ORDER

9840.1

Reprinted 12/10/84

U.S. NATIONAL AVIATION STANDARD FOR
THE VOR/DME/TACAN SYSTEMS

September 2, 1982

. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Distribution: A-W(FO/AF/AT/RD)-3; A-X(AF)-4 Initiated By: ARD-300

FOREWORD

Very High Frequency Omnidirectional Radio Range (VOR)/Distance Measuring Equipment (DME)/Tactical Air Navigation (TACAN) is the primary short distance navigational aid used in the National Airspace System (NAS) for air navigation and traffic control. Achievement of navigation system performance requires the definition of system functional and performance characteristics. The purpose of publishing a National Aviation Standard is to describe how the system is operated and how the different elements fit together. It should be noted that although the terms of measurement reference have been changed from Order 1010.55 dated 6/1/70 to allow standardization, the effect on component and system performance is minimal.

It should be recognized that the frequency bands used by the systems described in this standard have been exclusively allocated for aviation navigation. Due to the limited availability of frequencies, these bands will be increasingly utilized by common equipment and other systems. For this reason, designers, manufacturers, and operators of VOR/DME/TACAN equipment should be especially conscious of those paragraphs in the standard which impact on spectrum utilization. This is necessary to avoid present and future electromagnetic interference not only between common equipments but also between other systems as well.

Robert W. Wedan

ROBERT W. WEDAN
Director, Systems Research and
Development Service, ARD-1

TABLE OF CONTENTS

CHAPTER 1. GENERAL

SECTION 1. INTRODUCTION

1. PURPOSE. This order establishes the Very High Frequency Omnidirectional Radio Range (VOR)/Distance Measuring Equipment (DME)/Tactical Air Navigation (TACAN) standard defining the performance required of the system and its components.

2. DISTRIBUTION. This order is distributed to: a) branch level in the organizations of Flight Operations, Airway Facilities, Air Traffic, and Systems Research and Development in Washington headquarters; b) section leve in Airway Facilities Service in regions; and c) sector and sector field offices of the Airway Facilities Service.

3. CANCELLATION. Order 1010.55, "Selection Order: U. S. National Aviation Standard for the VORTAC System," dated 6/1/70 is cancelled.

4. IMPLEMENTATION CRITERIA. The National Aviation Standard applies to all VOR, DME, and TACAN round and airborne equipments used in the National Airspace System (NAS3.

5. DIRECTED ACTION. Subject to applicable rulemaking, programing and budgetary procedures, actions shall be taken by the FAA elements concerned to implement this Standard.

SECTION 2. OVERVIEW

6. GENERAL. Under Public Law 85-726, the Federal Aviation Adminlstration (FAA) is charged with providlng for the regulation and promotion of civil aviation in order to best foster its development and safety, and to provide for the safe and efficient use of the airspace by both civil and military aircraft. Explicitly, the Administrator shall develop, modify, test, and evaluate systems, procedures, facilities, and devices, defining their performance characteristics as needed. This effort is directed toward meeting the need for safe and efficient navigation and traffic control of all civil and military aviation operating in a common Civil/Military System.

7. THE VOR/DME/TACAN SYSTEM CHARACTERISTICS.

a. This Standard deflnes the application and performance characteristics of VOR, DME, and TACAN systems in the United States (U. S.). For ground and airborne components, the material identifies signal, functional, and performance characteristics required to meet operational requirements and to provide compatibility between components of the system.

b. The respective airborne component characteristics for VOR, DME, and TACAN apply In entirety to those components used in aircraft operations performed under Instrument Flight Rules (IFR). However, for other aircraft operations the applicability is limited to requirements identified in chapter 3, section 2 and chapter 4, section 2 as essential to prevent impairment of services to other NAS users.

c. In all cases, where a parameter and associated tolerance is identified herein, ground stations shall be maintained within these limits of quality assurance methods including either monitoring, periodic ground or flight inspections, or a combination of these methods.

d. Operators of airborne systems designed, installed, and operated in accordance with the Standard can expect to achieve the system performance which the standard is intended to provide.

e. It is recognized that certain existing components do not comply with all requirements of this Standard. Specific characteristics that are known to deviate from the requirements of this Standard will be corrected or replaced as practical.

8. REVISIONS. This Standard will be revised as the needs of the National Airspace System warrant.

9. RELIABILITY REQUIRED OF THE VOR/DME/TACAN SYSTEM. Due to the critical nature of the radionavigation service, it is essential that the VOR/DME/TACAN system provide high reliability. Both signal strength and frequency protection are provided on a basis of 95 percent time availability at the worst case points of the service volume. At other than worst case points, time availability substantially exceeds 95 percent. (See Appendix 1, paragraph 6.)

10.-19. RESERVED.

CHAPTER 2. VOR/DME/TACAN SYSTEM

20. VOR/DME/TACAN SYSTEM DESCRIPTION. The VOR/DME/TACAN system is a short distance air navigation system. The ground components provide properly equipped aircraft with bearing, identification, and distance Infotmatlon referenced to the selected ground component. When the airborne equipment includes a suitable area navigation (RNAV) device operating from data derived from the system, both radial and non-radial routes are afforded. The system provides navigation signals to all civil and military aviation for the safe and efficient conduct of aircraft operations, exercise of air traffic control, and use of airspace.

21. GROUND COMPONENTS. The principal ground components are VOR, DME, and TACAN. VOR and DME are the International Civil Aviation Organization (ICAO) standard navigational aids. VOR provides azimuth information and ground-to-air communications for the common NAS. DME provides distance Information to all users of the NAS. TACAN provides azimuth information primarily to military users and distance information to all users of the NAS.

22. STATION TYPE DESIGNATIONS. Ground components are Identified by type designations which indicate the service provided. VOR type designations are prefixed by the letter "B" when the component provides scheduled voice broadcasts. The letter "W" is used when the component does not provide voice transmissions.

Designation	Type of Facility
VOR	VHF navlgation facility, omni-directional azimuth only
DME	UHF navigation facility, distance only
TACAN	UHF navigational facility, omni-directional, azimuth and distance
VOR/DME	Associated VOR and DME navigational facilities
VORTAC	Associated VOR and TACAN navigational facilities

23. SERVICE VOLUMES. Maximum usable range is influenced by a large number of variables. These include factors such as antenna patterns, propagatlon variation, ground terrain, ground and avionics equipment performance, ground and avionics equipment installation and maintenance, traffic loading and traffic distribution. It should be noted that the aviation community has many years of operational experience with the VOR/DME/TACAN system. Service volumes are predicated on both experience and empirical measurements.

Suff icient safety margin has been incorporated to assure highly reliable system operation. Under worst case conditions, it is recognized that some combinations of avionics and older ground equipments may not provide service with a time availability of 95 percent. Based on operational experience and user feedback, no substantial evidence indicating an adverse operational impact has been shown. In addition, all service volumes are flight inspected prior to commissioning for operational use. Nonetheless, ground and airborne equipment should be brought into full compliance with this National Aviation Standard as soon as it is practical.

a. Standard Service Volumes (SSV).

(1) Ground stations are classified according to their intended use. These stations are available for use within their service volume. Outside the service volume, reliable service may not be available . For standard use, the airspace boundaries are called standard service volumes. They are defined, in the table below, for the three station classes.

SSV CLASS DESIGNATOR	ALTITUDE AND RANGE BOUNDARIES
T (Terminal)	From 1000 feet (305 m) AGL up to and includin 12,000 feet (3,658 m) AGL at radia3 distances out to 25 nmi (46 km). See Figures 2-3 and 2-4.
L (Low Altitude)	From 1000 feet (305 m) AGL up to and including 18,000 feet (5,486 m) AGL at radial distances out to 40 nmi (74 km). See Figures 2-2 and 2-5.
H (High Altitude)	From 1000 feet (305 m) AGL up to and including 14,500 feet (4,420 m) AGL at radial distances out to 40 nmi (74 km). See Figures 2-1 and 2-5. From 14,500 feet (4,420 m) AGL up to and including 60,000 feet (18,288 m) at radial distances out to 100 nmi (185 km). See Figures 2-1 and 2-5. From 18,000 feet (5,486 m) AGL up to and including 45,000 feet (13,716 m) at radial distances out to 130 nmi (241 km). See Figures 2-1 and 2-5.

(2) These SSV's are graphically shown in Figures 2-1 through 2-5. The SSV of a station is indicated by using the class designator as a prefix to the station type designation. (Examples: TVOR, LDME, and HVORTAC.)

(3) Within 25 nmi (46 km), the bottom of the T Service is defined by the curve In Figure 2-4. Within 40 nmi (74 km), the bottoms of the L and H service volumes are defined by the curve in Figure 2-S. In some cases, local conditions (terrain, buildings, trees, etc.) may require that the standard service volume be restricted. The public shall be informed of any such restriction by a Notice to Airman (NOTAM).

NOTE: Metric measurements are given for convenience and are approximations.

b. Expanded Service Volumes. When operational needs require facilities to be used beyond tneir standard service volumes, the same signal standards/tolerances and round/flight check certification procedures will be met. Expanded service vo3umes (ESVs) will only be authorized when conditions permit (reference Figures 2 through 13 of Appendix 1.).

c. Operational Service Volume. The airspace available for operational use includes:

(1) The SSV excluding any portion of the SSV which has been restricted, and

(2) expanded service volumes (ESVs).

d. Vertical Angle Coverage Limitations. Within the operational service volume of each station, azimuth signal information permitting satisfactory performance of airborne components is normally provided from the radio horizon up to an elevation angle of approximately 60 degrees for VOR components and approximately 40 degrees for TACAN components. At higher elevatlon angles, the azimuth signal information may not be usable. Distance information provided by DME and TACAN will permit satisfactory performance of airborne components from the radio horizon to an elevation angle of not less than 60 degrees.

24. ASSOCIATED COMPONENTS. A VOR and either a DME or TACAN shall be considered as associated components only when:

a. operated on a standard frequency pairing as associated with paragraph 28;

b. collocated as defined in paragraph 25; and

c. complying with the identification provislons of paragraph 32.

25. COLLOCATION LIMITS FOR ASSOCIATED COMPONENTS. DME or TACAN components are frequency-paired wlth VOR. For the common system, these components shall be collocated In accordance with one of the following.

a. Coaxial collocation. The VOR and DME or TACAN antenna are located on the same vertical axis. This is the usual collocation configuration.

FIGURE 2-1. STANDARD HIGH ALTITUDE SERVICE VOLUME

(refer to FIGURE 6 for altitudes below 1000 feet (305 m)

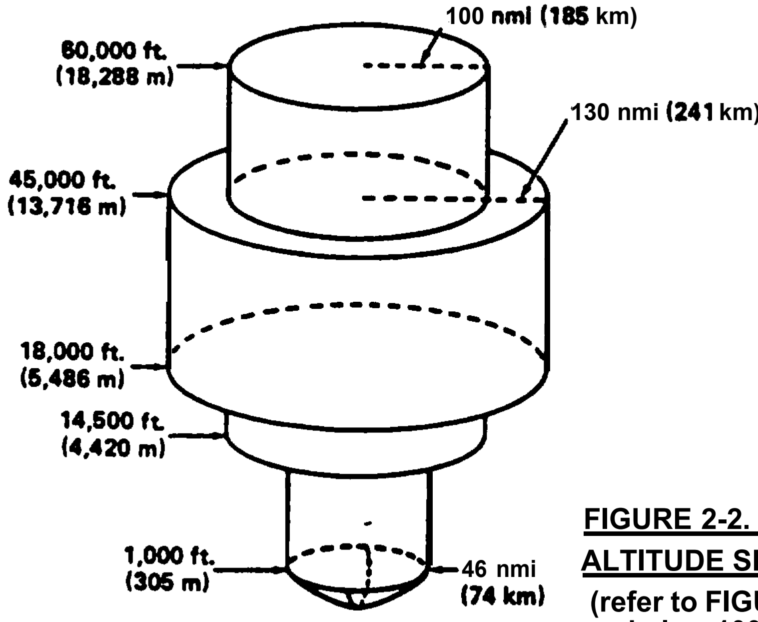


FIGURE 2-2. STANDARD LOW ALTITUDE SERVICE VOLUME

(refer to FIGURE 6 for altitudes below 1000 feet (305 m)

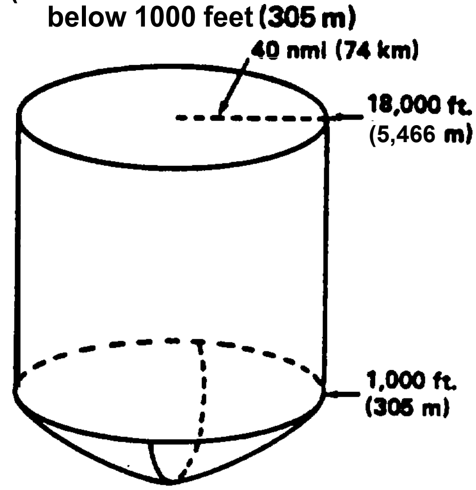
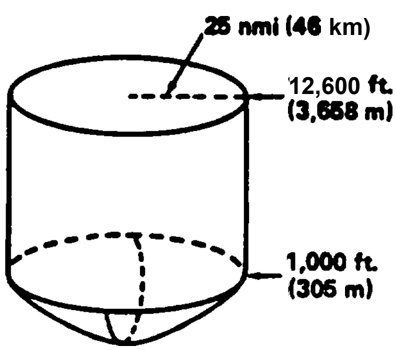


FIGURE 2-3. STANDARD TERMINAL SERVICE VOLUME

(refer to FIGURE 4 for altitudes below 1000 feet (305 m)



NOTE: All elevations shown are with respect to the station's site elevation (AGL). Metric Measurements are given for convenience and are approximations. These figures do not reference the area defined as the Vertical Angle Coverage Limitations (paragraph 23.d.)

FIGURE 24. DEFINITION OF THE LOWER EDGE OF THE STANDARD T (TERMINAL) SERVICE VOLUME

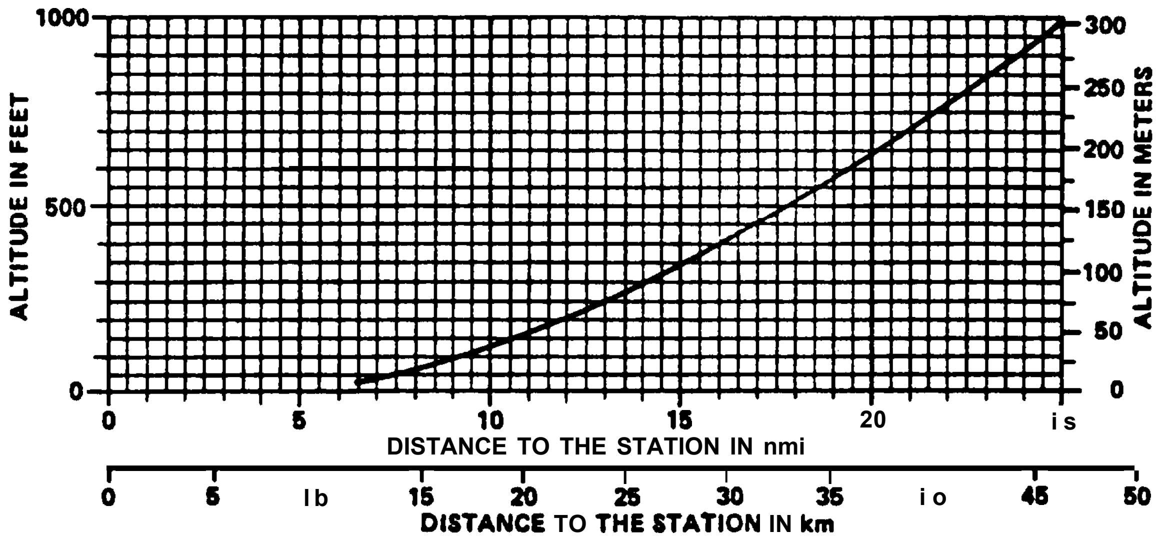
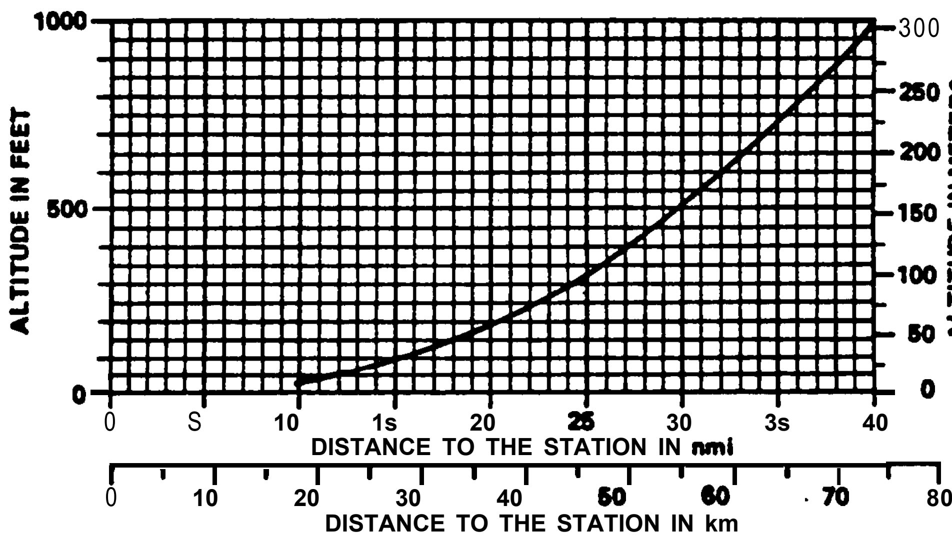


FIGURE 26. DEFINITION OF THE LOWER EDGE OF THE STANDARD H (HIGH) AND L (LOW) SERVICE VOLUMES



b. Offset collocation.

