

RDR-4B

Forward Looking Windshear Detection/Weather Radar System
User's Manual with Radar Operating Guidelines

The RDR-4B Forward Looking Windshear Detection Radar System is a pilot oriented tool from Honeywell International. It is an enhanced version of the industry leading standard weather radar, the RDR-4A.

Until now, there was no reliable way to predict the occurrence of windshear. The RDR-4B radar system with predictive windshear capability will give flight crews advance warning of the conditions. Windshear warnings, both visual and audible, typically are issued 10 to 60 seconds before the encounter.

The information contained in this manual is for reference use only. If any information contained herein conflicts with similar information contained in the Airplane Flight Manual, the information in the Airplane Flight Manual shall take precedence.

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Introduction

SCOPE

This pilot's manual has been prepared as an easy to use reference for the operation of the Honeywell RDR-4B Forward Looking Windshear Detection/Avoidance Airborne Weather Radar System. By acquiring an understanding of the straightforward procedures outlined in this manual, a pilot will be able to operate the RDR-4B system. Proficiency, though, as with any system, is a direct result of practice and experience on the RDR-4B radar system.

Section 2 of this manual covers the operation of the RDR-4B weather radar in its various modes. Included is a description of the RDR-4B System, a functional description of controls available for flight crew adjustment and recommended operational procedures to assist in achieving optimum results.

Section 3 of this manual provides a reference for basics, weather radar principles, cloud interpretation, storm considerations and weather radar operating tips. The operating tips contain radar display interpretation information. Pictures of typical and a few not-so-typical displays are presented and discussed.

Section 4 of this manual provides a brief overview of the effects of antenna stabilization upon the radar display. Characteristic stabilization situations are explained and illustrated.

Remember the RDR-4B does not detect clouds. However, it can detect moisture laden weather formations which usually do have turbulence and windshear associated with them. When properly used, radar becomes a powerful aid in avoiding or reducing the hazards of inadvertent penetration of storm areas and associated turbulence.



RDR-4B Equipment Description & Operating Instructions

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**GENERAL
DESCRIPTION**

The RDR-4B system provides weather avoidance with turbulence detection, windshear detection and terrain mapping modes of operation. Solid-state circuit design and the use of state of the art components enable the RDR-4B system to provide higher standards of performance and reliability than have ever been achieved in previous weather radar systems.

The RDR-4B radar system features a non-fading, high resolution color display of storm conditions at selectable ranges up to 320 nautical miles (NM). Special normalizing circuits extend the calibration range of storm cells beyond that of previous weather radars. The system also incorporates circuits that modify the receiver gain as a function of intervening rain attenuation. This function, called penetration compensation, allows more accurate presentation of storm cells even when viewed through intervening rainfall. Digitally generated system status cues are overlaid on the radar presentation to provide the flight crew with real-time information on system performance and integrity during preflight and flight operations. The built-in self-test circuit provides full time monitoring of the system. If a failure occurs, a fault message is sent to all display units.



NOTE

Some electronic displays do not display all fault messages. Consult the operator's manual for a list of radar failure displays.

The RDR-4B radar system's turbulence detection capability incorporates a sophisticated Doppler Turbulence Detection circuit that measures the variations in horizontal speed of precipitative particles. If particle horizontal speed variations (indicative of wind shift) exceed the threshold of moderate to heavy turbulence, a corresponding display is provided.

The Forward Looking Windshear feature detects the presence of windshear, giving 10 to 60 seconds of warning before the encounter. Windshear operates automatically below 2300' AGL with alerts given at 1500' AGL and below. The system scans $\pm 60^\circ$ ($\pm 40^\circ$ windshear display), 5 NM ahead of the aircraft and automatically operates antenna tilt during the windshear scans. If the radar is OFF while a windshear event is detected, the system turns on automatically, alerting the crew by way of an amber caution light, ICON and audio announcement. The windshear ICON will overlay the test pattern if windshear is detected during test.

NOTE

For some aircraft configurations the test pattern will be removed and the icon will pop-up in WX mode.

NOTE

The turbulence detection mode will not detect clear-air turbulence because of the lack of precipitation.

NOTE

The weather display corresponds to the selected range while the turbulence display is overlaid for the first 40 NM (regardless of range selected).

NOTE

Below 2300' windshear operations uses an alternate antenna scan technique for radar and windshear detection. Windshear operation is transparent to the crew unless an alert is issued, however, you might notice that the radar update rate could be delayed by as much as 12 seconds due to sharing of processing between windshear and radar.

**SYSTEM
CONFIGURATION**

The basic RDR-4B System consists of several units: The Receiver/Transmitter (RTA-4B), the Display Unit (PPI-4B), the Antenna Assembly (DAA-4A or -4B drive unit and REA-4A or -4B Array), and the control panel (CON-4A/B).

There is an optional display unit that contains all radar controls, thus eliminating the need for a separate control panel. This simplifies the aircraft installation and reduces cockpit panel requirements. The RDR-4B System is also available in a dual Receiver/Transmitter configuration with a common antenna and control panel that offers switch selection of either Receiver/Transmitter unit.

Many optional display configurations exist. In aircraft equipped with Electromechanical Flight Instruments, one or two radar displays are standard. In aircraft equipped with Electronic Flight Instruments, two electronic displays and up to two radar displays can be used.



**UNIT
DESCRIPTIONS**

**RTA-4B
RECEIVER/
TRANSMITTER**

The Receiver/Transmitter contains the electronics necessary to transmit, receive and process the radar pulses used to detect turbulence, windshear, weather and terrain targets as well as the system integrity monitoring, self test and fault memory circuits. The circuits necessary to interface to the aircraft's attitude reference for antenna stabilization are also contained in the RTA-4B.



**PPI-4B
DISPLAY UNIT**

The PPI-4B receives and processes the video data from the Receiver/Transmitter unit and presents this information as a continuous display of weather or terrain mapping. The information is displayed in up to four distinct colors — green, yellow, red and magenta. The weakest targets are displayed in green and the strongest in red. Areas of moderate to heavy turbulence within a 40 NM range are displayed as magenta if turbulence detection is selected.



In some installations, the PPI-4B Display Unit is also used as a cockpit multifunction display. In this configuration, a wide variety of data such as checklists, ACARS, EGPWS and TCAS can be displayed.



On some older generation EFIS equipment turbulence is displayed in red, the same as strong weather returns.

**DAA-4A/
REA-4B
ANTENNA
ASSEMBLY**

The component parts of the antenna assembly are the DAA-4A Antenna Drive Assembly and the REA-4B flat-plate array. The antenna assembly, located within the radome, forms the microwave energy into a 3 degree conical shaped beam that sweeps 90 degrees to the left and 90 degrees to the right of the aircraft centerline. The antenna also receives the same microwave energy, when reflected by weather formations or other objects and routes the signals to the receiver/transmitter for processing. The antenna assembly scans a 180 degree sector in azimuth and has a tilt (elevation) coverage of ± 15 degrees.

Stabilization limits are ± 25 degrees in the pitch axis and ± 40 degrees in the roll axis, as long as combined pitch, tilt and roll does not exceed ± 43 degrees.

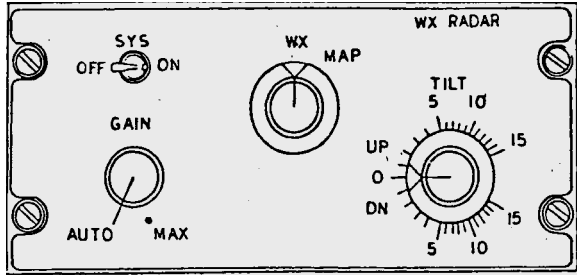


**DAA-4B/
REA-4A
ANTENNA
ASSEMBLY**

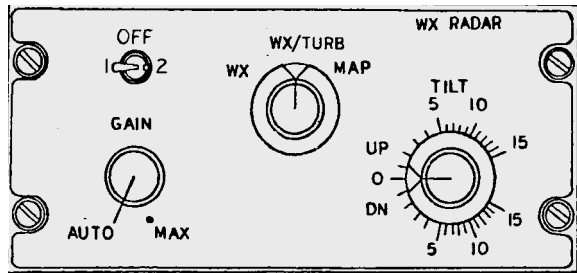
The DAA-4B Drive Assembly with the REA-4A flat-plate array offers lighter weight and smaller size for use in both commercial and large executive aircraft. Operation is similar to the DAA-4A/REA-4B Antenna assembly, however, the antenna scans a 160 degree sector in azimuth and has a tilt coverage of ± 15 degrees. Stabilization limits are ± 15 degrees in the pitch axis and ± 30 degrees in the roll axis for combined tilt/pitch/roll limits of ± 35 degrees.

**CON-4A/4B
CONTROL
PANELS**

The CON-4A/4B contains the controls for operating the radar system except for those located on the display unit. The CON-4A is used in a single system configuration while the CON-4B is the dual system control panel. Control functions are the same as typical units shown.



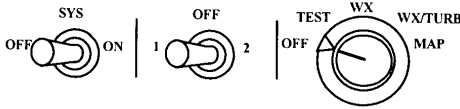
CON-4A



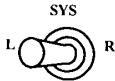
CON-4B

**CON-4A/4B
CONTROLS**

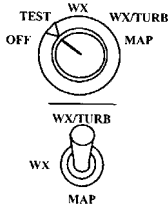
NOTE: For control panels with no "OFF" position, the radar is turned on when "WX" mode is selected on the EFIS control panel or the dedicated radar indicator.



SYSTEM ON – OFF: The OFF position can be found on a dedicated "SYSTEM OFF - ON switch or on the Mode Selector.



SYSTEM SELECTION: L or 1: selects number one RT.
R or 2: selects number two RT.



OFF - When in the "OFF" position the system is in standby, unless turned on by qualifiers. Additionally, below 1500 feet AGL, a windshear event automatically turns on the PPI- 4B, the antenna sweeps $\pm/60^\circ$ ($\pm/40^\circ$ display), 5NM range, annunciates W/S ONLY, TILT and Gain are removed and the display shows the windshear ICON only. A Windshear event is displayable on any mode.

MODE SELECTION: TEST - Turns system on and provides a normal Test Pattern, initiates automatic test and fault isolation of line replaceable units in the system. If a Windshear event is encountered while in the test mode, the windshear ICON overlays the test pattern.



NOTE: For some aircraft configurations the test pattern will be removed and the icon will pop-up in WX mode.

WX - Provides 180° of continuously updated weather information on the radar display, weather returns will vary from green to yellow to red with increasing intensity. Gain Control is optional.

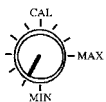
TURB or WX/TURB - Provides 180° display of weather and Turbulence up to 40NM and weather only beyond 40NM. Turbulence areas will appear magenta colored. Gain control will affect weather but not turbulence.

MAP - Displays Terrain Mapping. Gain Control is operational.



GAIN CONTROL: Controls receiver gain. Rotate fully counter-clockwise for automatic gain.

or



AUTO/CAL - Presets an optimum receiver sensitivity for a calibrated weather radar display. (In Windshear and Turb mode, gain is controlled automatically)

Manual - Rotating knob out of AUTO/CAL, varies gain and provides readout on upper right corner of the PPI-4B display.



NOTE: Variable gain in Weather mode is not available on all control panels. Refer to IB 1104-1 for detailed function list.

**CON-4A/4B
CONTROLS**

(CONTINUED)



TILT MAN - AUTO

AUTO: When in Auto, Antenna TILT setting is automatic using terrain data from EGPWS

MANUAL: Tilt is controlled by the manual tilt control knob.



NOTE: Manual Tilt should be used when Analyzing Terrain and Storm Characteristics.

MANUAL TILT CONTROL: Controls antenna tilt ($\pm 15^\circ$) angle with reference to horizon. Tilt angle is presented on radar display. Tilt is Automatic for wind-shear scans.

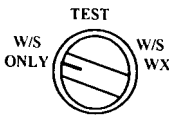


STABILIZATION ON - OFF: OFF: When in the OFF position disables antenna stabilization. Tilt is referenced to the aircraft.



WINDSHEAR AUTO – ON

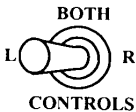
or PWS OFF - AUTO



AUTO: Windshear function is enabled.

OFF: Disables Windshear function.

W/S ONLY: Enables windshear only mode of operation. Displays only windshear ICONs, no weather return. Tilt and gain control are automatic in the windshear mode. On installation using PPIs-4B, above 2300' the PPI-4B will display "NO W/S AVAILABLE".



BOTH L – R CONTROLS: L or R: Enables the left or right side controls.

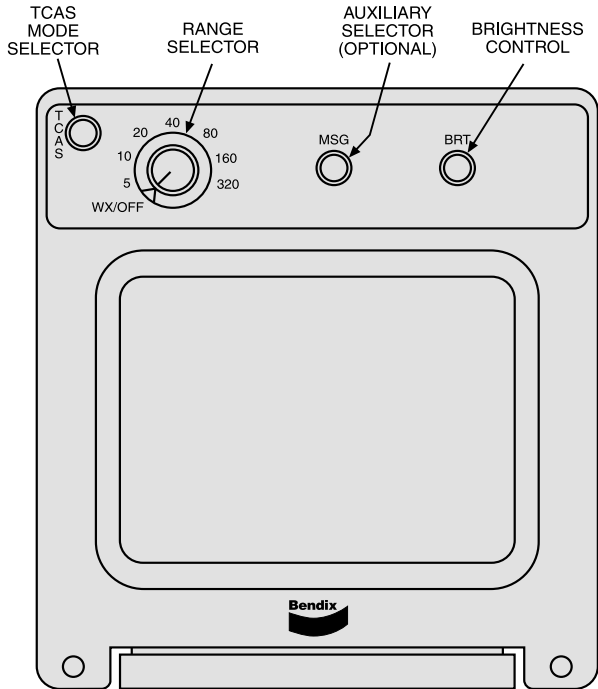
BOTH: Left side controls operate the left side display and right side operate right side display. Display is updated during alternate scans.

TYPICAL PPI-4B OPERATING CONTROLS
(WITH DISPLAY UNIT CONTROLS ONLY)

RANGE SELECTOR

Applies power to PPI-4B and selects range to be displayed. When OFF (or STBY), below 2300' AGL, the RDR-4B automatically turns on and starts scanning for windshear, the antenna sweeps $\pm 60^\circ$ ($\pm 40^\circ$ display), 5 NM range, annunciates W/S ONLY, TILT and GAIN are removed.

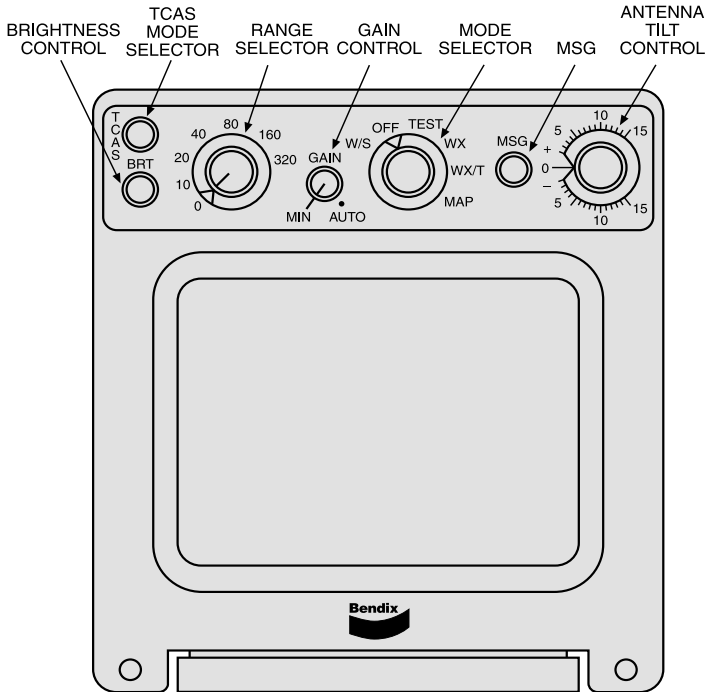
Power must be supplied to TCAS in order for windshear to turn on 2041222-3457, -3459, -3461 and -3462 units



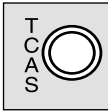
automatically.

PPI-4B configurations with TCAS and ACARS (MSG) controls: Refer to appropriate TCAS and ACARS operating handbook for instructions.

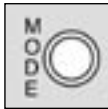
TYPICAL PPI-4B OPERATING CONTROLS
(WITH DISPLAY UNIT AND SYSTEM CONTROLS)



**PPI-4B
OPERATING
CONTROLS**



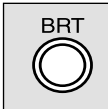
or



TCAS MODE SELECTOR

Windshear has priority over TCAS alerts. While in TCAS Only mode, a windshear event pops the system into WX/TCAS overlay mode displaying both windshear and TCAS information.

The crew can change mode by pressing the TCAS button again. Refer to appropriate TCAS operating handbook for instructions.



BRIGHTNESS CONTROL

Adjusts picture brightness.



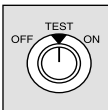
RANGE SELECTOR

Selects radar display range.



GAIN

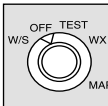
Controls receiver gain. Rotate fully clockwise for automatic gain. Gain is automatic in windshear only mode.



MODE SELECTOR

W/S

Windshear Only mode, ICON only, no weather returns. "W/S ONLY" annunciated, tilt and gain removed. When above 2300', "NO W/S DATA AVAILABLE" appears at the screen center indicating inappropriate mode selection.



OFF or STBY

Indicator is off unless turned on by ACARS, TCAS, EGPWS or Automatic Windshear activation.

TEST

Selects TEST mode.

WX

Radar is in weather mode.

WX/T

Combined weather and turbulence mode.

MAP

Ground mapping mode.



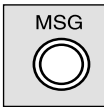
STAB

Control Antenna Stabilization.



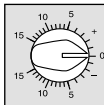
TILT

Selects Manual or Automatic Tilt Modes.



MSG or AUX

Enables ACARS mode. While in ACARS mode, a wind-shear event pops the system into WX/TCAS overlay mode. When advisories clear, the system reverts back to MSG mode. Refer to appropriate ACARS operating handbook for instructions.



TILT

Controls antenna tilt $\pm 15^\circ$. Tilt is automatic in wind-shear mode.



