U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Air Traffic Organization Policy

ORDER
JO 6315.4

Effective Date:
11/27/2024

SUBJ: Siting Criteria for Terminal Doppler Weather Radar (TDWR)

This order establishes the siting criteria for the selection of suitable site locations for Terminal Doppler Weather Radars (TDWR) and in the selection of remote site locations for Moving Target Simulators (MTS) which provide checks of the radar's main beam performance. The primary requirement for siting the TDWR facilities is to provide the necessary radar coverage for timely detection and reporting of hazardous wind shear around the terminal approach and departure zones of an airport.

Compliance with this order is required to provide pilots with representative weather information.

FRANKLIN J MCINTOSH

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Chapter 1. General Information

1-1. Purpose. This order provides the necessary guidance to establish the site location for Terminal Doppler Weather Radar (TDWR) facilities and to ensure that future building and construction (See Appendix A, Guidelines for Future Development) near a TDWR facility does not interfere with the TDWR mission of providing accurate and timely hazardous wind shear information to air traffic controllers and pilots. There is no change to the baseline TDWR equipment; therefore, no Configuration Control Decision (CCD) is required.

1-2. Audience. This order provides guidance for all personnel responsible for planning, implementation, siting, and accomplishing installation of TDWR.

1-3. Where Can I Find This Order?

a. FAA Personnel. For electronic copies, FAA personnel can use one of the following websites to locate this order.

(1) On the Technical Library website at: https://nas.amc.faa.gov/phoenix/views/technicalLibrary.xhtml.

(a) In order to receive notifications when documentation is released or updated, users should subscribe to the system(s) within their areas of responsibility. Individuals can subscribe to receive email notifications on the NAS Technical Library Subscribers website.

(b) Users requiring electronic copies of documentation available for offline viewing may download the NAS Document Distribution Application (DDA) available at: https://nas.amc.faa.gov/nasdda/ and select documents for download. For additional information on the DDA, refer to the DDA User Guide, available at: https://nas.amc.faa.gov/nasdda/docs/NASDDA_USER_GUIDE.pdf.

(2) On the Directives website at: https://employees.faa.gov/tools_resources/orders_notices/.

(3) The Airway Transportation System Specialists (ATSS) and all administrative personnel must subscribe to the Auto-Notifications Services for electronic library release notifications at https://technet.faa.gov/. This document can be printed for local use as required.

b. Department of Defense (DoD).

(1) All DoD customers must register for an Aeronautical Data Exchange (ADX) website account at https://www.adx.faa.gov. When registering, the user must request access to the NAS Engineering tab of the application. The FAA does not distribute hard copies to DoD customers. For problems accessing the ADX website contact 9-ACT-ADX-PM@faa.gov.

(2) For DoD customers who have questions related to the maintenance handbook, contact Weather Systems Team at (405) 954-8427.

1-4. Cancellation. None.

1-5. Exceptions. If systems are installed in accordance with this order, there is a high probability that, as far as location is concerned, the systems will be able to provide the usable information desired. Since desired locations are not always available due to excessive physical or economic reasons, compromises may have to be considered and less than desired locations may have to be selected. If this occurs, it must be understood that the alternative location must still allow the system to provide accurate information. Actual commissioning or approval of an installed site may be delayed until it functionally demonstrates the validity of the information provided. If the information meets the requirements, it must be commissioned/approved. Corrective action will be required if TDWR information does not demonstrate valid data. This may mean removal of the radar, correction of whatever is adversely affecting the radar, or relocation of the radar. Since the desire is to provide accurate and reliable weather information, and since deviation from the standard may result in less than desired results, economic expediency should not be the sole basis for acceptance of a less than desired site location.

1-6. Scope. This order is intended to serve as the fundamental reference for TDWR siting. While this order is not of itself regulatory in nature, it is to be implemented through appropriate agency orders. Likewise, this order may be modified or enhanced by agency directives. This document does not require the agency to relocate existing TDWR facilities solely to comply with this order. It will be applied to the siting of new and/or the relocation of facilities and to the correction of siting problems.

In applying this order to the planning of TDWR at an airport, final siting location must obtain the approval of the control tower manager. Additionally, FAA District Office (DO) Manager approval is required for the use of any FAA facilities such as power, communications, shelters, towers, etc.

Sensor siting in accordance with this order meets the requirements of Federal Aviation Regulations (FAR) Part 77, Title 49 and the latest edition of Order JO 7400.2. An FAA Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) study in accordance with 14 Code of Federal Regulations (CFR) Part 77 of the FAR may be required to determine if the proposed equipment installation is an obstruction to air navigation, navigational facilities/equipment, and communication facilities/equipment.

1-7. Request for Assistance. If a suitable site cannot be located that meets the criteria provided in this document and all reasonable options have been exhausted, AJW-141 may be contacted to provide further assistance in TDWR siting, provide an FAA meteorological evaluation as well as the demonstration of operational/functional validity.

Weather Systems Team (AJW-141)
6500 S. MacArthur Blvd, Bldg. 201
Oklahoma City, OK 73169
Telephone: (405) 954-8427

Chapter 2. TDWR Equipment Function and Characteristics

2-1. Equipment Functions.

a. The TDWR is an automated system consisting of sensor, communication, processing, and display components used to detect hazardous weather phenomenon. The TDWR's primary function is to enhance the safety of air travel through the timely detection and reporting of microbursts, gust fronts, and other hazardous weather products in and near the terminal approach and departure zones of airports. Government furnished algorithms detects and derive hazardous weather information from the radar base data. Alarms warn that a weather hazard has been detected and is in a region of concern to Air Traffic Control (ATC) controllers and pilots.

b. TDWR equipment siting and scan patterns are influenced by meteorological considerations. For example, current microburst detection schemes require repeating surface radar scans once per minute to enable detection of fast forming microbursts. Microburst features aloft typically precede initial surface outflows by about 10 minutes so requirements have been developed to scan the entire coverage region up to an altitude of 19,700 feet (6 kilometers (km), to detect these precursory signatures. Current hazardous weather scanning strategies for off-airport sitings scan up to 19,700 feet (6 km) altitude at least every 180 seconds. Consequently, the TDWR provides more than the required 1 minute (on average) of warning (prior to hazardous outflows) of a forming microburst to allow ATC additional time to notify affected pilots.

2-2. Secondary Functions.

a. The secondary TDWR function is to improve the management of air traffic in the terminal area through the forecast of gust front induced wind shifts at the airport. Gust fronts are low reflectivity, large scale weather systems extending approximately 4925 feet (1.5 km) above the ground surface which are associated with a substantial wind shift. In this context, a wind shift represents a transition zone of a substantial change in the horizontal wind speed or direction and often results in the need to change active runways. These wind shifts may have a major impact on airport operations. Gust fronts are forecasted by detection of the wind shift magnitudes and estimation of the time of arrival in the terminal area.

b. The TDWR sensor component automatically detects wind shifts and generates a 20 minute warning of impending wind shifts to ATC to allow for operational planning of changes in active runways. Based on current monitoring mode scanning strategies calling for low elevation wind shift scans every 6 minutes and typical gust front velocities, the TDWR begins tracking gust fronts at a distance of approximately 16.2 nautical miles (nm) or (30 km) from the target airport.

2-3. Area Coverage Background.

The TDWR will generally be located at off-airport sites. Consequently, the TDWR operational requirements, with respect to the airport locations, cannot be directly converted to basic TDWR coverage requirements and are separated into basic and operational requirements below. Weather features located outside the target airport operational coverage region are used in the weather algorithms and must be detected by the radar. Thus, the basic TDWR equipment coverage requirements are accordingly greater than the target airport operational requirements.

2-4. Basic TDWR Coverage.

TDWR data is processed from the ground level to an altitude of 70,000 feet, (21.4 km) above ground level (AGL) out to 48 nm (89 km) from the system. However, for radar elevation angles less than 2 degrees, TDWR range limitations may influence the maximum scanning altitude achieved. The data is processed up to an altitude of 70,000 feet (21.4 km) where such an altitude is achievable by virtue of the scan elevation angle and a range of 48 nm (89 km). When the TDWR is sited on or near the target airport these requirements may not be possible due to the cone of silence above the radar dish. In no case will coverage be required which would result in the need of an antenna elevation angle above 60 degrees, since it would exceed the capability of the radar. The required minimum range is 0.25 nm (0.5 km).

2-5. Operational Coverage. There are two operational coverage regions extending from the airport which must be examined by the TDWR. They are the microburst region and the gust front region.

a. Microburst/Wind Shear Hazardous Detection Region. The microburst region is that region in which the automated TDWR microburst identification algorithm will operate. Microburst detection coverage is required for approaching and departing aircraft from the ground surface up to an altitude of 1500 feet (0.5 km) above ground level (AGL) and to a distance of 6 nm (11 km) from the geographical center of the target airfield. The microburst region, which is also called the Wind Shear Hazard Detection Region, will hence forth be referred to as the principal coverage region (PCR). The center of the principal coverage region (CPCR) corresponds to the geographic center of the airport.

b. Gust Front Region. The gust front region is that region in which the automated gust front algorithm will operate on data collected within a 40 nm (74 km) radius of the CPCR.

2-6. Equipment Characteristics Background. A thorough knowledge of the performance characteristics of the radar to be sited is important when selecting a candidate site. Characteristics such as beam width, antenna pattern, and clutter suppression capability can affect the site selection decision.

2-7. Antenna and Signal Characteristics. The purpose of the TDWR antenna system is to efficiently radiate the pulse energy in a directional beam and to receive returning echo signals.

a. Antenna Characteristics.

(1) **Main Beam Characteristics.** The TDWR antenna provides a pencil beam of 0.55 degrees at the half power points in azimuth and elevation.

(2) **Side Lobe Level Control.** The first side lobe is below -27 dB relative to the peak gain of the main beam.

b. Signal Characteristics. The radio frequency operation is in the C-band of frequencies at 5.6 GHz to 5.65 GHz.

c. Receiver Characteristics.

(1) **TDWR Sensitivity.** The TDWR has an overall single-pulse sensitivity such that a -10 dBz (reflectivity) range bin filling target (a weather target extending across a range sample interval) and beam filling target (a weather target which extends across the main beam to at least the half power points) provides signal-to- noise-ratio (SNR) of +8 dB at a range of 16 nm (30 km).

(2) **Ground Clutter Suppression.** The TDWR provides 35-50 dB of ground clutter suppression for all Doppler measurement scans by the use of moving target indicator (MTI) filters. Additionally, there is a clutter residue editing map which flags received data in individual range bins whose measured reflectivity is not greater than the nominal clutter residue level for that range bin.

d. Scanning Constraints. The TDWR cannot scan below - 1^0 nor above + 60^0 in elevation angle.

2-8. Radar Radiation Hazard Considerations.

TDWR radiation considerations are indicated in the TDWR Radiation Hazard Report contained in Appendix B of this order. Based on TDWR system characteristics the maximum power density was found to occur at a distance of 711 feet (217 meters (m)) from the TDWR antenna with no radio frequency (r-f) radiation hazards to personnel.

2-9. Typical Facility Components. A site is considered adequate and reasonable in cost if the construction, installation and logistics requirements approximate those of an average FAA unmanned radar support facility as determined by a cost per square foot or other approved analysis. The principal components of an average facility are:

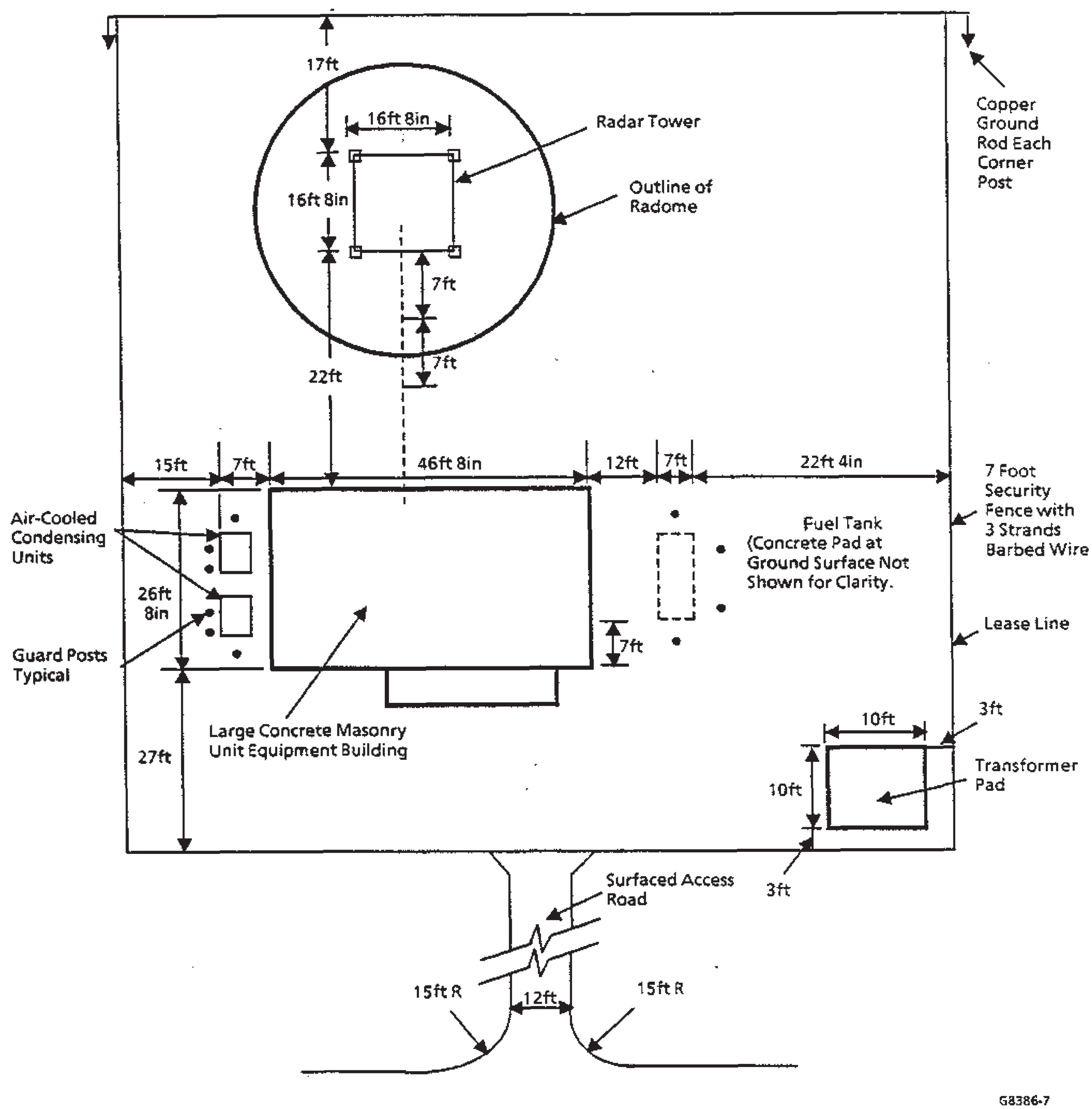
a. A 110 foot by 110 foot plot of land including a chain-link outer security fence surrounding the property which is required for physical security reasons. A lockable chain-link security fence is required. TDWR facilities contain an intrusion alarm with a 60 second delay for maintenance personnel. Figure 2-1, Standard TDWR Facility Site Plan, indicates a standard TDWR site layout.

b. Easements to preclude construction of any structure which projects above antenna platform level causing blockage or be built of reflective materials within a 1500 foot (preferably up to 1 mile) radius of the site property in the direction of the target airport.

c. An access road to allow access from local county or state road systems, but with a selected location that minimizes its total length and cost. Access roads to FAA facilities are specified in the latest edition of FAA Order JO 6940.3, Maintenance of Roads and Grounds.

d. A TDWR standard large Concrete Masonry Unit (CMU) Building houses the electronic transmitter/receiver equipment, including HVAC and an engine generator unit. The standard design also requires the site subgrade be capable of supporting a floating slab with a uniform design live load of 500 pounds per square foot (PSF) and a concentrated live load of 1000 pounds as specified in FAA Specification FAA-C-2814, Specifications for Construction of Large CMU Building for Electronic Equipment.

Figure 2-1. Standard TDWR Facility Site Plan



e. A TDWR antenna and radome mounted on an antenna tower structure. The tower height shall elevate the antenna over existing obstructions to obtain a clear line of site to the airport. The towers are available in heights from 16.4 to 100 feet (5 to 30 m) in 16.4 feet (5 m) increments.

f. A Moving Target Simulator (MTS) requiring electrical wiring and mechanical mounting at a site location remote from the main TDWR facility.

g. A standard transformer substation and a government furnished engine generator.

h. Utility lines (i.e.; power, telephone) or installations.

i. A fuel tank installed to meet the requirements of NFPA-58, Liquefied Petroleum Gas Code.

2-10. Space and Functional Requirements. Space and functional requirements for the TDWR transmitter/receiver building are defined in FAA Specification FAA-C-2814, Specifications for Construction of Large CMU Building for Electronic Equipment. Planned minimum facility dimensions include a 46' - 8" by 26' - 8" building inside a 110 foot by 110 foot area surrounded by a security fence. Actual site property dimensions may be larger based on additional requirements.

2-11. Electrical Power Requirements.

a. The TDWR System operates from a commercial primary power source of three phase, four wire, AC in accordance with specification FAA-G-2100, Electrical Equipment Grounding Requirements. The design center voltages will be 208 VAC, phase-to-phase, and 120 VAC single phase at a frequency of 60 hertz (Hz). The operating range will be at least 102V to 138V, 177V to 239V, and 57 to 63 Hz.

b. The MTS requires a 60 Hz, 120 VAC commercial power source and consumes 100 watts or less. The operating range is at least 102V to 138V and 57 Hz to 63 Hz.

2-12. Communications Requirements. Base data is transmitted to the Integrated Terminal Weather System (ITWS) Product Generator via high speed data communication lines.