(1) For those facilities used in terminal areas for approach purposes or other procedures where the highest position fixing accuracy of system capability is required, the separation of the VOR and DME or TACAN antennas will not exceed 100 feet (30 m). However, at Doppler VOR sites the antennas may be separated by not more than 260 feet (80 m).

(2) For purposes other than those indicated in (1), the separation of the VOR and either the DME or TACAN antennas will not exceed 2000 feet (610 m).

26. RADIO FREQUENCY ALLOCATIONS. Radio frequencies allocated for VOR, DME, and TACAN are those listed in Appendix 3.

27. RADIO FREQUENCY ASSIGNMENTS. Radio frequency assignments for the paired system-components shall be selected from the frequency pairings listed in Appendix 3. Channels 1 through 16 and 60 through 69 for both X and Y modes of operation shall not be assigned to components of the common system.

28. RADIO FREQUENCY CHANNEL PAIRING. Appendix 3 shows the pairing of the VHF and UHF components of the VOR/DME/TACAN System. Components associated according to paragraph 24 shall be assigned on paired frequencies in accordance with this table. Non-associated VOR, DME, and TACAN components shall not be assigned on paired frequencies unless the separation between the respective components is sufficient to satisfy paragraph 29. This latter separation shall be determined as if each station was in effect an associated frequency pair.

29. FREQUENCY INTERFERENCE PROTECTION. Frequency assignments must not result in interference between stations. Within a station's operational service volume, the ratio of the desired signal to any undesired signal must not fall below the selection/rejection capability of the airborne equipment. Paragraphs 29.a through 29.c discuss interference protection needed. The usable distance and altitude of aeronautical navigation aids are often limited by the frequency protection provided from other ground stations. The operational service volume shall not extend beyond the frequency protected service volume.

a. Interference Protection of VHF NAVAIDS (ILS and VOR). The following interference signal protection ratios shall be provided within the operational service volume of all Instrument Landing System (ILS) and VOR stations with a 95 percent time availability. This is done by controlling the station separation in certain situations.

(1) The desired to undesired (D/U) signal ratio between co-channel stations shall not be less than +20 dB.

(2) The D/U ratio between VHF NAVAIDS with a nominal 50 kHz frequency separation shall be -34 dB or greater. (-34 dB or -30dB are permissible; -40 dB is not.) Frequency assignments made under this criteria (called the "Final" criteria) insure protection to narrow bandwidth (i.e., 50 kHz) receivers considering both ground and airborne frequency tolerances. A minimum D/U ratio of -7 dB is required to insure protection to wideband (i.e., 100 kHz) receivers using 100 kHz (i.e., even multiples of 50 kHz) ground stations. This value is called the "Interim" criteria. In highly congested parts of the country, the "Interim" criteria may not allow frequency assignments to any new systems. New assignments in these areas would have to be made under the final criteria (-34 dB). As a safeguard when this is done, flight publications will indicate any nearby 100 kHz ground stations which cannot be used without the narrow bandpass characteristics associated with a 50 kHz receiver. This is required due to the insufficient rejection, in the 100 kHz receivers, to signals 50 kHz removed.

(3) The D/U ratio between VHF NAVAIDS with 100 kHz frequency separation shall not be less than -46 dB. In those parts of the country where 50 kHz assignments are made, the D/U ratio between stations with 100 kHz frequency separation shall not be less than -50 dB.

(4) The D/U ratio between VHF NAVAIDS with more than 100 kHz frequency separation shall not be less than -50 dB.

(5) Some peak power deterioration is allowed before the system is shut down. In order to account for this decrease in power, the actual D/U values used for station separation calculations are 3 d8 more protective, e.g. +23 dB vice +20 dB, -31 vice -34 dB, etc.

b. Interference Protection of DME/TACAN. The following interference signal protection ratios shall be provided within the operational service volume of all DME/TACAN stations with a 95 percent time availability. This is done by controlling the station separation in certain cases.

(1) The D/U signal ratio between co-channel DME/TACAN stations shall not be less than +8 dB.

(2) The D/U signal ratio between adjacent channel DME/TACAN stations shall be as follows. The various D/U ratios have been established recognizing the spectrum control characteristics reflected in paragraph 124 and the spectrum differences between DME and TACAN.

(a) When the undesired station is a TACAN, the D/U ratio shall not be less than -42 dB.

(b) When the undesired station is an LDME (1000 W transmitter), the D/U ratio shall not be less than -39 dB.

(c) When the undesired station is a TDME (100 W transmitter), the D/U ratio shall not be less than -29 dB.

(3) The O/U ratio between DME/TACAN stations with more than 1 MHz frequency separation shall not be less than -50 dB.

(4) Some peak power deterioration is allowed before the system is shut down. In order to account for this decrease in power, the actual D/U values used for station separation calculations are 3 dB more protective, e.g., +11 dB vice +8 dB, -39 dB vice -42 dB, etc.

c. Protection of Service Volumes Which Extend Beyond National Borders. Stations near the border are normally not frequency-protected for that airspace which lies beyond the national border. Standard service volume and expanded service volume protection may be provided upon proper coordination with Canada or Mexico. This must be done whenever specific airways, routes, or procedures beyond the border are based on ground stations in the U.S.A.

30. COMPONENT IDENTIFICATION SIGNALS. Each ground component shall transmit an identification signal consisting of three letters in International Morse Code. It shall be transmitted at a rate of approximately 7 words per minute. In addition, voice identification in accordance with paragraphs 31 through 33 may be provided by a VOR.

a. Identification Code Characteristics. The identification code characteristics shall conform to the following.

(1) The dots shall be a time duration of 0.1 second to 0.125 second and the dashes three times the dot duration;

(2) The duration between dots and dashes of a code letter shall be equal to that of one dot plus or minus 10 percent;

(3) The time duration between consecutive letters of the identification code group shall not be less than three dots; and

(4) The total period of transmission of an identification code group shall not exceed 5 seconds.

b. Identification Cycle and Synchronization. The repetition and synchronization of component identification signals shall conform to paragraphs 31 through 33.

31. INDEPENDENT COMPONENTS. Whenever a facility is operated as a VOR, a DME, or a TACAN only, its identification signal shall be transmitted as follows.

a. For VOR providing only code identification signals, each 30 second interval is divided into either four or five equal periods. The code identification shall be transmitted during each period.

b. For VOR providing code and voice identification signals, each 30 second interval is divided into four equal periods. The code identification signal shall be transmitted during alternate periods or during three of four periods. Subject to paragraph 33, voice identification signals will occur during the remaining period(s).

c. When voice communication signals are being transmitted by a VOR, the VOR code identification signals shall not be suppressed.

d. For DME and TACAN, the International Morse Code identification signal shall be repeated at intervals of 3Ø seconds.-

32. IDENTIFICATION OF ASSOCIATED COMPONENTS. When a VOR and either a DME or TACAN are operated as collocated components (see paragraphs 24 and 25), the identification signals shall conform to the respective requirements of paragraph 31 except that:

a. The identification code shall be the same for each component;

b. For VOR of paragraphs 31.a and 31.b, the DME or TACAN identification signal shall be transmitted during one of the periods allocated for VOR code identification. The VOR code shall not be transmitted during that period;

c. The International Morse Code identification signals of VOR, DME, and TACAN shall be synchronized and interlocked such that simultaneous identification transmissions of VOR/DME or VOR/TACAN or ILS/DME do not occur;

d. When voice communications are being transmitted on the VOR, the Code identification signals of DME and TACAN shall not be suppressed; and

e. Whenever one component is temporarily out of service, the component still operating shall transmit facility identification si nals in accordance with paragraph 32 without regard to the facility type des3gnation.

33. PRECEDENCE OF VOR VOICE COMMUNICATIONS. VOR voice identification signals shall not be suppressed for the duratlon of voice communications or broadcasts.

34. VOR VOICE COMMUNICATIONS SIGNALS. If required, a VOR may provide ground-to-air voice communications.

35. AIRBORNE COMPONENTS. Airborne components of the system consist of VOR components conforming to chapter 3, section 2 and DME and TACAN components conforming to the applicable requirements of chapter 4, section 2 of this Standard.

36. SYSTEM TRAFFIC HANDLING CAPACITY. Each VOR and TACAN ground component of the system provides azimuth and facility identification information to an unlimited number of airborne components. DME and TACAN ground components can provide slant range adequate for a peak traffic load of 3375 interrogations per second.

NOTE: As the traffic density increases beyond full load, the system replies at a rate reduced proportionately-to the number of additional interrogators. The ground component could be capable of servicing higher density traffic only if the airborne component could maintain satisfactory operations with reduced reply efficiency (see paragraph 130). The apparent change in numbers from Order 1010.55 dated 6/1/70 does not represent a change in beacon radiated power (for example, see Appendix 1). Therefore, increases in receiver sensitivities of existing airborne equipments are not required to achieve the same ranges that users have experienced in the past. Future designs should not be restricted by this fact.

37. VOR/TACAN/VORTAC SYSTEM AZIMUTH ACCURACY. System azimuth accuracy, expressed in terms of error, is a function of the error factors associated with the ground and airborne components. The total system azimuth accuracy is ± 4.5 degrees. (See Appendix 2)

38. SYSTEM DISTANCE ACCURACY. System distance accuracy is a function of the ground and airborne component accuracies. The component values in this standard provide a system distance accuracy of ± 0.5 nmi (926 m) or 3 percent of the slant range distance, whichever is greater (95 percent probability), when the error values are combined by the root-sum-square method.

39. HIGH ACCURACY CERTIFICATION. Some system accuracy requirements exceed those specified in paragraphs 37 and 38. Some area navigation routes are an example. In order to support prescribed operations, flight inspections will validate the signal and certify its adequacy.

40.-49. RESERVED.

CHAPTER 3. VOR SYSTEMS

SECTION 1. OPERATIONAL CHARACTERISTICS FOR VOR GROUNO COMPONENTS

50. INTRODUCTION. This section identifies standard signal characteristics and tolerances for the VOR portion of the system. These characteristics represent performance which shall be provided throughout the operational service volume as defined in paragraph **23.c.**

51. POLARIZATION. The ground component antenna shall radiate horizontally polarized signals. Any vertically polarized signal components shall be at least 26 **dB** weaker than the horizontally polarized component.

52. RADIO FREQUENCY ACCURACY. The radio frequency **carrier** shall be within **± 0.002** percent of the assigned frequency.

53. SIGNAL STRENGTH IN SPACE. The ground station shall provide a minimum signal power density of -120 **dBW/m²** (95 percent time availablllty) throughout the operational service volume as defined In paragraph **23.c.** At the nearest aircraft position expected during operations, the maximum signal power density expected at an aircraft will be on the order of -34 **dBW/m²**.

NOTE: At 118 **MHz,** the value -120 **dBW/m²** corresponds to -123 **dBW** at the output of a **lossless** isotropic receiving antenna. The apparent change In numbers from Order 1010.55, dated **6/1/70,** does not represent a change in radiated power (for example, see Appendix 1). Therefore, increases in receiver **sensitivities** of existing airborne equipments are not required to achieve the same service ranges that users have experienced in the past. Future designs should not be restricted by this fact.

54. AZIMUTH SIGNAL CHARACTERISTICS. The VOR shall radiate a radio frequency carrier with two associated 30 **Hz** modulations. The phase of one of these modulations shall be independent of the **azimuth** of the point of observation (reference phase). The other modulation (variable phase) shall differ from that of the reference phase by an angle equal to the magnetic bearing of the point of observation with respect to the VOR.

a. The radio frequency carrier shall be amplitude modulated by two signals in accordance **with** the following.

(1) Subcarrier Frequency Modulation. One **signal** component shall be a subcarrier of 9,960 Hz of constant **amplitude.** It shall be **frequency** modulated at 30 **Hz** having a deviation **ratio of 16 ±** 1 **(i.e.,** 15 to 17**)** as follows.

NOTE: The deviation ratio of the signal from a Doppler VOR decreases from the value at the facility by the **cosine** of the vertical angle (i.e., will be as low as 8 at a point 60 degrees above the horizon).

(a) For the conventional VOR, the **phase** of the 30 Hz component of the FM subcarrier Is fixed without respect to azimuth. It **is** termed the **"reference** phase.*

(b) For the Doppler VOR, the phase of the 30 Hz component of the FM subcarrier varies with azimuth. It is **termed** the *variable phase."

(2) Subcarrier Frequency and Accuracy. The subcarrler modulation **mid-frequency** shall be **9,960** Hz **within** + **1.0** percent, and shall carry the 30 Hz frequency modulation.

(3) Subcarrier **Modulation** Frequency and Accuracy. The modulation frequency shall be 30 Hz within ± 1.0 percent.

(4) Subcarrier Amplitude Modulation. Amplitude modulation of the subcarrier shall conform to the following.

(a) For the conventlonal VOR, the percentage of amplitude modulation of the 9,960 Hz subcarrier shall not exceed **5** percent.

(b) For the Single **Sideband** Doppler VOR, the percentage of amplitude modulation of the 9,960 Hz subcarrier shall not exceed 40 percent when measured at a point at least 1000 feet from the VOR. **When** Double Sideband Doppler VOR **is** installed, this **modulation,** for each sideband, shall not exceed **50** percent.

(5) Sideband Level Subcarrier Harmonics. When **50 kHz** channel asslgnments are made, the sideband level of the harmonics of the 9,960 Hz component in the radiated signal shall not exceed the following levels referenced to the level of the 9,960 Hz sideband.

Subcarrier	Level
9,960 Hz	0 **dB** reference
2nd harmonic	- 30 **dB**
3rd **harmonic**	- 50 **dB**
4th harmonic and subsequent **harmonics**	- 60 **dB**

55. 30 Hz AMPLITUDE MODULATION. The other signal component shall be 30 Hz **ampl**itude modulation as follows.

a. For the conventional **VOR,** thls component results from a rotating **field pattern,** the phase of which varies **with** azlmuth. It Is termed the **"variable phase"** and Is of constant amplitude.

b. For the Doppler VOR, this component of constant phase with relation to azimuth, is radiated omnidirectionally. It is termed the "reference phase" and Is of constant amplitude.

56. AMPLITUDE MODULATION FREQUENCY AND ACCURACY. The modulation frequency shall be 30 Hz wlthin ± 1.0 percent.

57. DEPTH OF REFERENCE AND VARIABLE PHASE MODULATIONS. The depth of modulation of the radiofrequency carrier due to the 30 Hz or 9,960 Hz signals shall be within the following limits for each signal.

28 to 32 percent at all elevation angles from 0 to 5 degrees above the h&iron; and

b. 25 to 35 percent at all elevation angles between 5 and 60 degrees above the horizon.

58. PHASE RELATIONSHIPS OF REFERENCE AND VARIABLE PHASE SIGNALS. The fundamental of the reference and variable phase modulations shall be in phase along the radial corresponding to magnetic north.

NOTE: The reference and variable phase modulations are in phase when the maximum value of the sum of the radio frequency carrier and the sideband energy due to the amplitude modulation signal occurs at the same time as the highest frequency of the frequency modulation signal.

59. CODE IDENTIFICATION SIGNAL CHARACTERISTICS. The characteristics of the code identification signal shall conform to the following.

a. Tone Modulation Frequency and Accuracy. The modulation frequency shall be 1,020 ± 50 Hz.

b. Depth of Modulation. The depth to which the radio frequency carrier is modulated by the code identification signal shall be:

(1) 5.0 ± 1 percent where voice services are provided.

(2) 4 to 10 percent at components where voice services are not provided.

60. VOICE IDENTIFICATION AND COMMUNICATIONS SIGNAL CHARACTERISTICS. The characteristics of voice identification and voice communications signals, when provided, shall conform to the following.

a. Voice Channel Frequency Response. Throughout the frequency range from 300 to 2 200 Hz, the frequency response characteristics for the voice channel shall'be within 3 dB of the response at 1,000 Hz.

b. Depth of Modulation. The depth to which the radio frequency carrier is modulated by voice signals shall not be greater than 30 ± 2 percent.

61. MONITORING. The radiated signal shall be monitored and removed from service upon recognition of unsafe operation.

62.-79. RESERVED.