ABOVE / NORM / BELOW

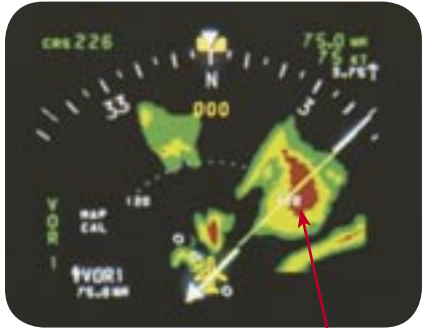
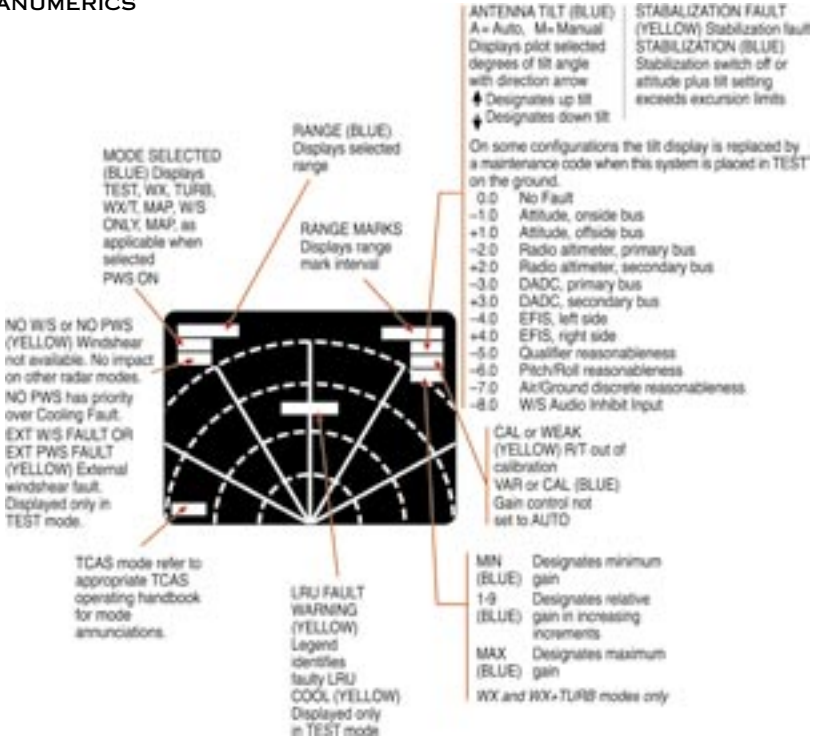
Switches the display mode between TCAS above (Climb phase), TCAS below (Descent phase) and Normal (Enroute phase).



FL

Changes TCAS target altitude to absolute altitude above MSL in FL format. Pressing the switch again transitions targets back to relative altitude reference.

DISPLAY ALPHANUMERICS



FOR AIRCRAFT EQUIPPED WITH EFIS, RADAR DISPLAY WILL APPEAR IN THIS AREA.

**TURN-ON
AND TEST**

Prior to leaving the gate, perform a system TEST. This will provide a comprehensive check of system performance. For turn-on and test use the following procedure.



Check that the following circuit breakers are set to ON.

- Attitude (IRU, IRS, AHRS, ADIRU)
- Rad Alt. (LRRA, radio altimeter, radar altimeter)
- Air Data (ADC, DADC or ADIRU)
- AMU (Audio Management Unit)



1. Set the radar system controls as follows:
 - a. Mode selector to TEST

Test function not available in some aircraft configurations.

- b. ANTENNA STAB (if provided) to ON
- c. GAIN to AUTO
- d. Range Selector to any range
- e. BRT to desired viewing level



Since the RDR-4B employs a solid-state transmitter, no warm-up period is necessary.

Selecting TEST mode begins a check of the system. The table below indicates approximate timing sequence of

TIME AFTER TEST IS INITIATED	Approx. 2 Sec.	Approx. 4 Sec.	Approx. 6 Sec.
PWS FAIL/INOP	ON	OFF ("ON" if failure is detected)	
PWS VISUAL ALERTS	OFF	Amber (CAUTION)	Red (WARNING)
PWS AURAL ALERTS	NONE	Tone "Whoop" "Whoop" or Monitor Radar Display"	"Go Around, Windshear Ahead, Windshear Ahead, Windshear Ahead"
DISPLAY	NORMAL TEST PATTERN (No PWS Icon)		

visual and aural alerts for normal operations.

Test Related Notes:

- PWS self test is inhibited when Windshear Mode is active (when in WX/TURB/MAP, or in TEST when engines-running/transponder-on).
- A PWS fault is considered a Soft Radar Fault and does not affect the Weather Radar operation
- If a fault is detected, the fail lamp will stay on during the entire Test sequence. In a fault condition, the Caution and Warning Annunciations and the Aural Alert may annunciate, although certain faults can inhibit these annunciations.
- The Test sequence shown above is the primary sequence. Certain early units do not inhibit PWS test effects in flight and use a sequence of the Test Pattern and Caution Annunciation together for two seconds followed by a Warning Annunciation for ten seconds.
- Optional Tone "Whoop" "Whoop" or "Monitor Radar Display" selected during installation.
- **Optional Configuration**—When in TEST and on the Ground, when Windshear mode is NOT active, the tilt value is displayed momentarily followed by maintenance codes.

- a. The presence of test bands.
- b. Observe that the alphanumeric legends (cues) appear.
- c. If the test bands are missing and the name of a line replaceable unit (LRU) appears on the PPI display, there is a fault in that unit. Refer to failure annunciations.

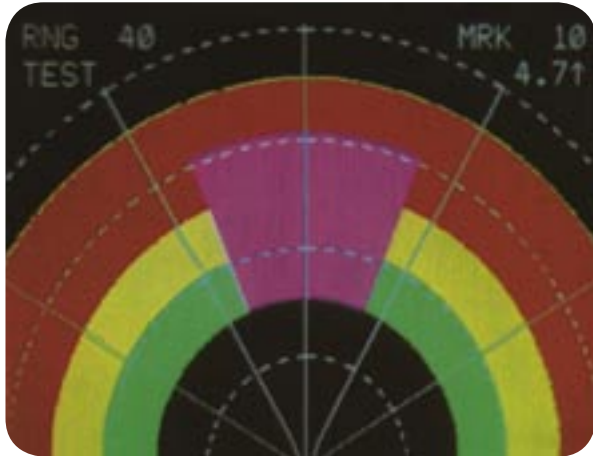


Some Electronic Flight Instrument System (EFIS) display units do not display all of the Test information shown on the PPI-4B display. Refer to the EFIS pilot instructions with regard to alphanumeric annunciations related to radar.



Test pattern display is similar for all ranges.

Typical Radar System Test Pattern for PPI-4B Indicators



If selected during system installation (Optional Configuration)—When in TEST and on the Ground, when Windshear mode is NOT active, the tilt value is displayed momentarily followed by maintenance codes.

Weather targets are color-coded by the intensity of the return. The display correlation to approximate

**WEATHER
AVOIDANCE**

Weather targets are color-coded by the intensity of the return. The display correlation to approximate rainfall is as follows:

		Rainfall Rate
Black	Very light or no returns	Less than 0.7 mm/hr.
Green	Light returns	0.7 - 4 mm/hr.
Yellow	Medium returns	4 - 12 mm/hr.
Red	Strong returns	Greater than 12 mm/hr.
Magenta	Turbulence	N/A

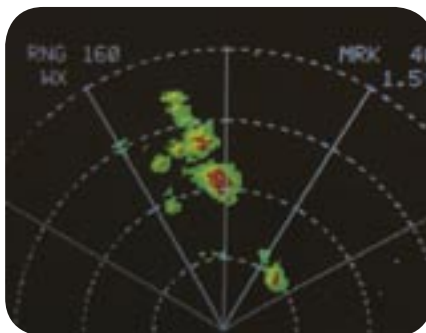
For weather avoidance operation, use the following procedures.



When weather appears within 40 NM on the display of a system equipped with TURB mode, use both WX mode and TURB mode to obtain the best analysis of the weather situation.



Effective tilt management is the single, most important key to more informative weather radar displays. Refer to Section 3 for Tilt Management guidelines.



TYPICAL WEATHER MODE DISPLAY

MANUAL
TILT

BEFORE TAKEOFF:

1. Perform TEST mode procedure.
2. Set Mode Selector to WX/TURB.
3. Set Range Selector to a range sufficient to display the area included in the planned flight path.
4. Adjust antenna TILT control down until ground returns appear. This ensures that the radar system is operational.
5. While observing for weather returns, slowly adjust the antenna TILT control in 1 or 2 degree steps to +15 degrees.
6. Return antenna TILT control to +4 degrees. Aircraft equipped with conventional gyros should use +7 degrees.

NOTE

The amount of background noise is not critical unless it obscures targets.

CLIMB-OUT

1. Shortly after takeoff, slowly rotate antenna TILT control to +15, then down to where ground returns appear, and then back to +4 degrees while searching for weather targets. Aircraft equipped with conventional gyros should use +7 degrees.

NOTE

Maintain tilt setting of +4 degrees (+7 degrees for aircraft equipped with conventional gyros) as long as aircraft's pitch attitude is approximately +15 degrees nose up or greater.

2. Repeat step 1 if course changes of 45 degrees or more are made during climb-out.

CRUISE

1. As soon as practical, after reaching cruise altitude, select the 40 NM range and set antenna TILT control to -10 degrees.



The following exercise ensures that the radar beam is not over-scanning any targets beginning at 30 or 40 miles out to the longest range.

- 2. While scanning and observing display for weather targets, adjust antenna TILT control clockwise until a sprinkle of ground return appears.
- 3. Repeat step 2 for each intermediate range through the longest range intended for use.

APPROACH

- 1. Just before descent from cruise altitude, note TILT control setting.
- 2. As descent begins, increase TILT control setting in +1 degree increments for each 10,000 feet of planned descent. This keeps the display relatively free of ground clutter.



After descending to approximately 15,000 feet and when flying over exceptional terrain such as mountains or cities, it may be necessary to adjust the TILT control setting in +1 degree increments of tilt for 5,000 feet of planned descent.

**TURBULENCE
DETECTION**

Turbulence detection is a weather radar system option. Refer to the Operating Controls section of this Pilot's Manual for turbulence detection control location to determine if this option is available on the weather radar system installed in the aircraft.

For turbulence detection and evaluation use the following procedure:



Turbulence detection requires the presence of precipitation. Therefore, turbulence detection does not display clear air turbulence.

CAUTION

Turbulence detection should be used only to isolate turbulence. Therefore, all areas displayed as red or magenta, whether turbulence or weather, should be avoided.

1. Select TURB mode.
2. Select desired range.

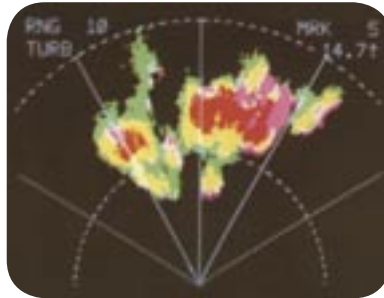
NOTE

Turbulence information is limited to the first 40 nautical miles. Turbulence within this range will be displayed in magenta along with the weather displayed in red, yellow and green. Some aircraft using an EFIS display will indicate turbulence as additional areas of red rather than magenta. Only weather will be displayed beyond the 40 NM turbulence limit when a range of more than 40 NM is selected.

3. Adjust antenna TILT control to eliminate ground returns within 40 NM if possible.

NOTE

Effective tilt management is important in obtaining the most informative displays. Excessive ground returns mixed with weather returns degrades the accuracy of the displayed information.



TYPICAL TURBULENCE DISPLAY

NOTE

Some EFIS lack the ability to display the magenta color. Those EFIS units display turbulence as additional areas of red. With those EFIS, alternately select TURB mode and WX mode as necessary to compare and obtain the best analysis of the weather situation.

MAP MODE

The RDR-4B Weather Radar System can be used in ground mapping mode to identify terrain features. The display colors in the MAP mode are the same as the WX mode. For ground mapping use the following procedure:

1. Set Mode Selector to MAP.
2. Select desired range.
3. Rotate antenna TILT control down (-) to obtain the most uniform display of terrain within the area of interest.

NOTE

Manual Tilt should be used when Analyzing Terrain and Storm Characteristics.

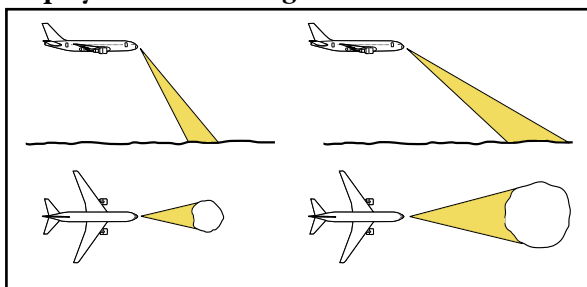
NOTE

Effective tilt management is the single most important key to more informative mapping displays. Refer to Section 3 for TILT Management guidelines.

4. If necessary, adjust GAIN control for optimum observation of terrain features.

NOTE

When Map Mode is selected and GAIN control is not set to AUTO, the blue CAL advisory will be displayed below tilt angle on the PPI.



ANTENNA TILT ANGLE VS. GROUND AREA COVERED

**REA-4A/B
PHASED
ARRAY**

Since short range terrain mapping has become a secondary requirement for many of today's air transport aircraft, the REA-4A/B antenna has been optimized for maximum performance when used for weather detection and long range (beyond 75 miles) terrain mapping utilizing only the pencil beam.

When scanning the terrain while flying at high altitude, the area covered by the pencil beam (at close ranges) will be significantly less than systems using the mapping beam or fan-shaped beam. It is also important to note that the greater the angle of down tilt, the closer the detected terrain will be to the aircraft and the smaller the area that will be covered by the antenna beam.

**MAPPING BEAM COVERAGE AT FL 330
(33,000 FT.)
AS A FUNCTION OF TILT ANGLE**

TILT ANGLE	AREA SCANNED
2° DN	100-190 NM
3° DN	72-190 NM
4° DN	56-190 NM
5° DN	47-190 NM
6° DN	41-96 NM
7° DN	36-70 NM
8° DN	32-56 NM
10° DN	26-41 NM
12° DN	23-32 NM

MANUAL GAIN

On some control panel configurations, the GAIN control is operative in the weather (WX) or turbulence (TURB) mode. In these systems, the GAIN control can be adjusted. An alphanumeric readout of the relative position of the GAIN control is provided on the indicator. Immediately after moving the GAIN control out of the detent (AUTO) position, the blue “CAL” or “VAR” annunciation appears in the upper right corner of the display indicating that the system is out of calibration. Also, a blue “MAX” will be displayed directly under the “CAL” legend. Rotating the GAIN control counterclockwise provides a decreasing numeric readout: 9, 8, 7, 6, 5, 4, 3, 2, and 1 to indicate gain control. At the fully counterclockwise position of the GAIN control (MIN), the legend “MIN” appears. Refer to Section 3 for operating guidelines.

NOTE

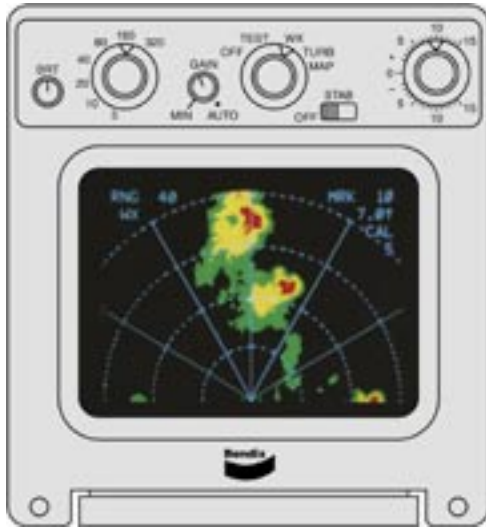
The GAIN control should always be returned to the AUTO position before evaluating weather in other areas or searching for distant targets.

NOTE

When updating from older RDR-4B to newer RDR-4B systems, the gain control may be perceived to be more sensitive. This is due to Gain Control Improvements introduced on newer units.



GAIN CONTROL JUST SWITCHED OUT OF AUTO POSITION



ROTATING GAIN CONTROL COUNTERCLOCKWISE
 CAUSES DECREASING NUMERIC READOUT
 FROM 9 TO 1



GAIN CONTROL FULLY COUNTERCLOCKWISE

**FORWARD
LOOKING
WINDSHEAR**

The **Forward Looking Windshear** feature detects the presence of windshear, giving 10 to 60 seconds of warning before the encounter. Windshear detection mode operates automatically below 2300' AGL with alerts given at 1500' AGL and below. The system scans for Windshear $\pm 40^\circ$ and 5 nm ahead of the aircraft and automatically operates antenna tilt during the windshear scans. If a windshear event is detected when the radar is OFF or STBY, the system automatically provides the crew with an Advisory, Caution and/or Warning annunciation, Windshear ICON and Audio announcement.

NOTE

The Forward Looking Windshear (FLW) feature is also addressed herein as “Windshear System” (W/S) or “Predictive Windshear System” (PWS).

ALERTS

The PWS can generate three types of alerts - **Advisory, Caution and Warning** depending on the location of the Windshear event, not the strength. When a Windshear event is encountered below 1500ft AGL, an alert is issued and the icon automatically appears on the display. Should the indicator be in a mode of operation other than weather (such as TCAS) when a windshear event takes place, the indicator automatically switches into the weather mode for presentation of the windshear icon.

NOTE

The system will operate in the Windshear mode continuously below 2,300 ft when the system is in the OFF, STBY or in the Windshear ONLY Mode (optional W/S ONLY Mode selection on Control Panel). If an active mode is selected (system turned on to WX/TURB/MAP) the Windshear will be operating in the alternate scan mode (See “PWS Alternate Scanning” in this section).

NOTE

This system is considered an adjunct to other means for detecting and avoiding hazardous Windshear conditions. It will not detect all possible hazardous Windshear conditions such as extremely dry events or events masked by unusual radar clutter.

**ADVISORY
ALERTS**

- **Standard Configuration:**
Between 1,500 and 1,200 ft AGL the system generates ADVISORY ALERTS which are presented on the radar indicator by displaying the Windshear Icon (no aural alerts).
- **Optional Configuration:**
NO ADVISORY ALERTs

**CAUTION
ALERTS**

- **Standard Configuration:**
Between 1,200 and 50 ft AGL the system generates visual and aural CAUTIONS alerts plus the Windshear Icon. (New Caution Alerts are inhibited above 100kts when radio altitude is below 50ft AGL for both take-off and approach)
- **Optional Configuration:**
Between 1,200 and 400 ft AGL the system generates visual and aural CAUTIONS alerts plus the Windshear Icon. (New Caution Alerts are inhibited above 80kts when radio altitude is below 400ft AGL for both take-off and approach).

**WARNING
ALERTS**

Between 1,200 and 50 ft AGL the system generates visual and aural WARNING alerts plus the Windshear Icon. (New Warning Alerts are inhibited above 100kts when radio altitude is below 50ft AGL for both take-off and approach)

**ALERTS
DISPLAYED
WHILE IN
“TEST”
POSITION**

If a Windshear event is encountered while the system is on TEST, the Windshear icon will be displayed as described below:

- **Standard Configuration:** If a Windshear event is encountered while in TEST, the windshear ICON will overlay the test pattern.
- **Optional Configuration:** If a Windshear event is encountered while in TEST, the Test Pattern will be removed and the windshear ICON pops-up in WX mode.

