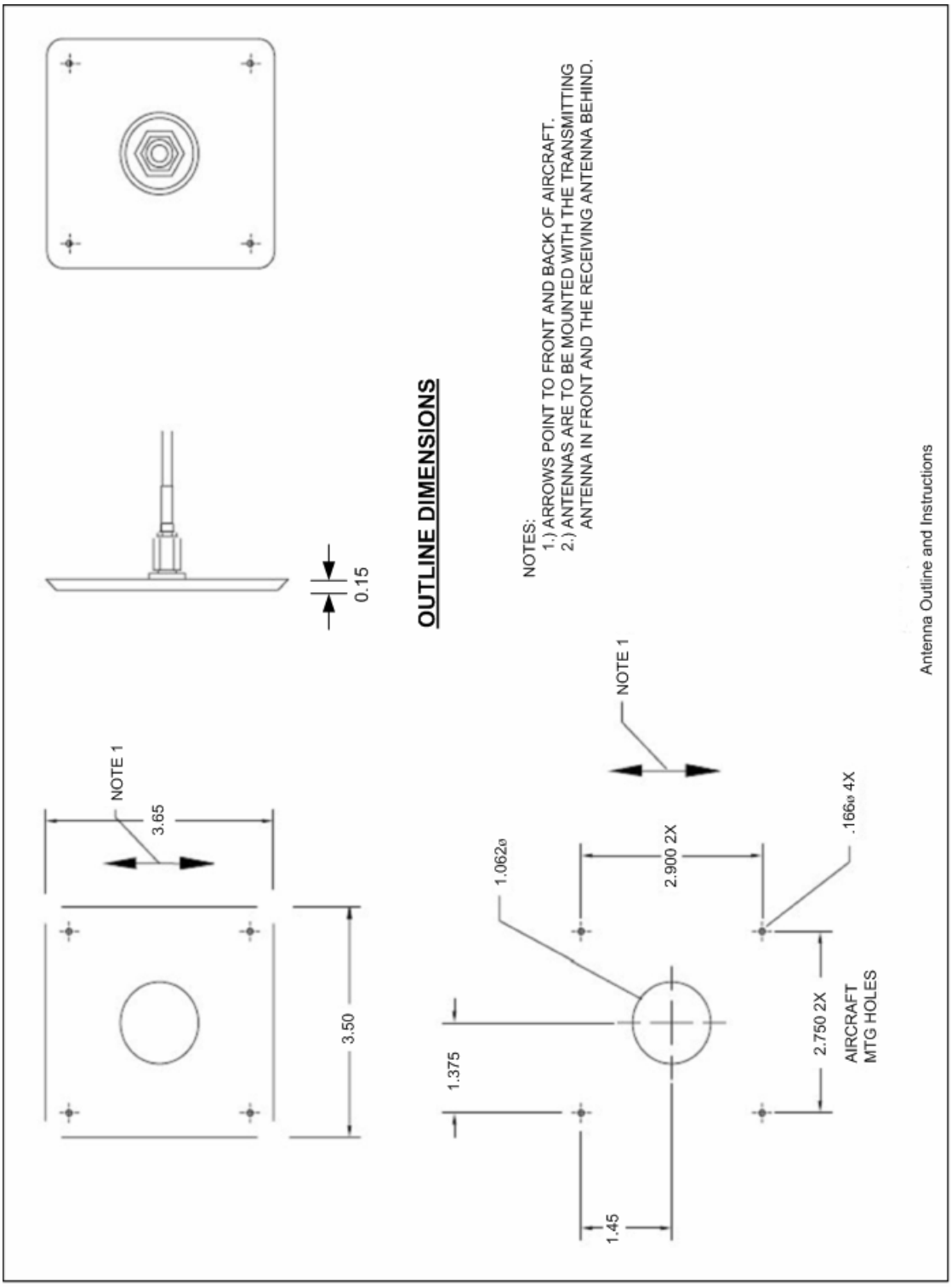

Figure 5-3: Antenna P/N 9-1203-115-00 Mounting Illustration #2

6. Installation

6.1. General Information

This chapter contains suggestions and factors to consider before installing an RA-4000e radar altimeter into an aircraft. Adherence to the suggestions will assure satisfactory performance from the system.

6.2. Unpacking and Inspecting Equipment

Exercise extreme care when unpacking each unit. Make a visual inspection of each unit for evidence of damage incurred during shipment. If a claim for damage is to be made, save the shipping container to substantiate the claim. When all equipment and the installation kit have been inspected, save the packing material and container in case the unit is to be stored or reshipped. See paragraph 2.4 for equipment and optional parts supplied.