2-13. Radar Tower Heights.

a. The tower height should elevate the antenna over existing and anticipated obstructions to obtain a clear line of sight to the desired altitude above the ground surface over the essential coverage region. The TDWR antenna tower heights are between 16.4 feet (5 m) and less than (or equal to) 100 feet (30 m) in increments of 16.4 feet. The proposed antenna height should not require the TDWR to elevate below a minus one degree inclination angle to aim at a spot 656 feet (200 m), or preferably 328 feet (100 m), above the ground surface over the essential coverage region. The antenna feed horn is 14.7 feet (4.5 m) above the top of the tower.

b. In the range of allowable tower heights (16.4 feet to 98.4 feet) there are six 16.4 feet (5 m) increments, or six possible tower heights. The preferred height is the lowest practical height which positions the center of the antenna level with the average height of nearby shielding ridges located in the directions of primary interest. This requires determining the depression angle to the horizon, relative to the average local horizontals for all azimuths, for each of the six possible radar tower heights. The average depression angle over 360 degrees and in the directions of primary interest, for each tower height can then be determined.

2-14. MTS Characteristics. The MTS provides a simulated weather target with a reflectivity of 50 dBz and a Doppler velocity of - 5 m/s used to verify main beam data quality and operation of the transmitter/receiver. The MTS consists of a 3-foot parabolic antenna with an electronics box which is approximately 2 feet x 2 feet x 2 feet. The MTS requires 120 v, 60 Hz nominal electrical power of 100 watts or less which is readily accessible (the operating range is 102 V to 138 V and 57 Hz to 63 Hz).

2-15. Scan Strategy Background. The TDWR has one maintenance mode and two operational modes of operations. The operational modes include a Monitor Mode and a Hazardous Weather Mode. The parameters for all scanning programs (i.e., scan speed, elevation angles and order of execution within the program) are site-adaptable and vary with the location of the radar with respect to the airport. Both on-airport and off-airport site types have each of the operational scanning modes (i.e., monitoring and hazardous weather detection modes). The general characteristics of the monitoring mode are the same for both types of radar sites, while the hazardous weather detection modes are different. The characteristics of these three different modes are described below.

2-16. Maintenance Mode. The Maintenance Mode is manually selected during those maintenance activities which may cause the system to become non-operational.

2-17. Monitor Mode.

a. The monitor mode consists of 360 degree azimuthal scans at various elevation angles from -1 to +60 degrees. This mode allows the same surveillance scanning program to be used in both on-airport and off-airport scenarios.

b. In the monitor mode, within a scan period of no more than 6 minutes, up to 17 azimuthal scans including the base elevation are performed at unique elevation angles. Scan speeds are chosen at each elevation angle to be compatible with the requirements for base product estimate accuracy. The primary purpose of the information collected in the monitor mode is to detect the onset of significant precipitation or weather returns in the terminal area.

c. The TDWR automatically switches between the monitor mode and the hazardous weather detection mode. The monitor mode is used when there are no significant weather returns within 24.3 nm (45 km) of the airport. Otherwise, the hazardous weather detection mode is selected. Because the TDWR is designed for unattended operation, the selection of the appropriate scan mode is an automated procedure. The criteria for switching to hazardous weather mode is the presence of one or more of the following, within 24.3 nm (45 km) of the airport and within a scan sector centered on the target airport (for off-airport sitings): (1) a microburst declaration, or (2) a reflectivity feature with maximum reflectivity of at least 20 dBz at or above 6550 feet (2.0 km) above ground level (AGL). Whenever one or more of these criteria are satisfied, then the significant weather condition is declared and the scan mode switches to hazardous weather detection mode upon completion of the current monitoring scan. The hazardous weather detection mode remains selected until the significant weather condition remains false for one entire hazardous weather detection mode scan. The monitoring mode is then selected for the scan following the next scan, unless the significant weather condition becomes true during the next scan.

2-18. Hazardous Weather Detection Mode. The Hazardous Weather Mode consists of 360 degree azimuth scans over any elevation range from -1 to +60 degrees. The TDWR does not continuously operate in this mode because increased accelerations and loadings occur that result in increased wear on antenna and pedestal components.

a. On-Airport Application. In the On-Airport Hazardous Weather Detection scanning mode, the TDWR antenna will perform a sequence of full 360 degree azimuthal scans. A total of 23 scans are performed in a six minute period, with one scan at the surface every minute. A remaining scan is a surface scan at a low pulse repletion frequency (PRF) and another is at a low elevation angle. The remaining scans are site adaptable and placed at elevation angles up to a maximum of 60 degrees elevation.

b. Off-Airport Application.

(1) In the Off-Airport Hazardous Weather Detection scanning mode the antenna performs a 360-degree scan, which is designed to optimize the observation of significant meteorological features in the coverage region. Gust front scans are performed at the surface and at low elevation angles every 6 minutes. An additional 360 degree azimuthal scan, at a low PRF, is performed at the surface every 6 minutes to identify false targets or echoes of weather systems at a distance further than the normal 48 nm 89 km maximum.

(2) The hazardous mode scan is required to return to the surface on average every 60 seconds during the volume scan. A scan aloft sequence is completed every 3.0 minutes. The elevation angles for scans aloft are site adaptable and provide coverage to a preferred maximum elevation angle that is site dependent based on the distance of the TDWR to the airport.

2-19. Low Pulse Repetition Frequency (PRF) Reflectivity Measurements.

a. Selection of PRF values is performed to minimize obscuration and range folding within the site adapted range/azimuth sectors due to out-of-trip weather echoes.

b. Government furnished algorithms employ a 360 degree scan performed once every 6 minutes at a low PRF to obtain a large unambiguous range. By comparing returns between the low PRF scan and other scans, an optimum PRF will automatically be selected to minimize range aliased returns and any remaining folded returns will be flagged as distant weather echoes. The TDWR also provides unambiguous velocity measurements over a wide range (+40 m/sec to -40 m/sec) of velocities which also necessitates making measurements for surface scans at more than one PRF.

c. An additional TDWR coverage requirement requires coverage of reflectivity measurements out to 248 nm (460 km) when demanded by the PRF / Range de-aliasing algorithms.

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Chapter 3. Coverage Factors and Siting Constraints

3-1. Purpose of Coverage Requirements. The purpose of coverage requirements establishes the primary physical siting constraints for required radar coverage. The constraints affect the location of a principal coverage region, the location of the radar and the physical relationship *between* the principal coverage region and the radar location. Both preferred off-airport and essential on-airport siting scenarios are considered.

3-2. Determination of the Coverage Region.

a. To enable the determination of a variety of coverage requirements, in the early phases of TDWR site selection, without plotting runways and approach/departure courses on local area plans, a circular coverage region will be established centered on the geometric center of an airport's runway region. Although it may conservatively over estimate coverage areas, a circular coverage region will allow a standardized, easily defined, coverage requirement which can be incorporated into a practical site selection procedure applicable at multiple airport locations.

b. Based on aircraft approach and departure characteristics, wind shear hazards must be detected as far out as 3 nm (5.6 km) from runway thresholds in order to protect approach and departure glideslope paths. Trigonometric relationships are used to determine that an airplane on a 3- degree glideslope will descend to 1000 feet (0.3 km) AGL approximately 3.1 nm (5.7 km) from the runway threshold. All controlled aircraft farther than 3.1 nm (5.7 km) from the airport are assumed to be above 1000 feet (0.3 km) AGL for TDWR coverage purposes. Considering these factors concurrently, a radius of a circular coverage region (conservatively selected to satisfy TDWR coverage requirements at multiple site locations) becomes the sum of 3 nm (5.6 km) and 2.2 nm (4 km), or 5.2 nm (9.6 km). A 1.1 nm (2 km) buffer region may be added to the radius to ensure a microburst centered at the edge of the 5.2 nm (9.6 km) coverage range would be detected. Otherwise, part of the outflow region would be outside the coverage area. Thus, the required microburst coverage area extends from the center of the coverage region to a radius of 6.3 nm (11.6 km) from the target airport.

3-3. Principal Coverage Region (PCR). TDWR coverage regions encompass runway arrival and departure warning areas termed, Areas Noted for Attention (ARENAs), where aircraft are close to the ground surface during takeoffs and landings. These ARENA's, as shown in Figure 3-1, Plan View Schematic of the Arrival and Departure Warning Areas, are 1 nm (2 km) wide by 3 nm (5.6 km) long (from the end of the runway along the extended runway center line), and include the 1 nm (2 km) wide area along the length of the runway. The principle coverage region (PCR) is that area surrounding a target airport where microburst and hazardous wind shear detection is necessary so that warnings may be provided to approaching and departing aircraft when hazardous weather is detected within the MAWA by the TDWR. Figure 3-2, Microburst Alert Warning Area (MAWA), indicates a typical MAWA when several runways are considered simultaneously, superimposed on a 6 nm (11 km) PCR. Hazardous weather is detected within the PCR, but aircraft alerts are mandatory only when it is detected within the MAWA. Otherwise, warnings are discretionary. The actual TDWR coverage areas are site adaptable parameters within the TDWR.

Figure 3-1. Plan View Schematic of the Arrival and Departure Warning Areas

(Superimposed Upon a 9000-foot Runway, and Taken From TDWR/LLWAS User Working Group Report)

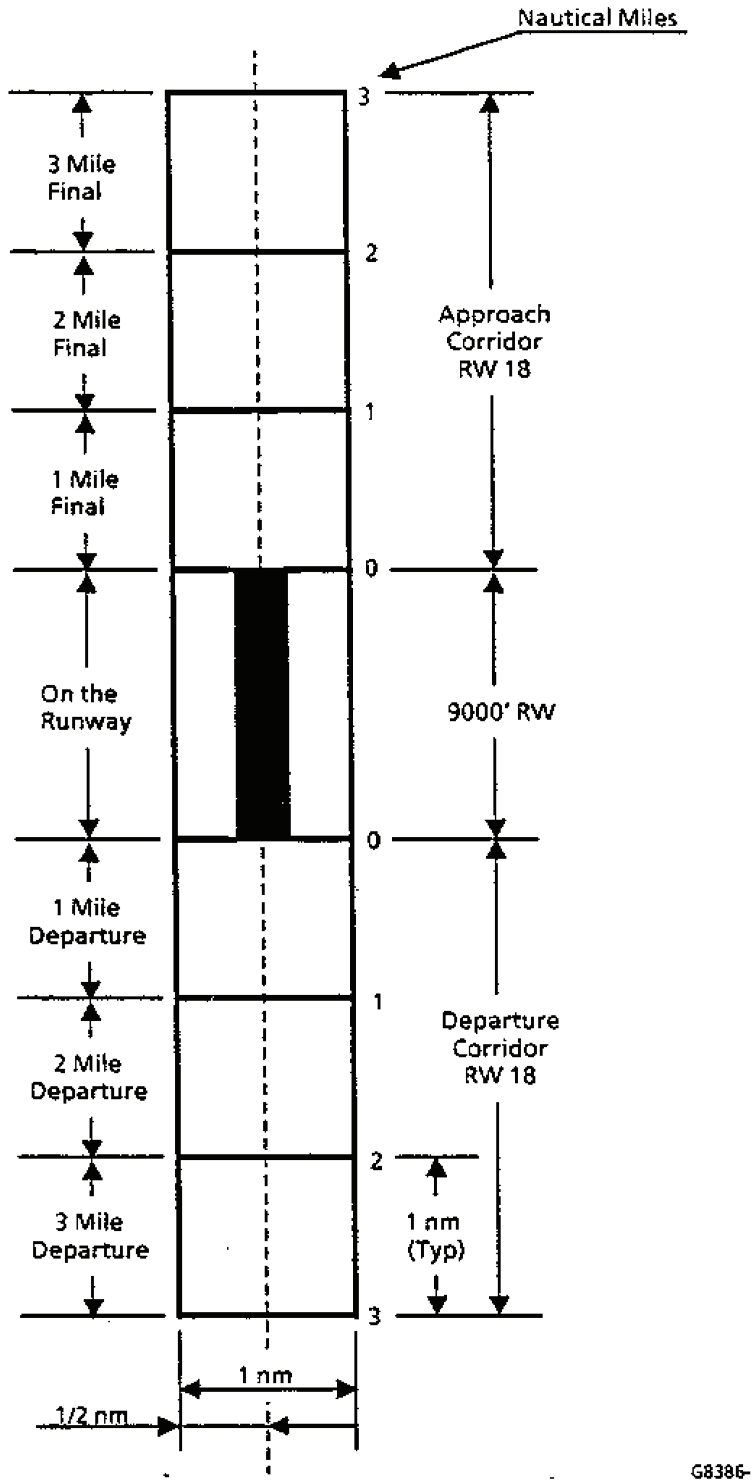
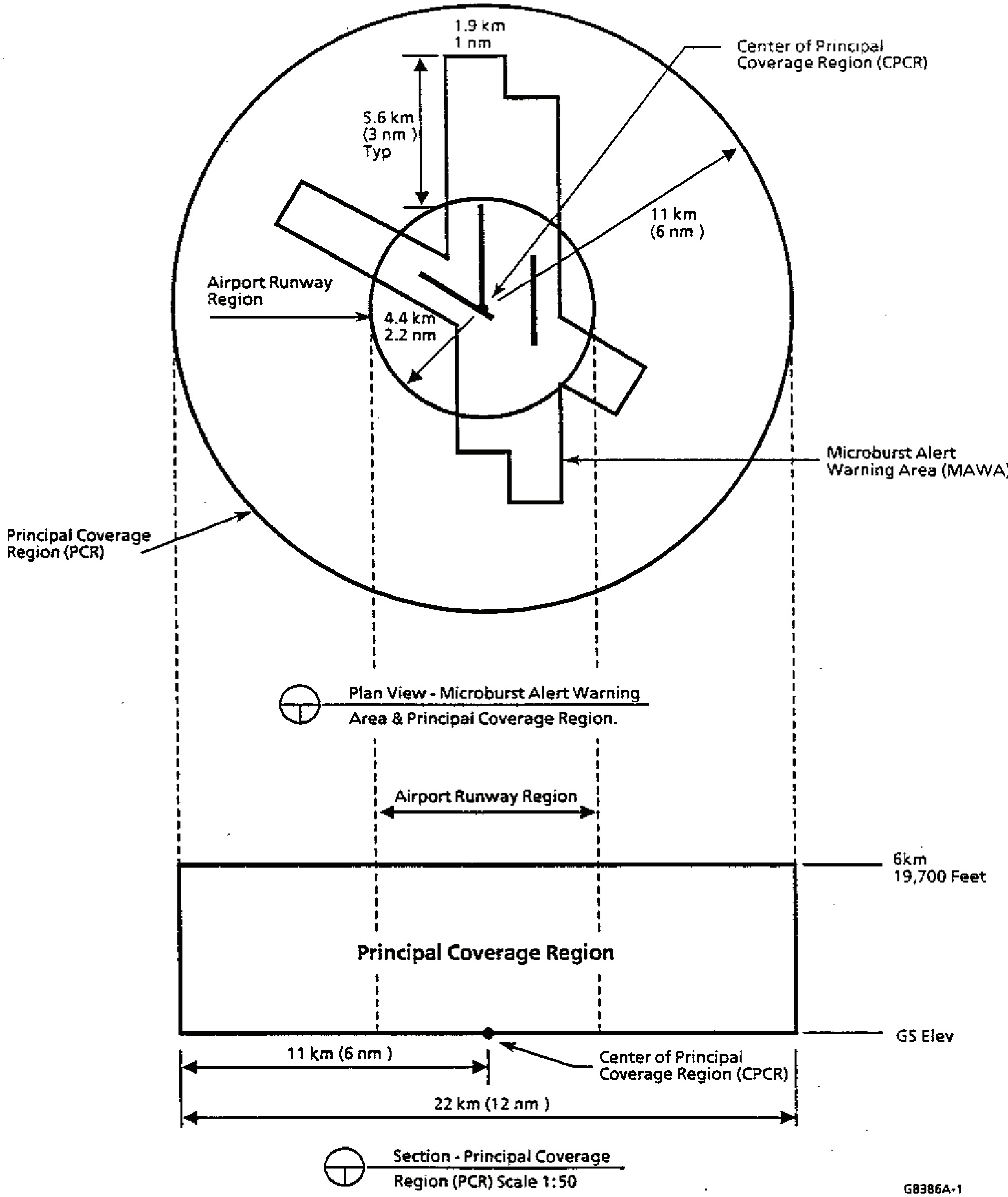


Figure 3-2. Microburst Alert Warning Area (MAWA)

(Superimposed on 6 nm Principal Coverage Region)



3-4. Preferred Off-Airport Siting Scenario.

a. The preferred location for off-airport sitings is a distance between 8 nm (15 km) to 12.4 nm (23 km), preferably 10 nm (18 km), from the Center of the Principal Coverage Region (CPCR) at the target airport and must optimize attainment of the coverage factors and siting constraints discussed below. A particular site location may not be available that meets all of the requirements listed. In such situations, the site with the optimal combination of high priority factors shall be selected.

b. The desired coverage region, as with the on-airport option, includes all airspace within 6 nm (11 km) of the airport. The distinction between the on- and off-airport sitings is, therefore, derived from the position of the radar with respect to the required operational coverage region. The off-airport scenario is required to cover substantially the same operational airspace, which is preferred over the on-airport application, but from radar located a specified distance from the airport. Coverage will extend to a maximum altitude of 19,700 feet above the entire PCR.

3-5. **Airport to Radar Distance Requirements.** The following cases influence the distance required between the TDWR antenna site and the target airport's CPCR in a preferred siting situation. The specific cases are analyzed to determine the required distance based on each particular constraint so competing constraints can be compared to determine the governing distance requirement. All cases are considered whether or not they govern the distance requirement between the CPCR and the TDWR site.