**AIRCRAFT
CONFIGURA-
TION**

The RDR-4B system operates by receiving inputs from the following aircraft systems, and supplies the flight crew with aural and visual alerts annunciations and Icon displays in the event of a Windshear encounter:

- Radio Altimeter, Air Data Computer, VG/DG/AHRS/IRS/ADIRS, EGPWS (Optional), Transponders, Engines - Oil Pressure, Air/Ground Discrete and Landing Gear Discrete.

**AUDIO
PRIORITIZATION**

Depending on the installation and equipment in the aircraft, the RDR-4B can be configured to allow the following Audio messages priorities for warnings and advisories.

BASIC AUDIO PRIORITIZATION

1. Reactive Windshear System (RWS)
2. Predictive Windshear System (PWS)
3. Ground Proximity Warning System (GPWS)
4. Traffic Collision And Avoidance System (TCAS)



NOTE

When the RDR-4B is interfaced to the Enhanced Ground Proximity Warning System (EGPWS) the message/display prioritization can be enhanced.

**AUDIO PRIORITIZATION AVAILABLE WHEN
INTEGRATED WITH THE EGPWS**

1. Reactive Windshear
2. GPWS Mode 1 Warning
3. GPWS Mode 2 Warning
4. EGPWS Terrain Warning
5. Predictive Windshear Warning
6. GPWS Mode 1-5 and EGPWS Caution
7. Predictive Windshear Caution
8. TCAS RA
9. TCAS TA



NOTE

When a PWS aural alert is set and generated through the cockpit audio system and a higher priority GPWS alert condition becomes active, the PWS will finish its aural alert prior to the GPWS alert being generated.

**AUTOMATIC
WINDSHEAR
ACTIVATION**

For the Windshear mode to be automatically turned-on, some specific Aircraft Systems must be in normal operating modes, such as:

Transponder = ON and Engine = Running or Engine = Take-Off Thrust



NOTE

Some aircraft use engine take-off thrust alone, instead of a combination of engine running and transponder.



NOTE

In case of a windshear alert, refer to your air-line recovery procedures for avoiding a windshear encounter.

**WINDSHEAR
OPERATION
DURING TAKE-
OFF**

Caution: Take-Off Caution Alert region is $\pm 25^\circ$ from the aircraft heading and up to 3.0 nm and at least 0.5 nm in front of the aircraft.

Warning: Take-Off Warning Alert region is ± 0.25 nm from the aircraft centerline (heading) and up to 1.5 nm and at least 0.5 nm in front of the aircraft. On the ground, the Warning range is extended to 3.0 nm (See Take-Off figure on page 44).

The airplane is considered in the windshear take-off condition when the following occurs.

- The airplane is on the ground.
- The landing gear transitions from DOWN to UP (normal takeoff and touch and go's).



NOTE

For Standard Configuration, Caution and Warning Alerts are Inhibited above 100 kts when radio altitude is below 50 feet AGL.



NOTE

For Optional Configuration, Caution Alerts are Inhibited above 80 kts when radio altitude is below 400 feet AGL.

**WINDSHEAR
OPERATION
DURING
APPROACH**

Caution: Approach Caution Alert region is $\pm 25^\circ$ from the aircraft heading and up to 3.0 nm and at least 0.5 nm in front of the aircraft.

Warning: Approach Alert region is ± 0.25 nm from the aircraft centerline (heading) and up to 1.5 nm and at least 0.5 nm in front of the aircraft. Below 375 feet AGL, the warning range is gradually reduced from the 1.5 nm range to 0.5 nm depending on aircraft radio altitude. This feature prevents any Windshear alerts for Windshear events located beyond the assumed landing portion of the runway (see Windshear Approach figure in this section).

The airplane is considered in the windshear approach condition when the following occurs:

- For Standard Configuration Radio altitude has exceeded 2,000 ft AGL, after Takeoff.
- For Optional Configuration Radio Altitude has exceeded 2,400 ft AGL, after Takeoff.
- Landing gear transitions from UP to DOWN.



For Standard Configuration, Caution and Warnings Alerts are Inhibited above 60 kts when radio altitude is below 50 feet AGL



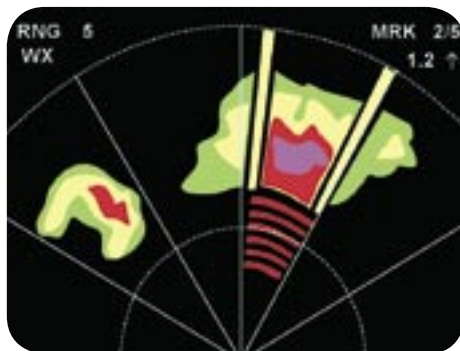
For Optional Configuration, Caution Alerts are Inhibited above 60 kts when radio altitude is below 400 feet AGL

PWS AIRCRAFT PERFORMANCE PARAMETERS

The following shows functionality differences (selected during installation) between Standard Configuration and Optional Configuration.

STANDARD Configuration	OPTIONAL Configuration
Advisory Alert Enabled below 1500	NO ADVISORY ALERT
Advisory, Caution and Warning Alerts are INHIBITED above 100Kts when radio altitude is below 50FT AGL. In Take-Off, Alerts are INHIBITED below 50 FT SOFT AGL and above 60Kts in Approach.	<ul style="list-style-type: none"> • Caution Alert is INHIBITED above 60Kts approach 80Kts takeoff when radio altitude is below 400FT AGL. • Warning Alert is INHIBITED above 100Kts when radio altitude is below 50FT AGL.
NOTE: Existing Caution and Warning events will not be removed, New events will be inhibited.	
In air, Windshear Mode is NOT activated if Auto Activation Inputs are invalid.	Windshear Mode is AUTO-ACTIVATED in air regardless of Auto Activation Inputs condition. When in air, if Auto Activation Inputs are OFF, PWS FAIL annunciation is delayed and then annunciated on landing when below 80Kts.
NOTE: Auto Activation Inputs - Specific systems interfaces to the aircraft must be in normal operating condition for auto-activation of the Windshear mode. Depending on installation these systems may be such as Engine Running, Transponder-On or Engine Take-off trust.	
If a Windshear event is encountered while in TEST mode, the Windshear Icon overlays the test pattern.	If a Windshear event is encountered while in TEST mode, the test pattern is removed and the Icon pops-up in WX mode.
When selected to TEST and on the Ground, when Windshear mode is NOT active, the tilt indication is normal (reads tilt setting).	When selected to TEST and on the Ground, when Windshear mode is NOT active, the tilt value is displayed momentarily followed by signal input maintenance codes.

FLIGHT DECK
EFFECTS/
ANNUNCIATION
VISUAL &
AURAL



Windshear Icon

- Windshear Icon is displayed for Advisory, Caution and Warning.

Windshear Icon - The Windshear icon shown on the screen represents size and location. Windshear is detected 2 miles ahead and slightly to the right.

The Windshear Icon will be displayed for Advisory, Caution and Warnings. The type of Alert displayed depends of several factors including your present altitude, flight phase (approach or takeoff) and proximity to the windshear event.

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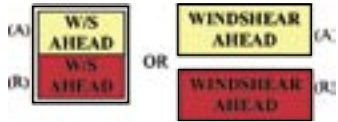
**WINDSHEAR
VISUAL
CAUTION AND
WARNING**

VISUAL ANNUNCIATION

Visual Caution and Warning Alerts can be annunciated on Electronic Displays and/or dedicated annunciator lamps on the Pilot's and Copilot's Panels (typical annunciation legend below)

Dedicated Annunciator Lamps (typical)

- **Caution:** Amber "W/S AHEAD"
- **Warning:** Red "W/S AHEAD"



Electronic Displays Annunciation (typical)

- **Caution:** Amber "WINDSHEAR"
- **Warning:** Red "WINDSHEAR"

AURAL ALERTS

Caution and Warning Alerts are generated the cockpit audio system.

Caution Aural Caution Alerts may be generated as one of the following:

- Tone: "Whoop, Whoop"
- A message: "Monitor Radar Display"

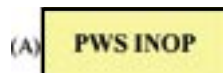
Warning Aural Alerts are generated as follows:

- **Take-Off:** "Windshear Ahead, Windshear Ahead"
- **Approach:** "Go Around, Windshear Ahead"

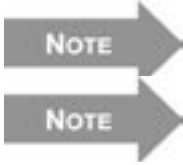
SYSTEM FAILURE ANNUNCIATION

A system failure is annunciated on the Radar Indicator (PPI-4B), Electronic Displays and/or dedicated annunciator lamp.

- PWS INOP or PWS FAIL: Amber annunciator typically located on the center instrument panel.



- NO W/S or NO PWS: Amber annunciation located on upper LH corner of the Radar Indicator (PPI-4B).



Windshear System Failure is considered a Soft Failure and may not impact other radar modes

EXT PWS FAULT is annunciated while in TEST mode due to loss of radar altimeter, air data or heading information (When in any operational mode (WX/TURB/MAP), loss of radar altimeter annunciates NO W/S or NO PWS).

PWS VISUAL AND AURAL ALERTS

WINDSHEAR VISUAL AND AUDIO ALERTS			
ALERT LEVEL	Advisory	Caution**	Warning
VISUAL ALERT	*ICON	Amber Annunciation	Red Annunciation
AURAL ALERT	NONE	Tone <i>“Whoop”</i> or <i>“Monitor Radar Display”</i>	Takeoff: <i>“Windshear Ahead, Windshear Ahead,”</i> Landing: <i>“Go Around, Windshear Ahead”</i>
DISPLAY	PWS ICON (Red Arcs with Yellow Strokes)		

*Optional Advisory Icon Inhibit selected during installation.

** Option Tone *“Whoop”*, *“Whoop”* or *“Monitor Radar Display”* selected during installation.

PWS ALTERNATE SCANNING

Below 2300 FT.AGL, windshear operations use an alternate antenna scan technique for radar and windshear detection. Windshear operation is transparent to the crew unless an alert is issued, however, you might notice that the weather update rate could be delayed by as much as 12 seconds due to sharing of antenna scan between windshear and radar.

The antenna scan pattern varies dependent on the mode of operation. When the system is activated an alternate weather/windshear mode, the antenna scan is as follows:



During the Windshear scans, the antenna tilt setting is automatic. The tilt setting displayed on the indicator reflects the tilt setting for weather scans.



When in the alternate scan mode, (below 2300 AGL), the weather display is updated during the weather scan ONLY (the display is updated in the clockwise sweep).

**WEATHER/
WINDSHEAR
SCAN**

When the system is in an alternate Weather/Windshear mode of operation, during the following conditions:

- *Between 2300-1500 AGL and*
- *Below 1500 AGL with NO DETECTION when in APPROACH*

1. Clockwise Scan: Weather (WX display is updated during all CW scans)
2. Counter Clockwise Scan: Windshear (Display not updated)
3. Clockwise Scan: Weather (At the end of this sweep the cycle starts again, step-2 (Approx. 4 sec.).

**WEATHER/
WINDSHEAR
SCAN BELOW
1500 AGL**

When the system is in an alternate Weather/Windshear mode of operation and the system DETECTS a windshear event during the following conditions:

- *Below 1500 AGL with DETECTION when in APPROACH*
- *Below 1500 AGL during TAKE-OFF condition.*

1. Clockwise Scan: Weather (Both WX and Windshear Icon is updated during all CW scans)
2. Counter Clockwise Scan: Windshear (Icon location is updated)
3. Clockwise Scan: Windshear (Icon location is updated)

-
4. Counter Clockwise Scan: Windshear (Icon location is updated)
 5. Clockwise Scan: Weather (At the end of this sweep the cycle starts again, step-2 (Approx. 9 sec).

**WINDSHEAR
ONLY SCAN**

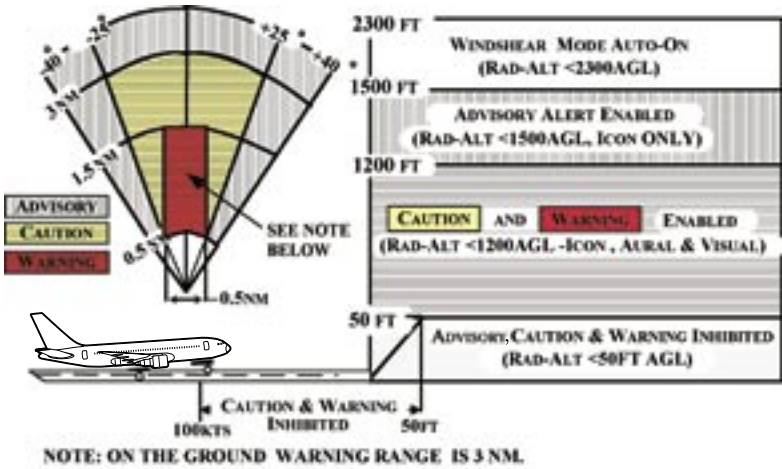
The Windshear ONLY Mode occurs if the operator has a windshear ONLY control panel or if the system is in STBY or OFF mode below 2300ft AGL. When in the Windshear ONLY Mode, there are no Weather Scans.

When the system is selected to STBY or OFF or W/S ONLY and a Windshear event is detected, the PPI-4B Radar Display will be automatically turned on to the windshear ONLY mode. (Except 2041222-6429)

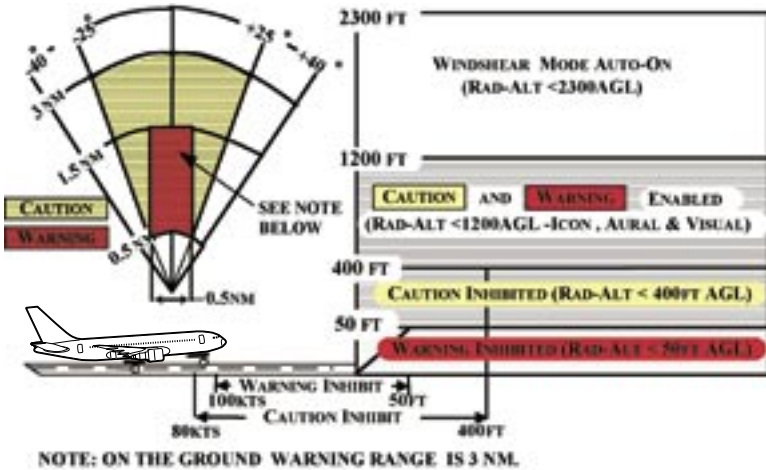
On some EFIS equipped aircraft, the Primary Flight Displays (PFD) do not allow radar display information to be automatically turned "On" (radar mode must be selected manually). However, windshear alerts, both visual and aural (CAUTION/WARNING), will be annunciated if a Windshear event is encountered.

1. All Clockwise and Counter Clockwise Scans : Windshear (No WX). Only the PWS Icon (if present) is displayed and updated every scan.

TAKE-OFF

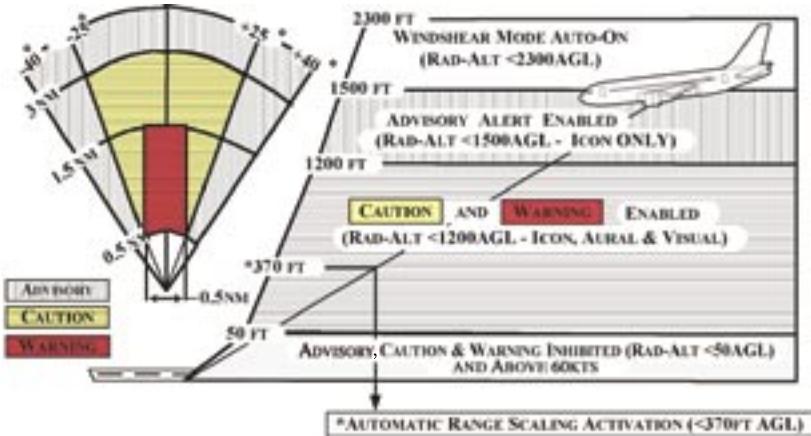


Standard Configuration—Windshear TAKE-OFF

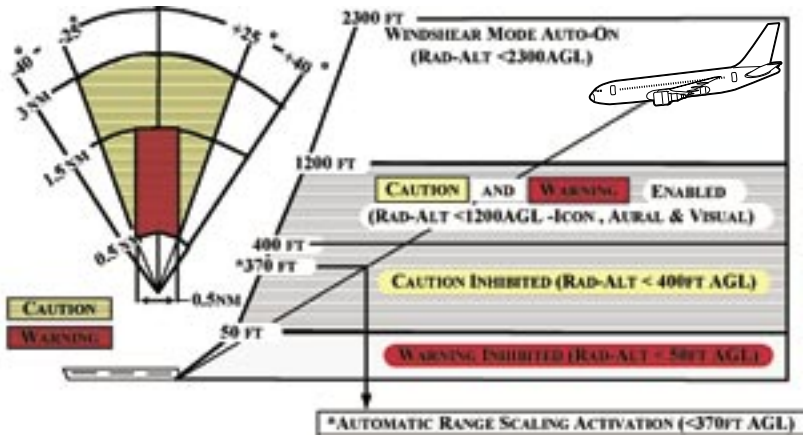


Optional Configuration—Windshear TAKE-OFF

APPROACH



Standard Configuration—Windshear APPROACH



Optional Configuration—Windshear APPROACH

**FAULT
ANNUNCIATIONS**

Fault annunciations are a method of alerting the pilot that the radar system is not performing to established standards. Built-in test equipment (BITE) automatically and constantly tests the radar system. If a fault occurs, the fault annunciation will be presented on the Display Unit. There are two general categories of faults: Soft Failures and Hard Failures. The actual fault annunciation on the display depends upon the system mode of operation. By careful observation of the display, you can quickly evaluate the condition of the RDR-4B.

If a system failure occurs when operating in the TEST mode, the test pattern will disappear and be replaced by the name of the unit in which the failure is located.

When the system is in WX, MAP, or TURB mode, Soft Failures will appear as yellow caution annunciations in the corner of the display unit. The radar display will be maintained during a Soft Failure. A Hard Failure, however, will cause the radar display to disappear entirely and be replaced by the name of the faulty unit. See PPI-4B Alphanumeric Displays for details.

EXT W/S FAULT OR EXT PWS FAULT is annunciated while in TEST mode due to loss of radar altimeter, air data or heading information. When in any operational mode, loss of radar altimeter annunciates NO W/S.



Soft Failures are those which can cause limited system operation. Radar data will still be displayed but the flight crew should be aware that the display does not truly represent the weather. Soft Failures are typically a result of reduced transmitter power, a cooling problem, a stabilization fault, or other similar problems.