SECTION 2. OPERATIONAL CHARACTERISTICS FOR VOR AIRBORNE COMPONENTS

80. INTRODUCTION. This section specifies functional capability and performance characteristics required of VOR airborne components. The term "component" describes the complete aircraft installation. This includes the antenna and its transmission line, the receiver, electrical power source(s), identification and voice communications signal reproduction devices, and selector and display instrumentation devices for bearing and course indication. Airborne components used in the performance of aircraft operations under IFR must meet all requirements. For other aircraft operations the requirements are limited to those of paragraphs 80 and 90. Components should be capable of performing as specified throughout the operational service volume of ground stations. The applicable performance requirements should be met when the ground stations are operating in accordance with this standard.

81. RECEIVER STABILITY. For each channel in use, the receiver's center frequency shall be in accordance with Appendix 3. The receiver stability shall be ± 0.005 percent or better.

82. RECEIVER SENSITIVITY. Based on the signal power density of paragraph 53, the airborne component shall provide the sensitivity necessary to display navigation information to the accuracy specified. Clear and distinct reproduction of communications and identification signals shall be provided. (See also Appendix 1.)

83. REJECTION OF UNDESIRED SIGNALS. The airborne component shall provide undesired signal rejection characteristics adequate to assure the specified performance. For co-channel and adjacent-channel ILS and VOR signals, the D/U ratios of paragraph 29.a shall apply.

84. MISTUNING PROTECTION. Mistuning by 50 kHz may result in erroneous information not readily apparent to the user if no VOR carrier is present on the tuned channel. Provision shall be made to protect against mistuning an airborne receiver by operational, mechanical, or electronic means.

85. FACILITY IDENTIFICATION AND VOICE SIGNALS. The airborne component shall provide the pilot with positive identification of the ground component.

86. BEARING AND COURSE DEVIATION INFORMATION. The airborne component shall provide devices for unambiguous determination of the aircraft magnetic bearing with respect to the selected ground component. This display shall show the aircraft deviation from the selected course.

87. COURSE DEVIATION DISPLAYS. The response, readability, and resolution of course deviation displays shall enable the pilot to determine the direction and extent of the aircraft deviation from the selected course.

88. WARNING FUNCTION. The airborne component shall provide a warning indication whenever the azimuth signals necessary for the prescribed performance are not present. This warning shall be clearly evident to the pilot.

89. ACCURACY OF BEARING AND COURSE DEVIATION INFORMATION. The total airborne component error, in bearing and course deviation information as displayed to the pilot, shall not exceed ± 3.0 degrees (95 percent probability) at any bearing.

90. RADIATION. Radiation from airborne components shall not result in derogation of operational use to other system users or in the derogation of other aeronautical services.

91.-109. RESERVED.

CHAPTER 4. DME AND TACAN SYSTEMS

SECTION 1. OPERATIONAL CHARACTERISTICS FOR DME AND TACAN GROUND COMPONENTS

110. INTRODUCTION. This section identifies standard signal and performance characteristics for DME and TACAN ground components. These characteristics represent the performance which shall be provided throughout the operational service volumes defined in paragraph 23.c. Requirements apply to both DME and TACAN components, unless noted otherwise.

111. POLARIZATION. The ground component antenna shall radiate and receive a vertically polarized signal. Any horizontally polarized signal components shall be at least 26 dB weaker than the vertically polarized component.

112. TRANSPONDER RESPONSE TO INTERROGATION SIGNALS. The response of the transponder to interrogation signals shall conform to paragraphs 113 through 120.

NOTE: At the ground component antenna, the presence of CW signals within ± 3.0 MHz of the nominal value of the interrogation frequency at a signal power density of -113 dBW/m^2 or more, will normally derogate the performance of the system. Steps should be taken to avoid this situation.

113. INTERROGATION RADIO FREQUENCY. For each channel in use, the center frequency of the transponder's interrogation and reply frequencies shall be in accordance with Appendix 3.

114. SENSITIVITY TO INTERROGATION SIGNALS. Transponder sensitivity is specified as that minimum value of peak pulse power density (prior to intercept by the ground component antenna) which will result in a transponder reply efficiency of 70 percent. (See Appendix 1)

NOTE: Ground components may not respond to interrogations as specified if the difference in level of the constituent pulses of interrogation pulse pairs is greater than 1 dB.

115. ON-CHANNEL SENSITIVITY. For interrogation signals within ± 100 kHz of the assigned frequency, having a repetition rate no greater than 200 pulse pairs per second and pulse pair spacing of exactly 12.0 microseconds (36.0 micro econds for Y channel), DME sensitivity shall be not less than -101.5 dBW/3 . Under thq same conditions, the TACAN sensitivity shall be not less than -104.5 dBW/m .

NOTE: At 1150 MHz, the value -101.5 dBW/m^2 corresponds to -124.0 dBW at the output of a lossless isotropic receiving antenna. Similarly, the value -104.5 dBW/m^2 corresponds to -127.0 dBW. (See Appendix 1)

116. SENSITIVITY AT OTHER PULSE SPACINGS. When the spacing of the constituent pulses of interrogation pulse pairs differs from the design center value (12.Ø microseconds for X channel; 36.Ø microseconds for Y channel) by ± Ø.5 microseconds or less, the sensitivity of paragraph 115 shall not be reduced by more than 1 dB. When the spacing differs by ± 3 microseconds and more from nominal, the reduction in sensitivity shall be at least 7Ø dB with respect to the level of paragraph 115.

117. VARIATION OF SENSITIVITY WITH INTERROGATION LOADING. When the beacon is loaded with 3175 additional pulse pairs per second at a level of -65 dBm (referenced at the input to the transponder receiver with the transponder's echo suppression circuits disabled), the sensitivity of the receiver shall not be reduced by more than 1 dB from the value measured in paragraph 115.

118. SENSITIVITY TO ADJACENT CHANNEL INTERROGATIONS. Interrogation signals removed 9ØØ kHz or more from the assigned channel interrogation frequency and having an amplitude up to 8Ø dB above the on-channel sensitivity of the component shall not elicit a reply from that component.

119. TRANSPONDER DEAD TIME. Dead time is the time immediately following an accepted interrogation decode for reply processing, during which succeeding interrogations receive no reply. The transponder dead time shall normally be 6Ø microseconds for X channels (72 microseconds for Y channels).

12Ø. ECHO SUPPRESSION DEAD TIME. The retriggerable blanking gate (RTBG) (see paragraph 145.b) is typically set such that the effective dead time is a nominal 15Ø microseconds. When required for a particular site, the effective dead time may be increased up to a nominal 25Ø microseconds.

121. TRANSPONDER OUTPUT SIGNAL CHARACTERISTICS. The transponder shall conform to paragraphs 122 through 15Ø.

122. FREQUENCY STABILITY. For each channel in use, the center frequencies of the ground station's transmitter and receiver shall be in accordance with Appendix 3. Frequency stability shall be ± Ø.ØØ1 percent or better for equipments purchased after July 198Ø. The stability of older ground stations shall be ± Ø.ØØ2 percent or better.

NOTE: Stabilities of older equipment need not be increased to ± Ø.ØØ1 percent.

123. SIGNAL STRENGTH IN SPACE. Within that part of the operational service volume that is above 18,ØØØ feet (5,486 m) AGL, a minimum signal power density of -91.5 dBW/m^2 (95 percent time availability) shall be provided. Within that part of the operational service volume that is below 18,ØØØ feet (5,486 m) AGL, a minimum signal power density of -86.Ø dBW/m^2 shall be provided. Signal power shall be determined by the average over one second of the equivalent peak pulse voltage waveform. At the nearest aircraft position expected during operations, the maximum signal power density expected during flight will be on the order of -17.Ø dBW/m^2 .

NOTE: At 1213 MHz, the value -91.5 dBW/m^2 corresponds to -114.5 dBW at the output of a lossless isotropic receiving antenna. Similarly, -86.0 dBW/m^2 corresponds to -109.0 dBW. The apparent change in numbers from the old standard does not represent a change in beacon radiated power (for example, see Appendix 1). Therefore, increases in receiver sensitivities of existing airborne equipments are not required to achieve the same service ranges that users have experienced in the past. Future designs should not be restricted by this fact.

124. RADIO SPECTRUM. The spectrum of the pulse modulated signal shall be as follows.

a. The equivalent isotropic radiated power (EIRP) contained in a 0.5 MHz band centered on a frequency either 0.8 MHz above or 0.8 MHz below the nominal channel frequency shall (in both instances) not exceed 200 milliwatts (except that the power relative to center frequency shall not exceed -50 dB).

b. The EIRP contained in a 0.5 MHz band centered on a frequency either 2.0 MHz above or 2.0 MHz below the nominal channel frequency shall (in both instances) not exceed 2 milliwatts (except that the power relative to center frequency shall not exceed -70 dB).

c. Each lobe of the spectrum will be generally of lesser amplitude than the adjacent lobe nearer the nominal channel frequency.

125. SPURIOUS RADIATION. The RF output level, during the interval between occurrence of the desired pulse pairs, shall not exceed a level which is 80 dB below the maximum power level during a pulse. In addition, between the'pulses of each pair there shall be an interval for 1.0 microsecond or greater in length during which the RF output level does not exceed a level which is 50 dB below the maximum power level of the weaker pulse of the pair.

126. PULSE SHAPE. The following, as limited by the requirements of paragraphs 124 and 125, shall apply to all radiated pulses.

a. Pulse Rise Time. The time required for the pulse to rise from 10 to 90 percent of its maximum voltage amplitude shall not be less than 0.1 microsecond nor more than 3.0 microseconds.

b. Pulse Top. Between the points on the leading and trailing edges which are 95 percent of the maximum voltage amplitude, the instantaneous amplitude of the pulse shall not fall below a value which is 95 percent of the maximum voltage amplitude of the pulse.

c. Pulse Duration. The pulse duration, as measured at the 50 percent maximun voltage amplitude points, shall be 3.5 ± 0.5 microseconds.

d. Pulse Decay Time. The pulse decay time, from the 90 percent point to the 10 percent point of the maximum voltage amplitude, shall be such that the remaining requirements of this standard shall be satisfied.

127. PULSE COOING. Transponder output signals shall consist of paired pulses. The spacing of the pulses is measured between the 50 percent maximum voltage amplitude points on the leading edge of each RF pulse. The pulse spacing shall be:

a. 12.0 ± 0.25 microseconds for X channels; or

b. 30.0 ± 3.25 microseconds for Y channels.

128. PULSE POWER VARIATION. The peak power of the constituent pulses of any pair shall not differ by more than 1 dB.

129. DISTANCE REPLY SIGNALS. Distance reply signals, consisting of pulse pairs, are transmitted in response to interrogations.

130. REPLY EFFICIENCY. Reply efficiency is defined as the percentage of interrogations from a specific interrogator to which the transponder replies within a given time interval when the transponder is under specified load conditions. The reply efficiency for interrogation signals at and above the minimum sensitivity levels of paragraph 114 shall be at least 70 percent for all interrogation loadings up to the maximum for which the transponder is designed (3375 interrogations per second).

NOTE: To provide service under adverse echo conditions or to handle increased traffic, it may be necessary to reduce the reply efficiency. To be able to receive the same service during traffic overload conditions, airborne receivers should be capable of operating properly with reply efficiencies at least as low as 50 percent.

131. REPLY DELAY TIME. Reply delay time is defined as the time of all delay introduced by the ground component in replying to interrogations. When airborne components are to indicate distance with respect to the transponder site, the zero-distance reply delay time shall be 50.0 microseconds ± 0.25 microseconds for X channels (56.0 microseconds ± 0.25 microseconds for Y channels). This represents the time between the 50 percent voltage point on the leading edge of the first pulse of the interrogation pulse pair and the corresponding point on the first pulse of the reply pulse pair.

NOTE: In older facilities, the reply delay time is referenced to the second pulse of interrogation and reply pulse pairs. The nominal value of reply delay time in these instances is 50 microseconds for both X and Y channels.

132. RANDOM PULSE PAIR SIGNALS. In addition to distance reply pairs, the ground component shall radiate random pulse pairs, defined as squitter, in order to maintain a total pulse pair rate in accordance with paragraphs 133 and 134.

133. DME COMPONENTS. For DME ground components, the total pulse rate, exclusive of identification pulses, shall be within the range of 700 up to 2850 pulse pairs per second, in the absence of high traffic density.

134. TACAN COMPONENTS. For TACAN ground components, the total pulse pair rate, exclusive of code identification signal and reference burst pulses, shall be 2700 ± 90 pulse pairs per second, in the absence of high traffic density. For a transponder dead time of 60 microseconds (for X channels), the distribution of random pulse pairs shall conform to Figure 4-1.

135. PULSE PAIR RATE. To provide greater traffic handling capacity (than the total output pulse pair rates of paragraph 133 and 134), the equipment shall have the capability to increase to as high as 5000 ± 150 pulse pairs per second as a function of actual traffic loading. Under this condition it will be impossible to maintain the output pulse pair spacing distribution of Figure 4-1. Accordingly, new TACAN airborne equipment design should avoid the use of circuits in which azimuth indication is sensitive to transponder output pulse count and spacing distribution. (See paragraph 130.)

136. GROUND COMPONENT RANGE ACCURACY. The ground component shall not contribute more than 0.1 nmi (185 m) to overall system error.

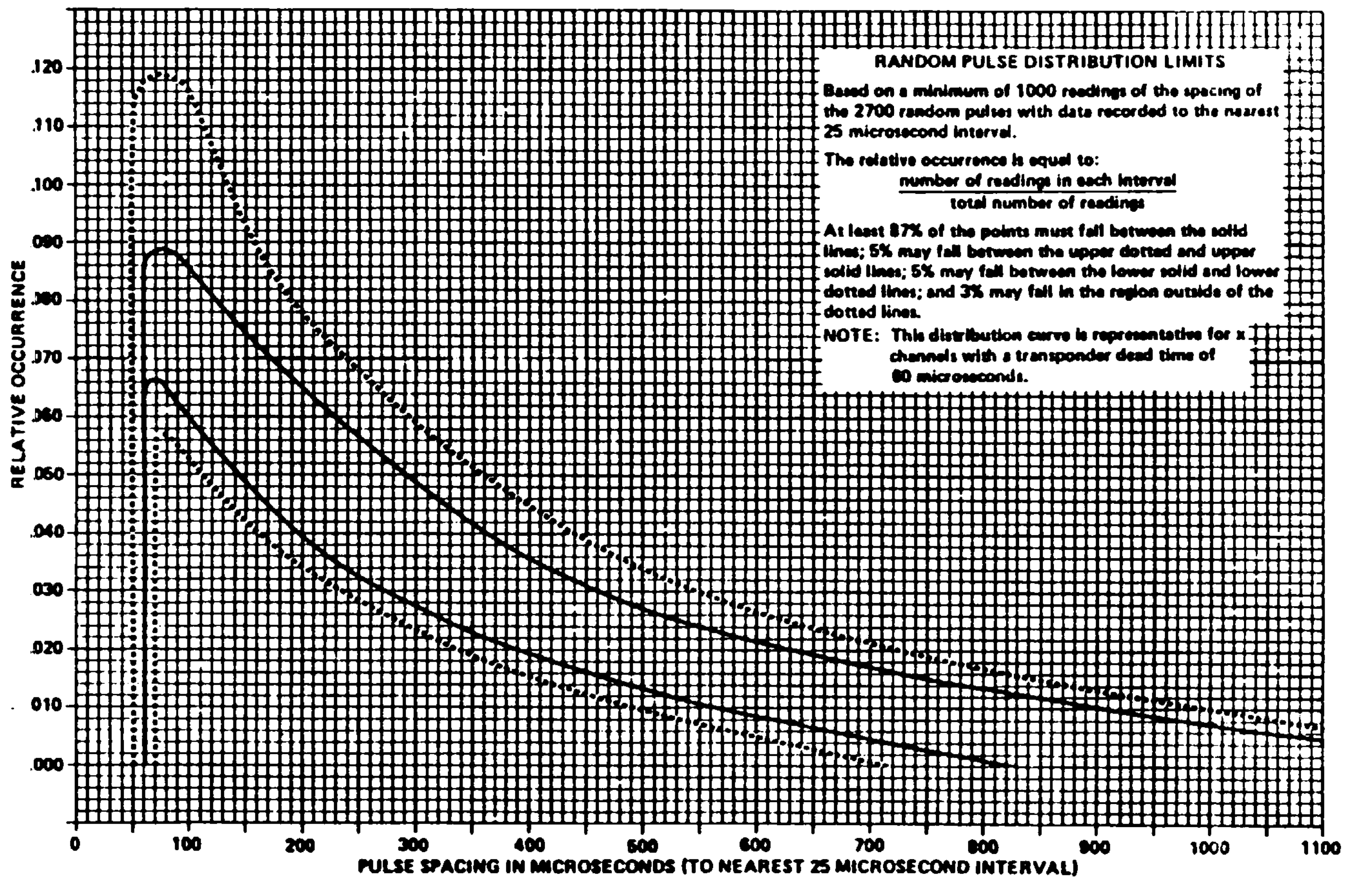
137. CODE IDENTIFICATION SIGNAL CHARACTERISTICS. Subject to the provisions of paragraph 137.a, code identification signals shall consist of groups of two pulse pairs transmitted for the duration of dots and dashes in accordance with paragraph 30.a. The spacing between the first and second pulse pairs constituting each pulse group, as measured between the 50 percent voltage amplitude points on the leading edge of the first pulse of each pair, shall be 100 ± 10 microseconds. The repetition rate shall conform to the following.

a. DME Components. For ground components providing DME service only, the identification signal may consist of either one or two pulse pairs in a group. The group repetition rate shall be 1350 ± 10 groups per second.

b. TACAN Components. For TACAN ground components, the repetition rate shall be 1350 groups per second (± 0.23 percent) which is phase-locked within ±50.0 microseconds of the tenth harmonic of the 135 Hz bearing reference signal. The first pulse of each identification signal pulse group shall occur 740 ± 50 microseconds after the first pulse of any 40 degree sector reference signals.