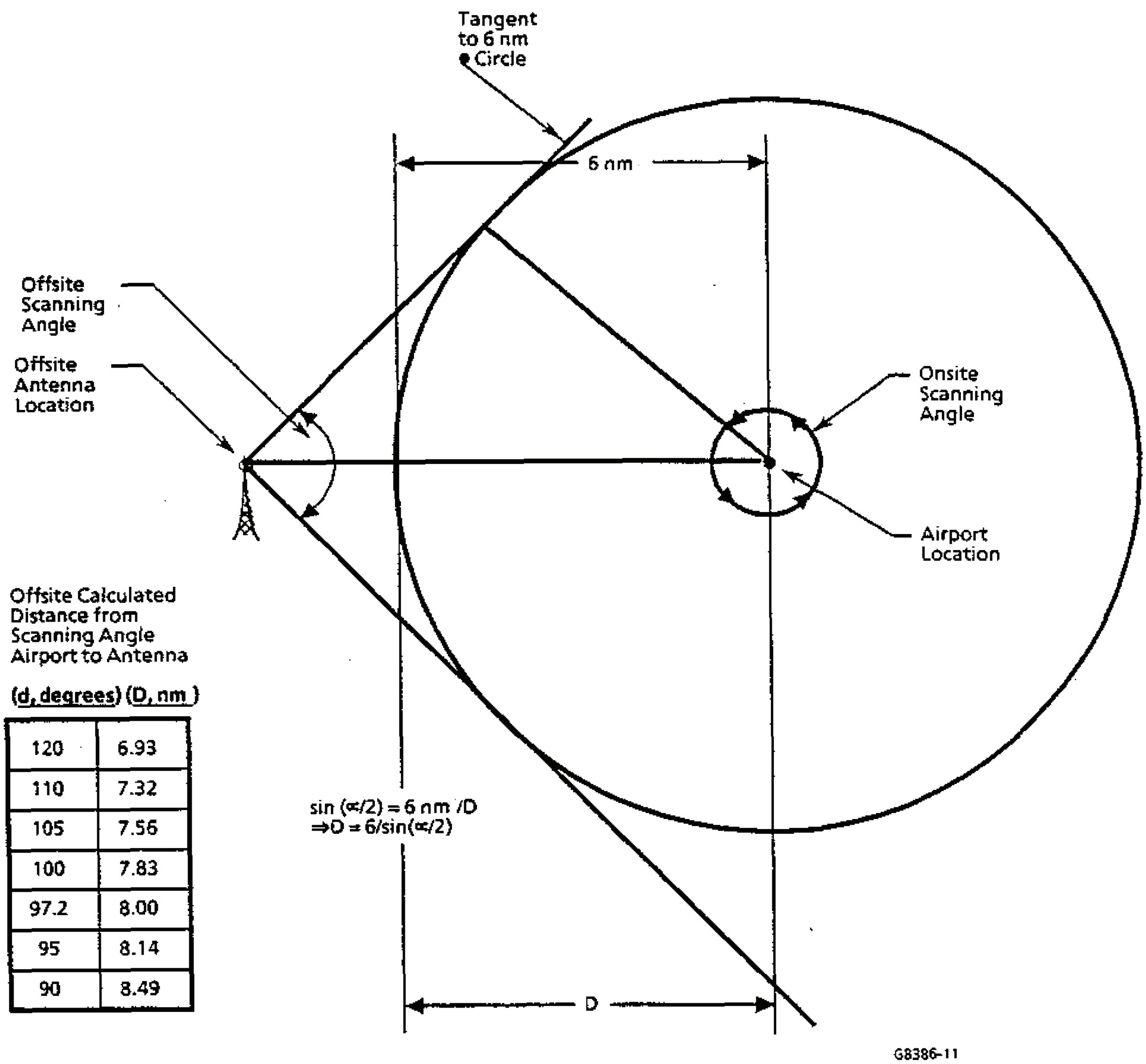
a. Azimuthal Scanning Requirements. Figure 3-3 TDWR On-site/Off-site Azimuthal Scanning Characteristics, indicates the required distance a TDWR antenna must be from the edge of the PCR so that the scanning angle indicated in the table accompanying Figure 3-3 may be achieved. If the radar is located too close to the target airport, it will require a larger scan angle and may increase the scanning time to the extent that operational objectives cannot be met. If a horizontal maximum scan angle of 120 degrees is selected to meet the scan time constraints, then the site needs to be at least 7 nm (13 km) from the CPCR. This is not a governing case since the azimuthal angle is not the only angle that must be considered in order to obtain a proper siting distance with respect to the CPCR.

b. High Altitude Scanning Aloft Requirements. The TDWR scans aloft for microburst precursor signatures to provide timely microburst warnings. Data from these microburst features aloft will help TDWR algorithms to declare microbursts sooner since features aloft typically precede surface outflows and provide data for automatic switching between scan modes for monitoring and hazardous weather detection. The preferred TDWR siting scenario will scan to altitudes of 19,700 feet for features aloft over the entire PCR. In addition, detecting gust fronts requires scanning above 5000 feet to a range of 31.8 nm (59 km). The altitude requirements summarized in this subparagraph are used below to determine the distance required between the CPCR and the radar.

(1) **Radar System Elevation Capability.** Although subsequent constraints based on scan patterns govern the CPCR to radar distance, this section is included for completeness. The minimum distance a TDWR site should be offset past the edge of the PCR (for this specific case)

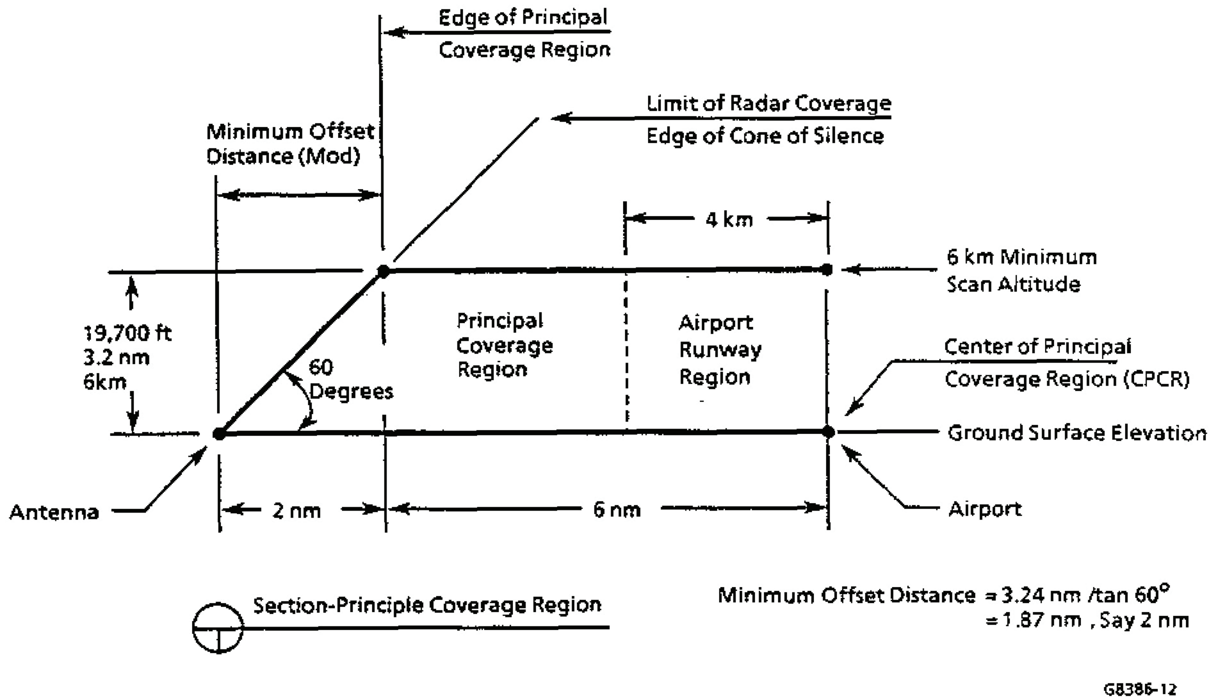
depends on how the 60-degree incline (based on the maximum radar elevation capability) of the cone of silence slopes up. As shown in Figure 3-4, Representation of Antenna with 8 nm Offset Distance and 60 Degree Scan Elevation, the radar must be at least 1.87 nm (3.5 km) beyond the PCR to allow room for the antenna beam to incline up to the required 19,700 feet (6 km) altitude and scan. Consequently, the required separation between the airport and radar would become 1.87 nm (3.5 km) + 6 nm (11 km) = 7.87 nm (14.5 km), or rounded up to 8 nm (15 km).

Figure 3-3. TDWR On-site/Off-site Azimuthal Scanning Characteristics



(d, degrees)	(D, nm)
120	6.93
110	7.32
105	7.56
100	7.83
97.2	8.00
95	8.14
90	8.49

Figure 3-4. Representation of Antenna with 8 nm Offset Distance and 60 Degree Scan Elevation



Note: In order to site the TDWR 8 nm (11 km) from the CPCR and maintain total coverage of the hazardous weather area, a radar elevation angle of 60 degrees must be used.

(2) **TDWR Hazardous Weather Scan Mode.** Due to velocity errors of the radar's main beam at elevation angles of 60 degrees, the current off airport hazardous weather scan strategy uses a maximum elevation angle of typically 40-45 degrees. As Figure 3-5, Coverage Region Analysis indicates, if the radar site is located 8 nm (15 km) from the CPCR, some of the coverage volume above the 40 degree incline, but below the 19,700 feet altitude, will be missed. Consequently, as figure 3-5 indicates, the radar would have to be located at least 10 nm (18 km) from the CPCR (a governing requirement) to allow room for the 40- degree incline (used in the scan strategy) to elevate up to the 19,700 feet altitude before entering the coverage volume. The required 10 nm (18 km) governs the distance requirement between the target airport's CPCR and the radar site. The following subparagraphs identify other coverage requirements which compete against this one.

c. TDWR Beam Width Range Limitations. The TDWR detects microbursts within the PCR and all outflows below 1500 feet (457 m) within the protected areas. In order to adequately scan surface outflows the vertical beam should extend no more than 300 m. Thus, the far end of a PCR should be no more than 18.4 nm (34 km) from the radar as shown in Figure 3-6, Weather Mode Scanning Aloft. For a coverage volume with a 6 nm (11 km) radius, off-airport sitings should be no more than 12.4 (23 km) from the CPCR. Assuming the off-airport radar site location is 10 nm (18 km) from the CPCR, a coverage region of from 3.8 nm (7 km) to 15.7 nm

(29 km) range will result as shown in Figure 3-7, TDWR Range Analysis. The 15.7 nm (29 km) represents 10 nm (18 km) from the CPCR at the target airport to the radar plus 6 nm (11 km) from the CPCR to the distant edge of the PCR.

d. TDWR Maximum Detection Range Limitations. The TDWR produces quantitative reflectivity, velocity, and spectrum width estimates to an unambiguous range of at least 48 nm (89 km). Since gust front operational coverage requires collection of gust front data within a 40 nm (74 km) radius of the target airport, the TDWR should be located within 8 nm (15 km) of the airport to satisfy this factor. Otherwise, coverage areas on the other side of the airport opposite the TDWR may be slightly out of range. It should be noted that this coverage requirement competes against, but is secondary to, the microburst high altitude aloft coverage requirements.

3-6. Aspect Angle Limitations Due to Asymmetric Wind Shear.

a. Wind shear in microburst outflows may be asymmetric, a condition where different wind shear magnitudes occur in different azimuthal directions from the outflow center point. The TDWR must estimate headwind - tailwind shear due to a microburst over a runway or glideslope path. It is preferable to estimate the magnitude of wind shear along the same direction an aircraft will travel for takeoffs and landings. Otherwise, as the aspect angle (the angle a TDWR antenna makes between the desired runway orientation and the line of sight to wind shear target) increases, and when asymmetry is present, the possibility that the TDWR wind shear prediction will incorrectly estimate the actual wind shear encountered also increases. For example, Figure 3-8, Asymmetric Wind Shear Problem, illustrates an elliptical asymmetric outflow situation. The TDWR would estimate a minimum wind shear value due to its asymmetric orientation along the ellipses minor axis. As an aircraft follows the approach path, however, it may get the full brunt of the wind shear along the ellipses major axis. In this case, the TDWR could underestimate what the aircraft will experience flying along the major axis.

b. Siting of TDWR's should be based on no more than a 30 degree (20 degrees preferred) aspect angle from the orientation of the most traveled runway in severe weather conditions as shown in Figure 3-9, TDWR Aspect Angle Siting Preferences.

c. Where an airport has two heavily traveled runways in bad weather at 90 degrees to each other (as is the case at many major airports) it is necessary to increase the aspect angle to 45 degrees and split the angular distance between each runway. With an aspect angle of 45 degrees, the radar will measure at least 70 percent of the along runway shear in asymmetric conditions. Consequently, the preferred site locations for airports with two heavily traveled runways at right angles to each other is limited to those areas bad weather near the bisectors of the runway intersection angles.