TYPICAL DISPLAY FOR STABILIZATION FAILURE



ANNUNCIATIONS (YELLOW)

Annunciation	Location	Failure	Effects
CAL	Below tilt angle	R/T out of calibration	Weak targets-use with caution
STAB	Replaces tilt angle	Stabilization input	System is stabilized with respect to aircraft, no pitch or roll stabilization.
COOL (TEST Mode) NO W/S (Operational Mode)	COOL Center NO W/S Below mode annunciation	R/T cooling air	System may fail if continued operation allowed. System should be checked at earliest convenience.

NOTE

Hard Failures are those which occur when a major function of the system is lost. Hard Failures are typically a total loss of transmitter power, receiver gain or no antenna scan. Turn off system or in a dual installation select the other system. Should the system be left on further damage to other system components could occur.

AUTOTILT® FAILURE ANNUNCIATION

The following will occur when the Automatic Tilt function is selected but unavailable:

- “NO AUTOTILT®” message is displayed and the weather display is removed.
- Tilt setting display is set to -15.5° down.



TYPICAL AUTOMATIC TILT FAULT INDICATION

If automatic tilt has failed, then the TILT switch on the radar control unit MUST be set to MAN. The failure message will be removed on the next weather scan.

NOTE

Windshear Icon has priority over the “NO AUTOTILT®” message.

NOTE

The Failure indication (message) may vary depending on EFIS interface



TYPICAL DISPLAY FOR R/T FAILURE

HARD FAILURE ANNUNCIATIONS (YELLOW)

Annunciation	Failure
R/T FAULT	R/T unit failure
ANT FAULT	Antenna fault
CON FAULT or	Control fault or Waveguide
ATT FAULT	Attitude fault
IND FAULT	Indicator fault
COOL FAULT	R/T unit cooling fault



LRU (line replaceable unit) fault warning legend may be one or more of the above.



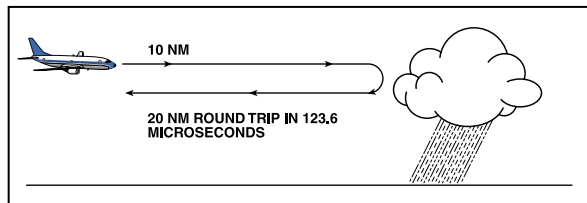
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RADAR PRINCIPLES

Radar is fundamentally a distance measuring system using the principle of radio echoing. The term RADAR is an acronym for Radio Detection And Ranging. It is a method for locating targets by using radio waves. The receiver transmitter unit generates microwave energy in the form of pulses. These pulses are then transferred to the antenna where they are focused into a beam by the antenna. The radar beam is much like the beam of a flashlight. The energy is focused and radiated by the antenna in such a way that it is most intense in the center of the beam with decreasing intensity near the edge. The same antenna is used for both transmitting and receiving. When a pulse intercepts a target, the energy is reflected as an echo, or return signal, back to the antenna. From the antenna, the returned signal is transferred to the receiver and processing circuits located in the receiver transmitter unit. The echoes or returned signals are displayed on a scope called a Plan Position Indicator (PPI).

Radio waves travel at the speed of 300 million meters per second and thus yield nearly instantaneous information when echoing back. Radar ranging is a two-way process that requires 12.36 microseconds for the radio wave to travel out and back for each nautical mile of target range. As shown in the distance illustration below, it takes 123.6 microseconds for a transmitted pulse of radar energy to travel out and back from an area of precipitation 10 nautical miles away.



RADAR WAVE TIME/DISTANCE RELATIONSHIP

The RDR-4B transmits and receives at an extremely high frequency (9.345 GHz) where the wavelengths are very short (3.2 CM). This makes it possible to build highly directional antennas that are small enough to fit into the nose cones of most aircraft. These short waves, called microwaves, travel in straight, searchlight beam fashion. Thus, the direction from which a reflection returns is indicated by the angular position of the antenna, at any instant, with respect to aircraft heading.

**WEATHER
RADAR
PRINCIPLES**

Airborne weather avoidance radar, as its name implies, is for avoiding severe weather-not for penetrating it. Whether to fly into an area of radar echoes depends on echo intensity, spacing between the echoes, and the capabilities of both pilot and aircraft. Remember that weather radar detects only precipitation; it does not detect minute cloud droplets. Therefore, the radar display provides no assurance of avoiding instrument weather in clouds and fog. Your display may be clear between intense echoes; this clear area does not necessarily mean you can fly between the storms and maintain visual separation from them.

The geometry of the weather radar radiated beam precludes its use for reliable proximity warning or anti-collision protection. The beam is characterized as a cone shaped pencil beam. It is much like that of a flashlight or spotlight beam. It would be an event of chance, not of certainty, that such a beam would come upon another aircraft in flight.



Weather radar is not practical as a pilot operable terrain or collision avoidance system. Weather analysis and avoidance are the functions of the radar system.

Weather radar detects droplets of precipitation size. The strength of the radar return (echo) depends on drop size, composition and amount. Water particles

return almost five times as much signal as ice particles of the same size. This means that rain is more easily detected than snow, although at times large, wet snowflakes may give a strong return.

Hail usually has a film of water on its surface; consequently, a hailstone is often reflected as a very large water particle. Because of this film and because hailstones usually are larger than raindrops, thunderstorms with large amounts of wet hail return stronger signals than those with rain. Although wet hail is an excellent reflector of radar energy, some hail shafts are extremely small (100 yards or less). These narrow shafts make poor radar targets. If hailstones are cold and dry, they give only poor target returns and might not appear on the display as targets.



NOTE

The best way to identify hail-containing storms is to recognize their characteristic shape as seen on the display. Refer to Path Planning Considerations.

Meteorologists have shown that drop size is almost directly proportional to rainfall rate. The greatest rainfall rate is in thunderstorms and therefore, the strongest echoes are from thunderstorms. Hailstones usually are covered with a film of water and act as huge water droplets giving the strongest of all echoes. Showers show less intense echoes and gentle rain, snow, and dry ice return the weakest of all echoes.

Since the strongest echoes identify thunderstorms, they also mark the areas of greatest hazards. Radar information can be valuable both from ground based radar for preflight planning and from airborne radar for severe weather avoidance.

**WEATHER
TIPS**

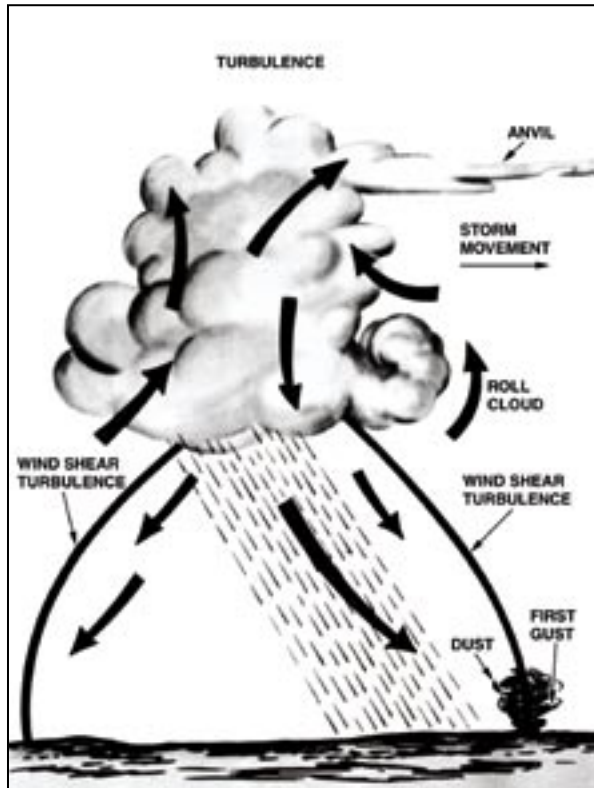
A weather radar is only as good as the operator's interpretation of the echoes that are displayed on the indicator. The pilot must combine his knowledge of how radar works and its limitations with such things as the prevailing weather pattern, the geographic location, and his personal experience to make a sound interpretation of the displayed targets. As a starting point, the operator should read FAA Advisory Circular number 00-24B, Subject: Thunderstorms, which is printed in section 5 of this Pilot's Manual.

**THUNDERSTORM
FLYING**

Thunderstorms build and dissipate rapidly. Therefore, you **SHOULD NOT** attempt to pre-plan a flight plan course between closely spaced echoes. The best use of ground radar information is to isolate general areas and coverages of echoes. You should avoid individual storms from in-flight observations either by visual sighting or by airborne radar.

Updrafts in thunderstorms support abundant water; and when carried above the freezing level, the water becomes supercooled. When temperature in the upward current cools to about -15°C , much of the remaining water vapor sublimates as ice crystals; and above this level, the amount of supercooled water decreases.

Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level; but at high levels, icing may be rime or mixed rime and clear. The abundance of supercooled water makes clear icing occur very rapidly between 0°C and -15°C , and encounters can be frequent in a cluster of cells.



**WINDSHEAR
WEATHER
RADAR
(MICROBURST
DETECTION)**

During both takeoffs and landings, microbursts have been the cause of numerous transport aircraft accidents. The Honeywell RDR-4B Forward Looking Windshear Detection/Avoidance Weather Radar System has the capability to detect the presence of microbursts up to 5 NM ahead of the aircraft flight path when below 1500 feet AGL.

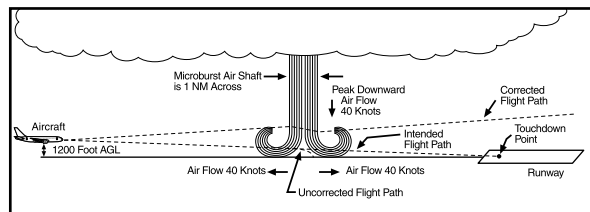
A microburst is a cool shaft of air, like a cylinder, between 1/2 and 1 1/2 NM across that is moving downward. When it encounters the ground the air mass mushrooms in a horizontal direction curling inward at its edges. The downward air velocities associated with these narrow air shafts range from 20 to 40 knots.

When the downward moving air flow is translated to a horizontal flow at the base of the air shaft, the outflow winds have front-to-back velocities ranging from 20 to 80 knots.

Two types of microbursts exist, wet and dry. A wet microburst is characterized by the rain droplets within the air shaft falling all the way to the earth's surface largely intact. This type of event is typical of humid areas like the southeastern part of the United States. A dry microburst is characterized by virga, rain that exits from the cloud base, but substantially evaporates before reaching the ground. Virga occurs in high based rainstorms found in places like the high plains and western United States. Regardless of whether the microburst is wet or dry, the air shaft's wind characteristics are identical.

The air shaft of a microburst creates problems for aircraft for two reasons. The first problem is due to the downward air movement. Since the aircraft is flying within the air mass, as the air mass plummets earthward, so does the aircraft. Second, the lift that is generated by the wing is related to the relative velocity of air traveling over the wing. If the air velocity suddenly changes, so does lift. When the lift is reduced, the aircraft descends. As an aircraft enters a microburst, depending on the point of entry, it will experience at least one of these conditions and most probably both.

The key to surviving a microburst is to enter it at a high enough aircraft energy state (high altitude and fast airspeed) so that you will exit while remaining well above the aircraft stall speed.



MICROBURST ENCOUNTER EXAMPLE

WINDSHEAR/
MICROBURST
DETECTION
PROCESS

When the airshaft of a microburst encounters the ground, it mushrooms outward carrying with it a large number of the falling raindrops. By measuring the horizontal velocity of these water droplets the Honeywell RDR-4B is able to infer the horizontal and vertical velocity of the winds carrying the raindrops.

The radar processor detects the doppler frequency shift imparted onto the reflected microwave pulses by a microburst. As the radar scans across the windshear event, it will detect raindrops moving toward it at one range and away from it at a slightly greater range.

The difference in the range between the raindrops moving toward and away is the width of the base of the microburst. After the radar detects this condition, it then proceeds to assess the severity of the event by measuring how fast the droplets are moving. If the assessment of the severity of the microburst exceeds a preset threshold value, a windshear alert is issued on the radar display and through the flight deck audio system.

ANTENNA
STABILIZATION
CONSIDERATIONS

Stabilization is the method of maintaining a constant angle between the weather radar antenna and the target area being scanned, regardless of variations in the aircraft pitch and/or roll attitude. To accomplish this, the RDR-4B Radar System receives roll and pitch stabilization input signals from either the aircraft's vertical gyro or Attitude Heading Reference System (AHRS) which is usually a part of the Inertial Navigation or Reference System.

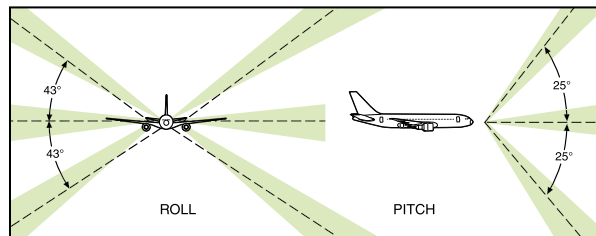


NOTE

Standard vertical gyros have inherent characteristics which greatly affect radar system operation, causing problems often erroneously attributed to the radar. Aircraft with AHRS have minimum stabilization errors and are immune to aircraft accelerations which cause the stabilization errors in aircraft equipped with a vertical gyro only.

Stabilization limitations of the antenna beam may be exceeded during aircraft maneuvers. For the DAA-4A Drive Assembly, these limitations are mechanically fixed at ± 25 degrees from zero in pitch and ± 40 degrees from zero in roll. For the combined Tilt/Pitch/Roll limit of ± 43 degrees.

MECHANICAL/ELECTRICAL STABILIZATION LIMITS
(DAA-4A)



For the DAA-4B Drive Assembly, stabilization limits are mechanically fixed at ± 15 degrees from zero in the pitch axis and ± 30 degrees from zero in roll, for combined tilt/pitch/roll limit of ± 35 degrees.

Combinations of pitch/roll and tilt which exceed these limitations will diminish stabilization effectiveness. Pitch/roll is a complex quantity, not an arithmetic sum.

Antenna stabilization is not effective when the pitch and roll stabilization excursion limits are exceeded. Remember, the degree of antenna tilt selected, using the antenna tilt control, is either deducted from or added to the stabilization excursion limits with regard to aircraft pitch and roll; e.g., if the antenna tilt control has been set for +7 degrees and the aircraft is banked 40 degrees, the stabilization excursion limit would be exceeded.

NOTE

Refer to Section 4 Antenna Stabilization for more detail.

**WEATHER
RADAR
OPERATING
TIPS**

PREFLIGHT AND CLIMB-OUT TIPS

Make it a part of your preflight to check the radar prior to leaving the ramp.

While taxiing or when the aircraft is clear of the terminal area and other aircraft, select the shortest range on the indicator, set the Mode Selector to WX, and then adjust the antenna tilt downward until ground echoes appear at the top of the display. This is a confidence check to ensure the radar is operational.



When viewing hazardous weather in the immediate airport vicinity, select a range between 20 and 60 miles, depending upon system configuration. While observing for weather returns, slowly rotate the antenna tilt in 1 or 2 degree steps from zero to +15 degrees and back to +4 degrees. Aircraft equipped with conventional gyros should use +7 degrees.

Repeat this avoidance procedure after take-off and during climb-out by tilting the antenna from full up to down tilt where ground returns appear, then back to +4 degrees. Again, aircraft equipped with conventional gyros should use +7 degrees.



Non-precipitating clouds generally are composed of very small droplets - too small to be detected by radar. Cloud echoes will be faint if seen at all.

Weather analysis and avoidance are the functions of the radar system. A typical profile of a thunderstorm is shown in the illustration below. Radar detects the various levels of precipitation and displays it on the display indicator as green (light), yellow (moderate) and red (heavy precipitation).

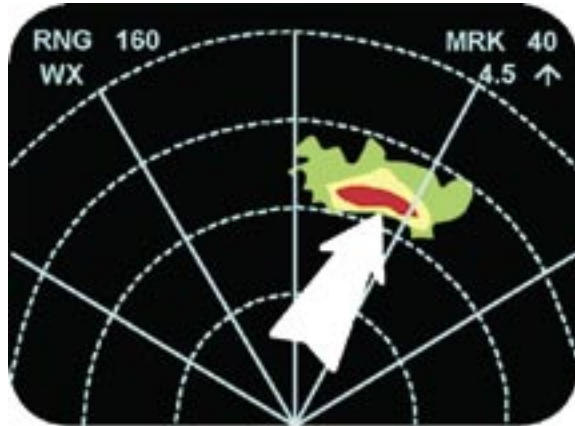


WEATHER CELL PROFILE

NOTE

During climb-out, aircraft using vertical gyros for antenna stabilization may experience lopsided radar presentations due to precession caused by acceleration forces. This will disappear as airspeed stabilizes. Aircraft using INS reference for radar stabilization are not affected by acceleration forces.

Rainfall gradients can also be observed and are very important. Closely spaced or thin lines between color gradations as shown below are usually associated with severe turbulence and should be avoided.



COLOR GRADATION VS. TURBULENCE INTERPRETATION

IN-FLIGHT OPERATING TIPS

Radar Target Reflectivity

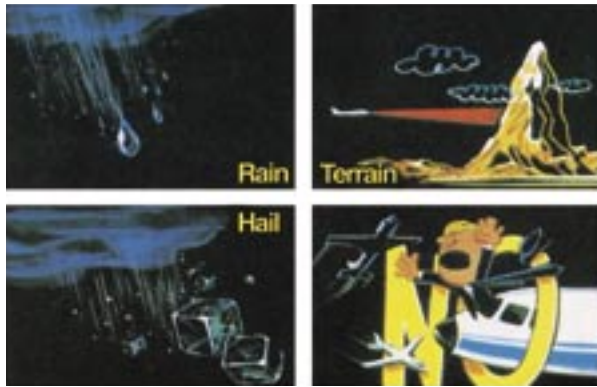
Weather radar's primary role is to detect droplets of precipitation which are generally associated with areas of turbulence and severe weather.



Radar detects rain drops and wet hail, not clouds, fog, snow or ice.

Because of their obvious mass, mountains and other large terrain features are also excellent reflectors of radar energy and provide strong radar echoes.

Large wet hail is an excellent reflector of radar waves because it appears as large water droplets. Small dry hail and ice crystals are poor reflectors of radar energy.



RADAR TARGET REFLECTIVITY

NOTE

Weather radar is not practical as a pilot operable collision avoidance system. Weather analysis and avoidance are the primary functions of the radar system.

NOTE

It is important to remember that radar detects the presence of precipitation. Storm associated turbulence without precipitation can extend several thousand feet above a storm and outward more than 20 miles.

NOTE

Manual Tilt should be used when Analyzing Terrain and when Analyzing Storm Characteristics.

