# ORDER

6740.6

U.S. NATIONAL AVIATION STANDARD FOR THE NDB/ADF SYSTEM

12/30/87

# DEPARTMENT OF TRANSPORTATION
## FEDERAL AVIATION ADMINISTRATION

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## FOREWORD

During the early 1960's, many thought that NDB's would disappear with the wide implementation of VOR/DME/TACAN. However, while the NDB has evolved from a primary to a secondary navigation aid, it has hardly disappeared. Quite to the contrary, it now outnumbers VOR stations by a factor of more than 2 to 1. No end of service is foreseen between now and the year 2000 because of the wide and increasing acceptance by aviation users and the lack of an acceptable replacement system.

The NDB/ADF System, like most aeronautical systems, will continue to evolve in response to user needs. The number of FAA NDB's will remain stable and future growth primarily will be non-Federal in nature. As the system evolves, proper operation and compatibility among elements of the system must be maintained. This order is intended to provide guidance in this endeavor.

Under the Federal Aviation Act of 1958, as amended, 49 USC Section 1301 et seq., the FAA is charged with providing 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 aircraft operating in a common civil/military National Airspace System.

T. Allan McArtor
Administrator

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# CHAPTER 1. GENERAL

1. PURPOSE. This order establishes the Nondirectional Beacon (NDB) Automatic Direction Finder (ADF) U.S. National Aviation Standard defining the performance required of the system and its components. This standard defines the application and performance characteristics as well as some operational limitations and restrictions for NDB and ADF equipment in the United States. For ground and airborne components, this material identifies signal, functional, and performance characteristics required to meet operational requirements and to provide compatibility between components of the system.

2. DISTRIBUTION. This order is distributed to branch level in the Offices of Flight Standards, Airworthiness, Aviation Policy and Plans, International Aviation, Europe, Africa, and Middle East Office, Systems Engineering Service, Program Engineering and Maintenance Service, Air Traffic Operations Service, and Air Traffic Plans and Requirements Service; division level in the Aviation Standards National Field Office; branch level in the regional Airway Facilities Divisions and the FAA Technical Center; and to the Airway Facilities Field and Sector Offices.

3. DEFINITIONS. Appendix 1, Definitions and Acronyms, contains the definitions and acronyms used in this order.

4. AUTHORITY TO CHANGE THIS ORDER. The Director, Systems Engineering Service, may issue changes to this order. The Administrator reserves the authority to approve changes which establish policy, delegate authority, or assign responsibility.

5. APPLICABILITY. The National standard applies to all NDB ground equipment and ADF airborne equipment used in the National Airspace System (NAS).

6. THE NDB/ADF SYSTEM CHARACTERISTICS.

a. The ADF component characteristics 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 4 as essential to prevent impairment of services to other NAS users.

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

c. Operators of airborne systems designed, installed, and operated in accordance with this order can expect to achieve the system performance which the order is designed to provide.

d. It is recognized that certain existing NDB equipment characteristics may not comply with all requirements of this order. Specific NDB equipment characteristics that are identified which deviate from the requirements of this order will be corrected or replaced as practical; but not later than 1 year from the date of this order unless a waiver is authorized by the cognizant regional office.

7.-19. RESERVED.

# CHAPTER 2. NDB/ADF SYSTEM

20. NDB/ADF SYSTEM DESCRIPTION. The NDB/ADF System is a short distance air navigation system. The ground component provides properly equipped aircraft with bearing and identification referenced to the selected ground component. 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. The NDB is an International Civil Aviation Organization standard navigation aid. The NDB/ADF System has been allocated radio spectrum in the aeronautical radionavigation service. The primary purpose of the NDB/ADF System is for navigation. While other services may be provided by the system, they are less important than the navigation information. The identification signal is an integral part of the navigation signal since, without the identification, the navigation information cannot be validated.

21. RATED COVERAGE VOLUME. Rated coverage is the volume of airspace around an NDB, within which the strength of the vertical field of the groundwave meets or exceeds the minimum field strength as specified in paragraph 63a.

22. EFFECTIVE COVERAGE VOLUME. Effective coverage is the volume of airspace around an NDB, within which bearings can be obtained with a total system accuracy of 10 degrees to the right or left of course. In general, a facility's effective coverage volume is smaller than the rated coverage volume.

23. OPERATIONAL SERVICE VOLUME. Operational coverage is the volume of airspace around an NDB which is advertised by the FAA as available for airborne use. The operational coverage shall not exceed the rated coverage or the effective coverage on any azimuth or at any elevation. NDB's are available for use within their operational service volumes. Outside this airspace reliable service may not be available.

24. STANDARD SERVICE VOLUMES. NDB's are classified according to their intended use. The ranges of NDB service volumes are shown in figure 2-1. The distances (radius) are the same at all altitudes.