Figure 3-5. Coverage Region Analysis

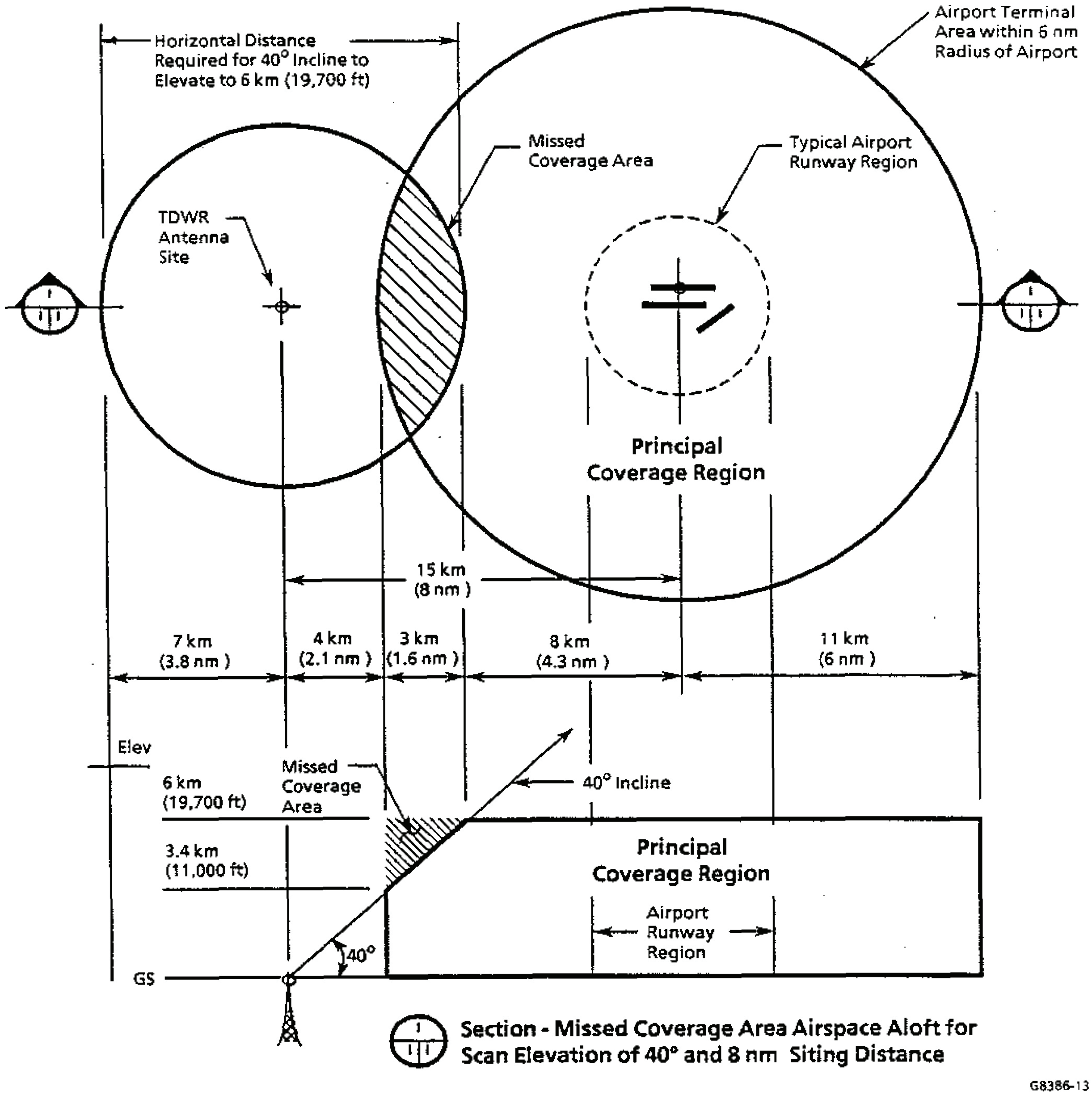


Figure 3-6. Weather Mode Scanning Aloft

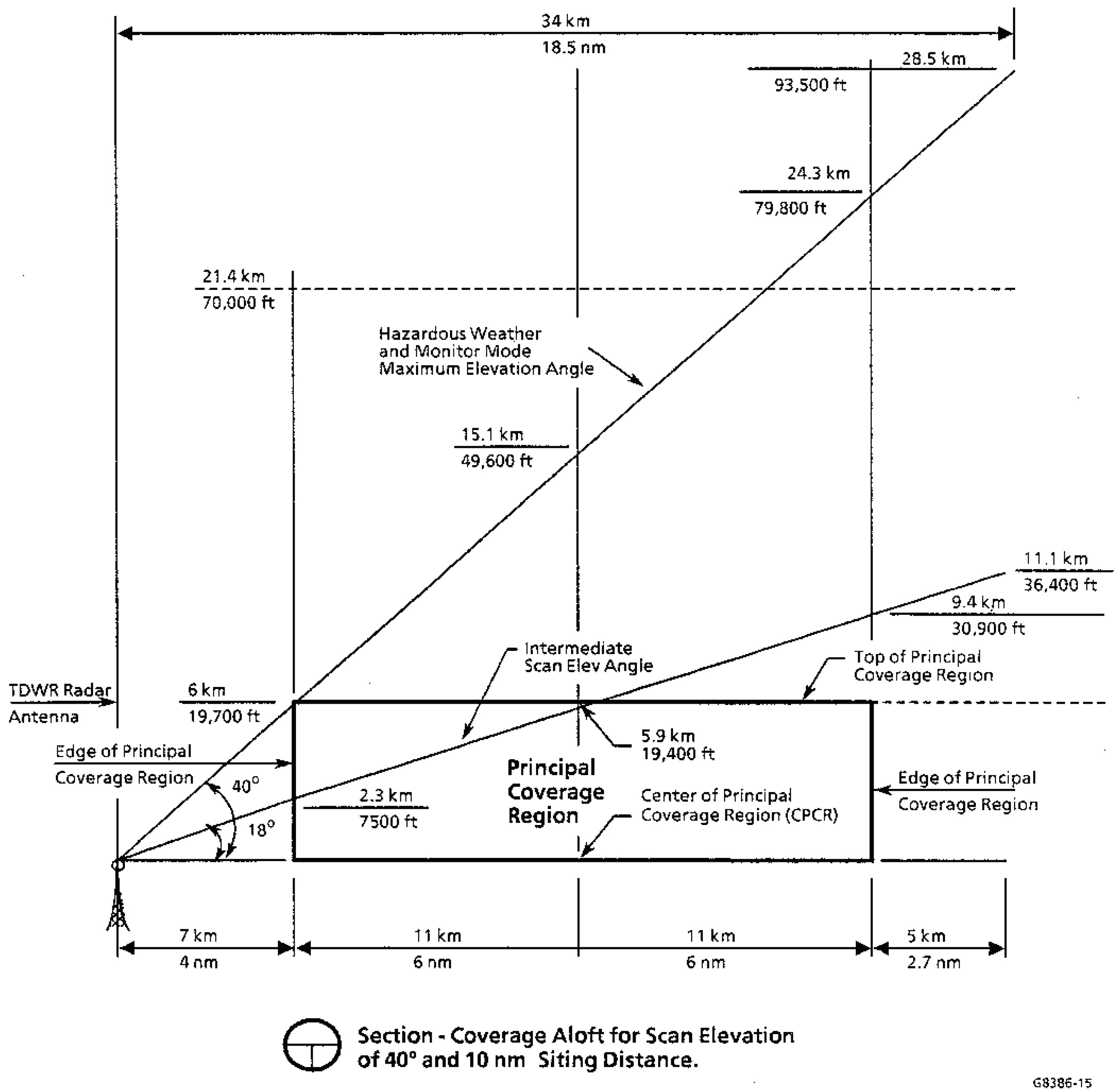


Figure 3-7. TDWR Range Analysis

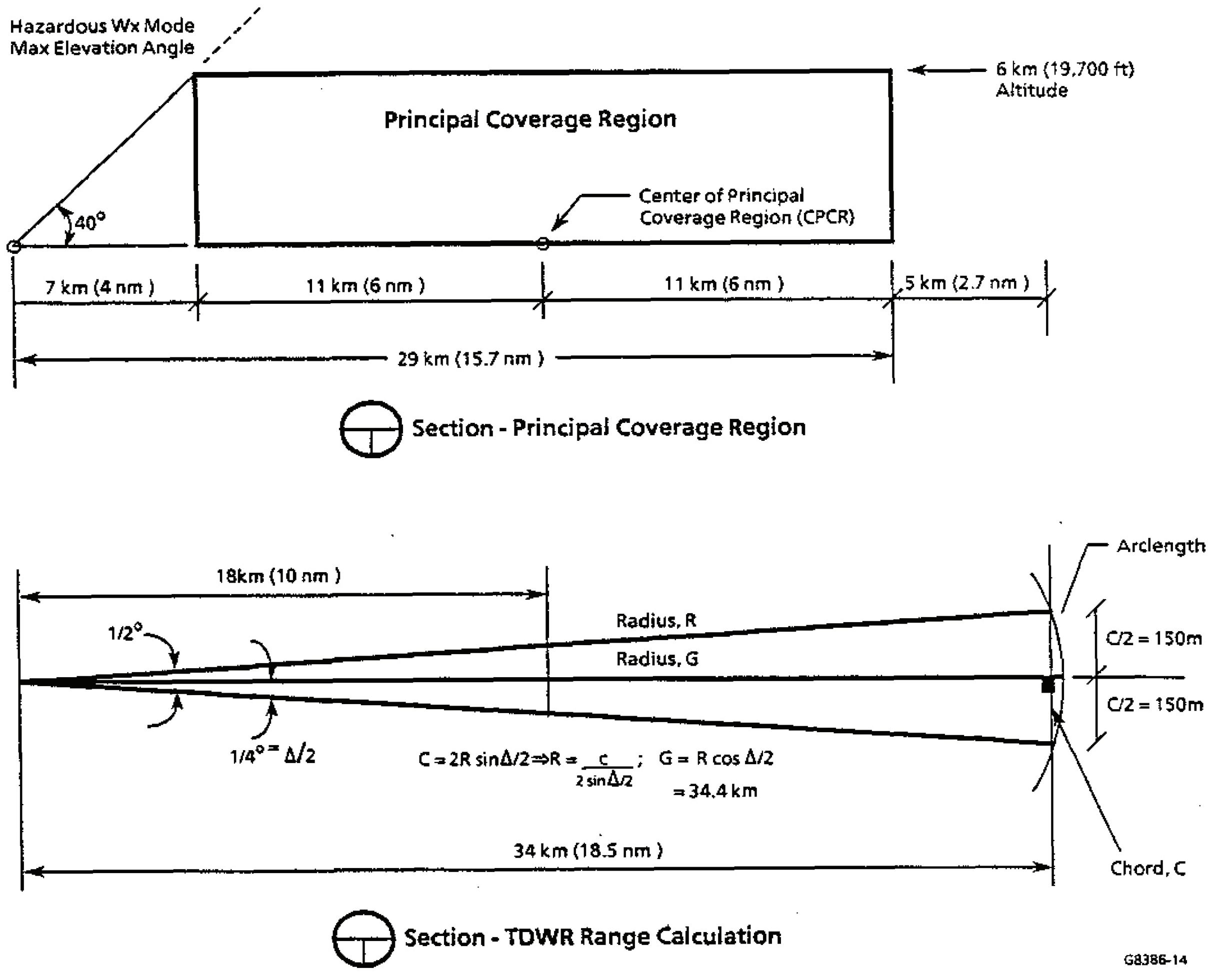


Figure 3-8. Asymmetric Wind Shear Problem

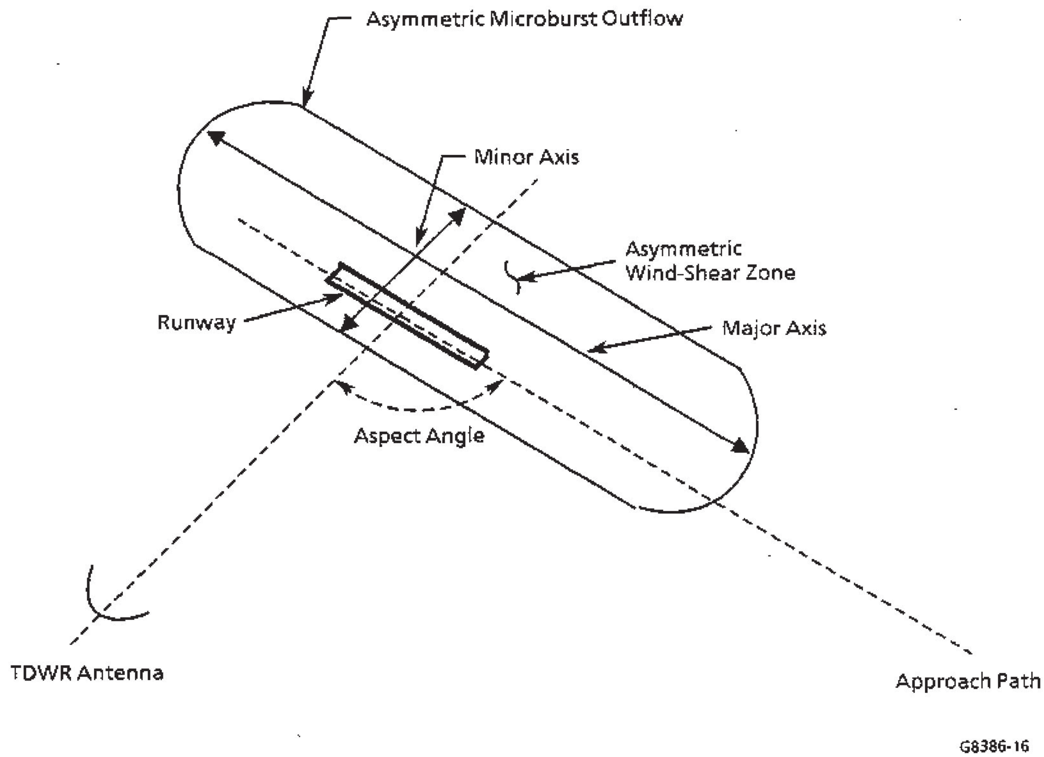
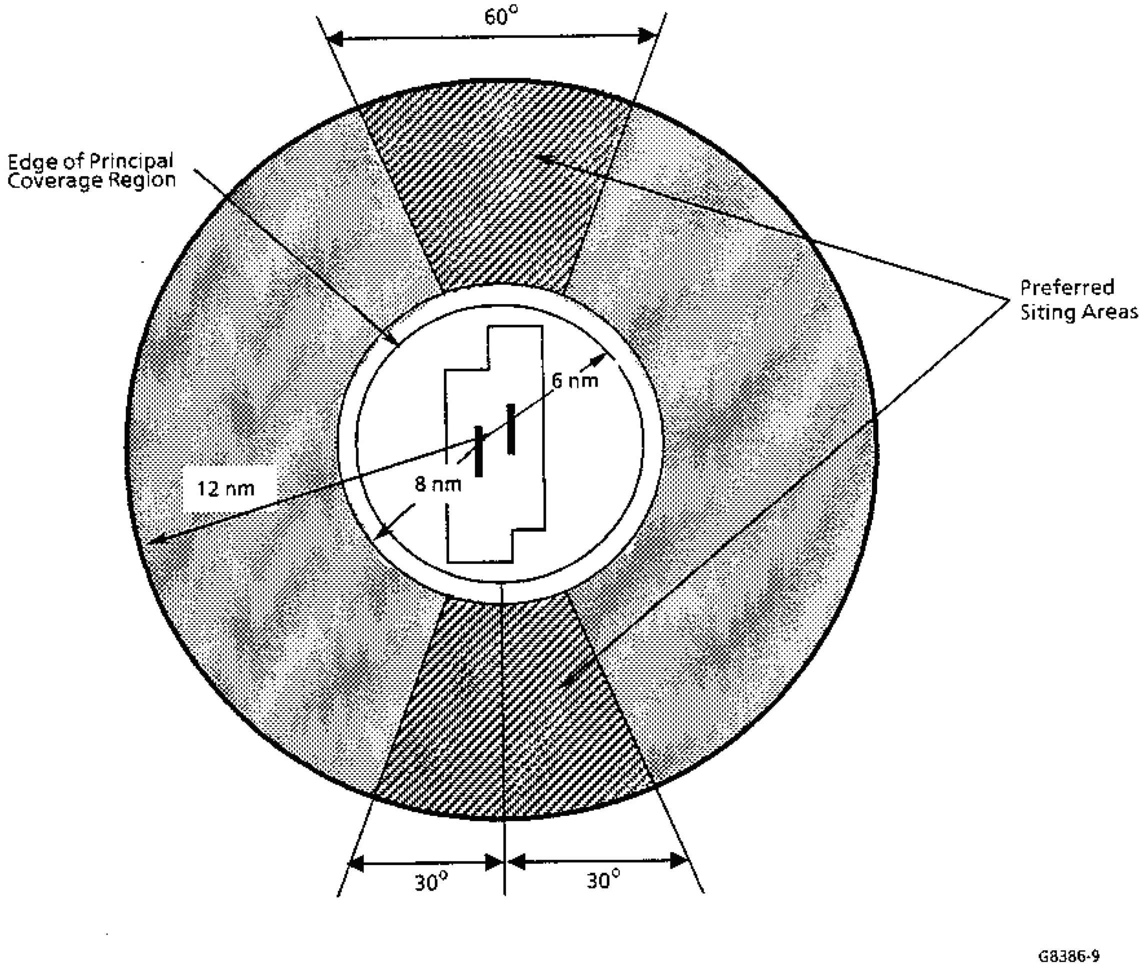


Figure 3-9. TDWR Aspect Angle Siting Preferences



3-7. Meteorological Trends. Although meteorological parameters may not change enough within the TDWR scan area to affect site selection, in some locations prevailing severe weather trends may be documentable and location dependent. Typical growth patterns of severe weather storms evolve over time with altitude and reflectivity profile characteristics which are expected to vary somewhat for different geographic locations. In such situations, the following meteorological factors should be considered in evaluating a site:

a. General weather trends and estimates including average temperature ranges, annual snowfall and the average wind speeds.

b. Historical severe weather occurrence data, including severe weather approach zones, and peak wind directions and magnitudes.

c. Location of areas where severe weather occurs substantially more often than that of surrounding areas.

Generally, unobstructed radar coverage towards severe weather approach zones is more important than toward other directions and a site should be selected which more readily monitors the above weather trends at the specific location in which they occur.

3-8. Summary of Principal Siting Constraints. The center of the principal coverage region is a point near the geographical center of the airfield, and may correspond to the airport reference point (ARP) when the ARP is close to the center of the airfield. The required radius of the PCR extending from its center is 6 nm (11 km). The volume of the PCR will extend to a required altitude of 19,700 feet to enable adequate precursor scanning aloft. The minimum distance a TDWR site may be located from the CPCR is 8 nm (15 km), preferably 10 nm (18 km), based on the radar system's elevation capability, while the maximum distance based on beam width limitations is 12.4 nm (23 km). The aspect angle should be 30 degrees or less off the most heavily traveled severe weather runways. Where two or more heavily traveled severe weather runway directions are encountered at close to right angles, then aspect angles close to the bisectors (i.e., approximately 45 degrees) may be required. Where maximum detection range limitations conflict with high altitude coverage requirements and maximum permissible inclination angles, the competing requirements should be balanced and site specifically adapted to optimize the coverage quality. Where site specific factors have a neutral influence, the following *order of precedence* (from highest priority to lowest priority, respectively) shall apply to any conflict between competing requirements:

a. High altitude scanning aloft requirements.

b. Maximum detection range limitations.

3-9. Essential Off-Airport Siting Requirements. In some cases, it may not be possible to identify potential sites which satisfy the preferred siting constraints listed in the previous section. It is necessary, therefore, to identify minimum acceptable siting constraints required to guarantee basic TDWR performance capabilities.

3-10. Essential Microburst Detection Zone (EMDZ). To be able to detect all potential microbursts in the MAWA the radar must be located some minimum distance away from the MAWA. If the radar is not located this minimum distance away, then a microburst forming directly over the radar in the MAWA may not be detectable in a timely manner due to the effects of the radar's cone of silence. By locating the radar some minimum distance from the MAWA, any microburst forming in the MAWA will be detectable since any microburst forming over the radar will be, by definition, outside the MAWA. The minimum distance required can be determined by adding a 0.5 nm (0.9 km) buffer zone around the MAWA to the 0.25 nm (0.5 km) TDWR minimum detection range, resulting in a 0.75 nm (1.4 km) minimum distance. Consequently, an area surrounding the MAWA is defined, termed the essential microburst detection zone (EMDZ). Any TDWR located inside this zone will be considered an on-airport siting (requiring 360 degree hazardous weather azimuthal scans), while any TDWR located outside it is an off-airport siting (provided no more than 180 degree sector scans are required to cover the MAWA of the target airport). Figure 3-10, TDWR Microburst Alert Warning Area and Essential Microburst Detection Zone, illustrates the layout of a typical airport runway region, MAWA, EMDZ and an EMDZ scanning aloft transition in relation to a 6 nm (11 km) PCR. Any site located outside the EMDZ scanning aloft transition will be able to scan the MAWA for outflows at the ground surface as well as the precursory signatures aloft (to an altitude of 19,700 feet. For sites at ranges less than 8 nm (15 km) from the target airport, it will be necessary to determine whether the radar is at least 1.9 nm (3.5 km) from the MAWA. If the radar is located less than 3.5 km, the TDWR Scan Strategy will not cover the desired altitude extent. In such cases, a performance trade-off analysis may need to be carried out and the Weather Systems Team, AJW-141, should be consulted for approval of proposed scanning limitations. The elevation angles used for scanning the TDWR antenna can be varied on a site specific basis and scans at elevation angles higher than 40 degrees may be utilized, although they are not preferred. Alternatively, not achieving coverage up to 19,700 feet over the entire high priority coverage region (i.e. the MAWA) may be acceptable in some cases since the coverage above 1640 feet (500 m) is principally for microburst precursor detection. The decision in such cases will revolve around the meteorological characteristics of microbursts at the particular airport and the location of the missed coverage region with respect to the airport runways.

3-11. On-Airport Siting. Where no other alternative exists an on-airport site location may be considered and evaluated for suitability. On-Airport locations are defined as TDWR sitings located within the essential microburst detection zone (EMDZ) as shown in Figure 3-10, TDWR Microburst Alert Warning Area and Essential Microburst Detection Zone. When the TDWR is sited in the EMDZ microbursts may form in the MAWA directly over the radar. Such microbursts may be detected with 360 degree scans but surface outflows may occur at a range inside the radars minimum detection range. Thus, the timeliness of the detection may be affected. The TDWR on-airport siting will operate with 360 degree scans with an elevation angle range of from -1 to +60 degrees. The required coverage region will include all airspace within 6 nm (11 km) of the airport and extend from the ground surface up to an altitude of 70,000 feet. However, no coverage is required that would require a radar elevation angle greater than 60 degrees.

a. Siting Constraints Based on Location. When the TDWR is sited on an airport, the hazardous wind shear detection coverage aloft may be difficult to achieve due to the cone of silence above the radar dish and the TDWR's minimum detection range of 0.25 nm (0.5 km). Based on a maximum antenna elevation capability of 60 degrees, the on-airport siting fails to provide precursor coverage in the cone of silence within 1.9 (3.5 km) from the radar site at 19,700 feet of altitude. Consequently, the region of less than adequate coverage aloft for the on-airport siting includes most of the airport runway region. The preferred off-airport siting, on the other hand, provides good scan coverage aloft over the entire PCR and optimum scanning response times. Figure 3-11, On-Airport/Off-Airport Siting Comparison, illustrates both siting types for the purpose of comparison.

b. Interference with Systems in Terminal Area. An acceptable on-airport TDWR location in the airport runway region that does not interfere with Instrument Landing System (ILS) and Very High Frequency (VHF) Omnidirectional Range Radio (VOR) installation operations (which are sensitive to large metal objects in their immediate vicinity) may be difficult to locate. For example, most ILS installations are subject to signal interference by either surface vehicles or aircraft and ILS critical areas on airports are established near each localizer and glideslope antenna, in which no vehicle or aircraft are authorized when arriving aircraft are inside a final approach fix, on an ILS approach, because of distortion to instrument indications. Also, it is difficult to site TDWR's side-by-side with ASR radars without hindering operational performance. In consideration of the above factors, the off-airport siting is recommended as the optimal location and the on-airport siting shall be used only when no other alternatives exist.