138. TACAN AZIMUTH SIGNAL CHARACTERISTICS. TACAN azimuth signals consist of North (main or coarse) and 40 degree sector (auxiliary or fine) bearing reference signals and 15 Hz (coarse) and 135 Hz (fine) amplitude modulation variable bearing signals. The azimuth signals radiated by the antenna shall conform to the following.

FIGURE 4-1. RANDOM PULSE DISTRIBUTION LIMITS



139. BEARING REFERENCE SIGNALS. Transmission of the North and 40 degree sector bearing reference signals shall occur synchronously with antenna pattern rotation. For each rotation of the antenna pattern, one North reference signal shall be transmitted. Following the North reference signal at each of eight consecutive angular increments of 40 degrees, the 40 degree sector reference signal shall be transmitted. A ninth 40 degree sector reference signal, which otherwise would coincide in time with the North reference signal, shall not be transmitted. The characteristics of reference signals shall be as follows.

a. North Reference Signal.

(1) For X channels, the North reference signal shall consist of a group of 12 pulse pairs. Spacing between the two pulses of a pair shall be 12 ± 0.25 microseconds. Spacing between the first pulse of each pulse pair shall be 30.0 ± 0.3 microseconds. Spacings are measured at the 50 percent voltage amplitude points on the leading edges of the pulses.

(2) For Y channels, the North reference signal shall consist of a group of 13 single pulses. Spacing between the pulses shall be 30.0 ± 0.3 microseconds. Spacings are measured at the 50 percent voltage amplitude points on the leading edges of the pulses.

b. 40 Degree Sector Reference Signals.

(1) For X channels, the 40 degree sector reference signal shall consist of a group of 6 pulse pairs. Spacing between the two pulses of a pair shall be 12 ± 0.25 microseconds. Spacing between the first pulse of each pulse pair shall be 24.0 ± 0.25 microseconds. Spacings are measured at the 50 percent voltage amplitude points on the leading edges of the pulses.

(2) For Y channels, the 40 degree sector reference signal shall consist of a group of 13 single pulses having a spacing of 15.0 ± 0.25 microseconds. Spacings are measured at the 50 percent voltage amplitude points on the leading edges of the pulses.

140. VARIABLE BEARING SIGNALS. The variable bearing signals shall be produced by a rotating directional antenna pattern which results in a composite amplitude modulation of the transponder radio frequency pulse signals at 15 and 135 Hz. The characteristics of the variable bearing signals shall be as follows.

a. Amplitude Modulation Frequencies and Accuracy. The amplitude modulation frequencies shall nominally be 15.0 and 135.0 Hz. Each frequency shall vary from the nominal values in exact synchronism with an antenna pattern rotation rate of 900 (± 0.23 percent) rotations per minute.

b. Depth of Modulation. At all elevation angles from -2 to +40 degrees relative to the horizon, the individual modulation components shall be 21 ± 9 percent. At all elevation angles from -2 to 50 degrees, the sum of the 15 and 135 Hz modulation components including the harmonics shall not exceed 55 percent. Further, within the angles from -2 to +2 degrees relative to the horizon, the maximum variation in depth of modulation for the 15 and 135 Hz components shall not, for each frequency, vary more than ± 4 percent from the respective median values within the angles specified.

141. RELATIONSHIPS OF REFERENCE AND VARIABLE BEARING SIGNALS. On the magnetic North radial from the antenna, the relationships of the reference and variable signals shall conform to the following.

a. Coarse Bearing Signal. The inflection point on the negative slope of the 15 Hz amplitude modulation component shall coincide within ± 2.0 azimuth degrees of the 50 percent amplitude points on the leading edge of:

(1) the tenth pulse of the North reference signals for X channels; or

(2) the sixth pulse of the North reference signal for Y channels.

b. Fine Bearing Signals. The inflection point on the negative slope of the 135 Hz amplitude modulation component shall coincide within + 0.33 degrees azimuth of the average position of the 50 percent amplitude point on the leading edge of:

(1) the twelfth pulse of the 40 degree sector reference signal for X channels; or

(2) the eleventh pulse of the 40 degree sector reference signal for Y channels.

142. PRECEDENCE OF PULSE TRANSMISSIONS. The order of precedence for transmission of transponder pulse signals shall be in accordance with the following.

a. DME Components. For ground components providing DME service only, the precedence shall be:

(1) International Morse Code Identification Signals
(2) Distance Reply Signals
(3) Random Pulse Pair Signals

Neither distance reply nor random pulse pair signals shall be transmitted during the "key-down" Interval of International Morse Code identification signal transmission.

b. TACAN Components. For TACAN components, the precedence shall be:

(1) Bearing Reference Signals
(2) International Morse Code Identification Signals
(3) Distance Reply Signals
(4) Random Pulse Signals

Neither code identification, distance reply, nor random pulse pair signals shall be transmitted during the interval required for transmission of all pulses in each bearing reference signal. Distance reply and random pulse pair signals shall not be transmitted during the "key-down" interval of code identification signal transmissions.

143. REJECTION OF UNDESIRED SIGNALS. The ground component shall provide undesired signal rejection characteristics adequate to assure the specified perfonance. This includes co-channel and adjacent-channel DME/TACAN signals.

144. RECEIVER DECODER. The decoder shall decode and produce an output pulse from interrogation signal pulse pairs occurring at spacings within the range of:

a. 12 ± 0.5 microseconds for X channels, or

b. 36 ± 0.5 microseconds for Y channels.

145. ECHO SUPPRESSION. Echo suppressions shall be provided in accordance with the following subparagraphs.

a. Short Distance Echoes. Synchronous pulse signals occurring between the constituent pulses of a direct path interrogation pulse pair and which are also superimposed on the leading or trailing edge of the second pulse of the direct path pulse pair, shall not affect the time of decoding of the direct pulse pair by an amount in excess of 0.15 microseconds. Neither shall the reply efficiency be reduced by more than 10 percentage points from that measured in the absence of the echo pulse. These requirements shall be met when the RF Input signal level of the direct path pulse pair has any level from 10 dB above threshold triggering level to an absolute level of -10 dBm and the echo pulse has any level up to the level of the direct pulse pair and for all direct pulse pair spacings of paragraph 175.

b. Long Distance Echoes. A separate echo suppression (Retriggerable Blanking Gate (RTBG)) circuit shall be provided in order to prevent the generation of multiple replies to aircraft interrogations having echoes which are delayed with respect to the direct path signal in excess of receiver dead time setting. The echo suppression circuit shall be triggered by the decoding of the direct signal pulse pair only when the level of the pulses exceeds a pre-established level. Such triggering shall result in the generation of a receiver desensitizing pulse starting at the time of pulse decoding nominally adjusted to 150 ± 10.0 microseconds with an upper limit of 300 microseconds. The degree of receiver desensitization shall be to a level 3.0 dB above the level of the direct path signal and shall hold over the entire duration of the echo suppression pulse, unless retriggered by a signal stronger by 0 to 6 dB than the direct path signal, and over a range of input signals from 10 dB above threshold triggering level to -15 dBm. The echo suppression circuit pre-established level will nominally be -70 dBm.

146. DECODER DISCRIMINATION. The decoder shall provide a minimum of 70 dB rejection to:

a. paired pulses whose spacing differs by 3.0 microseconds or more from the nominal value given in paragraph 144,

b. paired pulses with spacings within the range of paragraph 144 where either pulse has a width of 0.8 microsecond or less, and

c. single pulses of any width including widths within the range of pulse spacings of paragraph 144.

147. RECEIVER RECOVERY TIME. The recovery time of the receiver and its associated video circuitry shall be such that the sensitivity to desired interrogations is not reduced by more than 1 dB when desired interrogations occur 8.0 microseconds and more after the reception of undesired pulses of any width having levels up to 60 dB above the sensitivity of the receiver in the absence of such undesired pulses. The desired interrogations shall be RF pulse pairs conforming to the characteristics specified in paragraphs 173 through 179. Undesired pulses shall conform to the same requirements except that the pulse spacing shall be outside the limits of paragraph 175.

148. DESENSITIZATION BY CW. The presence of CW interference signals on the assigned channel frequency or elsewhere within the receiver pass-band shall not reduce the on-channel sensitivity by more than 2 dB from the value measured in the absence of CW interference provided that the level of the interference is no higher than 10 dB below the level of the desired on-channel signal. Additionally, the reply efficiency to a single aircraft interrogation shall not be reduced by more than 10 percent when the level of the interrogation signal is 6 dB and more above the level of the interfering CW signal. The CW sensing circuit shall not reduce the receiver gain by more than 1 dB when pulses 8.0 microseconds wide or wider are received at a rate of 37,000 per second at a level 10 dB below receiver sensitivity. (This is to preclude premature receiver desensitization, if the receiver is exposed to a high Pulse Repetition Frequency (PRF) pulse multiplexed signal.)

149. MONITORING. The radiated signals shall be monitored and removed from service upon recognition of unsafe operations.

150.-169. RESERVED.

SECTION 2. OPERATIONAL CHARACTERISTICS FOR DME AND TACAN AIRBORNE COMPONENTS

170. INTRODUCTION. This section specifies functional capability and performance characteristics required of DME and TACAN airborne components. The term "component" as used In this order, includes the complete aircraft installation. This includes such items as the antenna and its transmission line, the interrogator, the electrical power source(s), identification signal reproduction or display devices, and the distance indicator; when applicable, it also includes select and display instrumentation devices for bearlng and course indication. Airborne components used in the performance of aircraft operations under IFR must meet all requirements. For other aircraft operations the requirements are limited to paragraphs 170, 175, 176, 179 and 180. Requirements apply to both DME and TACAN components unless otherwise noted. Components should be capable of performing as specified throughout the operational service volume of ground stations. The applicable performance requirements should be met when the ground stations are operating in accordance with this standard.

171. INTERROGATOR SIGNAL CHARACTERISTICS. Paragraphs 172 through 180 identify interrogation signal characteristics and tolerances applicable to the radiated signal.

172. INTERROGATION RADIO FREQUENCIES AND ACCURACY. The Interrogator shall transmit on the appropriate frequency in accordance with Appendix 3. The center frequency of the interrogation shall be within ± 100 kHz of the channel frequency.

173. PULSE CHARACTERISTICS. The radio frequency pulse envelope shall have characteristics as follows.

a. Pulse Rlse Time. The time required for the pulse to rise from 10 to 90 percent of its maximum voltage amplitude shall nominally be 2.5 microseconds. It shall not exceed 3.0 microseconds. The minimum rise time is governed by the spectrum requirements of paragraph 179.

b. Pulse Top. Between the points on the leading and trailing edges which are 95 percent of the maximum voltage amplitude, the instantaneous amplitude of the pulse shall not fall below a value which is 95 percent of the maximum voltage amplitude of the pulse.

c. Pulse Duration. The pulse duration, as measured at the 50 percent maximum voltage amplitude points, shall be 3.5 ± 0.5 microseconds.

d. Pulse Decay Time. The time required for the pulse to fall from 90 to 10 percent of the maximum voltage amplitude shall nominally be 2.5 microseconds. It shall not exceed 3.5 microseconds. The minimum decay time is governed by the spectrum requirements of paragraph 179.

174. PULSE POWER VARIATION. The peak power of the constituent pulses of any pair shall not differ by more than 1 dB.

> Note: If the difference in level of the constituent pulses of interrogation pulse pairs is greater than 1.0 dB, ground components may not respond to interrogations.

175. PULSE CODING. Interrogation signals shall consist of paired pulses. Spacings are measured at the 50 percent voltage amplitude points on the pulse rise time of each pulse. The pulse spacing shall be:

a. 12.0 ± 0.5 microseconds for X channels; or

b. 36.0 ± 0.5 microseconds for Y channels.

176. INTERROGATION SIGNAL REPETITION RATE. The average interrogator pulse pair repetition rate shall not exceed 30 pairs of pulses per second. This assumes that interrogators are tracking at least 95 percent of the time. The repetition rate may be increased during search, but it shall not exceed 150 pulse pairs per second.

177. VARIATION OF REPETITION RATE. The variation in time between successive interrogations shall be sufficient to preclude mistaking distance reply pulses intended for another airborne component tuned to the same ground facility. It shall also preclude capture of the interrogations of one interrogator within the ground component dead time caused by the Interrogations of other avionics.

178. SIGNAL STRENGTH IN SPACE.

a. When referenced to a point in space prior to the ground station antenna intercept, the airborne component of aircraft operating above 18,000 feet (5,486 m) AGL shall provide a minimum signal power density of -102.5 dBW/m^2 (95 percent time availability). For aircraft operating below 18,000 (5,486 m) AGL, the minimum signal power density shall be -99.0 dBW/m^2.

b. These specified power densities will assure a minimum reply efficiency of 70 percent when:

(1) the pulse frequency is within ± 100 kHz of the assigned center frequency;

(2) the pulse spacing is within ± 0.5 microseconds of nominal design center; and

(3) the beacon loading is 3375 pulse pairs per second with the echo suppression circuits disabled.

c. For the various operational service volumes currently employed in the ATC environment, the interrogator's EIRP shall be a minimum of +29.0 dBW for those aircraft operating above 18,000 feet (5,486 m) AGL and +19.0 dBW for those operating below 18,000 feet (5,486 m) AGL. These EIRP's will provide to the ground beacon the power densities necessary for satisfactory performance. Since EIRP levels greater than +33.0 dBW may impair system performance, the interrogator's EIRP shall not exceed this value. (See Appendix 1)

179. RADIO SPECTRUM. The spectrum of the RF interrogation signal shall be such that at least 90 percent of the energy, including FM components, in each pulse shall be within a 0.5 MHz band centered on the nominal channel frequency.

180. RADIATION. Radiation from airborne components shall not result in derogation of the operational use of this system by other users or in the derogation of other aeronautical services. Neither shall other users derogate the operational use of this system by valid DME or TACAN users. At all frequencies between 960 and 1215 MHz, the level of radiated CW signals, as referenced to an isotropic radiator, shall not exceed -60 dBW.

181. COMPONENT FUNCTIONAL CAPABILITIES AND PERFORMANCE. These subparagraphs identify functional and operational performance requirements applicable to the airborne component.

182. RECEIVER RADIO FREQUENCIES. For each channel in use, the receiver's center frequency shall be in accordance with Appendix 3.

183. RECEIVER SENSITIVITY. Based on the signal power density of paragraph 123, the airborne components shall provide the sensitivity necessary to acquire and display navigation information to the accuracy specified. Clear and distinct reproduction of identification signals shall be provided. (See Appendix 1)

184. REJECTION OF UNDESIRED SIGNALS. The airborne component shall provide undesired signal rejection characteristics adequate to assure the specified performance. For co-channel and adjacent channel DME and TACAN signals, this requirement shall be met when the respective signals provide desired to undesired (D/U) signal ratios up to the maximum values stated in paragraph 29.b. At these D/U ratios, a positive identification signal shall be provided to identify the ground component.

185. DISTANCE INFORMATION. The airborne component shall measure and display the slant range distance (in nautical miles) between the aircraft and the selected ground component.

Note: The airborne component should not be capable of displaying excessive distances. Distances should be considered excessive for a given receiver if that receiver cannot reasonably be expected to operate at that distance.

186. WARNING FUNCTION, DISTANCE. The airborne component shall provide a warning indication whenever the airborne component is neither tracking a distance reply signal nor operating from memory (see paragraph 188). This warning shall be clearly evident to the pilot.

187. ACCURACY OF DISTANCE INFORMATION. When the airborne component error is combined by root-sum-square with a ground component error of Ø.1 nmi (185 m), the total error in slant range distance information, as displayed to the pilot, shall not (except during memory per paragraph 188) exceed Ø.5 nmi (926 m) or 3 percent of the actual distance, whichever is greater (95 percent probability).

188. MEMORY FUNCTIONS. The airborne component shall provide a memory function which, upon loss of a suitable reply signal while tracking, will cause the display of distance information to continue for a period not to exceed 15 seconds. The minimum distance memory shall be sufficient to cover the loss of distance reply signals during transmission of the ground component identification signal. The distance displayed during memory shall be within 1.Ø nmi (1852 m) of the indication upon resumption of the tracking function.