6.3. Antenna Installation

Optimum installation of the antennas is on the centerline of the belly of the aircraft.

1) The area should be parallel to the ground.

2) The antennas should be mounted such that no protrusion is visible to either antenna within a 45-degree cone below the aircraft.

3) The antennas should always be mounted with the arrows pointing in the same direction.

Good: (→ → or ← ←)	**Not Good**: (→ ← or ← →)

4) Antennas should have no more than a 6-degree pitch.

5) Antennas should be mounted at least 18" apart and within 40" of each other.

6) Transmit antenna mounts in front; Receive antenna mounts to the rear.

7) RA-4000e unit mounts inside, positioned such that the antenna cables connect to the rear of the unit.

8) DO NOT mount the antenna closer than three (3) feet to a DME, transponder, ADF or VHF antenna.

9) During installation, avoid locations near high heat sources or where fuel, oil or excessive moisture may collect. Bond and shield all parts of the aircraft electrical system such as generators and ignition systems.

10) Due to the Altitude Zero Calibration, the antenna cables can be cut to any length for better fit during installation. (See section 6.4.1 for Altitude Zero Calibration). Each antenna cable must not exceed 150" in length.

6.4. RA-4000e Installation

The RA-4000e unit installation layout is shown in figure 5-1. Route all data and power cables away from circuits carrying high current, pulse-transmitting equipment, 400 Hz circuits and other sources of interference. Do not route with ADF antenna cables.

> **Note:** Aircraft which exhibit electrical noise on the airframe or have surfaces or panels which are not properly bonded can cause the altimeter to attempt to "relock" above 2000 feet AGL, thus causing erratic altitude output. Thorough bonding of all control surfaces, gear doors, access panels, etc. should cure the symptom, but in certain extreme circumstances, it may be necessary to install an on/off switch to disable the unit above 2000 feet. This condition is only noticeable above 2000 feet and does not degrade performance below 2000 feet AGL.

6.4.1. Altitude Zero Calibration

Reflections due to surrounding obstacles may cause inaccurate calibration. It is recommended to Zero the RA-4000e in an open area away from buildings trees or other large reflecting surfaces to improve accuracy.

> **Note**: If this procedure is not performed on install, after service, or is improperly performed, altitude may not be correct.

1. Remove or disable the Strut input to the system.
2. Clear all obstacles from around aircraft (including personnel).
3. Turn unit on and let run for a minimum of 5 minutes to warm up.
4. Turn off unit and all aircraft power.
5. Short together Maint/Nav port TX and RX pins.
6. Switch power ON for approximately 30 seconds.
7. Switch power off and remove the short from the TX and RX lines.
8. Switch power on. After the self-test is complete, the unit should now output 0' while on ground.
9. Test and repeat as necessary.
10. Restore the Strut input, if necessary.

6.4.2. Pre-Flight Check List

Turn on power (after starting engines).
Verify the unit self-tests for approximately 20 seconds (during which it displays 40 feet and sets the self test flag).
After the self-test mode, the unit should output 0 feet.

6.4.3. Final Testing

1. During takeoff observe AGL and verify that it is increasing while the aircraft is climbing.
2. After aircraft exceeds 3000 feet AGL verify that unit indicates “unlocked”.
3. With the aircraft above 3000 feet AGL in an open area:
    a. Put the aircraft into a 500-foot per minute descent.
    b. The unit should lock and start outputting altitude by 2000 feet AGL.

Appendix A – Environmental

Refer to Table A-1 for a summary of RA-4000e Test Categories.

Environmental Test	DO-160E Section	Category	Compliance Method
Temperature and Altitude	4	D2	T
Temperature Variation	5	B	T
Humidity	6	B	T
Shock/Crash Safety	7	B	T
Vibration	8	S Curve C	T
Explosion Proofness	9	n/a	X
Waterproofness	10	n/a	X
Fluids Susceptibility	11	n/a	X
Sand and Dust	12	n/a	X
Fungus	13	n/a	X
Salt Spray	14	n/a	X
Magnetic Effect	15	Z	T
Power Input	16	B	T
Voltage Spike	17	A	T
Audio Frequency Conducted Susceptibility – Power Inputs	18	B	T
Induced Signal Susceptibility	19	ZC	T
Radio Frequency Susceptibility	20	RR	T
Emission of Radio Frequency Energy	21	M	T
Lightning, Induced Transient Susceptibility	22	A2XXX	T
Lightning Direct Effects	23	n/a	X
Icing	24	n/a	X
Electrostatic Discharge	25	A	T
Fire, Flammability	26	n/a	X

Table A-1: DO-160E Test Categories