TURBULENCE
DETECTION/

NOTE

It is important to remember that turbulence detection requires the presence of precipitation and clear air turbulence is not detected or displayed.

RDR-4B systems having the turbulence detection option process the weather returns to indicate areas of precipitation with moderate to high turbulence. This capability enhances the rainfall intensity information provided by the basic radar to enable pilots to avoid threatening weather.

Turbulence is displayed on the radar or Electronic Indicator in an extra color-magenta-which is overlaid on the conventional weather (precipitation) returns displayed in red, yellow, or green, depending on the rainfall rate. The system

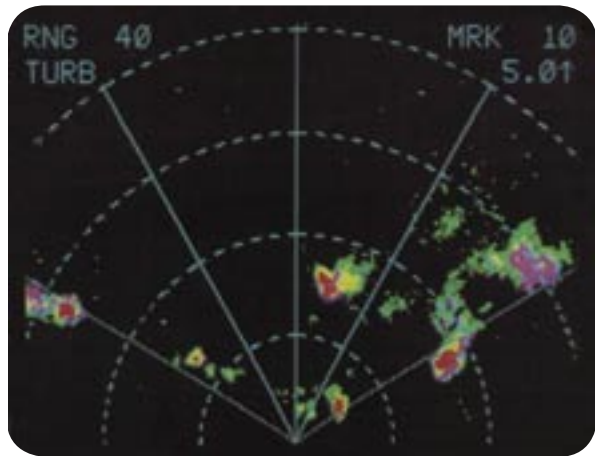
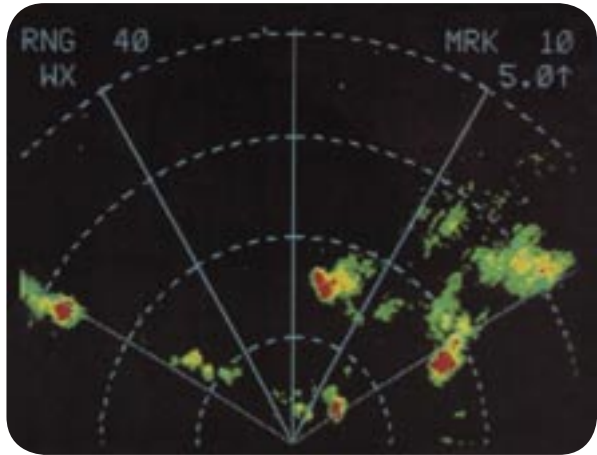
detects turbulence associated with precipitation, not clear air turbulence, up to a range of 40 nautical miles. The conventional weather display is available to the pilot for all selectable ranges when TURB is selected. For example, if the 80 NM range is selected, the system will display weather plus turbulence to 40 NM, and weather only from 40 to 80 NM.

The turbulence detection circuitry utilizes the Doppler phenomenon, which causes an apparent echo-signal frequency shift due to relative motion between the aircraft and the target. No attempt is made to measure the velocity of the aircraft relative to the storm cell since the aircraft's velocity is independent of the amount of turbulence within the storm cell. Only the return velocity variance is measured, and this provides the indication of the amount of turbulence present in the weather.

Weather turbulence causes random relative radial motion of rain drops. Wind shear can also cause similar relative radial target motions, and so will differences in fall speeds of various size drops. This random motion of droplets produces a spectrum spread of the radar's received signal. The radar detects the spectrum width parallel to the beam axis. A wide spectrum spread indicates the presence of turbulence. When the spectrum width exceeds the threshold of moderate to heavy turbulence, the return is displayed as turbulent weather.

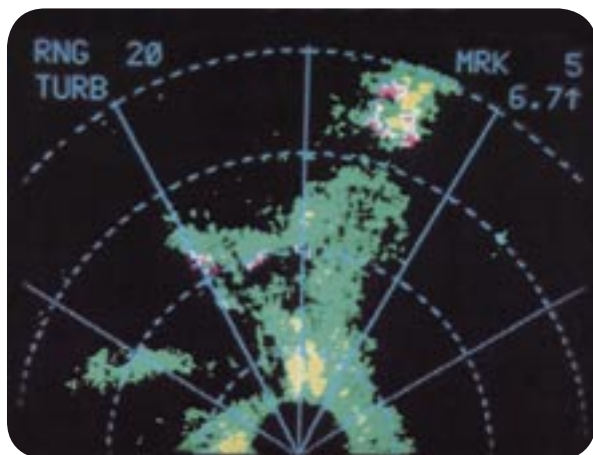
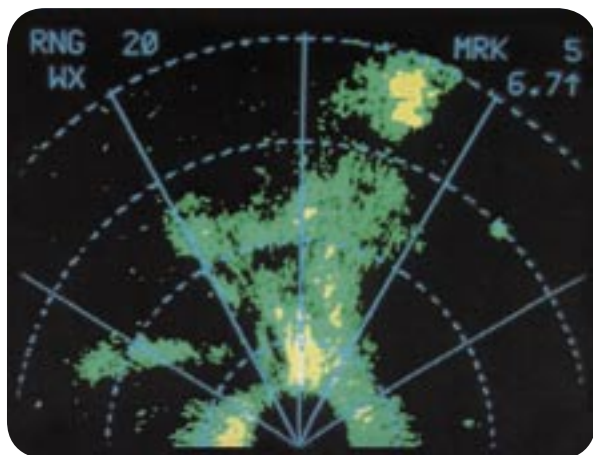
The system displays the areas of turbulence as an overlay to the radar's weather intensity returns. The turbulent weather is displayed in magenta on the radar indicator. Electronic Indicators display the areas of turbulence as red or magenta, depending on the type of Electronic Horizontal Situation Indicator (EHSI).

Doppler turbulence detection provides an additional tool to indicate to the pilot areas of turbulence that might not be fully indicated by conventional weather radar returns only. For example, it would be wise to avoid an area of green returns when magenta is overlaid on it. This turbulence would not be predicted by radar alone without Doppler enhancement.

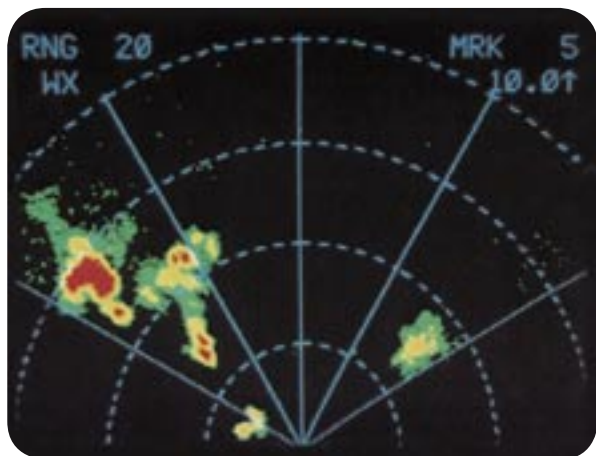


In this presentation most of the indicated turbulence is associated with the areas of heavy rainfall and shear zones.

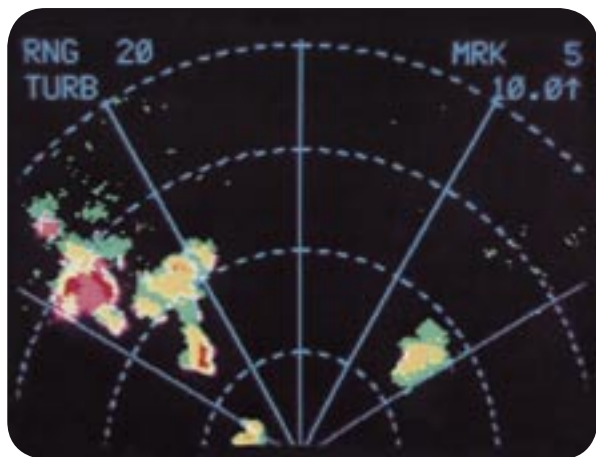
However, the largest area of turbulence, at 30 NM and 55 degrees right is associated with light to medium rainfall. This turbulence could not be predicted by observing the top picture.



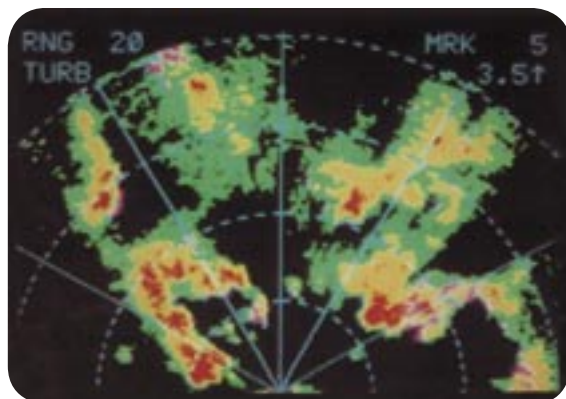
The areas of turbulence indicated in this storm system are associated with light to moderate rainfall. These areas should be avoided by 5 NM.



Many areas of indicated turbulence are predicted by the presence of large areas of heavy rainfall and shear zones, such as at 13 NM and 50 degrees left.



However, the small storm at 17 NM and 50 degrees left shows a large area of unpredicted turbulence.



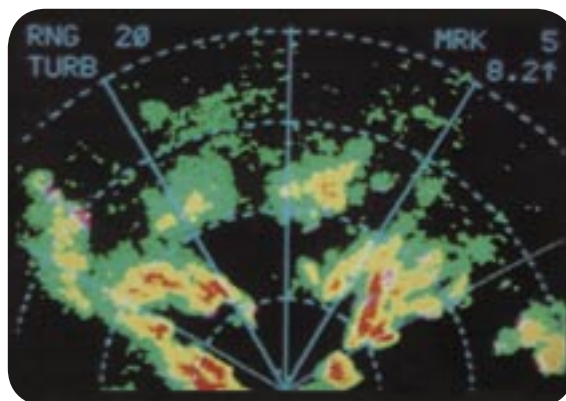
The location and amount of turbulence, like the location of heavy rainfall areas, can vary with the altitude of a storm. Note the differences in magenta areas as the tilt angle is changed.

NOTE

Manual Tilt should be used when Analyzing Terrain and when Analyzing Storm Characteristics.

NOTE

When using turbulence detection, set the TILT angle to eliminate all ground returns within 90 NM if possible.





NOTE

Non-turbulent areas below 40 NM and all turbulent/ non-turbulent areas beyond 40 NM will be displayed in the conventional black, green, yellow, and red as in weather (WX) mode. Storm cells should be analyzed taking both rainfall rate and the turbulence indications into account.

When some Electronic Display are used for weather displays, the TURB annunciation will not be displayed. Also, turbulent areas and areas of heavy rainfall will both be colored red. When compared with the display in weather (WX) mode, additional areas of red will appear on the display in those areas within 40 NM where the horizontal dispersion in the radar return exceeds the turbulence threshold.

USING THE
VARIABLE GAIN
OPTION - WX &
TURB MODES



NOTE

The variable GAIN Control is used to adjust the sensitivity of the receiver manually. **Variable GAIN should not be used to reduce ground returns.**

With this option, standard weather information displayed is variable, but TURB mode information is not affected.

It is used mainly to resolve nearby strong target returns or relative intensity of thunderstorms. The sensitivity decreases as the GAIN Control is rotated counterclockwise from the AUTO position. A blue "CAL" legend will be displayed in the upper right corner area of the PPI when the GAIN is in any setting but AUTO, indicating the radar is out of calibration. The sensitivity is increased as the GAIN Control is rotated clockwise from MIN position.

An alphanumeric read-out of the GAIN Control's position relative to MAX and MIN is displayed in the upper right corner area of the PPI. Decrements as well as increments are displayed as the GAIN is rotated. Adjustable gain range is minimized to reduce the possibility of eliminating strong targets when minimum gain is selected. The variable GAIN Control should only be used to reduce the receiver's sensitivity to aid in determining the relative

intensity of multiple thunderstorms and locating embedded cells in a rain front at low altitude and in terminal areas - not to locate a path to penetrate the storm area.

As the gain is reduced, level three (red) areas of the target will eventually be displayed as level two (yellow) and level two areas will turn into level one (green). The red area that is the last to change to the next lower level is the strongest part of the target. If there is a large area of level three displayed and the pilot desires to know which way to deviate to avoid the strongest part of the cell, he may reduce the gain slowly and note which part of the target remains red longest. That is the strongest part of the level three return and the area to avoid by the greatest distance.



NOTE

Thunderstorm (weather) evaluation should always commence with the GAIN Control in the AUTO position. If the situation requires that the GAIN be used, it should be used judiciously, and remember - no equipment can eliminate the need for sound pilot judgment and the pilot's knowledge of the performance characteristics of his aircraft. Reset GAIN Control to AUTO when weather evaluation is completed.



NOTE

PLANNING
A PATH

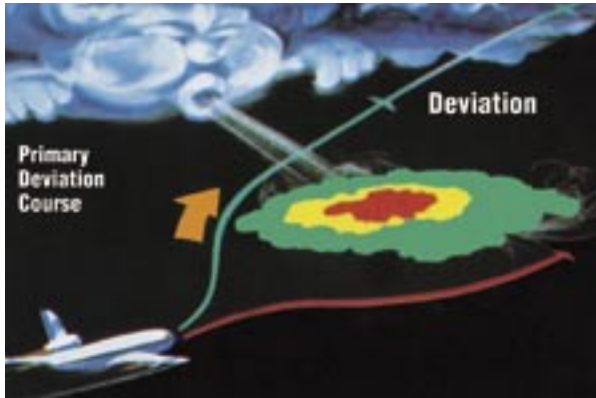
Manual Tilt should be used when Analyzing Terrain and when Analyzing Storm Characteristics.

Remember to plan a deviation path early. Simply skirting the red or magenta portion of a cell is not enough. Wherever possible, plan an avoidance path for all weather echoes which appear beyond 100 miles since this indicates they are quite dense.

Refer to the FAA Approved Airplane Flight Manual and to the FAA Advisory Circular in section 5 of this Pilot's Manual for detailed information on flying in the vicinity of and avoiding thunderstorms and turbulence.

The most intense echoes are severe thunderstorms. Remember that hail may fall several miles from the cloud, and hazardous turbulence may extend as much as 20 miles from the cloud. You should avoid the most intense echoes by at least 20 miles, if possible.

As echoes diminish in intensity, you can reduce the distance by which you avoid them.



PLAN A WEATHER AVOIDANCE PATH IN ADVANCE

PATH PLANNING CONSIDERATIONS

- You should avoid all cells containing magenta and red areas by at least 20 miles, if possible.
- You should not deviate downwind unless absolutely necessary. Your chances of encountering severe turbulence and damaging hail are greatly reduced by selecting the upwind side of a storm.
- Only use turbulence detection to isolate turbulence from precipitation. You should avoid all areas displayed as red or magenta.
- An area of displayed turbulence not within 20 NM of a red cell area should be cleared by 5 NM, if possible.

NOTE

Turbulence detection is limited to the first 40 NM regardless of the weather radar range selected and displayed.

- The shape of a storm displayed on your radar is just as important as the intensity levels. Some shapes are strong indicators of hail shafts such as:

- U-shapes
- Thin protruding fingers
- Scalloped edges
- Hooks



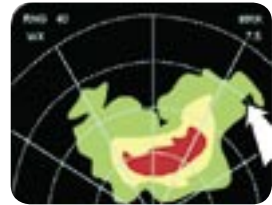
U-SHAPE



FINGER

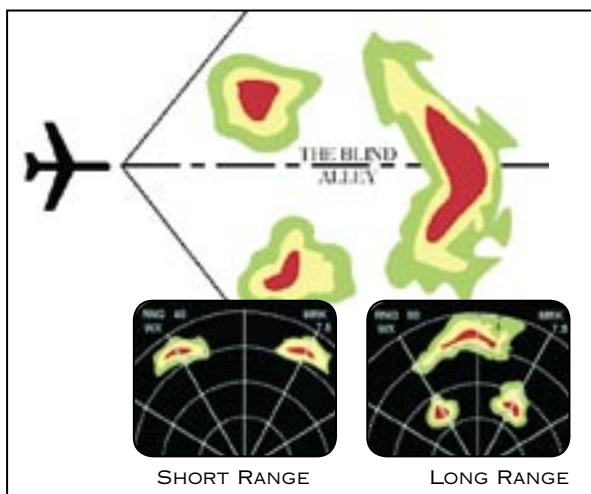


SCALLOPED EDGE



HOOK

WEATHER SHAPES INDICATING HAIL ACTIVITY



BLIND ALLEY AVOIDANCE

- A “Blind Alley” or “Box Canyon” situation can be very dangerous. When viewing the short ranges, periodically switch to longer-range displays to observe distant conditions. As shown below, the short-range returns show an obvious corridor between two areas of heavy rainfall but the long-range setting shows a larger area of heavy rainfall.

SCANNING FOR WEATHER

(1) Immediately after reaching cruise altitude, select the 30 or 40 mile range and set antenna TILT control 10° down. (2) While observing the display for WX targets rotate antenna TILT control up to just clear the display of all earth returns. Repeat step (2) for each intermediate range through the longest range you will be using. The above exercise ensures that the radar beam does not over scan any targets beginning at 30/40 miles out to the longest range.



The antenna Tilt control should be set to paint ground returns at the outer edge of the display when scanning for weather. See figure 1.



Manual Tilt should be used when Analyzing Terrain and when Analyzing Storm Characteristics.

Raise the beam and observe the ground return moving farther out in range. Stop adjusting the tilt when the ground return stripe moves to the out edge of the indicator but still be seen (Figure 2)

Range
80
WX



Figure 1

SCANNING FOR WEATHER BUILDUPS

Rapidly building storms may contain ice at their upper levels, therefore reflecting very little radar energy.

For the best indication of storm intensity, tilt the antenna down to the lower portion of the rainfall shaft. Remember that radar detects precipitation in the form of water droplets. Proper use of the tilt control to direct the radar beam at areas of water droplets is very important.

TILT MANAGEMENT

Effective antenna tilt management is the single, most important key to more informative weather radar displays. Three prime factors must be kept in mind for proper tilt management:

- The earth's curvature must be considered in determining the location of the beam at long distances.
- The center of the radar beam is referenced to the horizon by the aircraft vertical reference system.
- Adjusting the antenna tilt control will cause the center of the radar beam to scan above or below the plane of the attitude reference system.

AUTO TILT®

The RDR-4B is capable of AutoTilt® (automatic tilt angle), the Automatic Tilt function is recommended for use in WX and TURB modes.

The AutoTilt® function uses the Enhanced Ground Proximity Warning System (EGPWS) terrain altitude information. Based on the aircraft altitude above the terrain and terrain conditions in the area, the EGPWS determines the optimum tilt angle for the radar.

This automatic tilt angle setting results in minimum ground clutter on the display while maintaining the optimum weather detection capability. The exception to this is AutoTilt® MAP mode, where the radar beam is intentionally aimed at the ground as a function of range and altitude.