189. TACAN BEARING AND COURSE DEVIATION INFORMATION. The airborne component shall provide devices for unambiguous determination of the aircraft magnetic bearing with respect to each selected ground component and for display of the aircraft deviation from the selected course.

19Ø. COURSE DEVIATION DISPLAYS. The response, readability, and resolution of course deviation displays shall permit the pilot to determine the direction and extent of the aircraft deviation from the selected course.

191. WARNING FUNCTION, BEARING. The airborne component shall provide a warning indication whenever the azimuth signals are not present and when the component is not operating in memory. This warning shall be clearly evident to the pilot.

192. ACCURACY OF BEARING AND COURSE DEVIATION INFORMATION. At any bearing, the total airborne component error in bearing and course deviation information shall not exceed ± 3.Ø degrees (95 percent probability) as displayed to the pilot.

193.-209. RESERVED.

APPENDIX 1. COVERAGE.

1. RADIO PROPAGATION. Propagation losses vary as a function of time. For a given EIRP, the power density at a point in space will fluctuate. In addition, propagation loss will vary from site to site. This variation is a function of several factors including atmospheric refractivity, surface reflectivity, wave polarization, etc. Since the VOR/DME/TACAN system is a safety service, signals must be highly reliable. With this in mind, conservative assumptions have been made for the inputs to the propagation model. Figures 2 through 13 show standard VOR, DME, and TACAN signal strengths (95 percent time availability) at various points in space. A time availahility of 95 percent means that, at a given point in space, the instantaneous signal strength will be greater than or equal to the value shown 95 percent of the time. Although propagation losses will differ from site to site, the signal strength curves of this appendix are recommended for purposes of standardization. It is important to remember that for the distance function of DME and TACAN both the ground-to-air and air-to-ground transmissions must be considered.

2. GROUND STATION. The EIRP's and resultant signal strength in space curves given in Figures 2 through 13 are nominal. Allowances should be made for different EIRP's and for other variations in station characteristics. Some ground stations may have higher cable losses (e.g., mountain top installations sometimes require longer cable runs). In addition, intervening terrain may increase the transmission path loss. Should this occur, it may be necessary to reduce the service volume accordingly.

3. VOR COVERAGE.

a. The power density specified in paragraph 53 (-120 dBW/m^2) is equivalent to -123 dBW power available at the output of a lossless isotropic antenna (at 118 MHz). Allowance must be made for the airborne antenna and for cable and insertion losses. Users will balance their airborne power budgets in different ways. Two examples are shown below.

	Example 1	Example 2
Power Available	-123 dBW	-123 dBW
Airborne Antenna Gain*	+2.2 dBi	-1 dBi
Airborne Losses	-2.2 dB	-4 dB
Receiver Sensitivity	-123 dBW	- -

b. Many other examples could be given. It is the user's responsibility to insure that the airborne installation will allow proper operation at the minimum signal strength of paragraph 53. (In considerin airborne antenna gain, antenna pattern variation should not be neglected. 3

*NOTE: Does not consider variations due to antenna locations or other factors which influence antenna gain due to shielding.

4. DME/TACAN (UPLINK) COVERAGE

a. The power densities specified in paragraph 123 are referenced to the powers available at a point in space. Allowance must be made for the airborne antenna and for cable and insertion losses, Users will balance their airborne power budgets in different ways. Two examples of how users might balance their airborne power budgets for the DME and TACAN are shown as follows:

	Example 1		Example 2	
	DME (100W)	TACAN	DME (100W)	TACAN
Power Available	-109.0	-114.5 dBW	-109.0	-114.5 dBW
Airborne Antenna Gain*	+2.0	+2.0 dBi	+0.5	+0.5 dBi
Airborne Losses	-3.0	-3.0 dB	-1.5	-1.5 dB
Rx Sensitivity	-110.0	-115.5 dBW	-110.0	-115.5 dBW

b. Many other examples could be given. It is the user's responsibility to insure that the airborne installation will allow proper operation at the minimum signal strengths of paragraph 123. An airborne DME installation with 1 dB of loss (antenna pattern, cable and insertion losses, signal splitters, etc.) would require a sensitivity of -110.0 dBW. An airborne TACAN installation with 1 dB of loss would require a sensitivity of -115.5 dBW. When the total loss is different than 1 dB, a corresponding adjustment must be made to determine the required sensitivity. In considering airborne antenna gain, antenna pattern variation should not be neglected.

5. DME/TACAN (DOWNLINK) COVERAGE.

a. The minimum power density specified in paragraph 178 for the input to the ground station antenna is -99.0 dBW/m^2 for DME and -102.5 dBW/m^2 for TACAN. These power density values are necessary to generate a reply efficiency of 70 percent from the transponder during periods when the transponder is under heavy load and when the interrogation signal is within ± 100 kHz of the nominal channel frequency and its pulse pair spacing is within ±0.5 microseconds of the nominal system value. The association of interrogator signal strength and transponder sensitivity is as follows.

*Note: Does not consider variations due to antenna locations or other factors which influence antenna gain due to shielding.

DME	TACAN	
-94.Ø	-97.0 dBm	: Transponder Sensitivity per paragraph 115
+ 6.7	+ 3.0 dB	: Net coupling to receiver per (1) +8.2 dBi DME Antenna Gain on horizon -1.5 dB Net Losses (cable and insertion) (2) +4.5 dBi TACAN Antenna Gain on horizon -1.5 dB Net Losses (cable and insertion)
-87.3	-94.Ø dBm	: Receiver input for 7Ø percent Efficiency per paragraph 115
+ 2.0	+ 2.Ø dB	: Sensitivity Reduction per paragraphs 116 and 117
-85.3	-92.Ø dBm	: Receiver Input for 7Ø percent efficiency

b. It is the user's responsibility to provide that signal strength to insure proper operation for those conditions stated in paragraph 178. For the requirement of 7Ø percent reply efficiency:

DME	TACAN	
-85.Ø	-92.Ø dBm	: Receiver Input per conditions of paragraph 178
- 6.7	- 3.Ø dB	: Net coupling per Antenna
-91.7	-95.Ø dBm	: Signal Strength at the antenna input
-99.2	-1Ø2.5 dBW/m^2	: Power Density at the antenna input
-99.Ø	-1Ø2.5 dBW/m^2	: Value used in paragraph 178

6. TIME AVAILABILITY. At a point in space, signal strength will vary with time even when the ground transmitter's EIRP remains constant. A similar statement could be made for D/U signal ratios. This variation is largely due to propagation effects under different environmental conditions. Examples include atmospheric refractivity, seasonal changes in ground cover, and surface reflectivity. Numerous other factors are also involved. Although it is difficult to describe accurately all the variables involved, the situation can be adequately covered by statistical treatment. A helpful concept, in a statistical discussion of reliability, is time availability. It is that percentage of time that a given signal strength or D/U ratio is met or exceeded. Figure 1 shows an example of signal strength as a function of time availability. For a time availability of 95 percent, the signal strength is -12Ø dBW/m^2. This means that a signal strength of -12Ø dBW/m^2 or greater is present 95 percent of the time. For a time availability of 50 percent, the signal strength is -117 dBW/m^2 at the same point in space assuming the same constant ground station characteristics. In a similar manner, the signal strength present for any given percentage of the time can be read from the graph. This graph does not, however, take transmitter downtime into account.

FIGURE 1. SIGNAL TIME AVAILABILITY

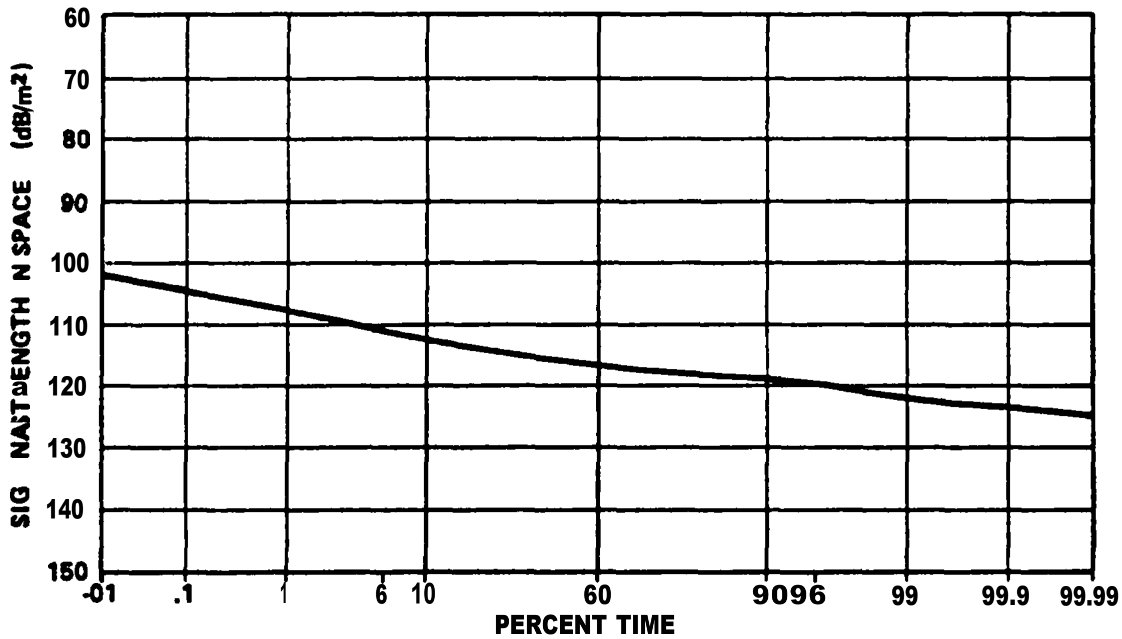
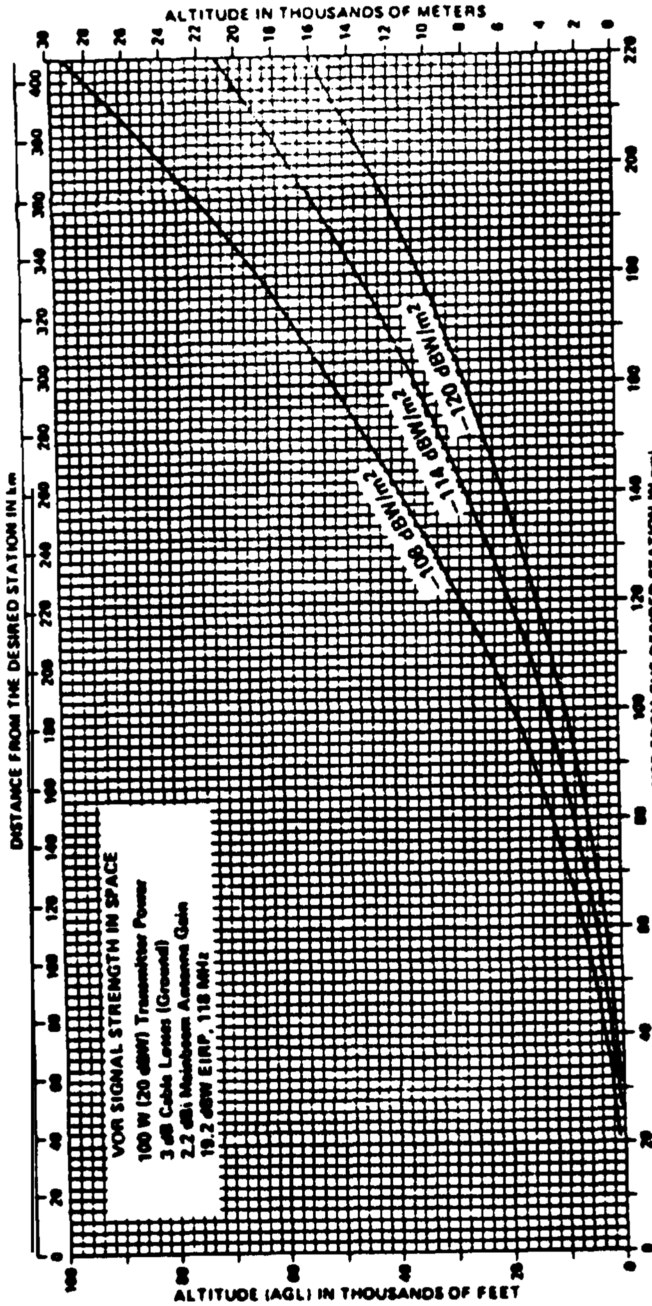


FIGURE 2. VOR SIGNAL STRENGTH IN SPACE – LONG RANGE



NOTE: This graph is not intended to show signal strength in the "cone of confusion" above the station.

