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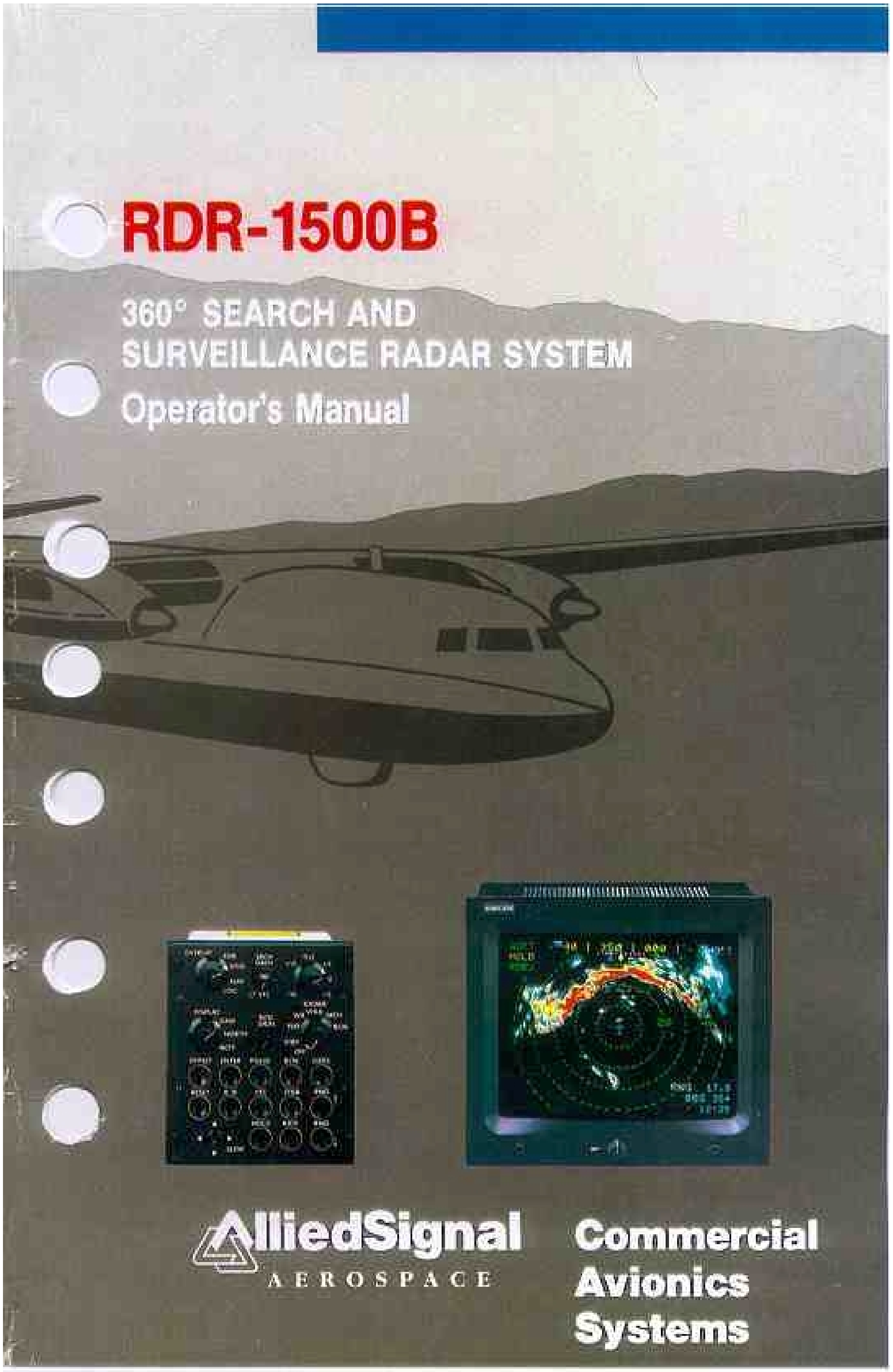

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The primary mission of the RDR-1500B Radar System is maritime search and surveillance. Secondary missions include terrain mapping, weather avoidance and beacon navigation. The system will also display navigation information from the aircraft navigation system.

RDR-1500B
Color Radar System

Introduction

The RDR-1500B Radar System is a lightweight digital color radar system designed primarily for fixed or rotary wing aircraft engaged in maritime patrol, surveillance, rescue missions and precision terrain mapping. The radar system also provides weather avoidance, transponder beacon location and waypoint navigation display. A color indicator, included with the system, displays the radar and navigation video and will also accept external FLIR and TV inputs for display in monochrome. A Bendix/King Checklist Unit can be added to the system.

The RDR-1500B Radar System consists of five basic units: an RT-1501A Radar Receiver-Transmitter, a cockpit-mounted IN-1502A or IN-1502B (not shown) Multifunction Color Radar Indicator, a 360° DA-1503A or 120° DA-1203A Sector Scan Antenna Drive Unit (not shown) with a flat-plate array, a CN-1506A Control Unit and an IU-1507A Interface Unit.

Contents

RDR-1500B System Components

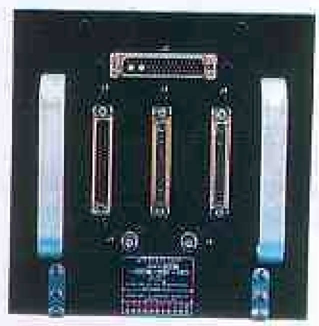
RT-1501A Receiver-Transmitter

The RT-1501A Receiver-Transmitter contains the electronics necessary to transmit, receive and process radar pulses. The unit functions as a short-range pulse radar for high resolution sea search and terrain mapping, and also as a long-range pulse radar for long range search, terrain mapping and conventional weather avoidance. It provides X-Band output signals to an antenna.

RT-1501A Receiver-Transmitter

IU-1507A Interface Unit

The IU-1507A Interface Unit provides the connection between the various aircraft and radar system components. It processes the digitized video output from the receiver-transmitter and supplies red, green and blue data in digital form to the multifunction indicator. It also supplies drive signals to the antenna drive unit and trigger and mode selection signals to the receiver-transmitter. The IU-1507A can drive two radar indicators with the same information.

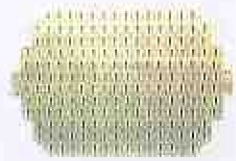


IU-1507A Interface Unit

AA-1504A Antenna Array

The AA-1504A Antenna Array is a 39-inch flat plate phased array with 2.6° azimuth and 10.5° elevation beamwidth. Also available are 32-inch and 29-inch flat plate phased arrays. The antenna is used for transmitting and receiving radar signals. It is remotely controlled in the elevation axis by a tilt control on the CN-1506A Control Unit.

AA-1504A Antenna Array



Optional AA-1812A Antenna Array

DA-1503A 360° and DA-1203A Sector Scan Antenna Drive Units

The DA-1503A and DA-1203A Antenna Drive units position the flat plate antenna array in azimuth and elevation axes. The antenna drive is motor driven with combined pitch, roll and tilt line-of-sight stabilization, up to ±25° of true vertical.

DA-1503A Antenna Drive

The DA-1503A scans 360° with selectable speeds of 45°/second and 90°/second.

The DA-1203A Drive Unit (not shown) is a sector scan drive unit. Sweeping 30°, 60° or 120° sectors, selectable from the CN-1506A Rate push-button switch, the rate of scan is 23° per second.

Stabilization is obtained with pitch and roll signals from the aircraft vertical gyro and the CN-1506A Control Unit **TILT** control. Tilt is selectable ±15° from horizontal. For additional information, refer to Bendix publication ACS-927, Airborne Weather Radar Antenna Stabilization Criteria.