NOTE

Manual Tilt should be used when Analyzing Terrain and when Analyzing Storm Characteristics.

The AutoTilt® function is integrated with the existing windshear submodes. On preparation for Takeoff through 2300 feet, the weather scans alternate with the windshear scans. This occurs on approach, as well, below 2300 feet. The AutoTilt® function controls the tilt only during the weather scans. The windshear scan algorithm is not changed with AutoTilt® functionality.

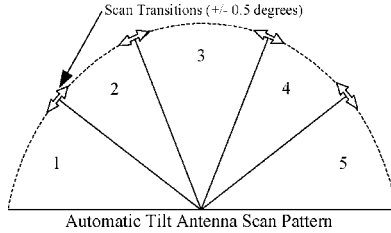


NOTE

When range settings are different (one display selected to greater than 80 NM and the other display selected to less than or equal 80 NM) the weather display alternately scans to cover the different range settings.

The AutoTilt® functionality is optimized for range settings less than or equal 80 NM (Short Range) and range settings greater than 80 NM (Long Range). If above 2300 feet AGL and all displays are set to the same setting (either all short range or all long range), the weather display will be updated in both directions (CW and CCW). If above 2300 feet AGL and at least one display is on short range with the others on

long range, then the weather display will be updated on alternate scans to account for the different AutoTilt® settings required. Below 2300 feet AGL, the AutoTilt® scans are based on short range tilt setting. There is no long range/short range alternate scanning in the windshear active region.

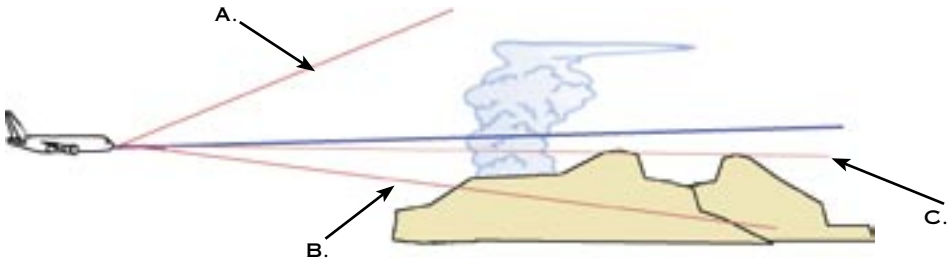


THE ANTENNA SCAN IS DIVIDED INTO FIVE SECTORS/AREAS (REF. FIGURE). THE TILT ANGLE DISPLAYED FOR EACH SECTOR IS CALCULATED BASED ON AIRCRAFT ALTITUDE, TERRAIN HEIGHT AND RANGE SELECTION.

**AUTO TILT®
VS. MANUAL
TILT**

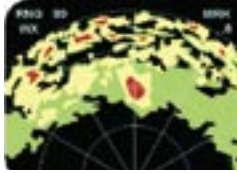
The integration of EGPWS and Radar functionality (AutoTilt®) provides a layer of protection against these extremes.

The following figures illustrate the benefits of AutoTilt®. With improper manual tilt there can be (A) Over Scan where the weather and terrain are below the radar beam and the display is blank, (B) Under Scan where the antenna scan is hitting the ground and the display contains too much ground clutter. (C) AutoTilt provides a layer of protection against These improper tilt settings. Providing an optimum tilt setting.

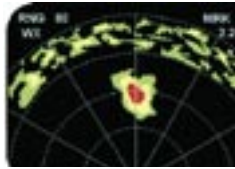




A. ERRONEOUS MANUAL TILT SETTING OVER SCAN)



B. ERRONEOUS MANUAL TILT SETTING (UNDER SCAN)



C. **AUTO TILT**[®] USING EGPWS TERRAIN DATA BASE (OPTIMUM PRESENTATION)

The AutoTilt mode contains an automatic bias to adjust for variation in terrain in addition to the information received for the EGPWS. If the ground returns presented on the radar display result in too much terrain or too little terrain display the pilots should use the manual tilt mode to present the desired amount of ground return on the display.

The manual tilt mode should only be used during times of reduced cockpit work load or weather analysis.

AUTO TILT[®]
SELECTION

Automatic Tilt is enabled by selecting the TILT (AUTO/MAN) switch to AUTO on the radar control unit (CON-4A/4B).



TILT (AUTO/MAN)

AUTO:Tilt setting for weather scans is automatic.

MANUAL:Tilt is controlled by the manual tilt control knob.

Autotilt Operation

Before Takeoff:

- in checklist:.....Select **TILT** on **AUTO**, on Control Panel
- Tilt can be set to **MAN** to evaluate the vertical weather content of the weather cells, using the **TILT** knob up and down. Set **TILT** back to **AUTO** once observations are done.

Climbout:

- Tilt can be set to **MAN** to evaluate the vertical weather content of the weather cells, using the **TILT** knob up and down. Set **TILT** back to **AUTO** once observations are done.

Cruise:

- Tilt can be set to **MAN** to evaluate the vertical weather content of the weather cells, using the **TILT** knob up and down. Set **TILT** back to **AUTO** once observations are done.
- Once the flight is stabilized at cruise altitudes, **TILT** can be set to **MAN** only if the crew needs to change the level of ground clutter of the radar picture on ND:

1. **TILT** knob slightly up will reduce ground clutter.

Note: Excessive ground clutter can be caused either by cities or by the dynamic tolerances of the antenna stabilization.

2. **TILT** knob slightly down will increase ground clutter.

Note: Flights over oceanic areas may produce very little or no ground clutter.

- Set **TILT** back to **AUTO** prior to initiating descent.

During Descent and Approach:

- **TILT** can be set to **MAN** to evaluate the vertical weather content of the weather cells, using the **TILT** knob up and down.

Set **TILT** back to **AUTO** once observations are done.

✈ **Never use GAIN out of AUTO to reduce the ground clutter.**

AUTO*TILT*
TILT MODE
ANNUNCIATION

Manual Tilt Message—If enabled by the aircraft installation, this message will be displayed when Manual tilt is selected and one of the following conditions occurs:

- Power Up
- Range Change
- Tilt (AUTO/MAN) switch is selected to **MAN**

The message (see figure) will be displayed:

- For Approximately 8 seconds when Windshear is not active.
- During the next WX scan (clockwise) and then removed during the next WX scan, when Windshear Mode is active.



TYPICAL MANUAL TILT
ENABLED INDICATION

Manual Tilt—Reminder Annunciation—If enabled by the aircraft installation, the “MANUAL TILT” message will also be annunciated on all radar indicators if the manual tilt setting is more than 1 degree above the calculated AutoTilt® tilt angle and a display(s) is selected to 80 nm or higher. The message will be repeated approximately every ten minutes (Approx. 10) if the condition persists. If EGPWS terrain data is not available (resulting in ‘NO AUTOTILT®’ with AUTO selected), then when MAN is selected the ‘MANUAL TILT’ reminder will be judged relative to a tilt setting of +0.5 degree.

NOTE

Windshear Icons have priority over the “MANUAL TILT” message.

Automatic Tilt Message—If enabled by the aircraft installation, the ‘AUTOTILT®’ message will be displayed when Automatic Tilt is selected and one of the following conditions occur:

- Power Up
- Tilt (AUTO/MAN) switch is selected to AUTO

The message will be displayed for:

- Approximately 8 seconds when Windshear is not active.
- During the next WX scan (clockwise) and then removed during the next WX scan, when Windshear Mode is active, or when alternate scanning between Short and Long range settings.



TYPICAL AUTOMATIC TILT
ENABLED INDICATION

NOTE

Manual Tilt Control Knob is inoperative when Automatic Tilt is selected.

NOTE

Windshear Icons have priority over the “AUTOTILT®” message.

**AUTO TILT®
FAILURE
ANNUNCIATION**

The following will occur when the Automatic Tilt function is selected but unavailable:

- “NO AUTOTILT®” message is displayed and the weather display is removed.
- Tilt setting display is set to -15.5° .
- Antenna scans at -15.5° to provide obvious indication of the failure.

If automatic tilt has failed, then the TILT switch on the radar control unit **MUST** be set to MAN. The failure message will be removed on the next weather scan.



TYPICAL AUTOMATIC TILT
FAULT INDICATION

NOTE

Windshear Icon has priority over the “NO AUTO TILT®” message.

NOTE

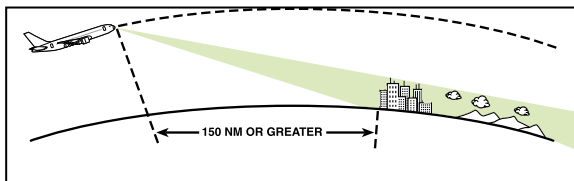
The Failure indication (message) may vary depending on EFIS interface`

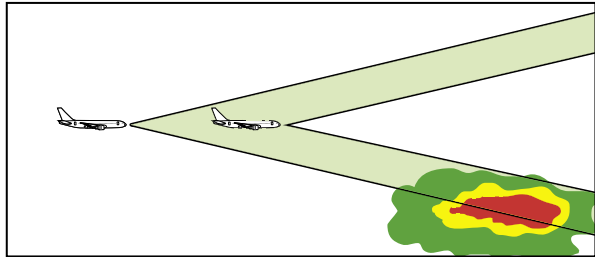
MANUAL TILT MANAGEMENT

A low tilt setting will result in excessive ground or sea returns while a too high tilt setting (although excessive returns are eliminated) can result in the radar beam passing over the top of a weather target.

For detecting weather targets at long ranges and to allow adequate time for planning the proper avoidance path, the tilt angle should be set to display ground target returns on the perimeter of the display. Note that under ideal conditions, the upper limit for ground returns is about 200 NM because of the curvature of the earth. By slowly raising the tilt angle, weather targets will emerge from the ground returns because of their height above the ground. In order to minimize ground returns when closely examining weather targets below the aircraft flight level, select the shortest range that allows full depiction of the area of interest.

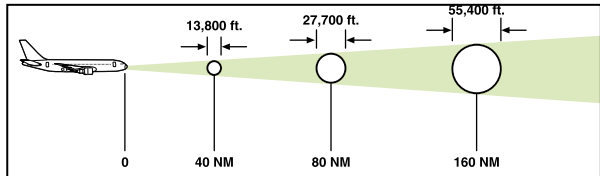
In practice, when flying at high altitude over fairly even terrain, ground returns are difficult to paint beyond 80 to 90 nautical miles because the radar beam and the earth's surface are practically parallel beyond this distance. However, objects such as large buildings in cities, steep hills, mountains or storms will reflect the signal and can show strong returns at distances greater than those shown below.





OVERSCANNING AND TILT MANAGEMENT

When flying at high altitudes, the use of proper tilt management ensures observation of weather targets without overscanning. For example, a low altitude storm detected on the long-range setting may disappear from the display as it is approached. While it may have dissipated during your approach toward the storm, don't count on it. It may be that you are directing the radiated energy from the antenna above the storm as you get closer. Judicious management of the antenna tilt control will avoid overscanning a weather target.



RADAR BEAM CROSS-SECTION

**BEAMWIDTH CROSS-SECTION DIAMETER
VERSUS DISTANCE**

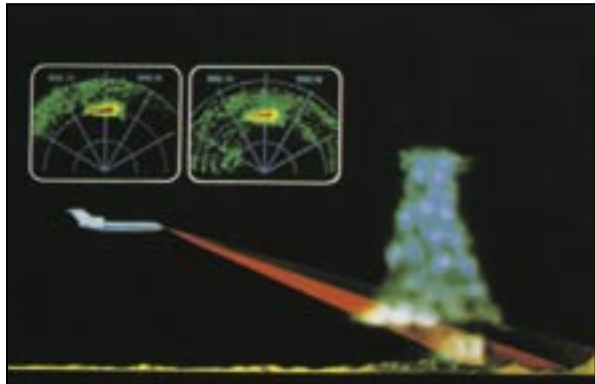
Distance from Aircraft (approx.)	Diameter of Beam Cross-Section	
10 Nautical Miles	3,500 Feet	.58 Nautical Miles
20 Nautical Miles	6,900 Feet	1.15 Nautical Miles
40 Nautical Miles	13,800 Feet	2.31 Nautical Miles
80 Nautical Miles	27,700 Feet	4.61 Nautical Miles
160 Nautical Miles	55,400 Feet	9.23 Nautical Miles
320 Nautical Miles	110,800 Feet	18.5 Nautical Miles

**WEATHER/
GROUND
TARGET
DISTINCTION**

It is sometimes difficult to differentiate between ground and weather targets. However, they can be identified by their differing characteristics. Ground returns tend to have well-defined features that are smaller and more angular in appearance than weather targets. There may also be a broken appearance to the pattern caused by mountain peaks and ridges. A shadow or blank area caused by the mountains and ridges, will normally be present behind ground echoes. Weather targets appear larger with less definite shape than ground targets. Progressive upward adjustment of the TILT control will change the shape, size and color of ground returns and eventually cause them to disappear while weather returns remain relatively unchanged.



Remember, mountains, cities, and other terrain features frequently return echoes strong enough to paint red (contour).



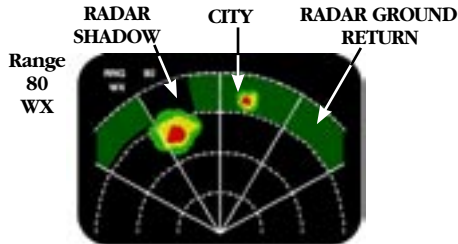
WEATHER/GROUND TARGET DISTINCTION

SHADOWED AREAS

Extremely heavy rainfall can reduce the ability of the radar waves to penetrate and present a full picture of the weather area. This condition is referred to as “radar attenuation”. It is a case where ground returns can be helpful in analyzing the weather situation. Tilt the antenna down and observe the ground returns around the radar echo. With very heavy intervening rain, the ground returns behind the echo will not be present but rather will appear as a shadow. This may indicate a larger area of precipitation than appears on the indicator.



If no ground return or other echoes can be seen behind a cell, a radar shadow is indicated. This shadow is an important indicator of hazardous weather; *avoid all shadowed areas!*



SHADOWED AREAS

MAPPING TIPS

The RDR-4B, although primarily a weather radar, can be used effectively to map ground targets. Mountains, cities, and other areas where large differences in signal strength exist, such as land/water boundaries, all map easily. Other ground targets, that are smaller or lack large differences in signal strength from the surrounding terrain are more difficult to resolve.

The following parameters determine the performance of the radar in both Weather and Map modes, but are more critical to operation in the weather mode.

TARGET RESOLUTION

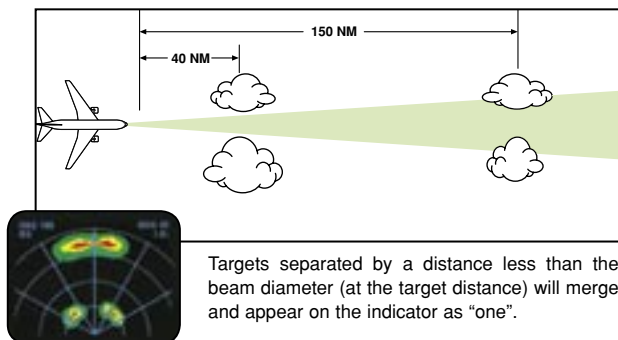
The ability of your Radar System to resolve and display two or more closely spaced targets is limited in range by the transmitted pulse width and display range, and in azimuth by the antenna beam width.

RANGE RESOLUTION

Range resolution is a function of the pulse width, signal processing, range being displayed, and display unit resolution capability. Range distance is equal to 1/2 the pulse width; therefore, the transmitted pulse width is the most important factor in determining range resolution. At selected ranges of 20 NM and below, the radar uses a 6-microsecond pulse. This amounts to a burst of energy approximately 6000 feet long. When two small targets are separated by 3000 feet (approximately 1/2 nautical mile) or less the radar will be unable to separate these targets. Any target feature separated by less than 1/2 NM will be merged. On the longest ranges the RTA-4B transmits an 18 microsecond pulse. The minimum range resolution now becomes approximately 1-1/2 NM. Since the RDR-4B will be interfaced with several different aircraft configurations and display units, it is beyond the scope of this manual to provide further detailed information on this subject.

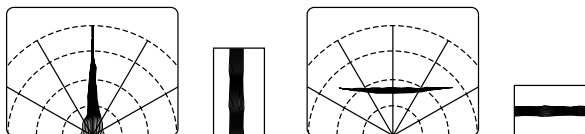
AZIMUTH RESOLUTION

Azimuth resolution is a function of the beam width. When two targets are closely adjacent and on the same range, the radar may display them as a single target. However, as the targets are approached they appear to separate. The ability of the radar system to resolve these targets is a function of the antenna's beam width and the range of the target.



AZIMUTH RESOLUTION

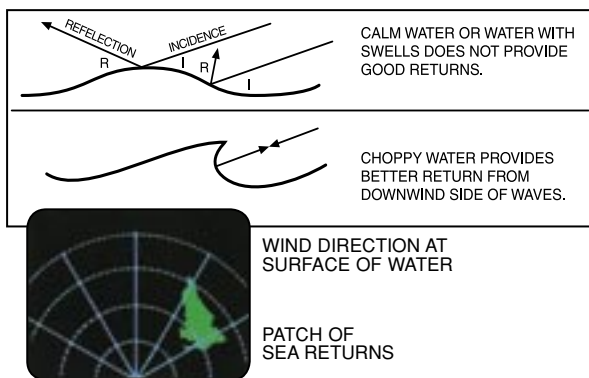
If, for example, you are flying over a river, the river display would tend to narrow and disappear at the extremities of the range.



AZIMUTH RESOLUTION CHARACTERISTICS

SEA RETURNS

Calm water provides very low radar returns since it reflects the pulses of radiation onward, much as a mirror reflects light directed on it at an angle. The same is true when viewing choppy water from the upwind side. The downward side of waves, however, may provide a strong reflection because of a steeper wave slope.



SEA RETURNS AND TYPICAL SEA RETURNS DISPLAY

NOTE

NOTE: Manual Tilt should be used when Analyzing Terrain and when Analyzing Storm Characteristics.

MAPPING TIPS SUMMARY

1. The TILT control is the most important control for getting a good map display.
2. When the antenna has the optional fan beam function, the MAP mode provides an enlarged coverage of close-range (up to 75 NM) terrain targets. For landfalls and longer-range (greater than 75 NM) mapping capabilities, use WX mode and longer range selection.
3. Because ground returns vary greatly with the angle of the radar beam illuminating them, the GAIN Control is used to obtain the optimum map display. Get in the habit of fine tuning a map display by varying the GAIN control whenever the TILT setting is changed.
4. When possible, practice mapping skills on known targets in good visibility, so that familiarity with the radar's capabilities is maintained.