FIGURE 3. TACAN (RTB-2) SIGNAL STRENGTH IN SPACE – LONG RANGE

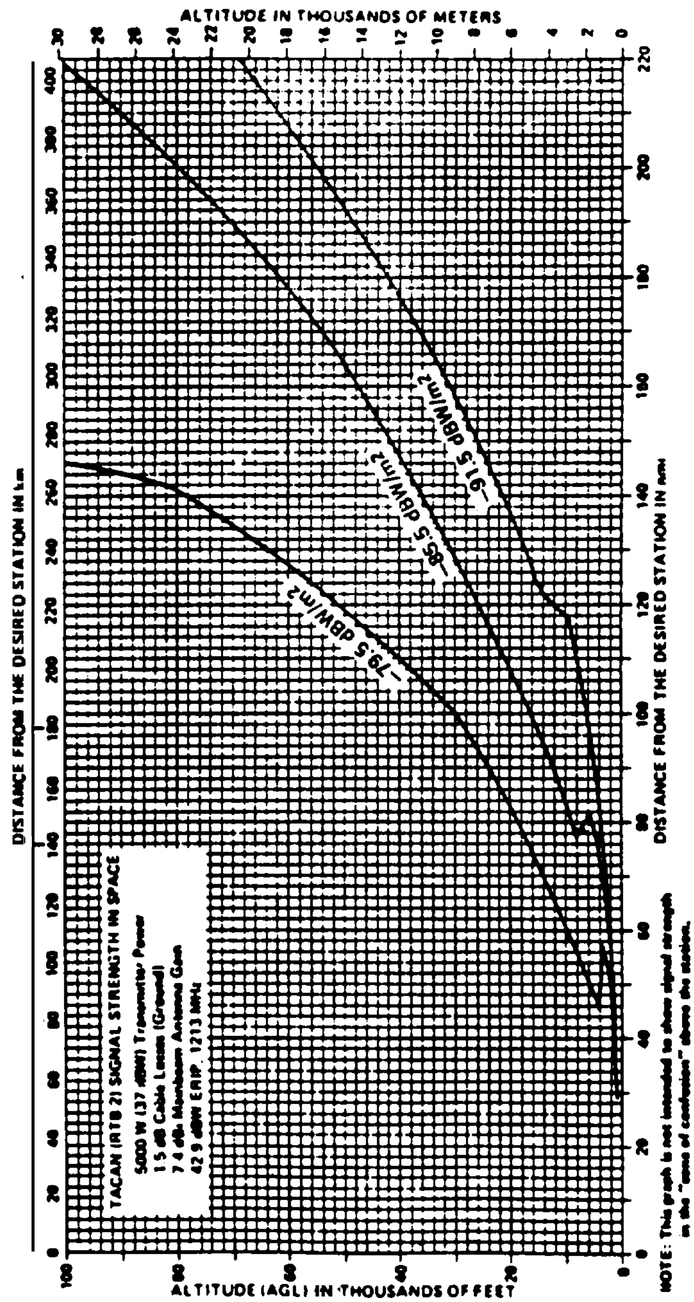


FIGURE 4. CARDION DME SIGNAL STRENGTH IN SPACE – LONG RANGE

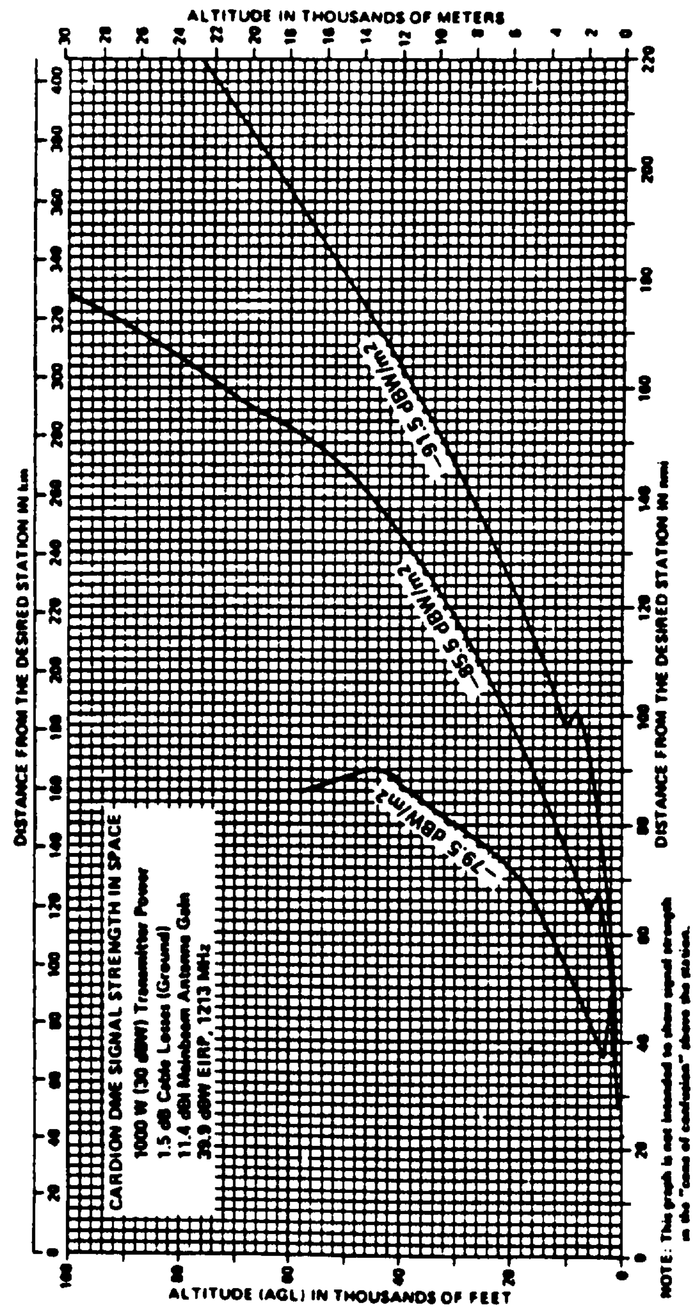


FIGURE 5. CARDION DME SIGNAL STRENGTH IN SPACE – LONG RANGE

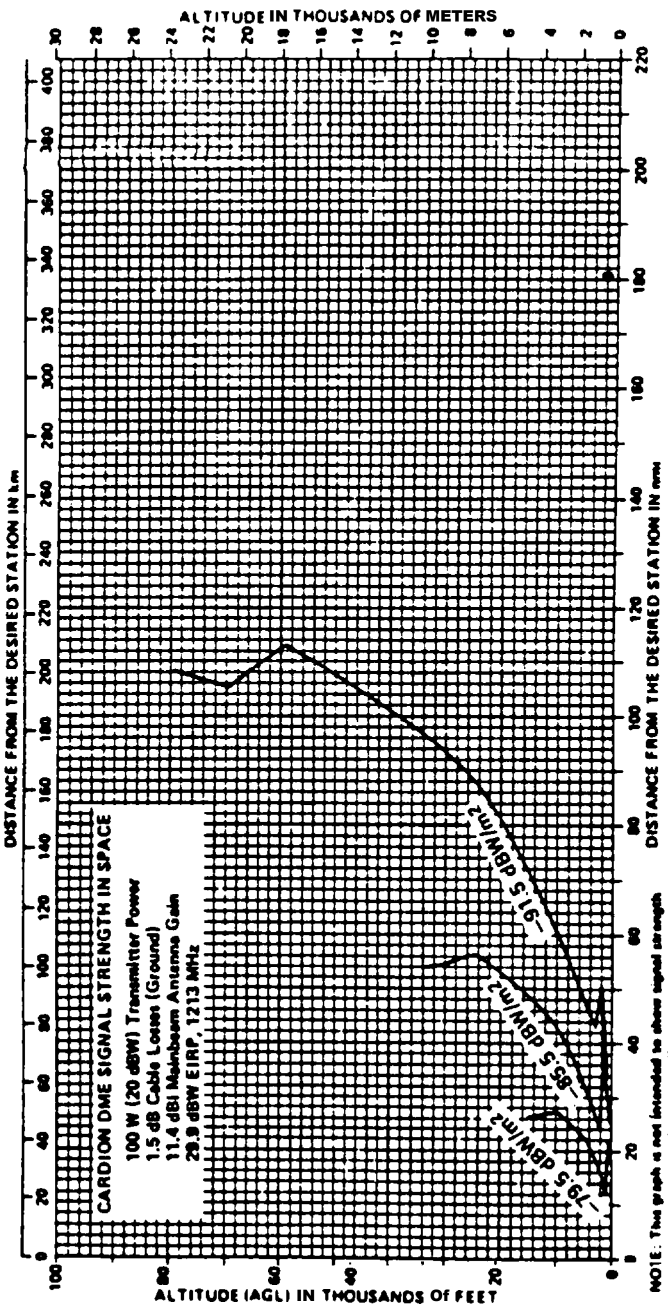


FIGURE 6. MONTEK DME SIGNAL STRENGTH IN SPACE – LONG RANGE

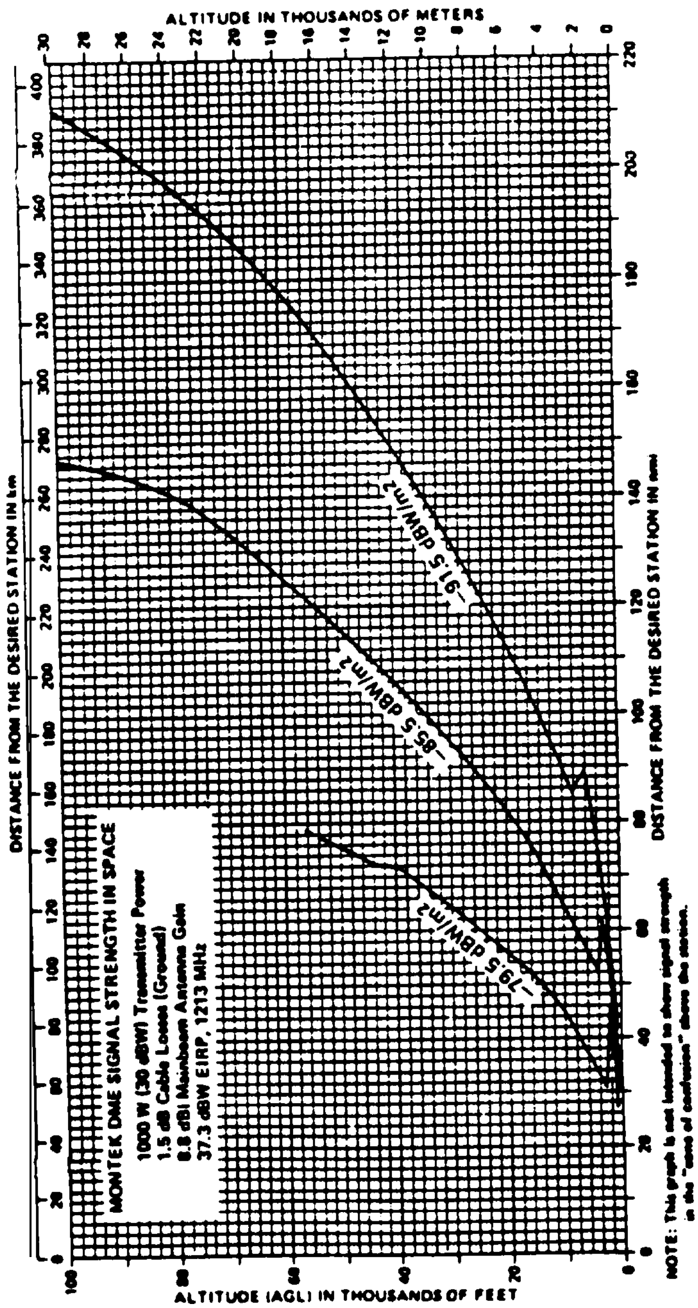
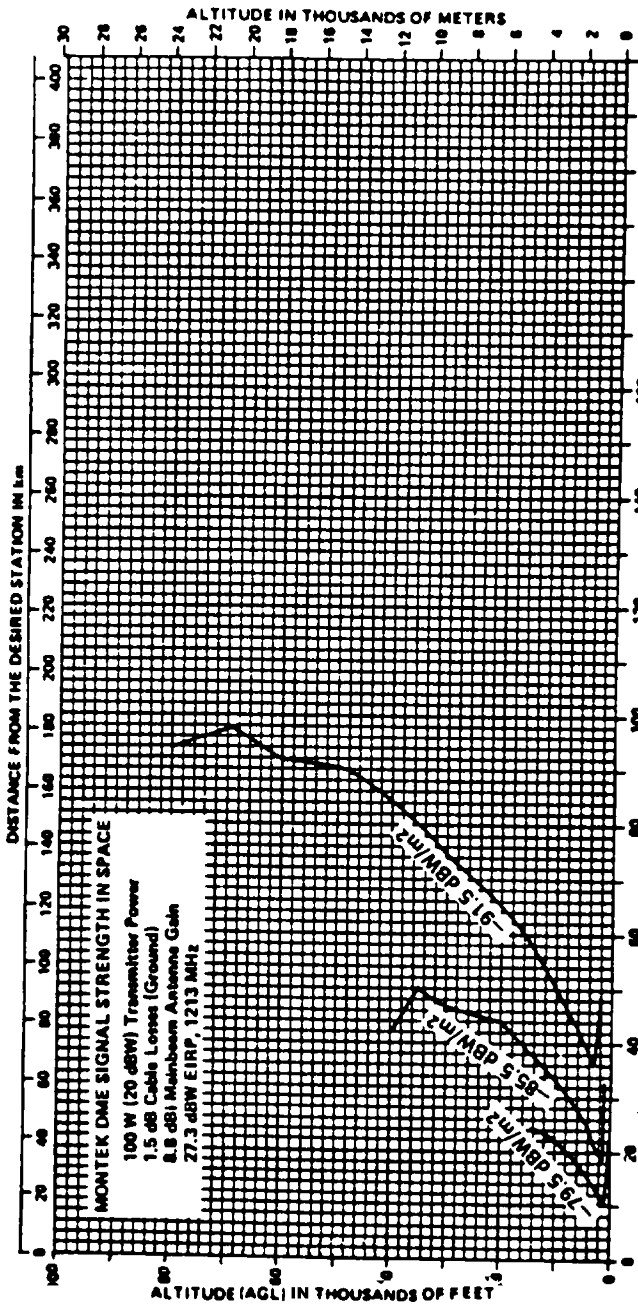
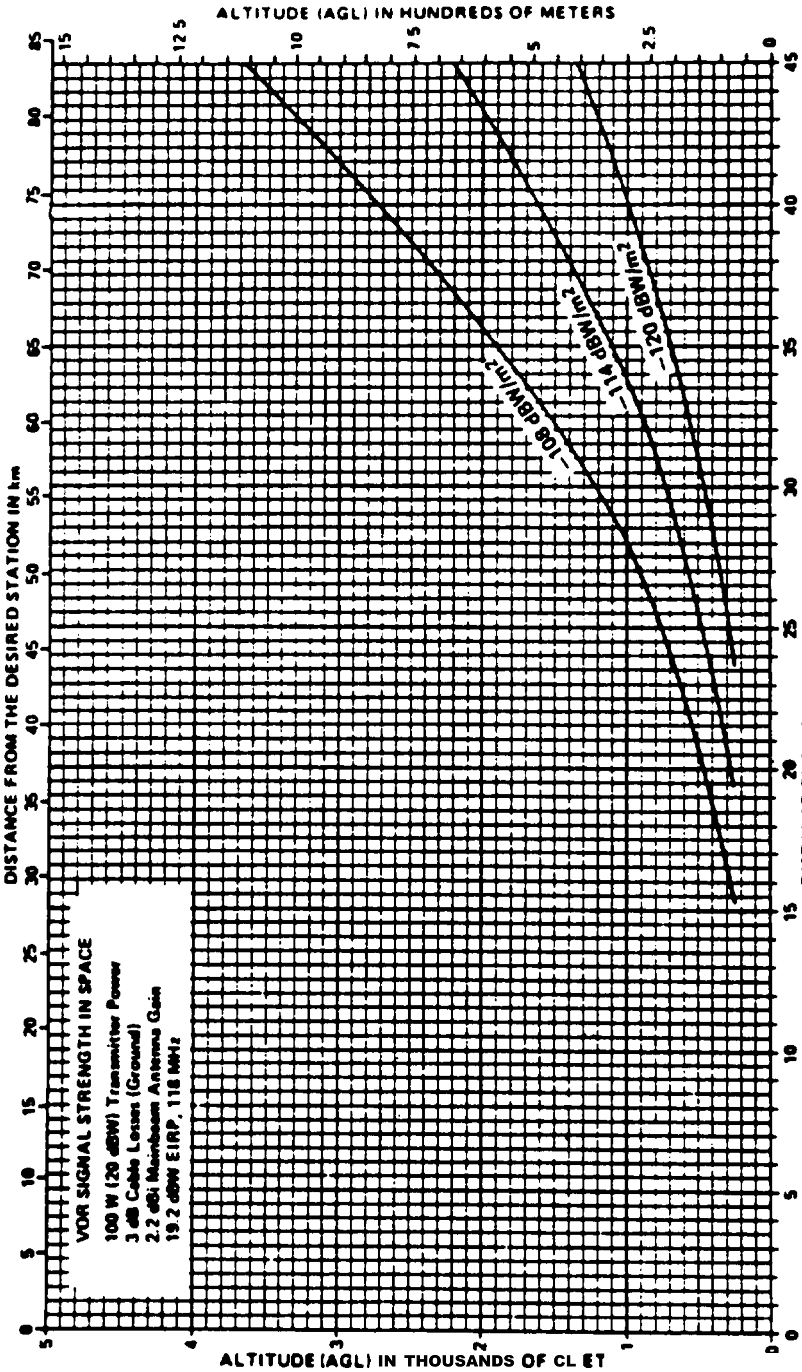


FIGURE 7. MONTEK DME SIGNAL STRENGTH IN SPACE — LONG RANGE



NOTE: This graph is not intended to show signal strength in the "cone of confusion" above the station.

FIGURE 8. VOR SIGNAL STRENGTH IN SPACE – SHORT RANGE



NOTE: This graph is not intended to show signal strength in the "cone of confusion" above the station.