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IN-1502A Multifunction Color Indicator

The IN-1502A Multifunction Color Indicator provides a three color display of sea and ground targets or weather within the 360° area scanned by the antenna at a distance of up to 160 nautical miles. This multifunction color radar indicator provides continuous color display of weather as well as ground mapping, beacon and NAV information. The display viewing area is 5.6 × 7.3 inches. The only control on the display is a brightness adjustment.

Similar in function but smaller, the IN-1502B indicator display measures 3.5 × 4.5 inches.

IN-1502A Color Indicator

IN-1502B Color Indicator

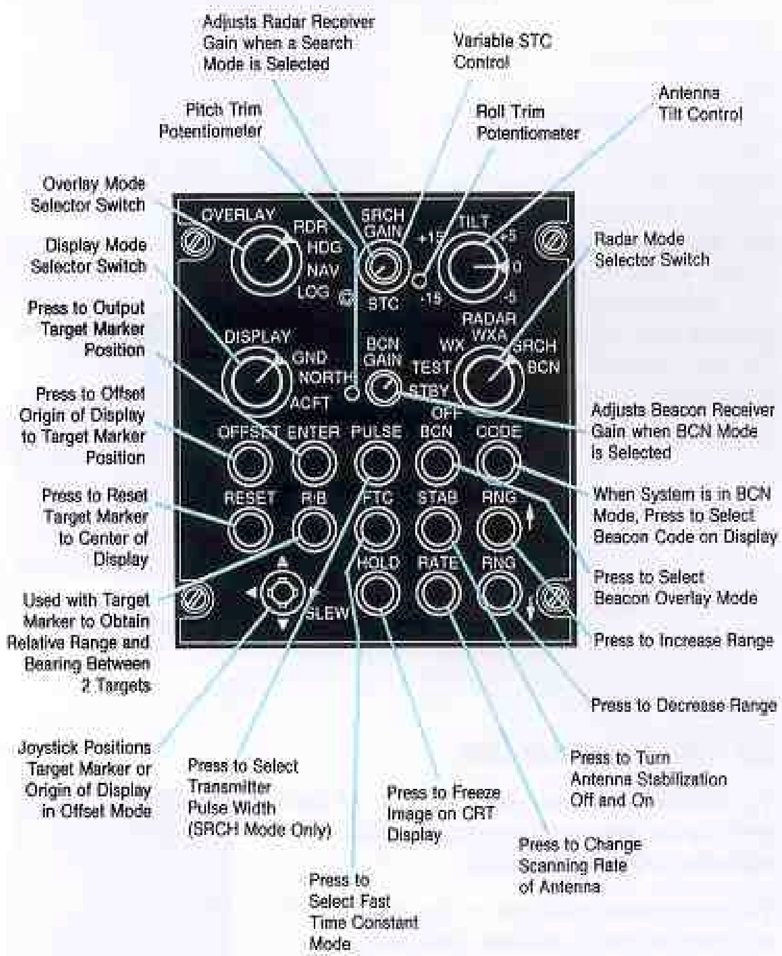
CN-1506A Control Unit

The CN-1506A Control Unit contains all the controls for the radar system except the indicator brightness control.

The pushbutton switches on the control unit are used to enable various functions. Some pushbuttons activate the function when pressed momentarily and deactivate or return to the original condition when pressed again.

CN-1506A Control Unit

CN-1506A Operating Controls



CN-1506A Control Unit

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OVERLAY Mode Selector

RDR position displays the selected **RADAR** information with no overlays.

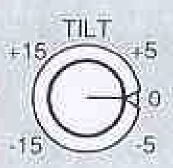
HDG position is the same as RDR with heading information superimposed over the radar data.

NAV position displays waypoint information from the navigation system. The display may be superimposed over the selected **RADAR** mode.

LOG position displays flight log information obtained from the navigation system. Radar data is not displayed in **LOG** mode.

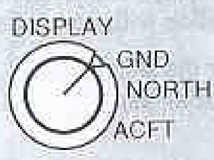
SRCH GAIN control varies the radar receiver gain when the Search (**SRCH**) mode is selected. Gain is preset in the **WX** and **WXA** modes.

STC Control varies the radar receiver STC (Sensitivity Time Constant) during Search mode to reduce clutter. **STC** is preset in the **TEST**, **WX**, **WXA** and **BCN** modes.



Adjusts the antenna tilt from +15° to -15°.

DISPLAY Mode Selector



GND position (Ground Stabilized mode), when first selected, places the aircraft symbol at the center of the screen with North at the top and range marks concentric with the aircraft symbol. The scene remains stationary while the aircraft symbol and concentric range rings move. The heading stroke and aircraft symbol point in the direction of the aircraft's heading.

NORTH position displays the radar image with North oriented at the top center of the screen. A North marker appears at the top confirming selected mode. A heading stroke, aligned with the aircraft symbol, points in the direction of the aircraft magnetic heading.

ACFT position displays the radar image with the aircraft heading oriented toward the top center of the screen.

Varies the beacon receiver gain when **BCN** mode is selected.

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RADAR Mode Selector

OFF position removes primary power from the system.

STBY places the radar system in the ready state while not in use. The overlay modes may be displayed on the indicator while in **STBY**. No radar transmission occurs in **STBY**.

TEST position displays a test pattern on the screen. The legend **TEST** appears in the upper left corner of the display and **RT FAULT** appears along the right edge. No radar transmission occurs in **TEST**.

WX position selects the Weather mode. **WX** appears in the upper left corner of the display.

WXA position selects the Weather Alert mode. **WXA** appears in the upper left corner and red areas on the display flash.

SRCH position selects the Search mode. **PULSE** and **FTC** pushbuttons, and **STC** and **SRCH GAIN** controls are activated.

BCN position selects the Beacon Only mode without the Search or Weather modes. The beacon only mode may be superimposed with **HDG** or **NAV** overlay mode.

OFFSET pushbutton, when pressed, clears the display and offsets the sweep origin to the current target marker position. The target marker is positioned by the joystick. In ground stabilized mode, (**GND**), the ground reference is relocated to the target marker position.

RESET

When in **R/B** mode, pressing **RESET** clears target marker. When not in **R/B** mode, **RESET** centers the target marker position.

ENTER

ENTER pushbutton, when pressed, transmits Target Marker Position to external equipment such as LNAV or data link equipment, provided valid NAV inputs are available. In some configurations, during target position transmission the displayed RNG/BRG or LAT/LON legend color changes as follows:

RADAR MODE	NORMAL COLOR	COLOR DURING TRANSMISSION
TEST or WX	Yellow	Blue*
SRCH	Yellow	Green*

*Same color as range marks

R/B

The **R/B** (Range/Bearing) pushbutton is used to mark a reference point on the screen with an X. Selecting any other target will display relative range and bearing from the X to the second target point.

Operation of the joystick will position the primary marker on a target of interest. Relative range and bearing between the marked reference point and the target of interest will be displayed.

Pressing either **RNG** pushbutton clears the display and advances the range to the next higher or lower range each time the button is pressed. The range selected is displayed along the left edge of the screen. The distance from the aircraft to various range rings is displayed along the right edge of some of the range rings.

The **PULSE** pushbutton, active only in the **RADAR SRCH** mode, selects the short, medium or long transmitter pulse width. A fourth automatic selection is provided. In **AUTO** mode the pulse width is controlled by the selected range.

BCN pushbutton, selects the Beacon mode. All operating beacons in the displayed areas will appear on the screen. **BCN** mode may be displayed alone (Radar mode selector set to **BCN**) or superimposed on radar returns (**SRCH, WX, WXA**).