3-12. Moving Target Simulator (MTS) Sitings. The MTS should be located between 1.1 and 11 nm (2 and 20 km) from the TDWR at a location which provides a clear line of sight between the TDWR phase center and the MTS. The path between the TDWR should remain unobstructed by normal vegetation growth and man-made structures over the life time of the system. Additionally, the MTS elevation angle with respect to the TDWR phase center shall be within 0.25 degree of the elevation angle which would be required to meet the desired microburst outflow detection altitude over the EMDZ. The range gate containing the MTS should not have ground clutter (or, clutter from the MTS mounting structure) with an equivalent reflectivity above 85 dBz (so that the MTS can be measured with the normal TDWR clutter filters). The preferred location for the MTS is on an existing structure or pole on government owned property where adequate power is available.

3-13. Clutter and Blockage Effects Background. Microbursts are typically small, short lived and contain maximum winds very close to the ground where radar echoes are severely contaminated by ground clutter. Thus, microburst detection requires TDWR antennas to scan closer to the ground surface than existing radar systems, and blockage and ground clutter problems are significantly increased. Because wind shear can occur when the precipitation content is low and the radar returns may be weak, the presence of clutter is an especially important issue for siting of TDWR radars.

Figure 3-10. TDWR Microburst Alert Warning Area and Essential Microburst Detection Zone
(Superimposed on a 6 nm Principal Coverage Region)

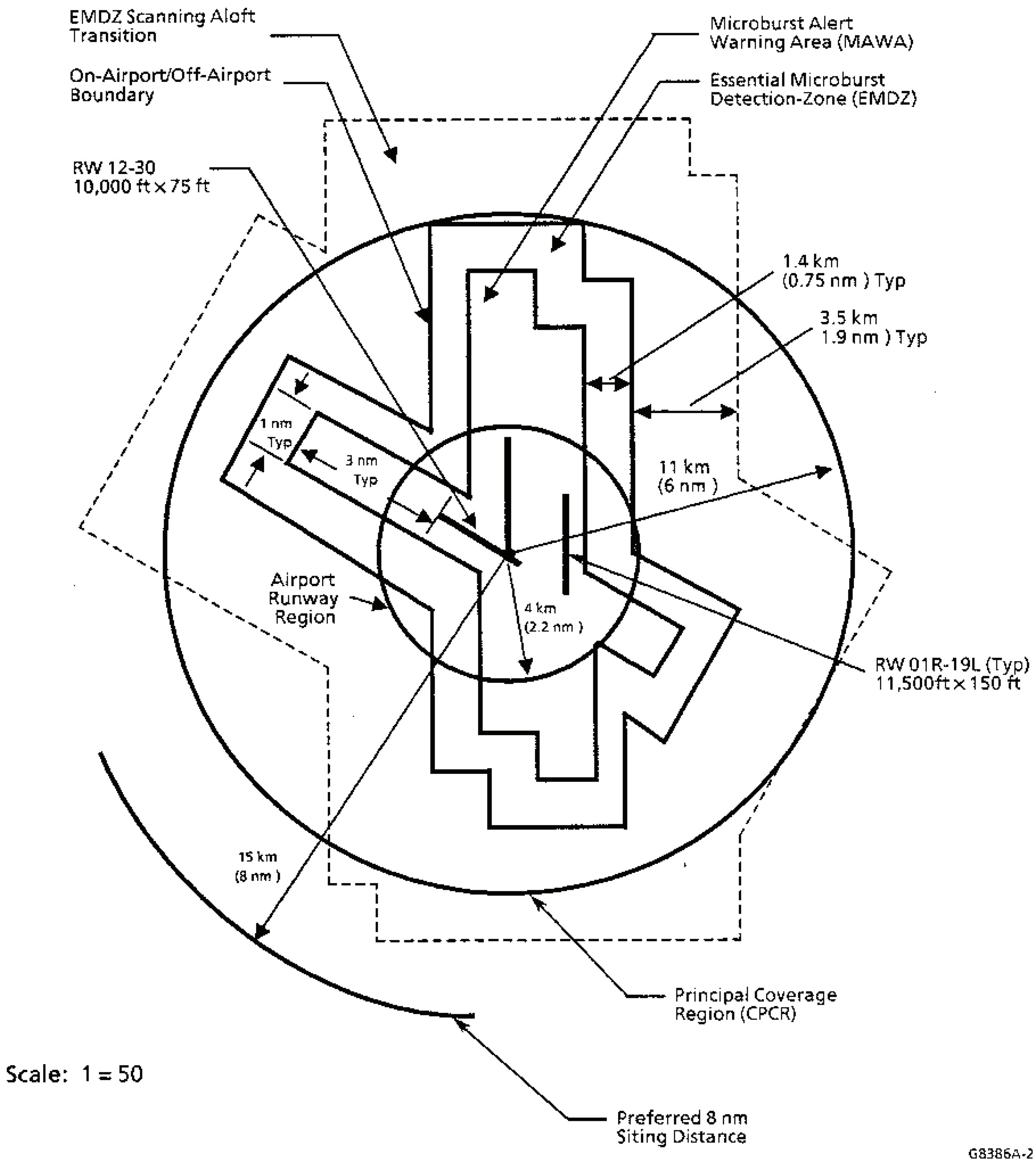
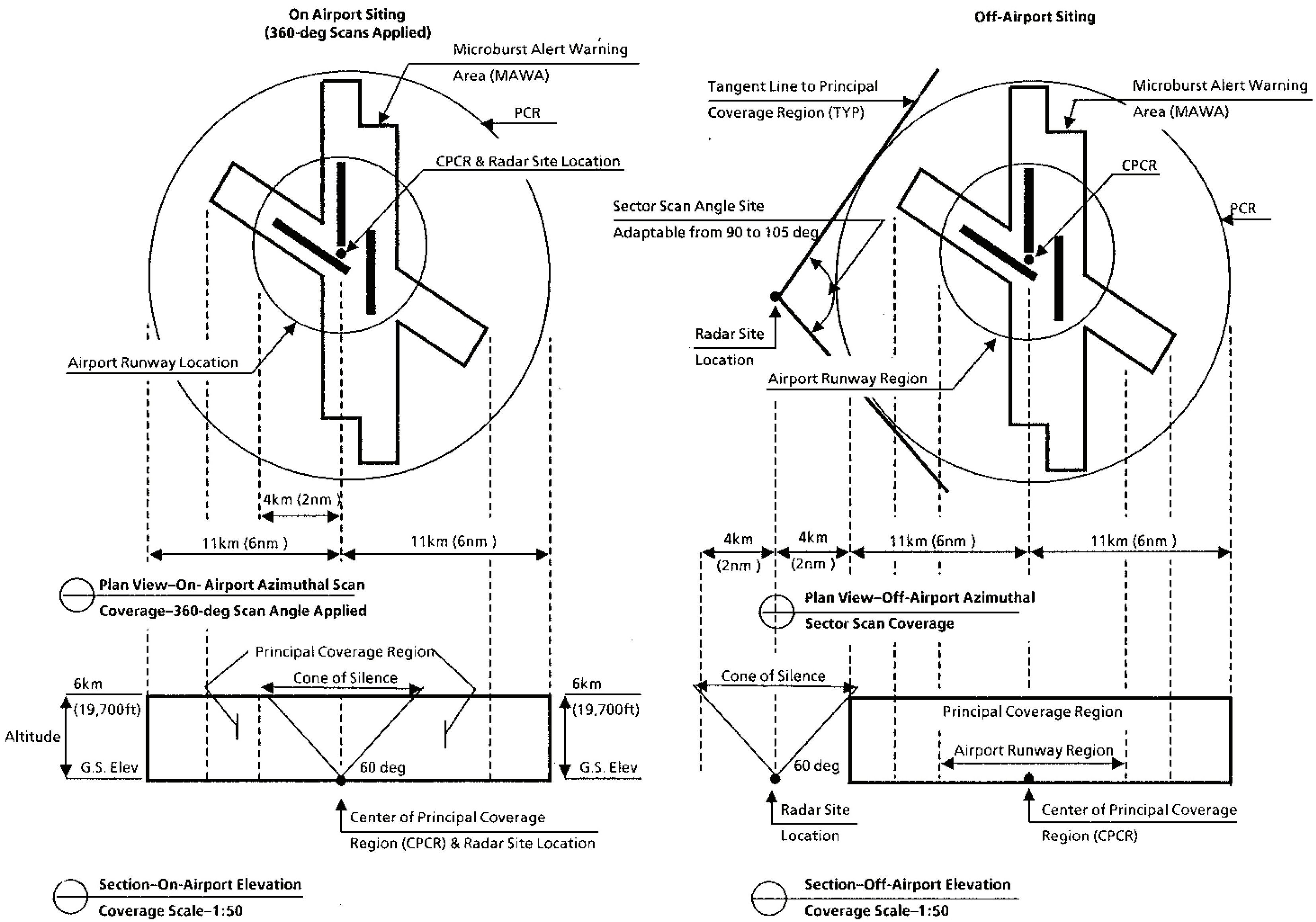


Figure 3-11. On-Airport/Off-Airport Siting Comparison



3-14. Ground Clutter Meteorological Considerations.

a. Weather Signal Characteristics.

(1) Microburst Characteristics.

(a) Research on microburst detection has determined that microburst features develop aloft prior to the beginning of surface wind outflow. In a typical microburst, a reflectivity core develops in the storm cell with convergence developing concurrently. As the reflectivity core descends, convergence and rotation may occur along with a weak surface outflow. When the reflectivity core reaches the ground surface the outflow will reach peak intensity and subsequently dissipate. Consequently, microburst features aloft typically precede initial surface outflows and the presence of microburst features aloft may be used to predict the occurrence of microbursts.

(b) The time evolution, spatial extent, outflow features and reflectivity characteristics of the microburst phenomena are key issues in the development of effective radar based detection system. The commonly agreed definition of a microburst is a divergent outflow which exhibits a horizontal wind speed difference (dV) of at least 10 meters per second (m/sec), or 19.4 knots, over a distance of no more than 2.2 nm (4 km), the windshear region can extend over 2.2 nm (4 km) as long as a shear of .0025 / sec exists over a 2.2 nm (4 km) segment). From an aviation safety perspective, the frequency of various dV values in relation to accidents is of paramount importance. Measurements in the Denver (CO), Memphis (TN) and Huntsville (AL) areas have shown that microburst outflows typically last approximately 10 to 15 minutes[1] with dV increasing over the first half of the lifetime and decreasing thereafter. Typically, microburst outflows have a diameter increase during the first half of the lifetime with the shear intensity (dV/diameter) remaining constant. During the decay stage, the size generally remains constant. Isolated outflows are approximately circular in shape and have a structure which is similar to that of a jet of air when it strikes a surface of air at right angles and spreads out radially over it. However, it is common for a number of microbursts and gust fronts to occur in a contiguous time period. In the High Plains, microbursts can occur close together in time and space to form a contiguous line of surface divergence with a typical length of 11 nm (20 km) and a lifetime of approximately 1 hour (much longer than the lifetime of the constituent microbursts). When microburst occur in close proximity, the various outflows interact such that individual outflows can show considerable asymmetry and differences of 2 to 1 in differential velocity as a function of orientation are not uncommon.

(c) From an aviation safety viewpoint, outflows below 984 feet (300 m) above ground level are of greatest concern due to the limited altitude for recovery. It appears that the strongest outflows occur between the surface and approximately 328 feet (100 m) above ground level (AGL) with outflow depths (defined as the altitude at which the outflow velocity is half its maximum value) ranging from 656 feet (200 m) to 1640 feet (500 m) AGL.

[1] Durations of microbursts can be as short as 2 minutes to over 20 minutes.

(d) The surface outflows have their genesis in a downdraft from a thunderstorm, rain shower or cumulous cloud. Driving mechanisms for the downdraft include evaporation of precipitation below the cloud base (particularly common in the dry sub-cloud environment of the high plains), melting of ice and graupel, (ice pellets) and precipitation loading. Thus, there are precursor phenomena aloft which furnish clues from 2 to 15 minutes in advance that a microburst outflow maybe imminent. The most common radar observable precursor phenomena identified to date are descending reflectivity cores, and divergence at the storm top.

(e) The reflectivity of microburst outflows is a key factor in radar system design. A typical dry microburst in a high plains environment is near the actual limits of sensitivity for detection and may consist of a 10 dBz return signal with no measurable amount of moisture on the ground surface. Midwest areas in high plains environments that have tall buildings may get clutter and reflection residue signals which are stronger than the dry microburst return values. In areas of the southeast, however, the typical microburst contains much precipitation and may have a very high reflectivity shaft.

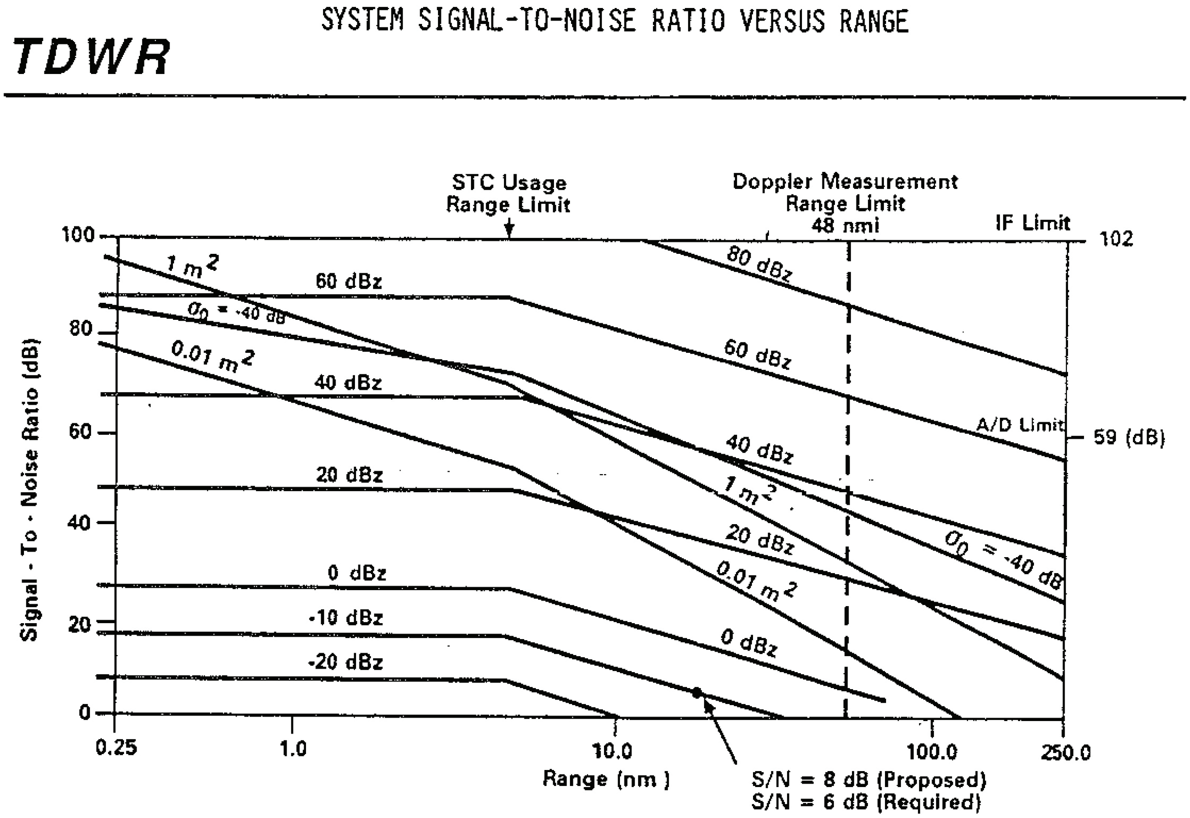
(2) **Gust Front Characteristics.** Gust fronts which are operationally significant from a safety viewpoint typically arise from strong long lasting outflows produced by a sizable convective storm. Wind speed changes associated with gust fronts from strong midwest squall lines often exceed 25 m/sec (49 knots) and may propagate at a ground speed of 20 m/sec (39 knots). The leading edge of such gust fronts is characterized by strong updrafts and turbulence over an altitude extent of 3300 to 9800 feet (1 to 3 km). On the other hand, runway shifts can be necessitated by much weaker gust fronts and wind shifts depending on the previous wind, and the runway orientation and length. Consequently, gust fronts with wind speed changes as weak as 5 to 10 m/sec (10 to 19 knots) which may move very slowly are potentially of concern for runway planning. Both strong and weak gust fronts typically have a length of at least 10 km (5 nm). Whereas the reflectivity of microburst outflows are closely related to the core reflectivity, gust front leading edges are often 40 to 50 dBz less reflective than the parent storm. An analysis of 18 Oklahoma gust fronts showed that a considerable number had outflow reflectivity of approximately 0 dBz. Similar reflectivity has been observed on Denver, CO gust fronts.

b. Ground Clutter Characteristics.

(1) Ground clutter is conveniently separated into discrete targets and distributed clutter. Figure 3-12, System Signal-to-Noise Ratio Versus Range, shows the equivalent reflectivity levels associated with discrete clutter sources (characterized by the radar cross section, sigma to the exponent o, in m^2/m^2).

(2) Discrete targets such as a large building or water tower typically create a high clutter level in 1-4 range-azimuth cells with the clutter levels in the cells adjacent to these cells generally much lower in amplitude. If discrete clutter sources are not adequately rejected by the clutter suppression filters, data from the range-azimuth cells will be flagged on a weather level dependent basis using the TDWR clutter residue map. If the density of such cells is small (e.g., less than 0.25 per km^2), visibility of such clutter sources from a candidate TDWR site should not be of significance for system operation.