FIGURE 9. TACAN (RTB-2) SIGNAL STRENGTH IN SPACE – SHORT RANGE

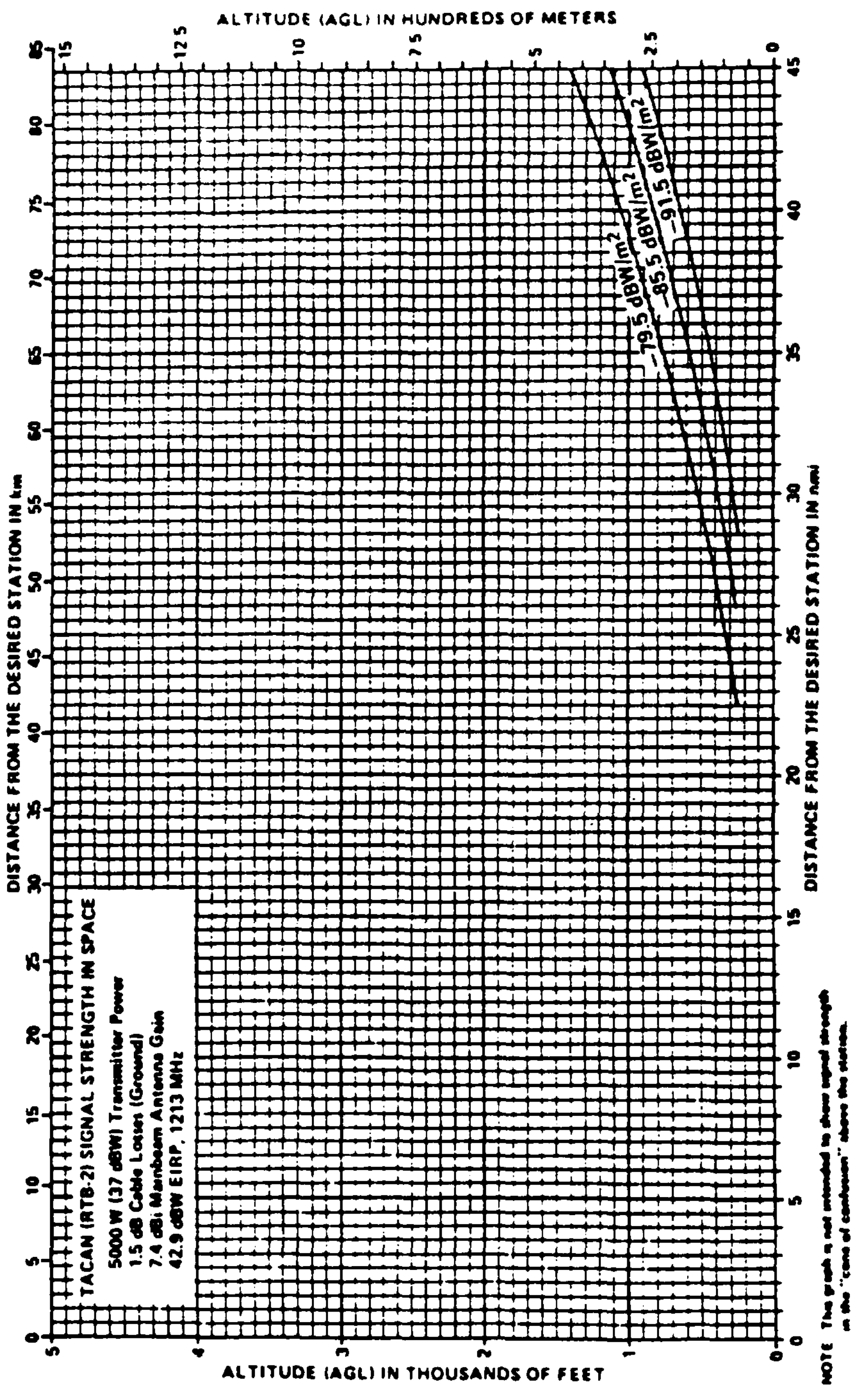
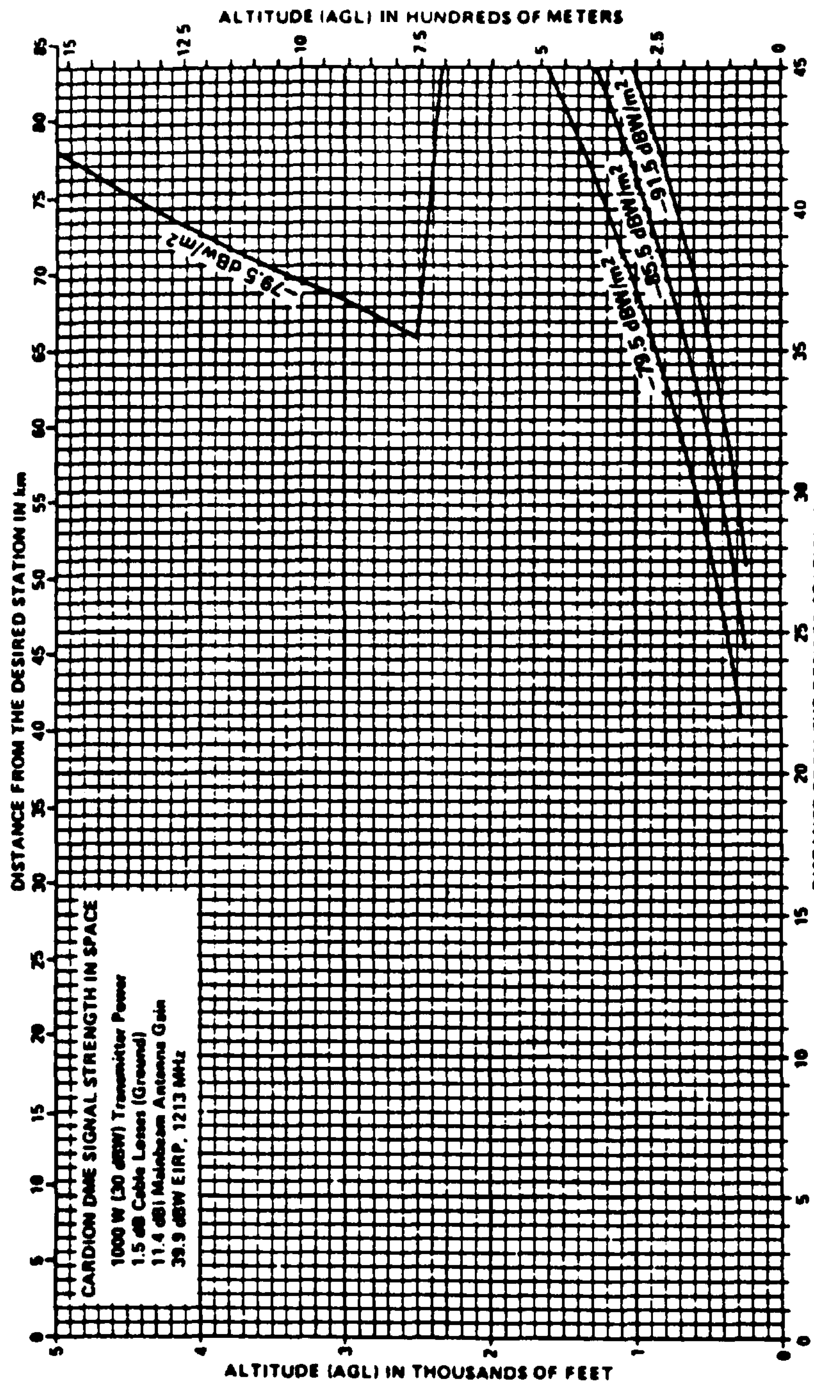
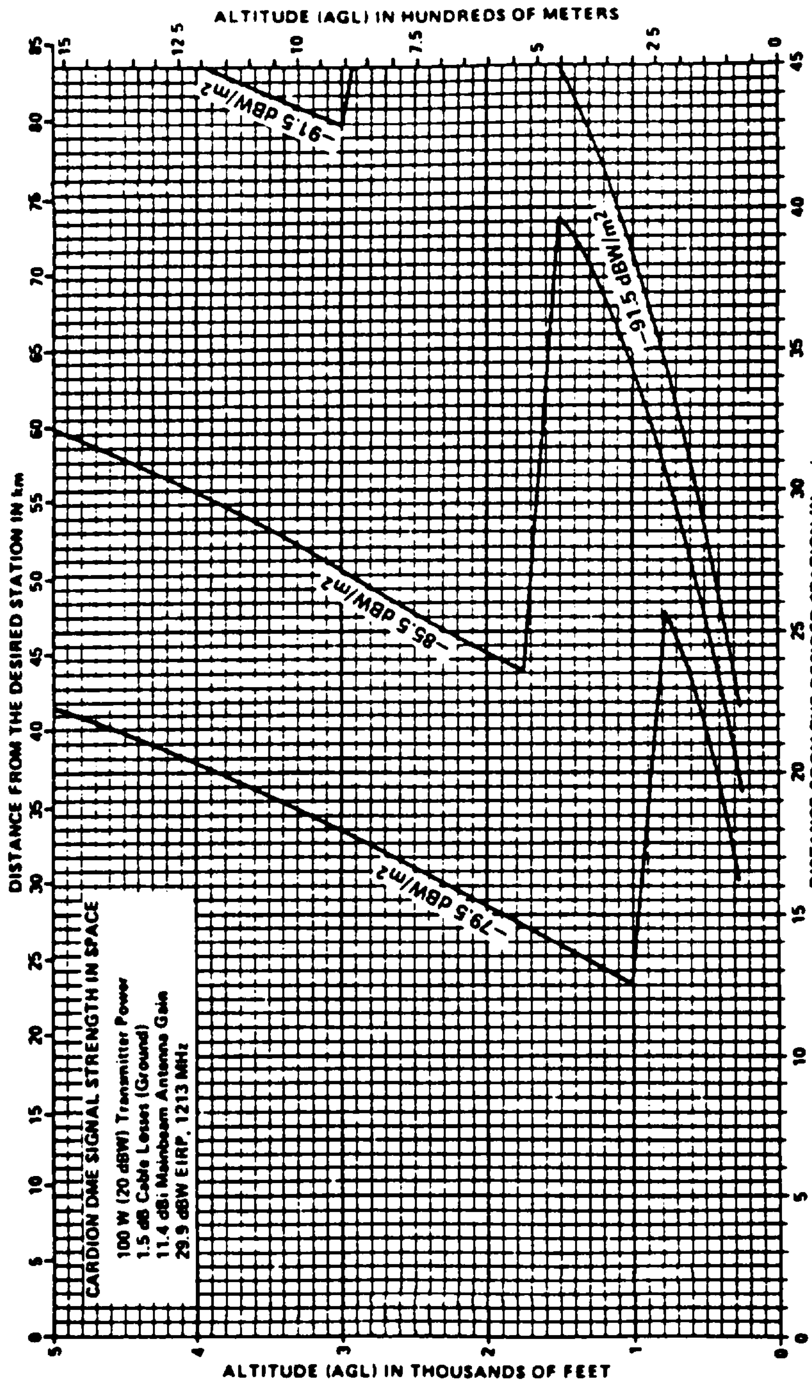


FIGURE 10. CARDION DME SIGNAL STRENGTH IN SPACE – SHORT RANGE



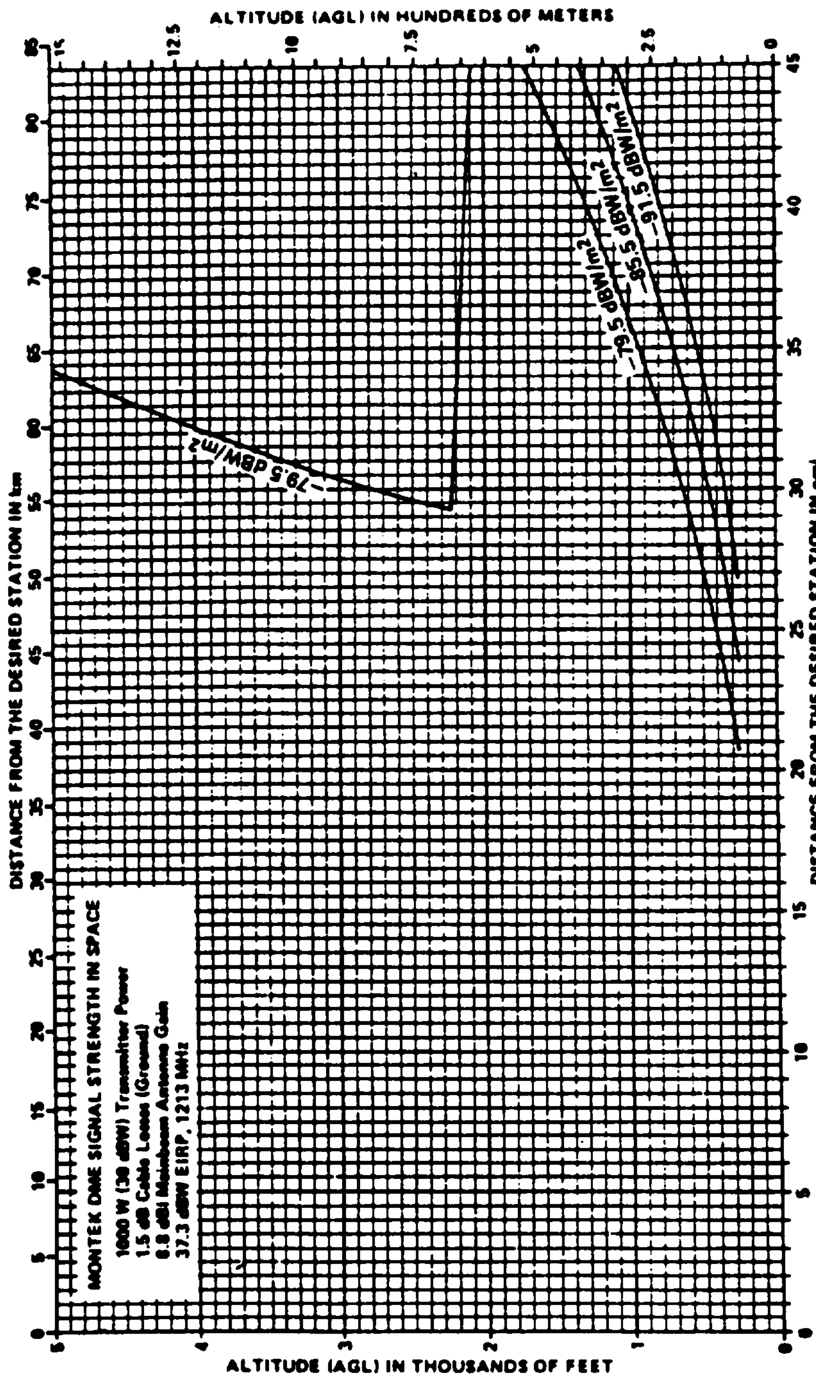
NOTE: The graph is not intended to show signal strength in the "cone of confusion" above the station.

FIGURE 11. CARDION DME SIGNAL STRENGTH IN SPACE – SHORT RANGE



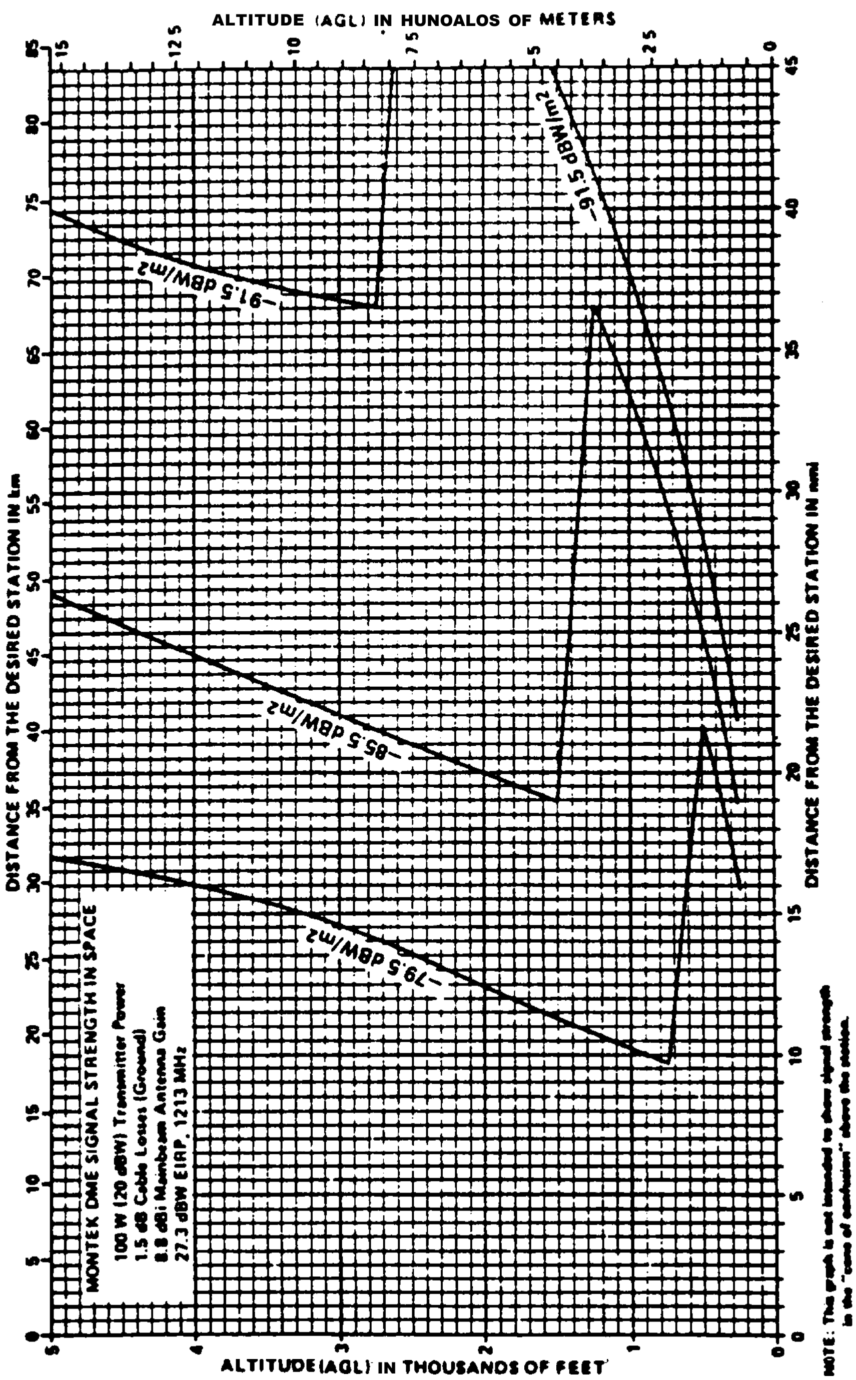
NOTE: This graph is not intended to show signal strength in the "cone of confusion" above the station.

FIGURE 12. MONTEK DME SIGNAL STRENGTH IN SPACE – SHORT RANGE



NOTE: This graph is not intended to show signal strength in the "cone of confusion" above the station.

FIGURE 13. MONTEK DME SIGNAL STRENGTH IN SPACE – SHORT RANGE



APPENDIX 2. SYSTEM ACCURACY.

1. SYSTEM ACCURACY. The accuracies described and quantified below represent the normal error budget for a VOR/DME/TACAN system that includes basic avionics with analog indicators, a typical ground station, and an environment that does not include errors caused by excessive multipath. Margin for pilot induced flight technical error is also included. The error terms* are defined as follows.

2. BEARING ERROR COMPONENT DEFINITION.

a. Radial Signal Error (Eg). Radial signal error is the difference between the nominal magnetic bearing to a point of measurement from the ground component and the bearing indicated by the ground component signal at the same point. The radial signal error is associated with the ground component and nominal signal path errors but excludes other error factors. It is made up of the following.

(1) certain constant elements such as course displacement errors and most site and terrain effect errors which may be considered as fixed for long periods of time.