Pressing the **CODE** pushbutton identifies each SST-181E type beacon displayed when in **BCN** mode. The letter **B** followed by a number appears next to the beacon marker in the display for identification.

Pressing the **FTC** pushbutton changes the time constant in the RT unit video circuits during Search mode to enhance clutter reduction.

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Pressing the **STAB** pushbutton turns off antenna stabilization. The words **STAB OFF** will appear along the left edge of the display. Pressing again turns stabilization back on.

Pressing the **HOLD** pushbutton freezes the radar data image in any mode. The legend **HOLD** flashes in the upper left corner of the display. During **HOLD** the radar stops transmitting energy. Pressing **HOLD** again unfreezes the display and the radar resumes transmission. **HOLD** is also discontinued by changing range or mode.

WARNING

IN SOME SYSTEM CONFIGURATIONS RADAR TRANSMISSION CONTINUES DURING HOLD. REFER TO MPEL WARNING ON PAGE 47 OF THIS BOOKLET.

Pressing the **RATE** pushbutton changes the antenna scan rate from 90°/second (15 RPM) to 45°/second (7.5 RPM). Pressing again returns the scan to 90°/second.

During sector scan operation (DA-1203A Antenna Drive) pressing **RATE** changes the scan angle from 120° to 30°. Another press of the button changes to 60°, and another press changes back to 120°.

Moving the joystick slews the target marker up, down, right or left. The speed of marker movement increases in steps as the joystick is held in place.

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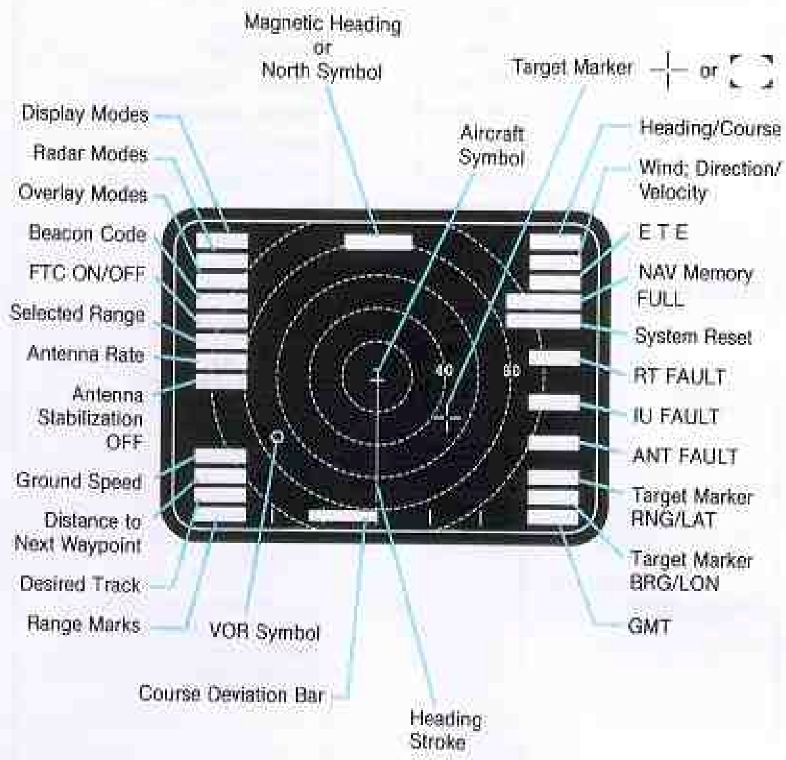
Display Format



The display format shown in this illustration is listed in the following table. The table lists the alphanumerics which appear on the display followed by a description. The table is keyed to the display shown in the illustration starting with Display Modes, Radar Modes, and Overlay Modes, then listing the balance of the display format.

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DISPLAY FORMAT	ALPHANUMERIC	DESCRIPTION
Display Modes	ACFT GND NORTH	Aircraft heading reference Ground reference Magnetic north reference
Radar Modes	TEST WX WXA SRCH S SRCH M SRCH L SRCH A BCN ONLY	Test pattern/Self-test Weather Weather Alert Search, Short Pulse Width Search, Medium Pulse Width Search, Long Pulse Width Search, Auto Pulse Width Beacon
HOLD FUNCTION	HOLD	HOLD flashes
Overlay Modes	RDR HDG NAV (NO NAV) LOG (NO LOG)	Radar with no overlay Radar with heading overlay NAV overlay (NAV not operational) NAV LOG (NAV LOG not operational)
Beacon Code	BCN--	One of 10 beacon codes
Fast Time Constant	FTC ON FTC OFF	Appears when FTC pushbutton is pressed
Selected Range	.125/.625 NM .25/1.25 NM .5/2.5 NM 1/5 NM 2/10 NM 5/20 NM 10/40 NM 20/80 NM 40/160 NM	One of nine ranges. First number is spacing between range rings, second number is selected range.
Antenna Rate	--°/SEC --DEG	45° or 90°/sec, 360° mode 120°, 60° or 30°, sector scan mode
Antenna Stabilization	STAB OFF	Annunciates when antenna stabilization is off
Ground Speed (NAV)	GS---	Knots, 3 digits
Distance to Next Waypoint (NAV)	DST---	Distance in Nautical Miles, 3 digits
Desired Track (NAV)	DTK---	Degrees, 3 digits
Range Marks	MKS--	Distance between range marks, 3 digits, NM

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DISPLAY FORMAT	ALPHANUMERIC	DESCRIPTION
Heading or Course	---° T ---° M	Degrees, True North Degrees, Magnetic North
Wind Direction and Velocity	WND---°---	Degrees, 3 digits Velocity, 3 digits
Estimated Time Enroute	ETE (Hrs:Min)	ETE up to 6 hrs, 40 min
NAV Memory Warning	NAV MEM FULL	NAV Unit Memory Full
System Reset	SYS RESET	Usually appears at Power On
RT Fault Indicator	RT FAULT	Appears when the RT unit fails
Interface Unit Fault Indicator	IU FAULT	Appears when the IU fails
Antenna Drive Unit Fault Indicator	ANT FAULT	Appears when the Antenna Drive Unit fails
Target Marker, RNG/LAT Information	RNG--- RRNG--- LAT---°---.-'	Distance in NM, when target marker is active Distance in NM, when R/B (Range/Bearing) is active Latitude
Target Marker, BRG/LON Information	BRG--- RBRG--- LON---°---.-'	Degrees, when target marker is active Degrees, when R/B (Range/Bearing) is active Longitude
GMT	Hrs:Min	Greenwich Mean Time
North Symbol and Heading Index	N ♦	Appears in NORTH and GND stabilized modes
Magnetic Heading and Heading Index	170 | 180 | 190 ♦	Compass Card, appears in ACFT mode
Course Deviation Bar		Each line represents 2.5 NM
Relative Bearing	X	Appears when R/B is active
Target Marker		Location of target marker
Heading Stroke		Represents Aircraft Heading
Aircraft Symbol		Located at sweep origin
VOR Symbol		Location of VOR/DME station

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System Operation

Various combinations of radar system and display modes may be selected and several overlay modes are available. The modes, **RADAR**, **DISPLAY** and **OVERLAY**, are each controlled by a dedicated multiple position rotary selector switch on the control unit. Selected mode annunciation appears in the upper left corner of the display. The radar, search or beacon data can be displayed alone or with HDG or NAV information superimposed over them. Range selection and certain other functions are controlled by pushbutton switches.