Figure 3-12. System Signal-to-Noise Ratio Versus Range

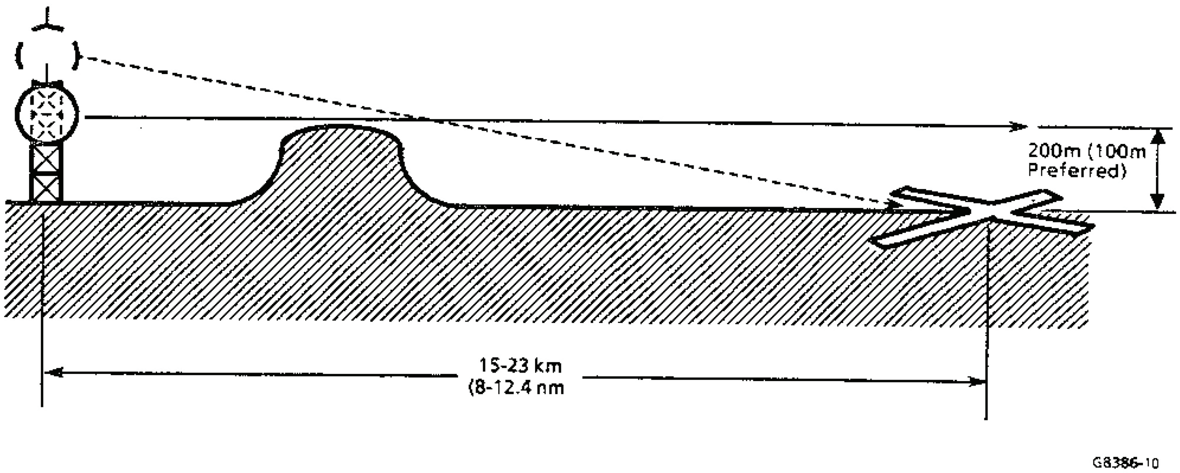


(3) Distributed targets such as trees, hills, or many closely spaced small buildings can cause significant clutter levels over many adjacent range gates. If the residue clutter level from these is too high in relationship to the expected weather target reflectivity levels over a substantial region (e.g., 4 km^2) in the EMDZ the detection of microbursts may be significantly degraded. Based on the experience to date with the TDWR test bed radar, it appears that the residue distributed clutter level will be approximately 35 dB below the clutter level measured without clutter filtering. If there is substantial high level distributed clutter in the EMDZ that cannot be avoided by the siting techniques discussed below, it will be necessary to use microburst surface scan elevation angles that are high enough so that the clutter is on the edge of the main beam or in the side lobe region of the antenna. In such cases, the resulting height of the beam over the EMDZ may be such that the detection of shallow outflow microbursts will be impaired. The loss in detection capability can be reduced by using a site close to the EMDZ so that a lower beam height above ground is achieved.

c. Clutter Mitigation by Use of Naturally Occurring Clutter Fences.

(1) The selection of sites having natural terrain features that act as clutter fences minimize the intensity and extent of clutter experienced by the TDWR. The probability of detecting clear air returns from wind shear sources masked by round clutter returns is significantly improved for environments which use a natural clutter fence between the radar and the target airport, as shown in Figure 3-13, TDWR Siting with a Natural Clutter Fence.

Figure 3-13. TDWR Siting with a Natural Clutter Fence



(2) If the TDWR antenna phase center can be sited at an altitude which is approximately 330–660 feet (100-200 m) above the EMDZ nominal elevation, the ground clutter in the EMDZ may be lower that would be the case otherwise. If the TDWR antenna height is appreciably above the EMDZ altitude so that the beam would point down toward the airport center, the potential for ground clutter at ranges beyond the airport center is increased. If the TDWR antenna must point up at an elevated airport location (e.g., on top of a hill), the height of the beam may be higher than is desired at ranges greater than the airport center.

(3) Choosing a radar location and radar tower height such that the blockage criteria below are met while the distributed clutter sources in the EMDZ are shielded by intervening terrain will also reduce the clutter levels.

3-15. Structure Specular Reflection Effects.

a. Structures such as buildings, metallic fences and water towers which are illuminated by the radar main beam when scanning over the EMDZ can cause significant data interpretation problems by reflecting the radar beam into a location where weather is present such that false weather targets are generated. Such structures are in the main beam only if their altitude is approximately that of the radar line of sight when scanning at an altitude of approximately 330 feet (100 m) over the EMDZ Building walls are particularly of concern if the wall extends a substantial fraction of a Fresnel zone [Rf= (range to building in m)(0.05 m)] and is located within the azimuth sector encompassed by the EMDZ. Roughly cylindrical structures such as water towers, oil storage tanks or silos are of concern only if within 2.2 mi (4 km) of the TDWR site. In such cases, the Weather Systems Team, AJW-141, should be consulted.

b. Power lines and the associated structures do not appear to produce deleterious reflection effects (albeit they are clutter sources).

3-16. Blockage Constraints.

a. Description of the Blockage Problem. Blockage of the radar beam by intervening obstacles is of considerable concern for coverage over the EMDZ since blockage of over 25% of the microburst outflow region may result in a missed detection. Blockage is not a "black and white" issue since signals can diffract over an obstacle or be affected by it even if there is a clear line of sight. For example, when the line of sight just grazes an obstacle, the received signal power will typically be reduced by some 12dB which would be of concern for detecting dry microburst at the far edge of the EMDZ. The ratio of diffracted signal power to the free space power when the line-of-sight lies (in meters) below the top of an obstacle is approximately 20 x $\log_{10}$ [.05R $_{min/}$ (2 x pi x delta x H)] dB where R(min)=minimum or (the distance to the obstacle from the radar in meters, the distance from the obstacle to the EMDZ in meters).

b. Allowable Blockage Estimates. A half degree beam, at a distance of 8 nm (15 km) from the antenna and pointed at a microburst 2.2 nm (4 km) in diameter will contain approximately 16 radials, 820 feet (250 m) apart, that will penetrate the microburst. If approximately 25 percent of the radials are blocked out then the algorithms may lose their ability to detect low reflectivity microbursts. Therefore, the allowable blockage near the airport may be estimated as 820 feet (250 m) horizontally. The vertical dimension only affects half the height of the scan and may be estimated at 410 feet (125 m) of allowable blockage. Allowable blockage criteria closer to the radar may be established by extrapolating back from the airport a 410 by 820 feet (125 m by 250 m) obstruction along the appropriate radials, thereby reducing the permissible size of blockage as an obstruction moves closer to the radar site.

Chapter 4. Site Specific Requirements and Limitations

4-1. Site Ownership, Availability and Cost.

a. A prerequisite for the consideration of any property for use as a TDWR site is that the land must be available through purchase or long-term lease. In addition, the property must be adequate to the extent that the construction, installation, and operational requirements of the TDWR facility can be met with reasonable cost and without undue environmental impact.

b. The TDWR site finally selected should minimize site preparation costs, installation costs, data communication costs, and minimize the cost for acquisition or lease of new land. Where feasible, the use of government land should be considered during selection of the site since land acquisition costs would be minimized.

4-2. Site Size and Present Land Use.

a. Site Size. The dimensions of TDWR site candidates must be sufficient to satisfy the space and functional requirements of the CMU building layouts established in FAA Specification FAA-C-2814, Construction of Large CMU Building for Electrical Equipment, the antenna support structure, the TDWR antenna, miscellaneous utility support elements, and all other facility components. Property of the dimensions indicated in paragraph 2-9, Typical Facility Components, is required for TDWR applications.

b. Land Use. The zoning constraints imposed by the cognizant municipalities for the selected sites must be compatible with TDWR installations. Zoning involves legislative action which divides municipalities into districts for the purpose of regulating the use of property and construction of building types within the established districts. Separate classes of districts deal with varying uses of land and buildings, allowable building heights, permissible percentages of land coverage and are presented on district zoning maps available through the municipalities. TDWR sites must be in districts which are presently zoned to permit land uses compatible with the TDWR function, allow construction of the intended CMU unmanned electronic equipment facility, permit the construction of TDWR antenna support structures up to the required height above ground surface elevations, and regulate the application of construction blasting near the radar.

4-3. Logistics and Availability of Utilities. The following logistical factors should be considered in evaluating TDWR sites.

a. Access Roads. The conditions and maintenance of existing roads (FAA Order JO 6940.3, Maintenance of Roads and Grounds) is an important factor to be considered when evaluating a potential TDWR site. Studies analyzing the feasibility of using access roads to bring construction materials to the site should be performed. Restriction of equipment by bridges or underpasses should be specified. The site must be accessible during all expected weather conditions. The amount and cost of road construction required for site access should be minimized and considered as a site selection criterion. If a TDWR site is to be located on existing airport property, the access roads in use are usually adequate. However, it is possible that a TDWR facility may be located at a site remote from existing roadways. Both cases are considered below.

(1) **Existing Roads.** Where existing roads provide all or part of the access necessary to the proposed site, a survey is needed to determine their adequacy for the vehicular traffic expected to utilize such roadways. Some of the important factors to be considered in the evaluation of existing access roads include:

(a) Maximum load limit of roads, bridges and culverts;

(b) Maximum clearance height of underpasses;

(c) Maximum grade, shoulder width and minimum turn radius of roads;

(d) Weather and seasonal considerations such as road surfaces;

(e) Volume and class of traffic handled; and

(f) Adequacy of and responsibility for road maintenance including snow removal.

Useful data of this type can often be obtained by contacting state, county, or local highway department officials or, in the case of airport roads contact appropriate airport officials.

(2) **New Road Construction.** When the construction of a new access road is required, a study of the construction cost, annual maintenance, traffic handling capacity, and the increased property value at future time of TDWR system replacement is needed for determining the relative economic merit of different surfaces for a given geographic area. No FAA improvements can be made to roads on which the FAA does not have a lease, easement, or similar legal arrangement. Some of the important factors to be considered when new construction is required are as follows:

(a) The length of road required from the point of entry to the site.

(b) The climatic and geological variables having an effect on road construction such as snow depth, rain, frost heavings, load bearing capacity, and subgrade soil.

(c) The requirements for grading and filling.

(d) The need for the construction of bridges, culverts, etc.

(e) The availability of local labor and construction materials.

b. Electrical Power.

(1) The principal utility requirement for a TDWR site is the need for electrical power. The primary source of electrical power will be commercially available power within the vicinity of the site. Consequently, sites nearest available power lines or distribution points are preferred when all other factors are equal.

(2) The selection of the site location should minimize the total cost for providing an adequate source of electrical power to the site. Total costs include the cost of providing an adequate power source (as defined below) to the site and the cost of purchasing the power during TDWR operations.

(3) External voltage regulating transformers will not be used.

(4) Site must have gravel around it for proper grounding capability.

c. Communications. Adequacy of existing telephone/data lines is highly desirable. Potential TDWR site locations must have the capability to upgrade, if necessary, to be compatible with the TDWR communications requirements.

d. Water and Sanitation. Water and sanitation at a TDWR site is typically not required since the site is to be unmanned. However, contact with local authorities should be made to establish the sufficiency of proposed water/waste water systems in meeting local requirements. Means for providing minimum conveniences required by local codes may utilize municipal, state or county facilities where readily available.

4-4. Clearing/Grading/Landscaping. The need for clearing, grading and landscaping of the site property represents an additional cost above those nominally required for an average site facility. Clearing costs would include such items as the removal of existing structures, trees, shrubbery, rocks, and debris. Grading may be necessary to improve drainage on or about the site, or to provide screening in a particular azimuth sector. The prevention of soil erosion about the site, esthetics from a local ordinance viewpoint, and reduction of visible reflection from the surrounding security fences may all add factors that could require special landscaping of the site.

4-5. Soils and Estimated Settlements.

a. Based on the results of the subsurface investigation a decision must be made by the TDWR contractor concerning whether or not to use the standard foundation design developed on a presumed allowable soil bearing capacity of 2000 pounds per square foot (PSF). Where the site soil conditions result in an allowable bearing capacity of 2000 PSF or better, the standard foundation design can be used. If the subsurface conditions are insufficient to justify such a bearing capacity, then a site specific foundation design will be required at a greater cost. Sites which can accommodate the standard foundation design are preferred.

b. Weak soils such as loose sands, soft clays and organic materials typically exhibit unsatisfactory strength characteristics as foundation subgrades. Such soils typically require either removing the unsuitable soils and backfilling with a compacted well graded fill or, if feasible, field compacting existing soils. The extent of work and cost associated with preparation of foundation subgrades should be considered as a site selection criterion, all other factors being equal.

c. Shallow rock layers or outcroppings may interfere with proposed foundation construction. Significant cost increases may be expected when rock excavation is required to pour foundation footings.

d. In city or metropolitan locations, municipal utilities or local governments may have underground utilities which must be avoided during construction excavation. Unexpected utility conflicts discovered during construction can significantly impede construction progress. Preferred sites will be free of utility conflicts.

e. Ground water levels may cause undue hardship and interfere with site construction efforts and can increase construction costs by requiring dewatering efforts. Also, the position of the ground water table may have a significant effect on bearing capacity of shallow foundations. The effective unit weight of submerged soils will be reduced to about one-half the unit weight of the same soils above the water table. Thus, through submergence, the bearing capacity of soils may be considerable reduced and it is essential that the bearing capacity analyses consider the highest design ground water level at the proposed TDWR site location for the expected lifetime of the TDWR structures. The assessment of this highest design level must be made taking into consideration the probability of temporary high levels that could be expected in some locations during heavy rainstorms or floods. All other factors being equal, the selected TDWR site should minimize additional design and construction costs resulting from high ground water tables.

The estimated rate of settlement for the CMU building foundation, the tower foundation, and any equipment at the site shall not exceed the maximum adjustment rate allowed by the TDWR design to meet the accuracy and preventative maintenance requirements.

4-6. Drainage and Flooding Factors.

a. The cost of providing drainage facilities (i.e., storm drains) is a significant cost in development of an area. Land use zoning categories are typically assigned to the area influenced by preliminary run off quantities and general alignment and quality of drainage facilities. For example, because of the high cost of drainage facilities, development of land-use maps and master plans by municipal officials typically give careful consideration to drainage problems. To a significant extent the land use zoning gives an indication of general drainage conditions. However, inadequate storm drains may flood and damage property and the site drainage characteristics should be thoroughly analyzed during the evaluation process.

b. Sites with an existing topography that slopes away from proposed building, tower and access road locations are preferred due to the reduced earthwork requirements and the corresponding cost reduction in preparing the site. Typical drainage details for access roads in FAA facilities are contained in FAA Order JO 6940.3, Maintenance of Roads and Grounds. Where feasible, all sites should be located above existing 100-year flood elevations for the local area surrounding the site to reduce the potential loss of operations due to flood damage.

4-7. Construction Engineering Factors.

a. Local Set Back Requirements. Local building codes sometime require buildings to be set back at the base of the building a minimum distance from lot lines. These regulations should not preclude locating TDWR facilities on the proposed site.

b. Local Building Permit Requirements. The TDWR contractor must apply for and obtain all local building permits and inspections required during construction. All building permit requirements should be compatible with the site construction.

c. Obstacle Clearance Requirements. Where the TDWR is installed on or in the vicinity of an airport, the maximum physical height of the TDWR structures must not constitute an obstruction as defined in the Federal Aviation Regulations (FARs), Part 77.

d. Facility Grounding Requirements. TDWR equipment and facilities will be protected from lightning strikes and satisfy grounding, bonding and shielding requirements in accordance with FAA-STD-019, Lightning Protection, Grounding, Bonding, and Shielding Requirements for Facilities and FAA-STD-020, Transient Protection Grounding, Bonding, and Shielding Requirements for Electronic Equipment. Soil conditions of selected TDWR sites must be able to cost efficiently accommodate foundations designed in accordance with the above standards.

e. Risks of Construction Analysis. The potential risks of constructing the TDWR facilities at the proposed site location shall be considered in site selection. Problem areas for sites with marginal subgrade soils may include foundation settlements, utility settlements, pavement and/or slab cracking and high water levels. The risk of construction analysis must include an assessment of the availability of construction materials required for construction of TDWR facilities.

f. Blasting Operations. Blasting caps have the potential (in a worst case scenario) to be detonated by radio frequency (rf) energy if used in the vicinity of the radar site. Since the TDWR scans are lower to the ground than other radar systems, the beam may be directed downward and the potential to illuminate near range objects close to the ground surface increases. Blasting operations for nearby construction projects may be jeopardized by any radar operation. For each potential TDWR site the distance the TDWR main beam could be directed downward but not illuminate objects close to the ground surface must be determined and compared against the distance required for the main beam peak intensity to disperse sufficiently so that blasting caps are not adversely affected. Calculations may be made in accordance with Explosives Safety Standards, USAF Regulation 127-100(C1), or the most recent edition. For cases where the main beam strikes the ground surface before the peak intensity adequately dissipates, negative easements must be purchased, zoning control measures implemented to restrict adjacent landowners from blasting on their property, or blasting operations must be restricted to times when the TDWR can be shutdown. Easements are preferred since zoning classifications are subject to change. Sites which will minimize the difficulty and cost in attaining such easements, where necessary, are preferred.

g. Environmental Impact. Any location considered as a TDWR site must have an acceptable environmental impact.

4-8. Physical Security Requirements.

a. Consideration must be given to the facilities necessary to prevent intrusion, and to protect the TDWR installation from vandalism or other damage. TDWR facilities will contain an intrusion alarm with a 60 second delay for maintenance personnel. A lockable chain-link security fence constructed in accordance with FAA-C-2814, Drawing D-6253-1, and the latest edition of FAA Order 1600.6, Facility Security Policy, is adequate for physical security purposes and all off-airport sites will require a fence. Consequently, site terrain elevations must be able to accommodate a 7-foot security fence (with 3 strands of barbed wire at its top) surrounding the site. The elevation of the top of the fence should not interfere with the TDWR antenna.

b. Distances to and response times from the nearest police and fire department headquarters should be reasonable. All other factors being equal, the quicker response times are preferred.

c. The location of the site should reduce likelihood of arson, vandalism and theft.

4-9. Zoning and Other Development Approvals.

a. Local authorities utilize zoning classifications to regulate the use of land by controlling the type of allowable occupancies and sizes of buildings which can be constructed. This is done to safeguard the public health, safety and welfare. Zoning regulations typically supplement local building code requirements. When selecting property for TDWR functions, the local zoning codes should be checked to ensure that the planned occupancy (i.e., residential, commercial and industrial) is permitted.

b. Zoning codes typically restrict the height and bulk of buildings, the number of stories, or place a maximum limit on the allowable building height above the street. Some codes control height and bulk by establishing a ratio between the total floor area permitted and the area of the site. The preferred scenario for TDWR sitings involves locating the site 8 nm (15 km) to 10 nm (18 km) from the target airport, with the property between zoned to restrict building heights. If the property between the site and target airport is zoned to restrict building heights, the chance that future high rise construction will become blockage and interfere with the TDWR's line of sight is greatly reduced, although still possible through variances or modification of zoning restrictions.