**ALTITUDE
RINGS AND
CAT'S EYES**

A phenomenon known in the industry as Cat's Eyes or Altitude Rings, example shown below, may appear on some radome/display combinations. This anomaly may appear at about +/- 45 degrees between 4 and 8 NM range. Increasing the radar gain well above the calibrated setting (AUTO) at higher altitudes can create the anomaly. These reflected targets could result from ground returns received from the antenna sidelobe. The false targets are created when the sidelobe energy increases enough to reflect ground returns and the receiver sensitivity is increased so the reflected ground returns exceed the minimum discernible signal (MDS) level.

The Cat's Eyes or Altitude rings are not considered a problem. They will not cover the weather returns since the energy reflected by the weather at those ranges would be higher than the sidelobe, thus displaying the weather and not the low energy sidelobe reflection. If the above patterns appear, verify the range is appropriate for current flight level and the gain setting adequate. Verify that the false targets disappear when gain is selected to AUTO.

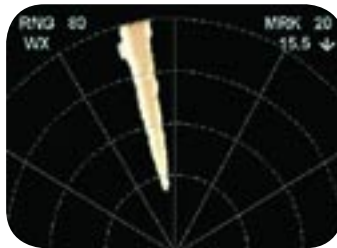


**EFFECTS OF
INTERFERING
CW RF
SOURCES**

An interfering RF source operating at a frequency close to the radar's operating frequency can create unusual return displays on the PPI (see figure below). These returns will appear as a single wedge of radar return that extends from very close range (< 5 NM) out to maximum range for the selected range scale. The wedge will typically cover from 3 to 5 degrees in azimuth and may, depending on the strength of the source, appear from green to red. These displays are caused by Continuous Wave (CW) sources of RF radiation. Types of CW RF source that can cause this effect include:

- CW Military Radar
- Radar Jamming Equipment
- Satellite Uplink equipment

Adjusting the manual gain or the antenna tilt angle may help alleviate the effect of the interfering source but the effect will not completely disappear until the interfering source is no longer in the radar's field of view.





Antenna Stabilization

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GENERAL

Antenna stabilization maintains antenna position relative to the earth's horizon regardless of aircraft attitude variations incurred during turns and moderate maneuvers. To accomplish this, the RDR-4B Radar System receives roll and pitch stabilization input signals from either the aircraft's vertical gyro or the Attitude Heading Reference System (AHRS). The AHRS is usually a part of the Inertial Navigation or Reference System.

Standard vertical gyros have inherent characteristics which greatly affect radar system operation, causing problems often erroneously attributed to the radar.

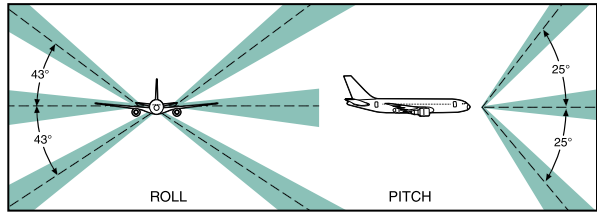
The AHRS uses a combination of gyro and accelerometer components of the conventional gimbal or strap-down variety to provide precise pitch and roll information. Aircraft with AHRS have minimum stabilization errors and are immune to aircraft accelerations which cause significant precession errors in aircraft equipped with a vertical gyro only.

Stabilization limits are a function of both the mechanical and the electronic limits of a particular system.

The elevation mechanical limit of the DAA-4A is ± 43 degrees and DAA-4B is ± 35 degrees. This value cannot be exceeded by any combination of tilt, pitch, and roll input. Additionally there are electronic limits on each of these functions, that if exceeded, cause partial loss of stabilization effectiveness and the blue STAB annunciation will be displayed on the PPI-4B Indicator.

DAA-4B		DAA-4A
± 30 degrees	Roll	± 40 degrees
± 15 degrees	Pitch	± 25 degrees
± 15 degrees	Tilt	± 15 degrees



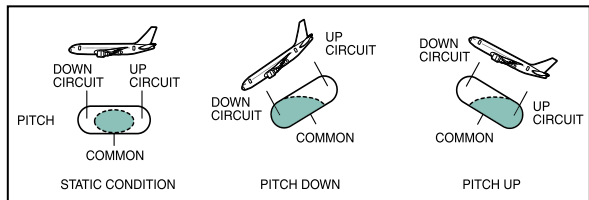


STABILIZATION LIMITS

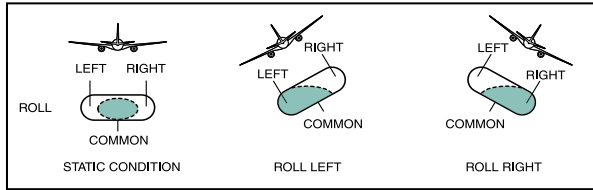
If stabilization reference signals are obtained from a vertical gyro source, the following description is directly applicable. If stabilization reference signals are developed from an INS or strapdown AHRS, the following description is useful for background information.

**VERTICAL
GYRO
OPERATION**

The vertical gyro is kept erect, i.e. the vertical axis is maintained perpendicular to the earth's surface, by gyro erection torquers. Each torquer, one for pitch and one for roll, acts to maintain vertical gyro position only when a deviation in its respective axis is sensed. This vertical deviation sensing is accomplished using liquid type level switches, one for roll and one for pitch. In the static condition, a drop of liquid, generally mercury, rests inside a glass bubble between two contact points. If the liquid moves within the bubble in either direction, the liquid completes an electrical circuit to indicate the direction of deviation.



PITCH DEVIATION SENSING



ROLL DEVIATION SENSING

**STATIC
CONDITION**

Since the liquid in these switches is free to move, a deviation may be indicated during a change in aircraft speed including roll maneuvers. This occurs due to the acceleration or deceleration forces acting upon the liquid even though the liquid level switch has remained in the static condition. When this happens the respective erection torquers begin to align the vertical gyro to a false vertical reference. When aircraft speed stabilizes, the liquid returns to its static condition and the vertical gyro is realigned to the correct vertical reference.

The movement of the vertical gyro is referred to as precession since the vertical gyro moving force occurs 90° away from the direction of movement. To avoid the technical explanation of this phenomenon it is enough to say that it is due to the rotation of the gyro.

Precession rate will vary between one and two degrees per minute. The roll erection torquer is automatically cut out while the aircraft is banking more than six degrees, allowing the gyro to become freely suspended in the roll axis and unaffected by the turning forces. In this mode, the gyro may drift from its initial position in space due to imbalance, friction, and earth's rotation. However, this movement is so slow, and the duration of turns generally so short, that this error is minimal.

Any aircraft may experience a noticeable amount of gyro drift during extended periods of turning flight. If you do encounter a vertical gyro which precesses abnormally during maneuvering (as evidenced on the artificial horizon in either pitch or roll), but subsequently precesses to normal attitude during straight and level flight, degrading gyro performance does not usually indicate a gyro failure, but rather a continued gradual degradation.

PITCH ERRORS

As the aircraft accelerates during takeoff, the gyro will precess in pitch. As soon as the aircraft speed becomes steady, the accrued pitch error will start diminishing. Average time required for the gyro to stabilize after takeoff is approximately three minutes, but will vary with acceleration time and rate. Acceleration and deceleration on approach can also cause the gyro to precess slightly. This precession problem is exhibited on jet aircraft because of their rapid acceleration capabilities.

TURN ERRORS

If a turn is accomplished after takeoff while the gyro is off vertical due to takeoff acceleration, the pitch error will be translated into the roll axis and will be observed as a roll attitude error when compared to the natural horizon. The roll error starts disappearing the moment the aircraft resumes straight and level flight.

SHALLOWED- BANKED TURNS

In turns made at less than six degrees bank (for example, intercepting a VOR with a shallow cut), the gyro continues to sense the lateral acceleration (lateral force) and, as a result, precesses in the same direction as the bank. If the turn is continued at the same indicated bank angle, the actual bank assumed by the aircraft will steepen at the same rate the gyro is precessing. When the aircraft is returned to straight flight and brought to wings level via the turn-and-bank indicator or the natural horizon (if visible), the roll error accumulated during the turn will be observed on the horizon indicator.

If the error is less than six degrees, it will start disappearing the moment the aircraft assumes straight and level flight. If it exceeds six degrees, it will not recover unless it drifts back to within the six degree cutoff threshold or is recycled through the initial erection mode. This will not cause the gyro flags to appear. The roll comparator monitor light will not illuminate unless there is a difference of four degrees or more between the horizons in roll attitude. Fast erection can be recycled by pulling the appropriate vertical gyro circuit breaker for 45 seconds or longer and then resetting the circuit breaker. The gyro flag will then remain in view during the fast erection cycle.

**RECOMMEND-
ATIONS FOR
REDUCING
THE INHERENT
TURN
(PRECESSION)
ERROR**

When possible, conduct turns at bank angles over six degrees to enable the roll erection cutoff to be activated.

When making turns at less than six degrees, keep the time to a minimum and bear in mind that the gyro will be developing a precession error during this time at a constant rate (also, that the error will be disappearing at the same rate after straight and level flight is resumed).

Realize also that aircraft lateral trim adjustments will be incorrect if based on a false vertical.

**RADAR
STABILIZATION
ERRORS**

Previously discussed gyro precessional errors will directly affect radar stabilization, and therefore the quality of return seen on the scope. Radar on aircraft flying at high altitude is normally operated on the 160 nautical mile range with the antenna tilted down slightly so the radar beam is just above the point of painting ground returns.

A 1/2 degree gyro error in roll would be hardly noticeable on the horizon indicator, but with the radar operating on the 160 nautical mile range, it could result in 40 nautical miles of ground returns on one side and no ground returns on the other.

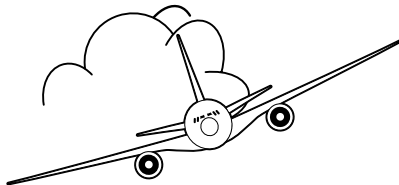
The vertical gyro is designed to sense verticality within 1/8 degree under normal operating conditions. Perfect radar antenna stabilization requires the following accuracies: The vertical gyro must maintain exact verticality, the antenna mounting bracket must be leveled perfectly to coincide with the gyro mounting base, the elevation servo amplifiers must be balanced precisely with a sharp null (no dead bank at null position), antenna follow-up signals must be linear over the full range of the antenna tilt, and the antenna must be adjusted properly with no backlash (play) in the elevation gear train. Even though extreme care is used during overhaul and adjustment of the equipment, minute variations can be cumulative, resulting in small stabilization errors.

If ground returns appear on one side first as the antenna tilt is lowered, continue lowering the tilt until ground returns are visible on the other side. If the difference in tilt is two degrees or less, the antenna can be tilted up to clear the ground returns with satisfactory radar operation due to the three degree radar beam width. Differences greater than two degrees warrant a log write-up, assuming proper gyro stabilization in level flight.

The following information on radar operation during aircraft maneuvers may be helpful.

TAKEOFF

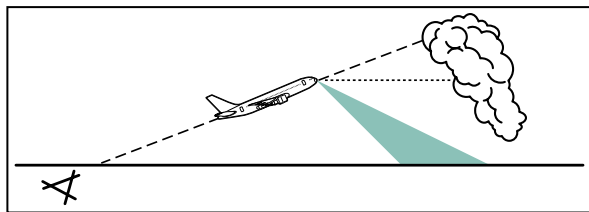
Since there is no advantage in having the antenna tilt level (zero degrees) while at low altitudes, raising the antenna tilt to clear ground returns caused by gyro acceleration error will result in satisfactory radar operation. Tilt can then be readjusted as the vertical gyro stabilizes. Turns during climb-out, while pitch acceleration error exists, will also cause a stabilization error in the roll axis.



SUMMARY

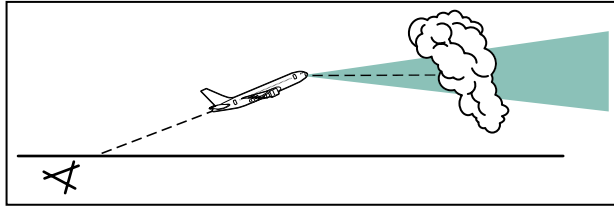
1. Stabilization limitations of the antenna beam may be exceeded during aircraft maneuvers. These limitations are mechanically fixed at ± 43 degrees for DAA-4A and ± 35 degrees for DAA-4B total combined tilt, pitch and roll excursion. Combinations of pitch/roll and tilt which exceed this limitation will diminish stabilization effectiveness. Pitch/roll is a complex quantity, not an arithmetic sum. However, as a rule-of-thumb, for small pitch angles, if the sum of tilt and bank angles is less than 40 degrees, the radar system will operate to its full capacity.
2. Gyro precession may be experienced during take-off or prolonged aircraft maneuvers such as rapid descents. Precession error may introduce a three to five degree antenna stabilization error which may persist as long as five minutes after the maneuver. Precession error results in a “lop-sided” antenna scan: low on one side, high on the reciprocal.

If picture is extremely “dirty” in the forward area, and the antenna is looking at terrain rather than precipitation, use a slight amount of up-tilt.



CLIMB/TERRAIN TILT ADJUSTMENT

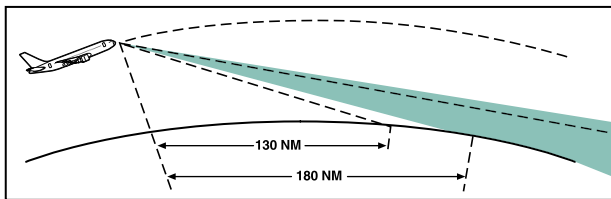
Rapid climb profile dictates that the tilt should not remain in the up position for extended periods. As the aircraft altitude progressively increases, the possibility of over-scanning weather cells also increases. The effective storm height is progressively reduced by the aircraft altitude.



CLIMB/OVER-SCANNING TILT ADJUSTMENT

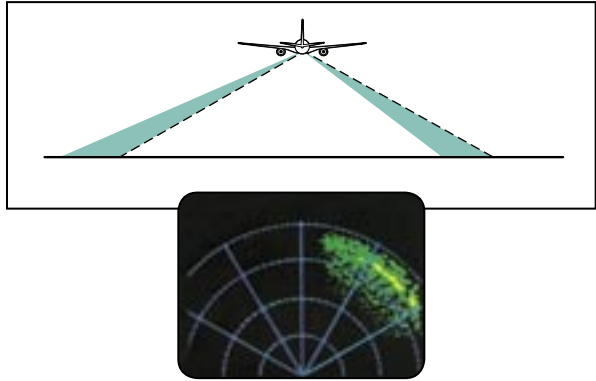
3. Stabilization of the radar beam compensates for moderate aircraft maneuvers. The system however, has limitations, particularly when used with vertical gyros. Learn to recognize limitation errors.

Tilt errors in the order of one-half degree or less can produce a dirty effect. With the beam just contacting the horizon at 180 nautical miles, a one-half degree of further down tilt moves this contact point in to 130 nautical miles. Isolated terrain targets would now appear.



TILT ERROR INDICATION

Introducing a 1/2 degree roll error compounds the effects; down on one side, up on the reciprocal (1° unbalance).



ROLL ERROR INDICATION

4. Analog gyro stabilization tips:
 - Adjust radar and obtain weather picture before take-off.
 - Plan wide clearance of cells.
 - Compensate antenna tilt for gyro precession.
 - Evaluate weather in the immediate sphere of operation.
 - Do not “over-scan” weather targets.
 - During severe aircraft maneuvers, recognize the limitations of stabilization.



Cautions

Operation Cautions Page 94



Radiation

WARNING

This instrument generates microwave radiation.
DO NOT OPERATE UNTIL YOU HAVE READ
AND CAREFULLY FOLLOWED ALL SAFETY
PRECAUTIONS AND INSTRUCTIONS IN
THE OPERATING AND SERVICE MANUALS.

**IMPROPER USE OR EXPOSURE MAY CAUSE
SERIOUS BODILY INJURY.**

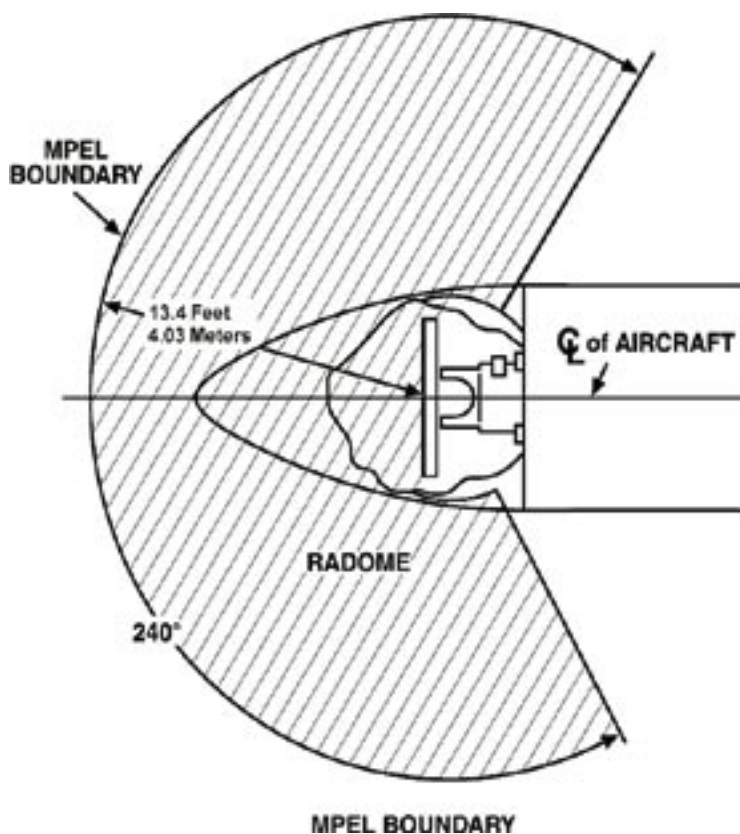
CAUTION

1. MAINTAIN PRESCRIBED SAFE DISTANCE WHEN STANDING IN FRONT OF A RADIATING ANTENNA.*
2. NEVER EXPOSE EYES OR ANY PART OF THE BODY TO AN UNTERMINATED WAVEGUIDE.

*Reference FAA Advisory Circular #20-68B

Maximum Permissible Exposure Level (MPEL)

In order to avoid the envelope in which the radiation level may exceed the U.S. Government standard of 10 milliwatt per square centimeter, all personnel should remain beyond the distance indicated in the illustration below. The distance to the MPEL boundary is determined by calculating the near field/far field intersection per FAA Advisory Circular 20-68B.





ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION Federal Aviation Administration Washington, D.C.