Radar Mode Selection (SRCH, WX, WXA)

WARNING

BEFORE SELECTION OF A RADAR MODE (SRCH, WX, WXA) OR THE BEACON MODE (BCN), MAKE CERTAIN THAT SAFE CONDITIONS EXIST FOR TRANSMISSION OF MICROWAVE ENERGY. DO NOT ALLOW PERSONNEL WITHIN 15 FEET OF THE ANTENNA WHILE IT IS RADIATING. DO NOT RADIATE RF ENERGY IN THE VICINITY OF FUELING OPERATIONS.

To select a Radar Mode, rotate the **OVERLAY** mode selector to the **RDR** position and **DISPLAY** selector to the **ACFT** position. Rotate the **RADAR** mode selector to the desired mode (**SRCH, WX, WXA**). The mode selected appears in the upper left corner of the display. In the **SRCH** mode, the **PULSE** pushbutton selects long, medium or short pulse width or auto-search.

NOTE: Selection of the RDR position on the OVERLAY mode selector combined with STBY on the RADAR mode selector will cause the screen to blank.

To change modes, rotate the **RADAR** mode selector to the desired position. The newly selected mode legend appears in the upper left corner of the display.

Search Mode (SRCH)

The RDR-1500B Radar System provides a Search mode with nine ranges using three operator selectable pulse widths. In sea search operations, the radar system can detect and display surface targets down to a minimum tracking range of 500 feet. Search mode permits searching for boats at sea, terrain mapping of topographical features such as bodies of water, islands and bridges, and mapping of oil slicks.

The radar returns are presented in three colors. Areas with the lightest return appear in blue. The next level of intensity is shown in yellow and the areas of greatest return are shown in red on the radar display.

The short and medium pulse widths can be used for precision terrain mapping with very high resolution or for sea search operations. The wide pulse width is designed for long range ground mapping and sea search operation. In **AUTO** mode the pulse width is controlled by the selected range.

AUTO PULSE WIDTH RANGES		
Range (NM)	Range Rings (NM)	Auto Search Selection Pulsewidth
0.625	0.125	Short
1.25	0.25	Short
2.5	0.5	Short
5.0	1.0	Short
10.0	2.0	Medium
20.0	5.0	Medium
40.0	10.0	Long
80.0	20.0	Long
160.0	40.0	Long

The **SRCH GAIN** control setting is an operator adjustment, important in obtaining a definitive picture with changing topographical conditions. For example, when searching for an oil slick in other than calm seas the long pulse is used, with sufficient **SRCH GAIN** to color the screen. The region of an oil slick shows up as a black area or a lower level of return within the sea clutter.

In the Search mode, the variable **STC** (Sensitivity Time Constant) control and the **FTC** (Fast Time Constant) switch are enabled to enhance clutter rejection. The variable **STC** control must be set together with the **SRCH GAIN** control. The **STC** control is used to reduce sea clutter on the display during Search mode.

STC ADJUSTMENT RANGES	
Pulse Width	STC Range
Short	10 NM
Medium	20 NM
Long	55 NM

Pressing the **FTC** pushbutton changes the time constant in the RT unit video circuits during Search mode to provide clutter rejection of either sea or terrain returns. **FTC** can also be used to reduce rain clutter in light to medium precipitation.

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Radar Mode Display Colors

DISPLAY COLORS	RADAR MODES		
	WX	WXA	SRCH
Light Returns	Green	Green	Blue
Medium Returns	Yellow	Yellow	Yellow
Strong Returns	Red	Flashing Red	Red

Traveling southbound parallel to and slightly offshore, the radar has detected three targets ahead in the water using the SEARCH S pulse.

Weather Avoidance Modes (WX and WXA)

NOTE: Employing the system for Weather Avoidance operation aboard aircraft using a belly mounted antenna may be difficult due to the blanking effect of the airframe structure and distortion of the antenna beam with uptilt.

The system furnishes continuous enroute weather information relative to rain cloud formation and rainfall rate. It provides a means of determining the relative density of rainfall areas. Viewing the color indicator, the operator can see storm areas in the flight path and can also distinguish corridors of relative calm through the storms.

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The system detects the strong returns from high density rainfall and converts them into red areas on the radar display. In the **WX** and **WXA** modes, the radar receiver gain is preset to obtain a calibrated red display at a predetermined storm cell level. Yellow areas, usually surrounding red, represent regions of lower rainfall rates. Areas with the lightest rainfall are green on the display. In Weather Alert **(WxA)** mode, the red areas flash.

The **STC** circuit ensures that echo signals are displayed with nearly equal intensity from similar targets from near zero range to approximately 55 nautical miles.

Beacon Mode

Beacon Mode Selection (BCN ONLY, BCN)

To display beacon returns alone, place the **RADAR** mode selector in the **BCN** position. The legend **BCN ONLY** appears in the upper left corner of the display. To remove **BCN ONLY** display, set the **RADAR** mode selector to another position.

To superimpose beacon returns over any other mode, set the **RADAR** mode selector to the desired mode and press the **BCN** pushbutton. The beacon mode can also be selected with the **HDG** or **NAV** overlay modes.

Adjust **BCN GAIN** control as required. Beacon returns are often very strong and gain may have to be reduced while approaching the target beacon to prevent ringaround.

To identify a particular beacon, press the **CODE** pushbutton until the desired number appears next to the beacon legend on the screen. Repeatedly pressing the **CODE** button sequences through while holding the **CODE** button depressed slews through the codes. The code number corresponding to the beacon pulse spacing appears on the screen next to the beacon return. One antenna sweep is required before the beacon legend appears.

To remove the superimposed beacon display, press the **BCN** pushbutton again.

Beacon Interrogation and Codes

The transmitter of the RT-1501A sends an interrogation signal to the beacon transponders when the **BCN** mode is selected on the control unit. All beacons of the SST-181E class (two-pulse beacons) receiving the signal reply by transmitting a two-pulse signal.

All beacons operate at the same frequency. Transponders in a given area are assigned deferent spacings between the two pulses broadcast upon each interrogation, thus allowing discrete identification.

All responding beacons within the area displayed, up to 160 NM, appear on the indicator screen. Each beacon location appears as two short curved white lines. Distance between the lines corresponds to pulse spacing from the transponder.

The first pulse received from the transponder generates the curved line closest to the aircraft symbol as the antenna scans the beacon. Actual beacon location is at the center of this curved line.

It is possible that the second pulse received from the transponder cannot be displayed when a short range is selected or when the beacon location is near the limit of the selected range. However, the system collects and processes beacon data for 13 miles beyond the selected range to allow identification of all beacons within range.

There is a delay between the time that the beacon transponder receives a radar pulse and sends a reply (first of two pulses). The delay time affects the beacon range location on the display and is usually adjustable on the beacon. If the transponder delay is longer, the beacon appears further away.

Since the responding beacon is known, a particular beacon in a crowded environment can be identified from the codes listed in the table.

Code Displayed	Spacing Between Beacon Pulses (In Miles)	Code Displayed	Spacing Between Beacon Pulses (In Miles)
	B1 Not Used	B6	7.1 to 8.7
B2	3.6 to 4.3	B7	8.0 to 9.8
B3	4.4 to 5.4	B8	8.9 to 10.9
B4	5.3 to 6.5	B9	9.8 to 11.9
B5	6.2 to 7.6	B10	10.7 to 13.7

NOTE: Pulse spacing is determined by the beacon manufacturer specifications for the SST-181E X-band radar transponder and similar type beacons. Because of the beacon spacing overlap, especially in the last five beacon codes, it is recommended that for positive identification in multiple beacon operations, even or odd spacing should be used to prevent wrong code identification. Also, after acquiring and identifying a beacon, it may be necessary to increase or decrease the code by one number to ensure that beacon transponders are not centered in code spacing.