4-10. Required Easements.

a. Affirmative Easements. Affirmative easements created by express agreement between the government and landowners of property adjacent to proposed TDWR site locations must be acquired to make lawful and beneficial the use of private property, by the government, for driveways, access roads, and utility right of ways where required. The feasibility of acquiring required affirmative easements should be considered during evaluation of proposed sites.

b. Negative Easements. In the absence of satisfactory zoning control measures, negative easements created by express agreement between the government and landowners of property adjacent to proposed TDWR site locations may need to be acquired to restrict adjacent landowners from performing activities which adversely affect TDWR performance or are potentially hazardous (i.e., blasting operations) which may be adversely affected by TDWR operations. For sites which warrant negative easements, the feasibility of acquiring them should be considered in site evaluation.

c. Federal Navigational Servitudes.

(1) Where possible, servitudes should be obtainable by the government to preclude construction of any structure which may: (a) project above the TDWR antenna elevation in the direction of the target airport causing unacceptable blockage or reflection effects or (b) project into any line of sight from the radar to the coverage region at the target airport when 25 percent blockage or more already exists.

(2) Local zoning control to prohibit future hi-rise construction cannot be relied on because it is subject to change. Thus, if the siting procedure utilizes district zoning maps to locate lines of sight which are free of obstructions and in zones where restrictions limit the height

of new construction, there is no guarantee the zoning won't be modified to remove the height restrictions at a later date. Consequently, a Federal Navigational Servitude should be obtainable by the government, if possible, to keep current lines of sight open and free of future construction.

(3) Any need to remove existing structures blocking otherwise clear line of sights will create an enormous takings issue and should be avoided. A regulatory taking is the act by the government of depriving a landowner of the use and possession of property which requires the landowner be given just compensation.

4-11. Future Development Plans. Future developments anticipated by local officials in the vicinity of the TDWR radar site should be considered as a site selection criteria. The potential for conflicts concerning future compatibility of TDWR operational functions with the surrounding area should be analyzed.

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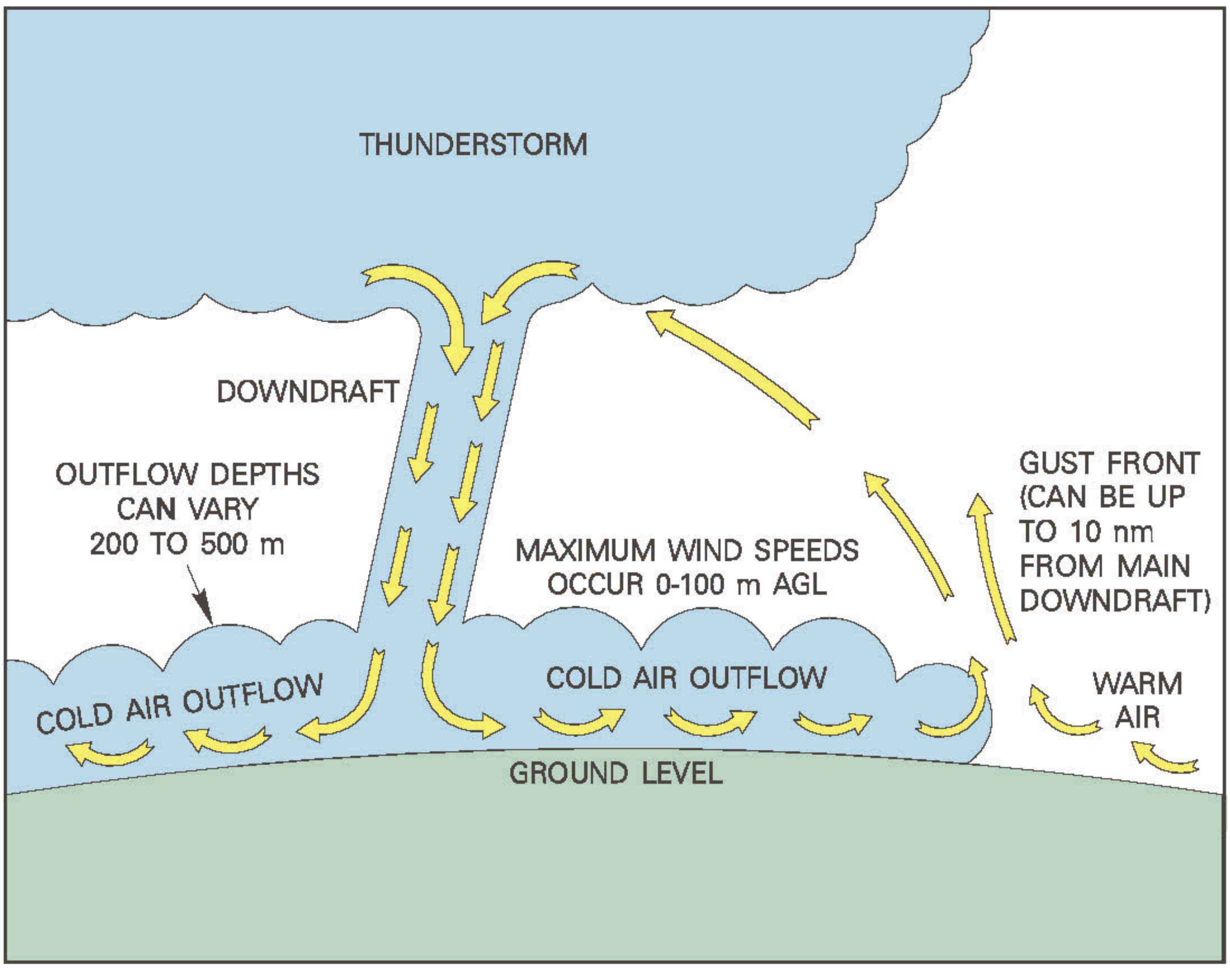
Appendix A. FAA Guidelines for Future Development Near TDWRs

1. General. This information is intended to provide guidance to local jurisdictions about construction of structures near TDWR facilities.

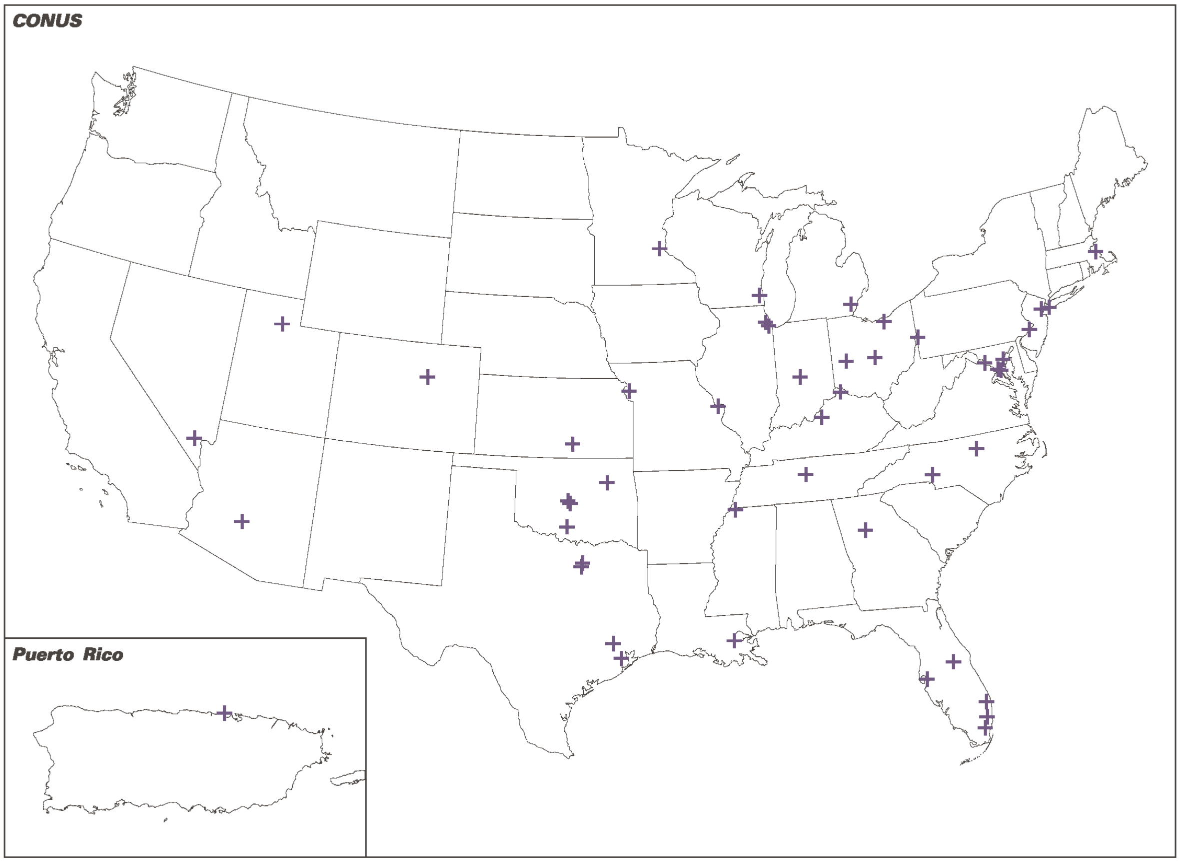
> **Note:** TDWR is an automated radar that detects severe weather, such as gust fronts, microbursts, and wind shear, that can be hazardous to aircraft in flight. TDWR processes radar returns from weather features to determine the hazard to aircraft and, if warranted, issues alerts to air traffic controllers and pilots. Aircraft can then take proper actions to avoid the severe weather or minimize risks while flying.

Figure A-1. Windshear Hazards for Aircraft



The FAA has installed 45 TDWR units to serve major commercial airports throughout the U.S. (See below for location of TDWRs).

Figure A-2. Location of TDWRs



Blockage of the radar beam by buildings or towers can adversely affect the quality of the radar data, and hence weather detection. Future construction around a TDWR should consider the height of the planned structures relative to the height of the radar beam. The following guidelines for future construction near the TDWR are provided as a resource for community planning and development. These guidelines are especially important in the direction of the associated airport. The elevation (E) of a structure is the sum of the ground elevation (H_1) at the base of the structure, plus the height (H_2) of the structure itself.

$$E=H_1+H_2$$

- Within 2500 feet of the radar, no structure should block the radar beam. The maximum elevation (E_{max}) of a structure should be less than the sum of the ground elevation (h_1) at the base of the TDWR tower, plus the tower height (h_2), where h_2 is either 16.4 feet, (5 m), 32.8 feet (10 m), 49.21 feet (15 m), 65.62 feet (20 m), 82.02 feet (25 m), or 98.43 feet (30 m).

$$E_{max}<h_1+h_2$$

- Beyond 2500 feet from TDWR, structures should not block the beam more than 0.25 degrees in elevation or azimuth when measured from the center of the radar antenna. The maximum structure elevation should be less than the ground elevation (h_1) at the base of the TDWR tower, plus the height to the center of the antenna (h_2 + 16 feet), plus the tangent of 0.25 degrees (0.0044) times the distance (d) from the radar.

$$E_{max} < h_1 + (h_2 + 15 \text{ feet}) + 0.0044d$$

- The maximum width (W_{max}) of a structure that is higher than the center of the antenna should be less than 0.0044 times the distance from the radar.

$$W_{max} < 0.0044d$$

Caution: TDWR is an important aviation safety facility. To prevent degradation to the TDWR's ability to protect aircraft from weather hazards, please carefully consider future construction in the radar's vicinity. Your cooperation in avoiding structural blockage of the TDWR radar beam is appreciated.

Figure A-3. Guidelines for Allowable Structural Blockage

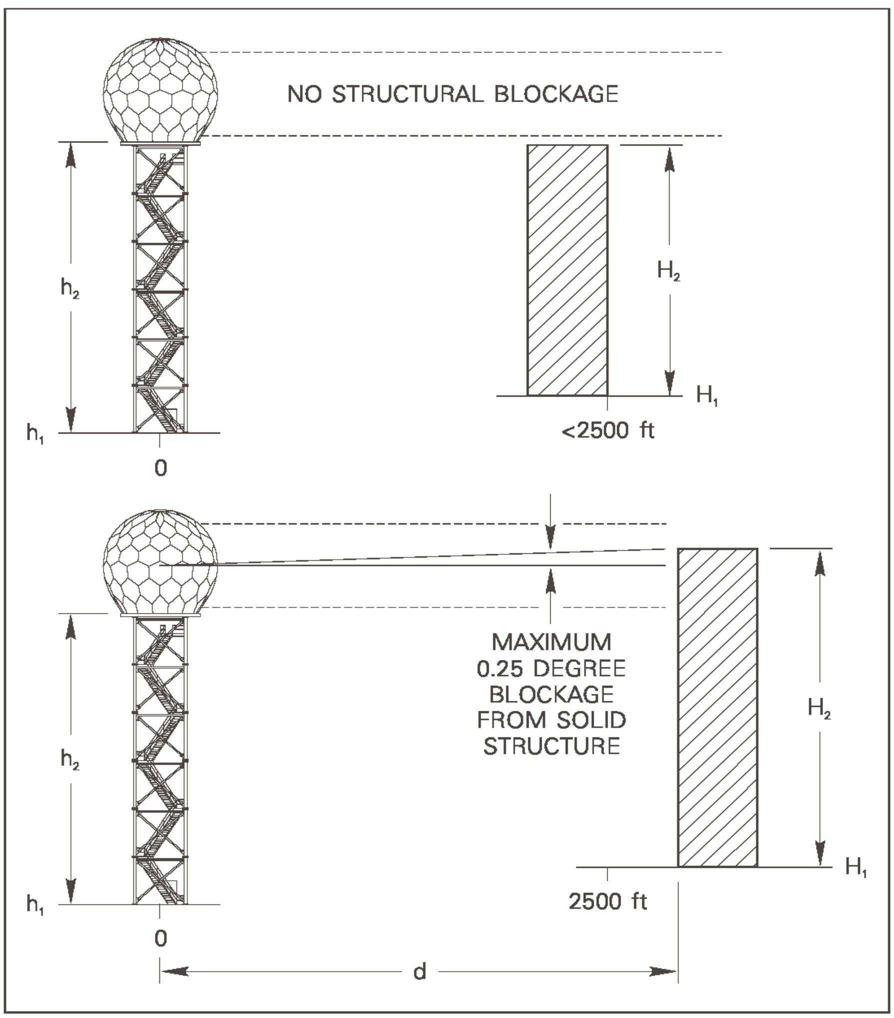
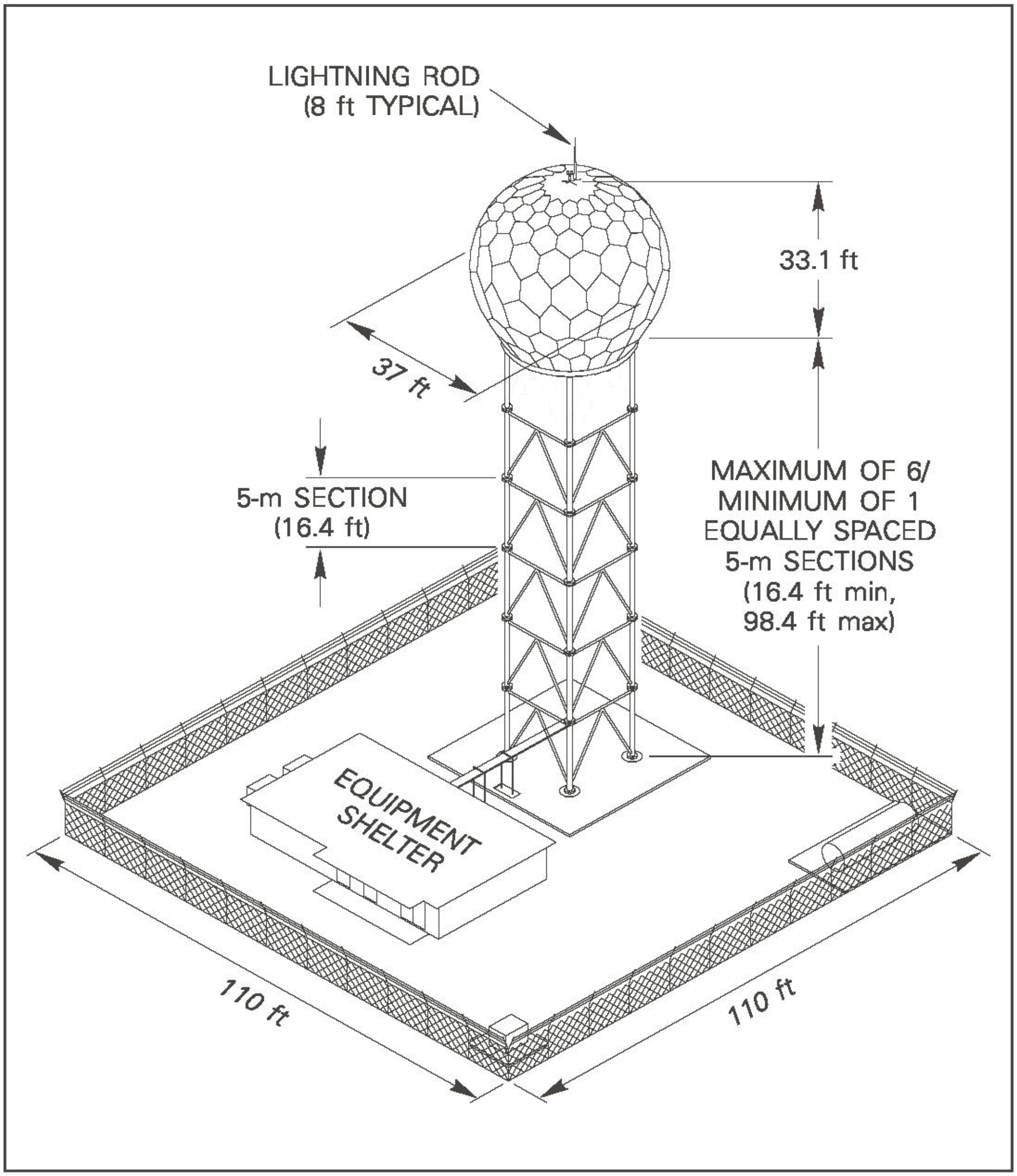


Figure A-4. Typical TDWR Installation



Appendix B. TDWR Radiation Hazard Report

1. Purpose. This engineering report determines a preliminary estimate of the TDWR antenna r-f radiation hazard to personnel. The calculations indicate that there is not an r-f radiation hazard to personnel exposed in the near-field or far-field of the TDWR antenna. The radiation hazards discussed in this report are based on theoretical calculations and not on actual field measurements.