SUBJECT: Recommended radiation safety precautions for ground operation of airborne weather radar

Issued by: AFD 517

- 1 **PURPOSE:** This circular sets forth recommended radiation safety precautions to be taken by personnel when operating airborne weather radar on the ground.
- 2 **CANCELLATION:** AC 20-65A dated April 11, 1975 is cancelled.
- 3 **RELATED READING MATERIAL:**
 - a. Garner and Foster: *Radiation Hazards and Protection*, London: George Newman, Limited, 1961, p. 211.
 - b. U.S. Department of Health, Education and Welfare: Public Health Service, Consumer Protection and Environmental Health Service: Environmental Health Program, *Use of Electromagnetic Radiation from Lasers and Telemetry Systems*, An Annotated Bibliography, FS-2-700, FH-75, Washington, U.S. Government Printing Office, pp. 56-57.
 - c. Muxflor, W.W.: Some technical aspects of microwave radiation hazards, Proceedings of the IRI, Washington, U.S. Government Printing Office, February, 1961, pp. 421-447.
- 4 **BACKGROUND:** Dangers from ground operation of airborne weather radars include the possibility of human body damage and ignition of combustible materials. Critical areas of the human body include the eyes and testes.
- 5 **PRECAUTIONS:** Management and supervisory personnel should establish procedures for advising personnel of correct line operating airborne weather radars on the ground. Precaution signs should be displayed in affected areas to alert personnel of ground testing.
 - a. General
 - (1) Airborne weather radar should be operated on the ground only by qualified personnel.
 - (2) Ground airborne radar should not be operated while the aircraft is in a hangar or other enclosure unless the radar transmitter is not operating or the energy is directed toward an absorption shield which dissipates the radio frequency energy. Otherwise radiation within the enclosure can be reflected through ducts to the area.
 - b. Safety Damage To prevent possible human body damage, the following precautions should be taken:
 - (1) Personnel should never stand nearby and in front of a radar antenna while it is transmitting. When the antenna is not scanning, the danger is reduced.
 - (2) A recommended safe distance from operating airborne weather radars should be established. A safe distance can be determined by using the equations in Appendix 1 or the graphs of Figures 1 and 2. This criterion is now accepted by many industrial organizations and is based on limiting exposure of humans to an average power density not greater than 10 mW/cm² (square centimeter).
 - (3) Personnel should be advised to avoid the end of an open waveguide unless the radar is turned off.
 - (4) Personnel should be advised to avoid looking into a waveguide or into the open end of a coaxial connector or the connector to a radar transmitter output, as severe eye damage may result.
 - (5) Personnel should be advised that when high power radar transmitters are operated out of their protective cases, brass may be melted. Since brass may separate from the glass envelope due to differential expansion of the materials, brass may be melted at high power.

: Consult the Manufacturer's representative for high priority, scheduled and weather radar should not be operated when an aircraft is being refueled or defueled.



MARK STARO
Director of Airworthiness

AC 20688

8-8-80

8 R 80

AC 20688
Appendix I

APPENDIX I. SAFE DISTANCE DETERMINATION

The following information can be used in establishing a minimum safe distance from the antenna for personnel near an operating airborne weather radar:

1. **NEAR FIELD/FAR FIELD INTERSECTION.** The distance to the near field/far field intersection can be computed by:

$$R = \frac{G \lambda^3}{8 \pi} \quad (1)$$

where R = Intersection distance from the antenna in meters
 λ = Wave length in meters
G = Antenna gain

2. **DISTANCE TO 10 MW/cm² SAFE LIMIT** (at a field power density of 10 MW/cm² the distance in meters from the antenna may be calculated as:

$$R_s = \sqrt{GP/400 P} \quad (2)$$

where R_s = The minimum safe distance in meters
P = Transmitted average power in watts
G = Antenna gain

3. **PROCEDURES.** The above formulas or the graphs of figures 1 and 2 may be used to determine the minimum safe distance. In either case the following procedure apply:

- Determine the distance (R₁) to the near field/far field intersection (paragraph 1)
- Determine the distance (R_s) to 10 MW/cm² power density (paragraph 2)
- If the distance (R_s) determined in 2b above is less than (R₁) found in 2a above, use distance (R_s) as the minimum safe distance.
- If the distance (R_s) determined in 2b above is greater than (R₁) found in 2a above, use distance (R₁) as the minimum safe distance.

4. EXAMPLE

a. Data: The following is typical data for an airborne weather radar:

Antenna Diameter: 27 inches 68.6 cm
Transmitter Frequency: 5175 - 530 MHz
Wave Length: 3.2 cm
Pulse Length: 1.5 microseconds 15000
Pulse Repetition: 400 Hz
Peak Power: 400 Watts
Average Power: 24 Watts (typical)
Antenna Gain: 1000 (10dBi)

b. Calculations:

(1) Distance (R ₁) to the near field/far field intersection	(2) Distance (R _s) to 10 MW/cm ² safe limit.
$R_1 = \frac{G \lambda^3}{8 \pi}$ $= \frac{1000 \times (0.032)^3}{8 \pi}$	$R_s = \frac{\sqrt{GP/400 P}}{\sqrt{1000 \times 24/400 \pi}}$ $= 4.33 \text{ meters } 14.3 \text{ feet}$

1.27 meters 4.2 feet

The distance (R₁) is greater than (R_s) therefore the minimum safe distance is 14.3 feet



U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject	THUNDERSTORMS	Date	1/20/83	AC No.	00-240
		Issued By	ATD-265	Change	

1. **PURPOSE.** This advisory circular describes the hazards of thunderstorms to aviation and offers guidance to help prevent accidents caused by thunderstorms.
2. **CANCELLATION.** Advisory Circular 00-24A, issued June 23, 1976, is canceled.
3. **RELATED READING MATERIAL.** Advisory Circulars 00-64, Aviation Weather; 00-450, Aviation Weather Services; 00-50A, Low Level Wind Shear.
4. **GENERAL.** We all know what a thunderstorm looks like. Much has been written about the mechanics and life cycles of thunderstorms. They have been studied for many years; and while much has been learned, the studies continue because much is not known. Knowledge and weather radar have modified our attitudes toward thunderstorms, but one rule continues to be true—any storm recognizable as a thunderstorm should be considered hazardous until measurements have shown it to be safe. That means safe for you and your aircraft. Almost any thunderstorm can spell disaster for the wrong combination of aircraft and pilot.
5. **HAZARDS.** A thunderstorm packs just about every weather hazard known to aviation into one vicious bundle. Although the hazards occur in numerous combinations, let us look at the most hazardous combination of thunderstorms, the squall line, then we will examine the hazards individually.

a. **Squall Lines.** A squall line is a narrow band of active thunderstorms. Often it develops on or ahead of a cold front in moist, unstable air, but it may develop in unstable air far removed from any front. The line may be too long to detour easily and too wide and severe to penetrate. It often contains steady-state thunderstorms and presents the single most intense weather hazard to aircraft. It usually forms rapidly, generally reaching maximum intensity during the late afternoon and the first few hours of darkness.

b. **Tornadoes.**

(1) The most violent thunderstorms draw air into their cloud bases with great vigor. If the incoming air has any initial rotating motion, it often forms an extremely concentrated vortex from the surface well into the cloud. Meteorologists have estimated that wind in such a vortex can exceed 300 knots; pressure inside the vortex is quite low. The strong winds gather dust and debris and the low pressure generates a funnel-shaped cloud extending downward from the cumulonimbus base. If the cloud does not reach the surface, it is a "funnel cloud"; if it touches a land surface, it is a "tornado."

11) Tornadoes occur with both isolated and squall line thunderstorms. Reports for tornadoes indicate that atmospheric conditions are favorable for nucleic turbulence. An aircraft entering a tornado vortex is almost certain to suffer structural damage. Since the vortex extends well into the cloud, any pilot inadvertently caught in a severe thunderstorm could encounter a hidden vortex.

12) Families of vortices have been observed as appendages of the main cloud extending several miles outward from the area of lightning and precipitation. Thus, any cloud connected to a severe thunderstorm carries a threat of violence.

c. Turbulence.

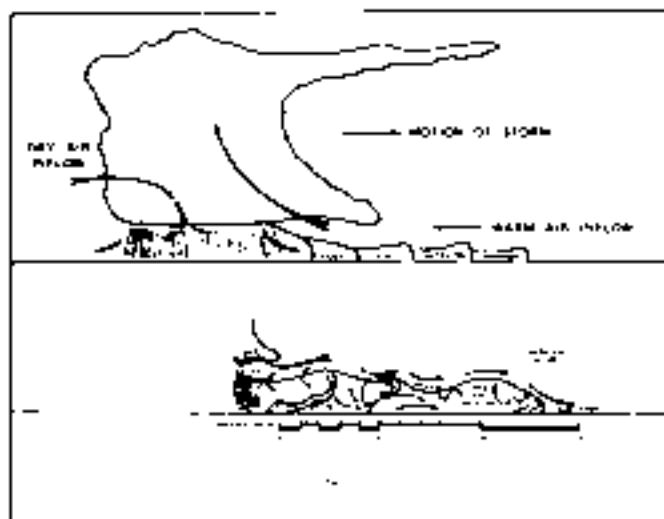
1) Essentially hazardous turbulence is present in all thunderstorms, and a severe thunderstorm can destroy an aircraft. Severe turbulence within the cloud occurs with shear between updrafts and downdrafts. Outside the cloud, severe turbulence has been encountered several thousand feet above and 20 miles laterally from a severe storm. A low level turbulent area at the shear zone associated with the gust front. (Shear, a "roll" cloud) on the leading edge of a storm marks the top of the eddy in this shear and it signifies an extremely turbulent zone. Gust fronts often move far ahead (up to 15 miles) of associated precipitation. The gust front causes a rapid and sometimes drastic change in surface wind ahead of an approach vector. Advisory Circular 00-56A, "Low Level Wind Shear," explains in greater detail the hazards associated with gust fronts. Figure 1 shows a schematic cross section of a thunderstorm with areas outside the cloud where turbulence may be encountered.

2) It is almost impossible to hold a constant altitude in a thunderstorm, and pilots should never attempt to do so, because usually increased stresses on the aircraft. It is understandable that the speed of the aircraft determines the rate of turbulence encounter. Strong air, at least if the aircraft is held in a constant altitude and allowed to "ride the waves." To date, we have in this way a pure "ride speed" in a thunderstorm.

3. icing.

1) Aircraft in a thunderstorm ingest abundant liquid water with relatively large droplets (size) and when carried above the freezing level, the water becomes supercooled. When temperature in the upward current cools to about -15°C, much of the remaining water vapor sublimates as the crystals and above this level, as lower temperatures, the amount of supercooled water decreases.

2) Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level, but at high levels, where the smaller droplets may be more numerous and vital. The abundance of large, supercooled water droplets makes clear icing very rapid between 0°C and -15°C and encounters can be frequent in a cluster of cells. Thunderstorm icing can be extremely hazardous.



A. Hail.

(1) Hail develops with turbulence as the greater thunderstorm hazard to aircraft. Supercooled drops above the freezing level begin to freeze. Once a drop has frozen, other drops later do and freeze to it. As the hailstone grows, sometimes into a large iceball. Large hail develops with severe thunderstorms with strong updrafts that have built to great heights. Eventually, the hailstones fall, possibly some distance from the storm core. Hail may be encountered in clear air several miles from dark thunderstorm clouds.

(2) As hailstones fall through air whose temperature is above 32°, they begin to melt and precipitation may reach the ground as either hail or rain. Rain at the surface does not mean the absence of hail aloft. You should anticipate possible hail with any thunderstorm, especially beneath the anvil of a large cumulonimbus. Hailstones larger than one half inch in diameter can significantly damage an aircraft in a few seconds.

f. Low Ceiling and Visibility. Generally, visibility is near zero within a thunderstorm cloud. Ceiling and visibility also may be restricted in precipitation and dust between the cloud base and the ground. The restrictions create the same problem as all ceiling and visibility restrictions; but the hazards are increased many fold when associated with the other thunderstorm hazards of turbulence, hail, and lightning which make precision instrument flying virtually impossible.

g. Effect on Altimeters. Pressure usually falls rapidly with the approach of a thunderstorm, then rises sharply with the onset of the first gust and passage of the cold downdraft and heavy rain showers, falling back to normal as the storm moves on. This cycle of pressure change may occur in 15 minutes. If the pilot does not observe a corrected altimeter setting, the altimeter may be low 100 feet or more.

5. Lightning. A lightning strike can penetrate the skin of an aircraft and can damage communications and electronic navigational equipment. Lightning has been suspected of igniting fuel vapors causing explosions; however, serious accidents due to lightning strikes are extremely rare. Heavy lightning can blind the pilot rendering him temporarily unable to navigate either by instrument or by visual reference. Heavy lightning can also induce permanent damage to the magnetron outputs of lightning dischargers, even distance beacon can disrupt radio communications on low and medium frequencies. Though lightning intensity and frequency have no simple relationship to other storm parameters, severe storms, as a rule, have a high frequency of lightning.

1. Engine Water Ingestion.

(1) No engine has a limit on the amount of water they can ingest. Updrafts are present in many thunderstorms, particularly those in the developing stages. If the updraft velocity or the thunderstorm updrafts exceeds the terminal velocity of the falling particles, very high concentrations of water may occur. It is possible that these concentrations can be in excess of the quantity of water turbine engines are designed to ingest. Therefore, severe thunderstorms may contain areas of high water concentration which could result in flameout and/or structural failure of one or two engines.

(2) At the present time, there is no known operational procedure that can completely eliminate the possibility of engine flameout during severe water ingestion. Although the exact mechanism of these water induced engine stalls has not been determined, it is felt that thrust changes may have an adverse effect on engine stall margins in the presence of massive water ingestion.

(3) Avoidance of severe storm systems is the only measure assumed to be effective in preventing exposure to this type of multiple engine flameout. During an unavoidable encounter with severe storms with extreme development, the best known recommendation is to follow the severe turbulence penetration procedure contained in the approved airplane flight manual with special emphasis on avoiding thrust changes unless excessive deceleration is not possible.

6. WEATHER RADAR.

a. Weather radar detects droplets of precipitation size. Strength of the radar return (echo) depends on drop size and number. The greater the number of drops, the stronger is the echo; and the larger the drops, the stronger is the echo. Drop size determines echo intensity to a much greater extent than does drop number. Raindrops usually are covered with a film of water and, therefore, act as huge water droplets giving the strongest of all echoes.

b. Numerous methods have been used in an attempt to categorize the intensity of a thunderstorm. To standardize thunderstorm language between weather radar operators and pilots, the use of Video Indicator Processor (VIP) levels is being promoted.

c. The National Weather Service (NWS) radar observer is able to objectively determine storm intensity levels with VIP equipment. These radar echo intensity levels are on a scale of one to six. If the Maximum VIP Levels are 1 "weak" and 2 "moderate," then 1000 to moderate turbulence is possible with lightning. VIP level 3 is "strong" and severe turbulence is possible with lightning. VIP level 4 is "very strong" and severe turbulence is likely with lightning. VIP level 5 is "intense" with severe turbulence, lightning, hail likely, and organized surface wind gusts. VIP level 6 is "extreme" with severe turbulence, lightning, large hail, intensive surface wind gusts, and turbulence.

4. Thunderstorms build and dissipate rapidly. Therefore, do not attempt to plan a route between echoes. The best use of ground radar information is to obtain general areas and coverage of echoes. You must avoid individual storms from flight observations either by visual sighting or by airborne radar. It is better to avoid the whole thunderstorm area than to detour around individual storms unless they are dissipated.

5. Airborne weather avoidance radar is, as its name implies, for avoiding severe weather not for penetrating it. Whether to fly into an area of radar echoes depends on echo intensity, spacing between the echoes, and the capabilities of you and your aircraft. Remember that weather radar detects only precipitation drops; it does not detect turbulence. Therefore, the radar scope provides no assurance of avoiding turbulence. The radar scope also does not provide assurance of avoiding instrument weather from clouds and fog. Your scope may be clear between intense echoes; this clear area does not necessarily mean you can fly between the storms and maintain visual sighting of them.

6. Remember that while radar always gives a radar echo, it may fall several miles from the nearest visible cloud and hazardous turbulence may extend to as much as 20 miles from the echo edge. Avoid intense or extreme level returns by at least 20 miles; that is, such echoes should be separated by at least 40 miles before you fly between them. With weaker echoes you can reduce the distance by which you avoid them.

7. DO'S AND DON'TS OF THUNDERSTORM FLYING.

a. Remember, remember this: never regard any thunderstorm lightly. Even when radar observers report the echoes are of light intensity. Avoiding thunderstorms is the best policy. Following are some do's and don'ts of thunderstorm avoidance.

1) Don't land or takeoff in the face of an approaching thunderstorm. A sudden quarter front of low level turbulence could cause loss of control.

2) Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and wind shear under the storm could be disastrous.

3) Don't fly without airborne radar into a cloud mass containing scattered embedded thunderstorms. Scattered thunderstorms are embedded usually can be visually circumvented.

4) Don't trust the visual appearance to be a reliable indicator of the turbulence inside a thunderstorm.

5) Do avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the area of a large cumulonimbus.

6) Do circumnavigate the entire area if the area has 6:10 thunderstorm coverage.

7) Do remember that vivid and frequent lightning indicates the probability of a severe thunderstorm.

8) Do regard as extremely hazardous any thunderstorm with tops 35,000 feet or higher whether the top is visually sighted or penetrated by radar.

b. If you cannot avoid penetrating a thunderstorm, following are some DO'S BEFORE entering the storm:

11) Tighten your safety belt, put on your shoulder harness if you have one, and secure all loose objects.

12) Plan and hold your course to take you through the storm in a minimum time.

13) To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of +35°C.

14) Verify that pitot heat is on and turn on carburetor heat or jet engine anti-ice. Icing can be rapid at any altitude and cause almost instantaneous power failure and/or loss of airspeed indication.

15) Establish power settings for turbulence penetration airspeed recommended in your aircraft manual.

16) Turn up cockpit lights to highest intensity to lessen temporary blindness from lightning.

17) If using automatic pilot, disengage altitude hold mode and speed hold mode. The automatic altitude and speed controls will increase maneuvers of the aircraft thus increasing structural stress.

18) If using airborne radar, tilt the antenna up and down occasionally. This will permit you to detect other thunderstorm activity at altitudes other than the one being flown.

c. Following are safe do's and don'ts during the thunderstorm penetration:

11) Do keep your eyes on your instruments. Looking outside the cockpit can increase danger of temporary blindness from lightning.

12) Don't change power settings: Maintain settings for the recommended turbulence penetration airspeed.

13) Do maintain constant altitude: Let the aircraft "ride the waves." Maneuvers in trying to maintain constant altitude increase stress on the aircraft.

14) Don't turn back once you are in the thunderstorm. A straight course through the storm most likely will get you out of the hazards most quickly. In addition, turning maneuvers increase stress on the aircraft.


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