Assume you are looking for a beacon with pulse spacing of 5.0 miles. This beacon signal is coded "B3" on the indicator. To find the beacon:

Turn on the system and press the **BCN** mode button. Observe that the word **BCN** appears at the left side of the display.

Press and hold the **CODE** button, or step through the codes to read the code number that appears after the word **BCN** in the display, e.g., **BCN1**, **BCN2**, **BCN3**.

Release the **CODE** button when code 3 appears after **BCN**.

If the desired beacon is within range, **B3** appears by the first mark in the beacon return.

Overlay Mode Selection (RDR, HDG, NAV, LOG)

RDR Overlay

When **RDR** (radar) mode is selected, radar information is displayed without overlay of **HDG** or **NAV** information. That is, the heading ribbon and navigation information are deleted from the screen.

RADAR and **DISPLAY** modes may be selected together. Range mark spacing is shown in the lower left corner. Aircraft heading and GMT are displayed in the upper and lower right corners of the screen, respectively, if the NAV input is connected.

HDG Overlay

HDG mode is similar to the **RDR** mode except that heading information is superimposed over the radar data and the range marks are located on every other range ring. The legend **HDG** appears in the upper left corner of the display, just below the selected **RADAR** mode identifier. No other **OVERLAY** data is displayed.

The heading format is displayed at the top center of the screen. In **ACFT** display mode, heading is presented on a compass card ribbon giving three 3-digit readouts. As the aircraft heading changes, the scale of heading digits changes accordingly. Compass heading markers appear at one degree increments for the initial five degrees left and right. In **GND** and **NORTH** display modes, a north marker replaces the compass ribbon.

NAV Overlay

NAV mode displays navigation information superimposed over the selected radar information. The **NAV** mode may be used alone or with the Search, Weather or Beacon mode.

NOTE: **If the radar system is using a sector scan antenna (DA-1203A) drive, place the RADAR mode selector to STBY to obtain a full 360° display of the NAV waypoints.**

Waypoint information from a compatible navigation system is processed by the radar system and waypoint positions are plotted on the display. Information displayed includes waypoint numbers and positions, courselines between waypoints, search patterns, left/right course deviation error on the deviation bar, desired track and distance. In **NAV** mode, ground speed **(GS)**, distance to waypoint **(DST)** and desired track **(DTK)** are displayed in the lower left corner. Also, wind direction, wind speed, and estimated time enroute **(ETE)** in hours

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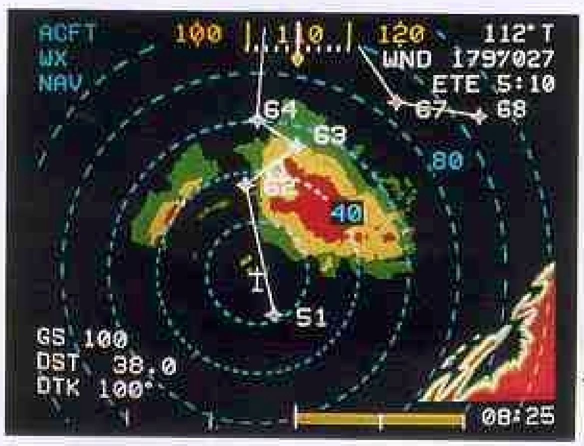
and minutes are displayed in the upper right corner. The legend **NAV** appears in the upper left corner of the screen. Greenwich Mean Time (**GMT**) is displayed in the lower right corner.

The waypoints programmed into the system are shown by stars (✧) on the indicator screen if the waypoints are within the field of view.
The number for each waypoint appears beside the star and corresponds to the waypoints that are displayed in the **LOG** mode. White course lines depict the course between waypoints within range.

The waypoint positions and course lines are continuously updated to reflect heading changes, range changes and distance traveled.



NAV Overlay Selected With Weather

A VOR symbol showing the location of the selected VOR/DME station is displayed when the signals are received.

In the **NAV** mode, the **SLEW** joystick and **ENTER** pushbutton are used to send the position of an extra waypoint to the **NAV** system, provided that the **NAV** system has the capability of processing and using this waypoint.

If the navigation system is not operational, the words **NO NAV** are displayed in the upper left corner of the screen.

LOG Overlay

The **NAV LOG** mode is selected to obtain a display of flight log information programmed into the LNAV system. In the **NAV LOG** mode, latitude and longitude of the waypoints are displayed as well as the waypoints the aircraft is flying to or from. Radar data (Search, Weather or Beacon) are not displayed in the **NAV LOG** mode. This display facilitates in flight reprogramming of the waypoints.

Up to ten programmed waypoints with course information are shown in the LOG mode.

The flight log display consists of ten lines of information separated into three columns. The column headings are as follows:

WPT — Waypoints are numbered sequentially.

LAT — Latitude of the waypoint.

LON — Longitude of the waypoint.

The letters **FR** appear to the left of the waypoint that the aircraft is traveling from and the **TO** appears beside the waypoints that the aircraft is traveling to. The FR line is shown in yellow and the rest of the screen is shown in blue.

If NAV data is not available the legend **NO LOG** appears instead. Radar data is not displayed in the **LOG** mode.

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Display Mode Selection (ACFT, NORTH, GND)

ACFT Stabilized Mode

In the **ACFT** position the radar image and overlays are displayed with the current aircraft magnetic heading at the top center of the screen (except when the **OVERLAY** mode selector is set to the **RDR** position). In the **NAV** mode, heading markers and a compass card are displayed. The deviation bar is displayed at the bottom center of the screen.

The legend **ACFT** appears in the upper left corner of the screen.

NOTE: A radar system using a sector scan antenna drive (DA-1203A) will not enter the NORTH or GND stabilized mode when the radar is operating. To use the following described modes the RADAR mode selector switch must be set to STBY.

Overlay Mode/Display Mode Selection Chart

DISPLAY MODES	OVERLAY MODES			
	RDR	HDG	NAV	Log
GND*	Stationary Radar Scene Acft Symbol Moves North Marker Range Mark Alphanumerics	Stationary Radar Scene Acft Symbol Moves North Marker Range Marks on Range Ring	Stationary Radar Scene Acft Symbol Moves North Marker Nav Info Range Marks on Range Ring	Log Only
NORTH*	Moving Radar Scene North Marker Range Mark Alphanumerics	Moving Radar Scene North Marker Range Marks on Range Ring	Moving Radar Scene North Marker Nav Info Range Marks on Range Ring	Log Only
ACFT	Moving Radar Scene Only Range Mark Alphanumerics	Moving Radar Scene Compass Card Range Marks on Range Ring	Moving Radar Scene Compass Card Nav Info Range Marks on Range Ring	Log Only

*Not with sector scan antenna drive.
RDR OVERLAY combined with STBY on the RADAR selector produces a blank screen.

NORTH Stabilized Mode

In the **NORTH** stabilized mode, the radar image is displayed with North at the top center of the screen. The magnetic heading ribbon does not appear since screen orientation is always North up. A heading stroke appears, pointing in the direction of the aircraft heading. A yellow diamond heading index (♦) with the letter **N** above indicates **NORTH** mode selected.

GND Stabilized Mode (Also known as True Motion Display)

In the **GND** stabilized mode, the display scene remains stationary while the aircraft symbol and concentric range rings move over the stationary display. The scene is continuously updated so that moving objects are repositioned on the screen. A North marker appears at the top and a heading stroke points in the direction of the aircraft movement. The scene center can be relocated using the control unit.

When the aircraft flies off the screen, the system automatically enters the **HOLD** mode.