These preliminary calculations have been provided as part of an effort to develop thorough, but preliminary, TDWR siting methodologies only.

2. Effective Date. 23 May 1989.

3. Background. The TDWR is a C-Band Doppler radar with a narrow pencil beam (≈0.55°), low side lobes (≤27dB) and which provides high quality data for identifying and locating wind shear on and around major commercial U.S. airports. The TDWR will optimally *be* located 6 nm to 13 nm (11 km - 23 km) from the target airport. In cases where land acquisition for off-airport siting is not possible, the TDWR will be sited on-airport. The TDWR will be an unmanned site with scheduled periodic maintenance.

4. Applicable Documents.

Military.

USAF T.O. 31Z-10-4, Electromagnetic Radiation Hazards, Air Force Communications Service.

Reference the following documents:

NTIA Report TR-12-486; "Case Study: Investigation into 5 GHz Weather Radars from Unlicensed National Information Infrastructure Devices, Part III", Authors John E. Carroll, Geoffrey A. Sanders, Frank H. Sanders, and Robert L. Sole; dated June 2012; (**Note**: National Telecommunications Information Administration (NTIA). This is an administrative unit in the Department of Commerce.)

https://www.its.bldrdoc.gov/publications/details.aspx?pub=2677

FCC 14-30 (14), 5GHz U-NII (R&O); adopted March 31, 2014, released April 1, 2014. This states that U-NII devices located within 35 km of a TDWR location must be separated by at least 30 megahertz by at least 30 megahertz (center-to-center) from the TDWR operating frequency. http://www.fcc.gov/document/5-ghz-u-nii-ro

5. TDWR Characteristics. The TDWR radiation hazard calculations in this report are based on the system characteristics shown below. The TDWR operating frequency is in the C-Band of the radar frequency spectrum. The TDWR system characteristics are:

a. Frequency, f = 5.60 - 5.65 GHz

b. Wavelength, h = 5.36 - 5.31 cm

c. Antenna Reflector Diameter, L – 25 feet (762 cm)

d. Antenna Gain, G = 50 dB

e. Radome Diameter, d = 37 feet (11.28 m)

f. Average Transmitter Power, P_t = 650 W

g. Permissible Exposure Limit , PEL = 10.0 mW/cm^2

6. Distribution of Energy in Transmitted Beam. Figure B-1, Distribution of Energy in Transmitted Beam, shows the near-field, crossover and far-field regions for TDWR.

7. Far-Field Calculations. The following calculation (using far-field equations) determines the distance from the antenna to a point where a level of hazardous radiation would be encountered.

$$D_h = \left[\frac{P_t G}{4\pi W_f}\right]^{1/2} \qquad D_h = \left[\frac{(650\text{ W})\,(10^5)}{4\pi(10\text{ mW/cm}^2)}\right]^{1/2}$$

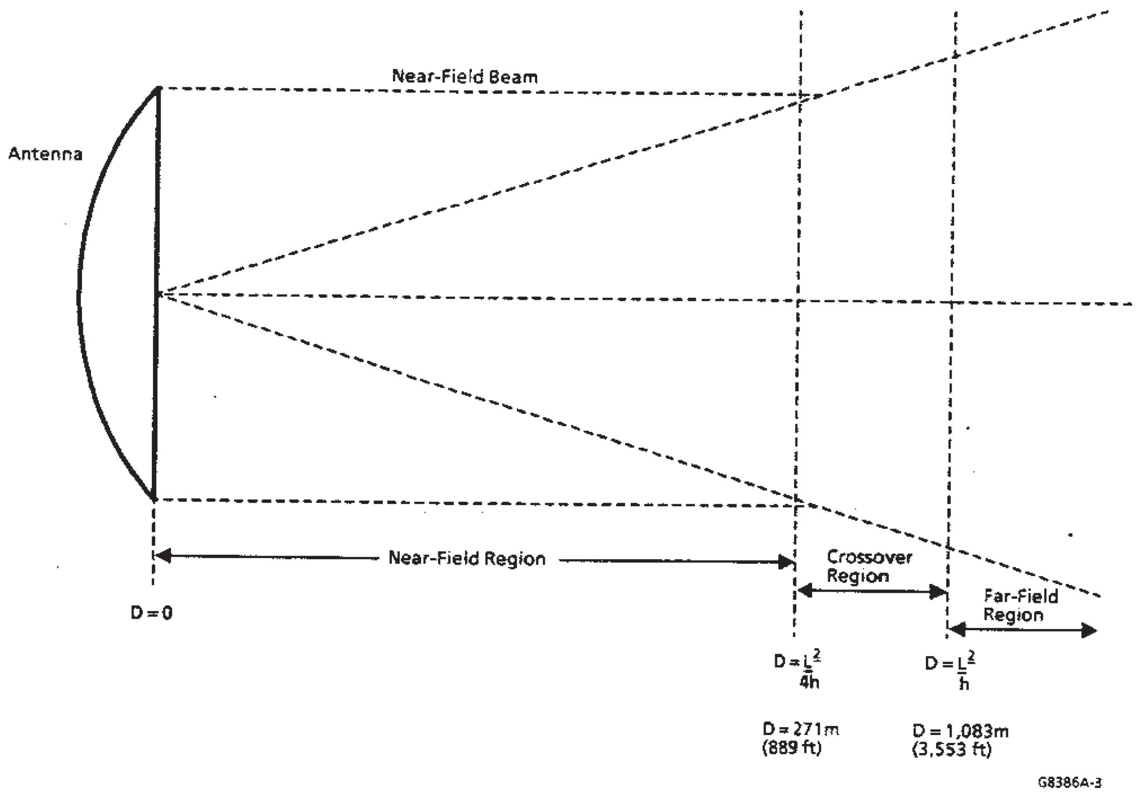
$$\boxed{D_h = 403\text{m } (1{,}322\text{ ft.})}$$

a. Power Density, $W_f = \dfrac{P_t G}{4\pi D^2}$

b. Setting W_f = PEL, the Hazard Distance (D_h) can be found.

c. The above calculations indicate that the hazard distance lies in the crossover region illustrated in Figure B-1, Distribution of Energy in Transmitted Beam. Far field equations do not apply in this region. At distances less than L^2/h, near-field equations are used for power density calculations. Consequently, the next section presents calculations used in determining the TDWR radiation hazard from the antenna by applying near-field equations.

Figure B-1. Distribution of Energy in Transmitted Beam



8. Near-Field Calculations. The radiation hazard will be calculated using the applicable methods described in document T.O. 31Z-10-4. The estimated antenna illumination is ($l-r^2$). With this illumination, Figure B-2, may be used in the calculations that follow.

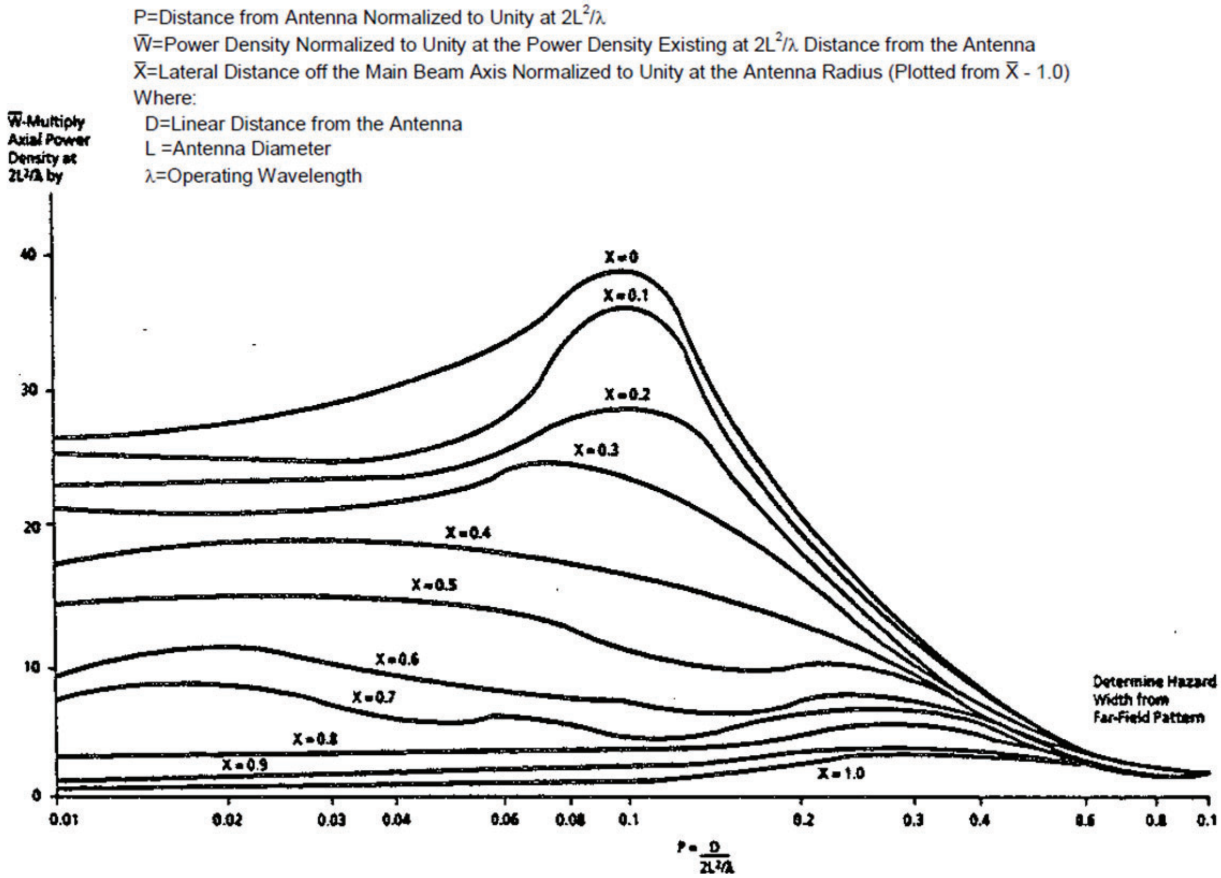
a. The r-f power density (W) may be calculated from the following equation.

$$\mathbf{W=wW_o}$$

where W_o is the reference power density and w is the normalized power density.

Figure B-2. Power Density Dispersion

(from a Circular Aperture Antenna with (1-r²) illumination ($\overline{X}$= 0 to 1)
(Taken from T.0. 31Z-10-4))



The reference power density is:

$$W_o = \frac{P_t G h^2}{16\pi L^4} \qquad W_o = \frac{(650\ W)\ (10^5)\ (5.36\ cm)^2}{16\pi(762\ cm)^4}$$

$$\boxed{W_o = 0.110\ mW/cm^2}$$

b. The reference power density (W_o) is based on TDWR characteristics and is a constant. The normalized power density ($\overline{w}$) is determined from the calculations above and varies with distance from the antenna and lateral distance off-axis of the main beam. Thus the r-f power density (W) will vary in proportion with the normalized power density ($\overline{w}$). Referencing the calculations below, the maximum power density will occur at the peak of the x-0 curve (on-axis of the main beam). The x-0 curve reaches a maximum normalized power density of $\overline{w}$-40.6 at a normalized distance P=0.1.

(1) **Distance From the Antenna.** The distance from the antenna where the maximum power density occurs is found below.

$$D = \frac{2L^2P}{h}$$

with P=0.1, $$D = \frac{2(762\ \text{cm})^2\ (0.1)}{5.36\ \text{cm}}$$

D = 217m (711 ft.)

(2) **Maximum Power Density.** The maximum power density (W) *is* found using the maximum normalized power density of $\overline{w}$-40.6.

$$W = \overline{w}W_o$$

$$W = (40.6)\ (0.110\ \text{mW/cm}^2)$$

$W = 4.47\ \text{mW/cm}^2$ at a distance of D=217 m (711 ft.) from the antenna

9. Summary. The permissible exposure limit in the TDWR frequency range is PEL=5.0 mW/cm^2. The r-f radiation power densities of the TDWR antenna were determined in accordance with T.O. 31Z-10-4. For the proposed TDWR system characteristics, the maximum power density was found to be 4.75 mW/cm^2 and occurred at a distance of 711 feet (217 m) from the TDWR antenna. Based on the forgoing calculations and maximum power density, there is not a near-field or far-field r-f radiation hazard to personnel. Also, since the TDWR antenna will be rotating, an additional margin of safety is obtained over the calculated power density.

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Appendix C. Administrative Information

1. Distribution. This order will be distributed electronically.

2. Other Links to this Order.

a. On the Technical Library website at: http://nas.amc.faa.gov/phoenix/views/technicalLibrary.xhtml?c=ORDER.

b. The Airway Transportation System Specialists (ATSS) and all administrative personnel must subscribe to the Auto-Notifications Services for electronic library release notifications at https://technet.faa.gov/. This document can be printed for local use as required.

3. Referenced Documents. The latest edition of FAA Handbooks, Orders, and other governmental documents that apply to the requirements, guidance, and procedures referenced in this order are:

FAA Order 1050.1, Environmental Impacts: Policies and Procedures
https://www.faa.gov/documentLibrary/media/Order/FAA_Order_1050_1F.pdf

FAA Order 1600.6, Facility Security Policy
https://employees.faa.gov/documentLibrary/media/Order/FAA_Order_1600.6E.pdf

FAA Order JO 6940.3, Maintenance of Roads and Grounds
https://employees.faa.gov/documentLibrary/media/Order/6940_3_mthb.pdf

FAA Order JO 7400.2, Procedures for Handling Airspace Matters
https://www.faa.gov/documentLibrary/media/Order/7400.2N_Basic_w_Chg1_2_and_3_dtd_11-3-22_508.pdf

FAA-STD-019, Lightning Protection, Grounding, Bonding, and Shielding Requirements for Facilities
http://nasdigitallibrary.amc.faa.gov/Images/SpecFiles/FAA-STD-019%20REV%20F.pdf

FAA-STD-020, Transient Protection Grounding, Bonding, and Shielding Requirements for Electronic Equipment
http://nasdigitallibrary.amc.faa.gov/Images/SpecFiles/FAA-STD-020%20REV%20B.pdf

FAA-STD-032, Design Standards for National Airspace System Physical Facilities
http://nasdigitallibrary.amc.faa.gov/Images/SpecFiles/FAA-STD-032.pdf

FAA Specification FAA-C-2814, Specifications for Construction of Large CMU Building for Electronic Equipment
http://nasdigitallibrary.amc.faa.gov/Images/SpecFiles/FAA-C-2814.pdf

FAA Specification FAA-G-2100, Electrical Equipment General Requirements
http://nasdigitallibrary.amc.faa.gov/Images/SpecFiles/FAA-G-2100%20REV%20H.pdf

Explosive Safety Standards USAF Regulation 127-100 (C1) Rev

FCC 14-30 (14), 5GHz U-NII (R&O); adopted March 31, 2014
https://www.fcc.gov/document/5-ghz-u-nii-ro

NFPA- National Fire Protection Association, NFPA-58, Liquefied Petroleum Gas Code
https://www.nfpa.org/assets/files/aboutthecodes/58/58-98-pdf.pdf

NTIA Report TR-12-486, Case Study: Investigation of Interference into 5 GHz Weather Radars from Unlicensed National Information Infrastructure Devices, Part 3 (NTIA Technical Report) - ITS

USAF T.O. 31Z-10-4, Electromagnetic Radiation Hazards, Air Force Communications Service

Title 14 U.S. Code (USC) Section 44718, Structures Interfering with Air Commerce
https://www.govinfo.gov/content/pkg/USCODE-2021-title49/pdf/USCODE-2021-title49-subtitleVII-partA-subpartiii-chap447-sec44718.pdf

Title 14 CFR Part 77, Objects Affecting Navigable Airspace
https://www.govinfo.gov/content/pkg/CFR-2011-title14-vol2/pdf/CFR-2011-title14-vol2-part77.pdf

Appendix D. Acronyms

AGL	Above Ground Level
ARP	Airport Reference Point
ATC	Air Traffic Control
ATSS	Airway Transportation System Specialist
CFR	Code of Federal Regulations
CMU	Concrete Masonry Unit
CPCR	Center of Principal Coverage Region
dB	Decibels
dBz	Reflectivity Factor of Weather Scatters in Decibels
DFU	Display Functional Unit
CCD	Configuration Control Decision
DMS	Directives Management System
dV	Horizontal Wind Speed Difference
EMDZ	Essential Microburst Detection Zone
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCC	Federal Communications Commission
HVAC	Heating, Ventilation and Air Conditioning
ILS	Instrument Landing System
ITWS	Integrated Terminal Weather System
km	Kilometer: 1.853 km/nm
LLWAS	Low-Level Wind Shear Alert System
MAWA	Microburst Alert Warning Area
m	meter
m/sec	Meters per second
MTI	Moving Target Indicator
MTS	Moving Target Simulator
nm	Nautical Mile: 1.152 Stat. mi/nm
NTIA	National Telecommunications Information Administration
OE/AAA	Obstruction Evaluation/Airport Airspace Analysis
PCR	Principal Coverage Region
PRF	Pulse Repetition Frequency
PSF	Pounds per Square Foot
RPG	Radar Product Generator
SNR	Signal-to-Noise-Ratio
TDWR	Terminal Doppler Weather Radar
TRACON	Terminal Radar Approach Control
USC	United States Code
USAF	United States Air Force
VAC	Volts Alternate Current
VOR	Very High Frequency (VHF) Omnidirectional Range Radio