(2) certain' random variable errors which can be expected to vary about the essentially constant value.

b. Airborne Component Error (Ea). Airborne component error is that error attributable to the inability of the airborne equipment to translate correctly the bearing information contained in the radial signal. This element embraces all factors in the airborne component which introduce errors in the information presented to the pilot. (Errors resulting from the use of compass information in some VOR and TACAN displays are not included.)

c. Instrumentation Error (Ei). This component consists of the limitation of the omni-bearing selector (OBS) units due to the resolution of the device and the inherent error of translating the pilot input to the avionic comparator. This comparator derives the difference between the actual radial computed and the selected radial which the pilot requires. This difference is normally displayed on a course deviation indicator (CDI) whose errors are considered a part of (Ea).

d. Flight Technical Error (Ef). Flight technical error refers to the accuracy with which the pilot controls the aircraft as measured by his success in causing the indicated aircraft position to match the indicated command for desired position. It does not include procedural blunders.

*Note: Quantitative values assume 95 percentile distribution.

e. Aggregate Error (Es). Aggregate error is the difference between the magnetic bearing to a point of measurement from the ground component and the bearing indicated by airborne components. This is the error in the information presented to the pilot (exclusive of any errors resulting from use of compass information). It takes into account not only the ground component and propagation path errors but also the error contributed by the airborne component and its instrumentation. The entire radial signal error, both fixed and variable, is used.

3. ERROR COMBINATION. Since the errors above, when considered on a total system basis (not any individual radials or components) are independent variables, they may be combined by the root-sum-square **(RSS)** method to calculate aggregate system error (Es) when the same probability is given to each element. For purposes of this standard, each element is considered to have 95 percent probability.

a. Radial Signal Error (Eg). In practice, based on a significant number of accumulated data points, the radial signal error value (Eg) has been found to be **±1.4** degrees (95 percent probability).

b. Airborne Component Error (Ea). This component is strictly limited to those errors attributable to the avionics. In other words. this value excludes that which is due to the auto-couple of navigation deviation signals to aircraft controls and other output devices such as the omni-bearing selector (OBS), either in the manual or auto-couple mode. This value (Ea) has been estimated to be approximately **+3.0** degrees and may vary as to the quality of the avionics. This distribution-is considered normal both from a capability standpoint between manufacturers and a quality standpoint by any one manufacturer. Recent avionics have shown the capability to reduce this error.

c. Instrumentation Error (Ei). This represents the remainder of the avionics error that is excluded from **paragraph** 3.b of this Appendix. This error is approximately **±2.0** degrees when **a** manual analog **OBS is** utilized. Digital **OBS** devices and auto-couple would decrease this error significantly. This latter configuration is not addressed in this analysis, but could represent a considerable improvement to the total error budget, if implemented.

d. Flight Technical Error (Ef). As defined in paragraph 2.d of this Appendix, the value which is attributable to this error component is **+2.3** degrees. Although this error may not be completely independent of **other** errors, independence is assumed in this analysis. Empirical data indicates that this value may be pessimistic.

e. System Use Error (Es). Airways, routes, and terminal area procedures in the United States are designed on the basis of a system use accuracy of ±4.5 degress (95 percent probability). The system use error value is derived as follows:

Radial Signal Error (Eg):	±1.4 degrees (95% probability)
Airborne Component Error (Ea):	±3.0 degrees (95% probability)
Instrumentation Setting Error (Ei):	+2.0 degrees (95% probability)
Flight Technical Error (Ef):	-2.3 degrees (95% probability)

System Use Error

$$= (Eg^2 + Ea^2 + Ei^2 + Ef^2)^{1/2}$$

$$= (1.4^2 + 3.0^2 + 2.0^2 + 2.3^2)^{1/2}$$

$$= (1.96 + 9.00 + 4.00 + 5.29)^{1/2}$$

$$= (20.25)^{1/2}$$

$$= \pm 4.5 \text{ degree (95\% probability)}$$

4. DISTANCE ERROR. Refer to paragraph 187 of this standard.

APPENDIX 3
VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING

Chan. No.	VHF Chan. Freq. MHz	DME-TACAN Tnterr. Freq. MHz	DME-TACAN Reply Freq. MHz
1X	—	1025	962
1Y	—	1025	1088
2X	—	1026	963
2Y	—	1026	1089
3x	—	1027	964
3Y	—	1027	1090
4x	—	1028	965
4Y	—	1028	1091
5X	—	1029	966
5Y	—	1029	1092
6X	—	1030	967
6Y	—	1030	1093
7x	—	1031	968
7Y	—	1031	1094
8X	—	1032	969
8Y	—	1032	1095
9X	—	1033	970
9Y	—	1033	1096
10x	—	1034	971
10Y	—	1034	1097
11X	—	1035	972
11Y	—	1035	1098
12x	—	1036	973
12Y	—	1036	1099
13x	—	1037	974
13Y	—	1037	1100
14x	—	1038	975
14Y	—	1038	1101
15x	—	1039	976
15Y	—	1039	1102
16X	—	1040	977
16Y	—	1040	1103

VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING-Continued

Chan. No.	VHF Chan. Freq. MHz	DME-TACAN Interr. Freq. MHz	DME-TACAN Reply Freq. MHz
17X"	108.00 VOR	1041	978
17Y*	108.05 VOR	1041	1104
18X*	108.10 ILS	1042	979
18Y	108.15 ILS	1042	1105
19x	108.20 VOR	1043	980
19Y	108.25 VOR	1043	1106
20X	108.30 ILS	1044	981
20Y	108.35 ILS	1044	1107
21x	108.40 VOR	1045	982
21Y	108.45 VOR	1045	1108
22x	108.50 ILS	1046	983
22Y	108.55 ILS	1046	1109
23X	108.60 VOR	1047	984
23Y	108.65 VOR	1047	1110
24X	108.70 ILS	1048	985
24Y	108.75 ILS	1048	1111
25X	108.80 VOR	1049	986
25Y	108.85 VOR	1049	1112
26X	108.90 ILS	1050	987
26Y	108.95 ILS	1050	1113
27X	109.00 VOR	1051	988
27Y	109.05 VOR	1051	1114
28X	109.10 ILS	1052	989
28Y	109.15 ILS	1052	1115
29x	109.20 VOR	1053	990
29Y	109.25 VOR	1053	1116
30X	109.30 ILS	1054	991
30Y	109.35 ILS	1054	1117
31x	109.40 VOR	1055	992
31Y	109.45 VOR	1055	1118
32X	109.50 ILS	1056	993
32Y	109.55 ILS	1056	1119
33x	109.60 VOR	1057	994
33Y	109.65 VOR	1057	1120

* The frequencies associated with Channels 17X, 17Y and 18X are test frequencies. Assignments may be made to VOR test signals (VOTs), ramp testers, radiating test generators, and other test facilities. ILS, VOR, and DME-TACAN assignments should not be made on these channels. This has been coordinated with the FCC. See 47 CFR Section 87.521(d); FCC Rules and Regulations, Part 87, paragraph 87.521(d).

VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING-Continued

Chan. No.	VHF Chan. Freq. MHz	DME-TACAN Interr. Freq. MHZ	DME-TACAN Reply Freq. MHz
34X	109.70 ILS	1058	995
34Y	109.75 ILS	1058	1121
35X	109.80 VOH	1059	996
35Y	109.85 VOR	1059	1122
36X	109.90 ILS	1060	997
36Y	109.95 ILS	1060	1123
37X	110.00 VOR	1061	998
37Y	110.05 VOR	1061	1124
38X	110.10 ILS	1062	999
38Y	110.15 JLS	1062	1125
39X	110.20 VOR	1063	1000
39Y	110.25 VOR	1063	1126
40X	110.30 ILS	1064	1001
40Y	110.35 ILS	1064	1127
41X	110.40 VOR	1065	1002
41Y	110.45 VOR	1065	1128
42X	110.50 ILS	1066	1003
42Y	110.55 ILS	1066	1129
43X	110.60 VOR	1067	1004
43Y	110.65 VOR	1067	1130
44X	110.70 ILS	1068	1005
44Y	110.75 ILS	1068	1131
45X	110.80 VOR	1069	1006
45Y	110.85 VOR	1069	1132
46X	110.90 ILS	1070	1007
46Y	110.95 ILS	1070	1133
47X	111.00 VOR	1071	1008
47Y	111.05 VOR	1071	1134
48X	111.10 ILS	1072	1009
48Y	111.15 ILS	1072	1135
49X	111.20 VOR	1073	1010
49Y	111.25 VOR	1073	1136
50X	111.30 ILS	1074	1011
50Y	111.35 ILS	1074	1137
51X	111.40 VOR	1075	1012
51Y	111.45 VOR	1075	1138
52X	111.50 ILS	1076	1013
52Y	111.55 ILS	1076	1139

VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING-Continued

Chan. No.	VHF Chan. Freq. MHz	DME-TACAN Interr. Freq. MHz	DME-TACAN Reply Freq. MHz
53x	111.60 VOR	1077	1014
53Y	111.65 VOR	1077	1140
54x	111.70 ILS	1078	1015
54Y	111.75 ILS	1078	1141
55x	111.80 VOR	1079	1016
55Y	111.85 VOR	1079	1142
56X	111.90 ILS	1080	1017
56Y	111.95 ILS	1080	1143
57x	112.00 VOR	1081	1018
57Y	112.05 VOR	1081	1144
58X	112.10 VOR	1082	1019
58Y	112.15 VOR	1082	1145
59x	112.20 VOR	1083	1020
59Y	112.25 VOR	1083	1146
60X	—	1084	1021
60Y	—	1084	1147
61X	—	1085	1022
61Y	—	1085	1148
62X	—	1086	1023
62Y	—	1086	1149
63X	—	1087	1024
63Y	—	1087	1150
64X	—	1088	1151
64Y	—	1088	1025
65X	—	1089	1152
65Y	—	1089	1026
66X	—	1090	1153
66H	—	1090	1027
67X	—	1091	1154
67Y	—	1091	1028
68X	—	1092	1155
68Y	—	1092	1029
69X	—	1093	1156
69Y	112.30 VOR	1094 1093	1030
70X			1157
70Y		1094	1031
71x	112.40 VOR	1095	1158
71Y	112.45 VOR	1095	1032
72X	112.50 VOR	1096	1159
72Y	112.55 VOR	1096	1033

VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING-Continued

Chan. No.	VHF Chan. Freq. MHz	DME-TACAN Interr. Freq. MHZ	DME-TACAN Reply Freq. MHz
73x	112.60 VOR	1097	1160
73Y	112.65 VOR	1097	1034
74x	112.70 VOR	1098	1161
74Y	112.75 VOR	1098	1035
75x	112.80 VOR	1099	1162
75Y	112.85 VOR	1099	1036
76X	112.90 VOR	1100	1163
76Y	112.95 VOR	1100	1037
77x	113.00 VOR	1101	1164
77Y	113.05 VOR	1101	1038
78X	113.10 VOR	1102	1165
78Y	113.15 VOR	1102	1039
79x	113.20 VOR	1103	1166
79Y	113.25 VOR	1103	1040
80X	113.30 VOR	1104	1167
80Y	113.35 VOR	1104	1041
81X	113.40 VOR	1105	1168
81Y	113.45 VOR	1105	1042
82X	113.50 VOR	1106	1169
82Y	113.55 VOR	1106	1043
83X	113.60 VOR	1107	1170
83Y	113.65 VOR	1107	1044
84X	113.70 VOR	1108	1171
84Y	113.75 VOR	1108	1045
85X	113.80 VOR	1109	1172
85Y	113.85 VOR	1109	1046
86X	113.90 VOR	1110	1173
86Y	113.95 VOR	1110	1047
87X	114.00 VOR	1111	1174
87Y	114.05 VOR	1111	1048
88X	114.10 VOR	1112	1175
88Y	114.15 VOR	1112	1049
89X	114.20 VOR	1113	1176
89Y	114.25 VOR	1113	1050
90x	114.30 VOR	1114	1177
90Y	114.35 VOR	1114	1051
91X	114.40 VOR	1115	1178
91Y	114.45 VOR	1115	1052
92x	114.50 VOR	1116	1179
92Y	114.55 VOR	1116	1053
93x	114.60 VOR	1117	1180
93Y	114.65 VOR	1117	1054

VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING-Continued

Chan. No.	VHF Chan. Freq. MHZ	DME-TACAN Interr. Freq. MHZ	DME-TACAN Reply Freq. MHz
94x	114.70 VOR	1118	1181
94Y	114.75 VOR	1118	1055
95x	114.80 VDR	1119	1182
95Y	114.85 VOR	1119	1056
96X	114.90 VOR	1120	1183
96Y	114.95 VOR	1120	1057
97x	115.00 VOR	1121	1184
97Y	115.05 VOR	1121	1058
98X	115.10 VOR	1122	1185
98Y	115.15 VOR	1122	1059
99x	115.20 VOR	1123	1186
99Y	115.25 VOR	1123	1060
100x	115.30 VOR	1124	1187
100Y	115.35 VOR	1124	1061
101x	115.40 VOR	1125	1188
101Y	115.45 VOR	1125	1062
102X	115.50 VOR	1126	1189
102Y	115.55 VOR	1126	1063
103x	115.60 VOR	1127	1190
103Y	115.65 VOR	1127	1064
104x	115.70 VOR	1128	1191
104Y	115.75 VOR	1128	1065
105X	115.80 VOR	1129	1192
105Y	115.85 VOR	1129	1066
106X	115.90 VOR	1130	1193
106Y	115.95 VOR	1130	1067
107x	116.00 VOR	1131	1194
107Y	116.05 VOR	1131	1068
108X	116.10 VOR	1132	1195
108Y	116.15 VOR	1132	1069
109X	116.20 VOR	1133	1196
109Y	116.25 VOR	1133	1070
110x	116.30 VOR	1134	1197
110Y	116.35 VOR	1134	1071
111x	116.40 VOR	1135	1198
111Y	116.45 VOR	1135	1072
112x	116.50 VOR	1136	1199
112Y	116.55 VOR	1136	1073
113x	116.60 VOR	1137	1200
113Y	116.65 VOR	1137	1074
114x	116.70 VOR	1138	1201
114Y	116.75 VOR	1138	1075

VOR-DME-TACAN CHANNEL FREQUENCIES AND PAIRING-Continued

Chan. No.	VHF Chan. Freq. MHz	DME-TACAN Interr. Freq. MHz	DME-TACAN Reply Freq. MHZ
115X	116.80 VOR	1139	1202
115Y	116.85 VOR	1139	1076
116X	116.90 VOR	1140	1203
116Y	116.95 VOR	1140	1077
117x	117.00 VOR	1141	1204
117Y	117.05 VOR	1141	1078
118X	117.10 VOR	1142	1205
118Y	117.15 VOR	1142	1079
119x	117.20 VOR	1143	1206
119Y	117.25 VOR	1143	1080
120X	117.30 VOR	1144	1207
120Y	117.35 VOR	1144	1081
121X	117.40 VOR	1145	1208
121Y	117.45 VOR	1145	1082
122x	117.50 VOR	1146	1209
122Y	117.55 VOR	1146	1083
123X	117.60 VOR	1147	1210
123Y	117.65 VOR	1147	1084
124X	117.70 VOR	1148	1211
124Y	117.75 VOR	1148	1085
125X	117.80 VOR	1149	1212
125Y	117.85 VOR	1149	1086
126X	117.90 VOR	1150	1213
126Y	117.95 VOR	1150	1087

APPENDIX 4. DEFINITIONS.

AGL	Above Ground Level
AIM	Airman's Information Manual
ATC	Air Traffic Control
CDI	Course Deviation Indicator
CW	Continuous Wave
dB	Decibels
dBi	Gain in decibels relative to an isotropic antenna
dBm	Decibels of power with respect to a milliwatt
dBW	Decibels of power with respect to a watt
dBW/m^2	Power density per square meter
DME	Distance Measuring Equipment
DSBDVOR	Double Sideband Ooppler Very High Frequency Omnidirectional Radio Range
D/U Ratio	Desired to Undesired Ratio
EIRP	Equivalent Isotropic Radiated Power
ESV	Expanded Service Volume
FAA	Federal Aviation Administration
FTE	Flight Technical Error
H	High Altitude Service Volume
HVORTAC	High Altitude Very High Frequency Omnidirectional Radio Range and Tactical Air Navigation
HZ	Hertz
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
kHz	Kilohertz
L	Low Altitude Service Volume
LDME	Low Altitude Distance Measuring Equipment
m	meter
MHZ	Megahertz
NAS	National Airspace System
NAVAIDS	Navigational Aids
nmi	Nautical Mile
NOTAM	Notice to Airman
OBS	Omni Bearing Selector
RF	Radio Frequency
RNAV	Area Navigation
RSS	Root-Sum-Square
SSV	Standard Service Volume

APPENDIX 4. DEFINITIONS (continued)

T	Terminal Service Volume
TACAN	Tactical Air Navigation
TVOR	Terminal Very High Frequency Omnidirectional Radio Range
UHF	Ultra High Frequency
VHF	Very High Frequency
VOR	Very High Frequency Omnidirectional Radio Range
VOR/DME	Very High Frequency Omnidirectional Radio Range/ Distance Measuring Equipment
VORTAC	Very High Frequency Omnidirectional Radio Range and Tactical Air Navigation
X Channel and Y Channel	Frequency pairing for Distance Measuring Equipment and Tactical Air Navigation