When in the **GND** mode, briefly selecting, then deselecting the **HOLD** mode causes moving targets to jump to their new location, aiding in identification of moving targets over a fixed ground reference. Operation of the **R/B** function accurately provides direction of target movement and distance of displacement.

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During the **GND** stabilized mode, operation of the **OFFSET** feature may place the system in the **HOLD** mode if the target marker position is near the edge of the screen. The scene center can be relocated by pressing the **OFFSET** pushbutton and moving it with the joystick on the control unit.

Offset Mode Selection

The sweep origin may be offset to any location on the screen. The **SLEW** joystick moves the target marker to the desired position. Pressing the **OFFSET** pushbutton clears the display and relocates the sweep origin to the target marker. In ground stabilized mode, (**GND**), pressing **OFFSET** relocates the ground reference to the target marker position.

The system processes radar data out to twice the selected range, thus, when the sweep is offset to one edge of the indicator screen, no targets are lost at the opposite side of the screen. Additional range rings may appear in the offset mode, depending upon the amount of offset selected.

Pressing the **RESET** pushbutton twice centers the target marker. Then pressing **OFFSET** centers the aircraft symbol on the screen. Pressing reset again eliminates the target marker.

By using the joystick control, the operator is able to offset the sweep origin. In the above display the operator has selected NAV Overlay mode allowing the operator to concentrate on the programmed search pattern.

Range Selection

Pressing the **RNG** ↑ or **RNG** ↓ pushbuttons increases or decreases the range displayed as desired. The range is incremented or decremented for each push of the button.

The display is erased completely and the screen is redrawn on the newly selected range.

Observe that the range selected and distance between range marks are shown at the left side of the display. In **RDR** mode the range mark distance is shown in the lower left corner. The distance to the second and fourth range rings is shown on the right side of the screen.

NOTE: Additional range rings may be generated in the OFFSET mode.

Target Marker Operation

Pressing the **RESET** pushbutton or moving the **SLEW** joystick produces the target marker on the screen at the sweep origin. To relocate the target marker, move the joystick up, down, left or right until it is positioned at the desired location.

The target marker will wrap around the screen top to bottom or left to right and vice versa. That is, when the target marker is moved off the left side of the screen, it reappears at the right side.

Range and bearing relative to the aircraft position are displayed in the lower right corner of the screen. (A valid navigation input signal to the system is required.) Movement of the joystick in any direction changes the readout back to range and bearing.

To clear the target marker and remove the range and bearing legend press the **RESET** pushbutton.

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Range and Bearing To A Selected Target

Automatic Range and Bearing Between Two Selected Targets

To find range and bearing between two selected targets, position the target marker over target 1 using the **SLEW** joystick. Range and bearing are displayed at the bottom right corner of the screen.

Mark the first target by pressing the **R/B** pushbutton. An **X** marks the spot of the target. This designates target 1 as the base from which relative range and bearing are to be measured. **RRNG = 0** and **RBRG = 0** are now displayed at the bottom right corner of the screen. A green or blue **X** appears to mark this position.

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Place the target marker over target 2 using the **SLEW** joystick. The relative range and bearing from target 1 to target 2 are now displayed in place of the range and bearing from your own aircraft to the target.

Pressing the **RESET** pushbutton returns the range and bearing base to the aircraft position.

Range and Bearing Between Two Selected Targets

Antenna Operation

Antenna Rate

Each press of the **RATE** pushbutton changes antenna scan rate between 45° per second (7½ RPM) and 90° per second (15 RPM). The scan rate is annunciated along the left edge of the display for approximately 30 seconds, then disappears. The antenna rate can be observed on the indicator as the scanning speed increases and decreases.

NOTE: Scan rate in the 360° system affects the clutter rejection capability of the radar. It is better to select 45° per second when searching in heavy sea clutter.

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Sector Scan

In addition to 360° operation, 120° sector scan is available with the DA-1203A Antenna Drive Unit. Sector scan operation is compatible with all of the radar modes of operation but is limited in the number of display modes available. **NORTH** stabilized mode and **GND** stabilized mode are provided only with **NAV** overlay mode without radar. If the DISPLAY selector switch on the control unit is set to either the **GND** or **NORTH** stabilized operation, the system remains in the **ACFT** stabilized mode. Annunciation of the display mode is then shown in yellow.

NOTE: **A radar system using a sector scan antenna drive (DA-1203A) does not change antenna speed. During sector scan operation pressing RATE changes the scan angle from 120° to 30°. Pressing the pushbutton again changes to 60°, and another press changes back to 120°.**

The selectable rate function is the same during sector scan as it is in 360° scan operation. The purpose is to change the rate at which a target is updated. In 360° mode, the update rate changes by selecting a different antenna speed. In sector scan, update rate is changed by selecting the number of degrees over which the antenna scans; 30°, 60° or 120°.

The **NAV** overlay mode is available in sector scan operation. In any of the radar transmission modes, **SRCH**, **WX**, **WXA**, and **BCN**, the NAV waypoints in the sector scan display are shown. If a full 360° presentation of NAV waypoints is desired, the 360° display can be acquired by placing the radar system into the standby mode.

Tilt Control

The **TILT** control is used to center the radar beam over the target of importance. A constant height approach to a target requires downward adjustment of the **TILT** control to keep the target within the radar beam.

Stabilization (STAB Function)

Pressing the **STAB** pushbutton turns off antenna stabilization. The legend **STAB OFF** appears along the left edge of the display. The antenna is not stabilized and the display varies with aircraft attitude.

NOTE: This control is normally not used. It is intended to be used only when the antenna stabilization system is inoperative or is suspected of failure.

Pressing the **STAB** pushbutton again restores stabilization to the antenna. The legend **STAB OFF** disappears and normal stabilization display returns.

Display Hold Function

Pressing the **HOLD** pushbutton freezes the display on the screen. The legend **HOLD** flashes in yellow letters in the upper left corner of the display. While in **HOLD** mode the antenna continues to scan and the radar is still transmitting.

WARNING

THE EXISTING DISPLAY IS THE LAST IMAGE STORED IN THE INDICATOR MEMORY AND DOES NOT REPRESENT THE TRUE OR CHANGING CONDITIONS RELATIVE TO THE MOVING AIRCRAFT.

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The **HOLD** mode is cleared by pressing the HOLD pushbutton again, or by changing operations, modes or ranges. The flashing legend disappears and the display is updated by the next scan of the antenna.

The operator selects HOLD to freeze the display.

External Display Input Mode

Forward Looking Infrared (FLIR) or composite TV video inputs can be selected for display by a remotely mounted switch. Both FLIR and TV are displayed in green.

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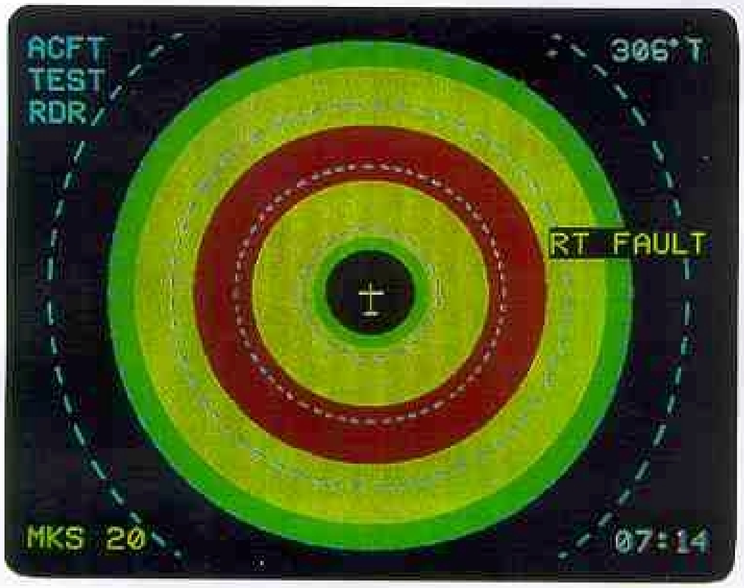
Preflight Check



Typical Test Pattern

NOTE: In later configurations, RT FAULT is displayed *only* when an actual fault is detected.

WARNING

DO NOT TURN THE RADAR ON WITHIN 15 FEET OF GROUND PERSONNEL OR CONTAINERS HOLDING FLAMMABLE OR EXPLOSIVE MATERIAL. THE RADAR SHOULD NEVER BE OPERATED DURING FUELING OPERATIONS.

WARNING

WHENEVER THE RADAR MODE SELECTOR SWITCH IS IN ANY POSITION EXCEPT "OFF", "STBY" OR "TEST", RF ENERGY IS RADIATED FROM THE ANTENNA. DO NOT ALLOW PERSONNEL WITHIN 15 FEET OF THE ANTENNA WHILE IT IS RADIATING. TESTS INVOLVING THE RADIATION OF RF ENERGY MUST NOT BE MADE IN THE VICINITY OF REFUELING OPERATIONS. USE ONLY "TEST" OR "STBY" POSITIONS IN SUCH AN ENVIRONMENT.

1. Rotate the **RADAR** mode selector from **OFF** to the **TEST** position. Wait 60 to 90 seconds for the equipment to warm up. When working normally the test pattern will appear in the **TEST** mode.

NOTE: Placing the RADAR mode selector to STBY will also warm up the equipment. The antenna does not scan in STBY, however overlay functions may be selected and displayed.

Set **SRCH GAIN** control and variable **STC** control to maximum position (fully clockwise). The word **TEST** appears in the upper left corner. In some earlier configurations, **RT FAULT** appears along the right edge of the display. Adjust the indicator **BRT** control for desired screen brightness.

2. Set range to 80 NM. Check that the test pattern displays five colored bands. Starting with the closest band to the origin, the bands are green, yellow, red, yellow and green. All range rings are visible and displayed in blue.

3. Observe the screen update activity indicating that the antenna is scanning the full 360°.

NOTE: The test pattern simulates a target extending from approximately 30 NM to 70 NM. While stepping through the ranges, the test pattern position is altered accordingly on the screen.

4. Select a range of 0.625 NM. The test pattern is beyond the area being scanned. Increase range one step at a time. Observe that the test pattern appears in the correct range when within the field of view and that proper range marks appear on the display.

5. When the aircraft is taxied to a clear area where metal buildings or similar obstructions do not block the line of sight, place the mode selector switch in the **WX** position. The legend **WX** appears in the upper left corner of the indicator.

6. Adjust the **TILT** control up (+ degrees) in small increments until a clear picture of any local weather develops. Close in ground targets may also appear in the display.

NOTE: Tiltup scanning may not be possible with certain belly mounted antenna installations at any time.

7. Check the rest of the ranges while repeating **TILT** control adjustment.

8. Set the **RADAR** mode selector switch to **SRCH** and sequentially step through **SRCH S**, **SRCH M**, **SRCH L** and **SRCH A** with the **PULSE** pushbutton. Observe that for each pulse selected, the relevant annunciation appears in the upper left corner of the display and that the fault display remains off.

9. Set the **RADAR** mode selector switch to **BCN** and the range to 20 NM. Observe that the legend **BCN ONLY** appears in the upper left corner of the display. Press the **BCN** pushbutton. The fault indicator should be off and the display should be free of all noise and ground clutter. If a beacon station of 9310 MHz is within range, a beacon target is observed on the screen.

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Glossary

DME	Distance Measuring Equipment. Refers to VOR/DME navigation.
DST	Distance. Refers to aircraft distance to waypoint.
DTK	Desired Track.
ETA	Estimated Time of Arrival.
ETE	Estimated Time Enroute.
FLIR	Forward Looking InfraRed.
FTC	Fast Time Constant.
GS	Ground Speed.
GMT	Greenwich Mean Time.
GND	Ground. Refers to GND stabilized mode of operation.
HDG	Heading. Refers to aircraft magnetic heading or HDG overlay mode.
IAS	Indicated Air Speed.
INS	Inertial Navigation System.
LNAV	Lateral Navigation system.
NAV	Navigation. Refers to NAV mode using navigation systems capable of locating waypoints.
NM	Nautical Miles.
PPI	Plan Position Indicator.
PRF	Pulse Repetition Frequency.
SRCH S, SRCH M, SRCH L, SRCH A	Search Ranges; Pulse Widths Used — Short, Medium, Long and Automatic.
STC	Sensitivity Time Constant.
VOR	VHF Omni Range. Refers to navigation system.
Wx	Weather. Refers to Weather mode of operation.
WxA	Weather Alert. Refers to Weather Alert mode of operation.

US Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: THUNDERSTORMS

Date: 1/20/83
Initiated by: AFO-260
AC No: 00-24B
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, dated June 23, 1978, is canceled.

3. RELATED READING MATERIAL. Advisory Circulars 00-6A, Aviation Weather, 00-45B, 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 200 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."

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(2) Tornadoes occur with both isolated and squall line thunderstorms. Reports for forecasts of tornadoes indicate that atmospheric conditions are favorable for violent 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 on instruments in a severe thunderstorm could encounter a hidden vortex.

(3) Families of tornadoes 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.

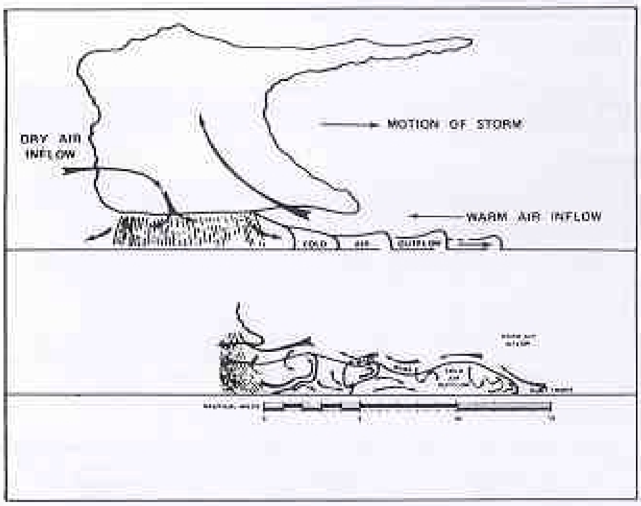
(1) Potentially hazardous turbulence is present in all thunderstorms, and a severe thunderstorm can destroy an aircraft. Strongest turbulence within the cloud occurs with shear between updrafts and downdrafts. Outside the cloud, shear turbulence has been encountered several thousand feet above and 20 miles laterally from a severe storm. A low level turbulent area is the shear zone associated with the gust front. Often, a "roll cloud" on the leading edge of a storm marks the top of the eddies 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 approaching storm. Advisory Circular 00-50A, "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 maneuvering in an attempt to do so produces greatly increased stress on the aircraft. It is understandable that the speed of the aircraft determines the rate of turbulence encounters. Stresses are least if the aircraft is held in a constant attitude and allowed to "ride the waves." To date, we have no sure way to pick "soft spots" in a thunderstorm.

d. Icing.

(1) Updrafts in a thunderstorm support abundant liquid water with relatively large droplet sizes; 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, at 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, icing from smaller droplets may be rime or mixed rime and clear. 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.



e. Hail.

(1) Hail competes with turbulence as the greatest thunderstorm hazard to aircraft. Supercooled drops above the freezing level begin to freeze. Once a drop has frozen, other drops latch on and freeze to it, so the hailstone grows--sometimes into a huge iceball. Large hail occurs 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 0°C, 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.

40 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 arrival 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 receive a corrected altimeter setting, the altimeter may be more than 100 feet in error.

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h. Lightning. A lightning strike can puncture the skin of an aircraft and can damage communications and electronic navigational equipment. Lightning has been suspected of igniting fuel vapors causing explosion; however, serious accidents due to lightning strikes are extremely rare. Nearby lightning can blind the pilot rendering him momentarily unable to navigate either by instrument or by visual reference. Nearby lightning can also induce permanent errors in the magnetic compass. Lightning discharges, even distant ones, 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.

i. Engine Water Ingestion.

(1) Turbine engines have 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 in the thunderstorm approaches or exceeds the terminal velocity of the falling raindrops, 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 more engines.

(2) At the present time, there is no known operational procedure that can completely eliminate the possibility of engine damage/flameout during massive 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 assured to be effective in preventing exposure to this type of multiple engine damage/flameout. During an unavoidable encounter with severe storms with extreme precipitation, 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 airspeed variations occur.

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. Hailstones 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 Integrator 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 light 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, extensive surface wind gusts, and turbulence.

d. Thunderstorms build and dissipate rapidly. Therefore, do not attempt to plan a course between echoes. The best use of ground radar information is to isolate general areas and coverage of echoes. You must avoid individual storms from in-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 scattered.

e. 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.

f. Remember that while hail 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 echoes by at least 20 miles; that is, such echoes should be separated by at least 40 miles before you fly between them. With weaker echos you can reduce the distance by which you avoid them.

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

a. Above all, 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 gust 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 not embedded usually can be visually circumnavigated.

(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 anvil 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 determined by radar.

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

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

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

(3) To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of -15°C.

(4) 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.

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

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

(7) 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.

(8) 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 some do's and don'ts during the thunderstorm penetration:

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

(2) Don't change power settings; maintain settings for the recommended turbulence penetration airspeed.

(3) Do maintain constant attitude; let the aircraft "ride the waves." Maneuvers in trying to maintain constant altitude increase stress on the aircraft.

(4) 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.

William T. Brennan

WILLIAM T. BRENNAN
Acting Director of Flight Operations

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AC NO: 20-68B **DATE:** 8/8/80

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Washington, D.C.

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

Initiated by AFO-512

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 20-68A, dated April 11, 1975, is cancelled.

3 **RELATED READING MATERIAL.**

a Barnes and Taylor, Radiation Hazards and Protection (London: George Newnes Limited, 1963), p. 211.

b U.S. Department of Health, Education and Welfare, Public Health Service, Consumer Protection and Environmental Health Service; "Environmental health microwaves, ultraviolet radiation and radiation from lasers and television receivers—An Annotated Bibliography," FS 2.300: RH-35, Washington, U.S. Government Printing Office, pp. 56-57.

c Mumford, W. W., "Some technical aspects of microwave radiation hazards," Proceedings of the IRE, Washington, U.S. Government Printing Office, February 1961, pp. 427-447.

4 **BACKGROUND.** Dangers from ground operation of airborne weather radar include the possibility of human body damage and ignition of combustible materials be radiated energy. Low tolerance parts of the body include the eyes and testes.

5 **PRECAUTIONS.** Management and supervisory personnel should establish procedure for advising personnel of dangers from operating airborne weather radars on the ground. Precautionary 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) Installed 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 throughout the area.

b Body 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 which is transmitting. When the antenna is not scanning, the danger increases.

(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 milliwatts per 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 line 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, X-rays may be emitted. Stray X-rays may emanate from the glass envelope type pulser, oscillator, clipper, or rectifier tubes, as well as magnetrons.

c. Combustible Materials. To prevent possible fuel ignition, an installed airborne weather radar should not be operated while an aircraft is being refueled or defueled.

M.C. BEARD
Director of Airworthiness

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8/8/80

AC 20-68B
Appendix 1

APPENDIX 1. 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

$$R_i = \frac{G\lambda}{8\pi} \quad (1)$$

where Ri = Intersection distance from the antenna (in meters)
λ = Wave length (in meters)
G = Antenna gain

2. **DISTANCE TO 10 mw/cm² SAFE LIMIT.** For a far field power density of 10 mw/cm² the distance (in meters) from the antenna may be calculated by

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

where Rs = 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 procedures apply:
a. Determine the distance (Ri) to the near field/far field intersection (paragraph 1).
b. Determine the distance (Rs) to 10 mw/cm² power density (paragraph 2).
c. If the distance (Rs) determined in 3b above is *less* than (Ri) found in 3a above, use distance (Ri) as the minimum safe distance.
d. If the distance (Rs) determined in 3b above is *greater* than (Ri) found in 3a above, use distance (Rs) as the minimum safe distance.

4. **EXAMPLE**
a. **Data.** The following is typical data for an airborne weather radar.

Antenna Diameter	22 inches = 56 cm
Transmitter Frequency	9375 ±30 MHz
Wave Length	3.2 cm
Pulse Length	1.5 microseconds (search)
Pulse Repetition	400 Hz
Peak Power	40 kilowatts
Average Power	24 watts (search)
Antenna Gain	1000 (30db)

b. **Calculations.**
(1) **Distance (Ri) to the near field/far field intersection.**

$$R_i = \frac{G\lambda}{8\pi} = \frac{1000 \times 0.032}{8\pi} = 1.27 \text{ meters} = 4.2 \text{ feet}$$

(2) **Distance (Rs) to 10 mw/cm² safe limit.**

$$R_s = \sqrt{GP/400\pi} = \sqrt{1000 \times 24/400\pi} = 4.37 \text{ meters} = 14.3 \text{ feet}$$

The distance (Rs) is greater than (Ri), therefore, the minimum safe distance is 14.3 feet.

45

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 RADIATION ANTENNA.*
2. NEVER EXPOSE EYES OR ANY PART OF THE BODY TO AN UNTERMINATED WAVEGUIDE.

*Reference FAA Advisory Circular #20-68B

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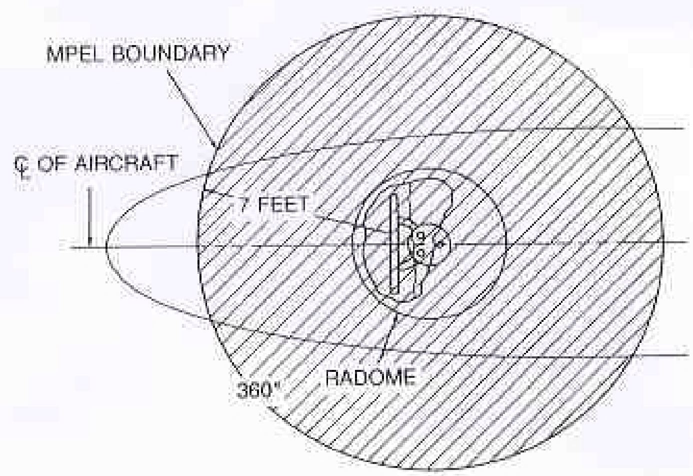
Maximum Permissible Exposure Level (MPEL)

In order to avoid the envelope in which the radiation level exceeds the U.S. Government standard of 10 mW per square centimeter, all personnel should remain beyond the distance indicated in the illustration below. The distance to the MPEL boundary is calculated upon the basis of the largest antenna available with the system, rated output power of the transmitter and in the non rotating or bore-sight position of the antenna. With a scanning beam the power density at the MPEL boundary is significantly reduced.



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