FIGURE 2-1. NDB SERVICE VOLUME RANGES

| CLASS | DISTANCE (RADIUS) |
|---|---|
| COMLO | 15 nmi |
| MH | 25 nmi |
| H | 50 nmi |
| HH | 75 nmi |

NOTE: Service volume ranges of individual facilities may be less than that indicated. Restrictions to service volumes are first published in the Notice to Airmen (NOTAM) and then with the alphabetical listing of the navigation aid (NAVAID) in the Airport/Facility Directory.

25. SERVICE LIMITATIONS DUE TO IONOSPHERIC REFLECTIONS. Low frequency (LF) radiation propagates both as a groundwave and as a skywave. The groundwave is used for navigation. The skywave is generally unreliable for navigational use due to bearing inaccuracies. A given NDB's groundwave is sometimes simultaneously receivable with a skywave which can cause interference and degrade, or make unusable, the navigation signal. This interference can occur in two ways called "night effect" and "skywave interference."

a. Skywave interference is a situation in which any skywave is large enough to interfere with a given NDB's groundwave. At night, the reflective properties of the ionosphere increase and the skywave can be substantially larger than during the day. When a skywave is large enough to interfere with a groundwave, this situation is aptly called "skywave interference." When the skywave of a facility interferes with its own groundwave, this type of skywave interference is called "night effect." Skywave interference is subject to diurnal, seasonal, and irregular changing properties of the ionosphere. It is not possible to predict precisely when and where skywave interference will occur or the severity of its effect on the NDB/ADF System operations. Skywave interference manifests itself in one or more of the following ways: erroneous bearings, "hunting" of the ADF needle, garbling of the identification signal, and/or the presence of more than one identification signal. Skywave interference is most likely to occur from shortly before sundown until shortly after sunrise.

b. Night effect is a situation in which the groundwave and skywave of a given NDB are simultaneously receivable at large distances from the NDB. When this occurs, it is unlikely that reliable bearings can be obtained if the groundwave does not exceed the skywave by at least 10 decibels (dB). In most cases, this is not an operational concern because NDB's are generally used at short ranges as terminal or transition facilities. At short range night effect is not a problem. At very long ranges, however, night effect can present bearing accuracy problems. Therefore, the maximum operational service volume shall not extend beyond the range where the groundwave will exceed the skywave by 10 dB. The maximum allowable range is dependent on the NDB frequency and on ground conductivity. However, it is independent of NDB power since increasing the transmitter power increases both the groundwave and the skywave.

26. RADIOFREQUENCY (RF) ALLOCATIONS. The NDB/ADF System is allocated radio spectrum in the aeronautical radionavigation service. Specific frequencies allocated for NDB/ADF use are listed in Appendix 3, NDB Frequencies.

27. FREQUENCY CONGESTION.

a. Background. During the 1975-1985 time period, there was a dramatic growth in the number of NDB's. Of the more than 2,000 NDB's in this country, over two-thirds are non-Federal ground stations. Growth in the number of non-Federal systems has been many times larger than growth in the number of Federal systems. This trend is expected to continue. Eventually, the NDB/ADF System will be replaced; however, at this time the replacement system has not been identified. No end of service can be foreseen in this century because of the wide and increasing user acceptance and the lack of an acceptable, proven replacement system.

b. Congestion. NDB frequency congestion has been a longstanding problem both in this country and in Europe. In the United States, congestion is most severe in California, along the East Coast, and along the Gulf of Mexico. In these and other areas, frequency congestion makes it difficult or impossible to make frequency assignments for new NDB's. In an effort to alleviate this problem, the FAA requested that the Radio Technical Commission for Aeronautics (RTCA) form a special committee to develop and recommend improved ADF standards. This effort was completed and the resulting standards were published in 1982. In the long term, the tighter selectivity of such avionics will provide some relief to the congestion problem. In the near term, however, frequency congestion will continue to constrain the number of new NDB assignments which can be made.

28. STATION PASSAGE. The sharp reduction in signal strength directly over the station known as the cone of confusion or cone of silence shall not exceed a total of 40 degrees (i.e., ±20 degrees as measured from the vertical above the NDB).

29. STATION IDENTIFICATION CODE CHARACTERISTICS. Each NDB shall transmit an identification signal in International Morse Code at least three times each 30 seconds, equally spaced within that interval. Voice identification shall not be permitted. The characteristics of the identification code shall be as follows:

a. The dots shall be a time duration of 0.1 second to 0.125 second and the dashes shall be three times the duration of a dot.

b. The time between dots and dashes of a code letter shall be the length of a dot.

c. The time between consecutive letters of the identification code group shall be the length of three (3) dots.

30. IDENTIFICATION CODE. The NDB identification code shall be as follows:

a. Standard Identification Code. With the exception of the two cases outlined in subparagraphs b and c, all NDB's shall transmit a three-letter identification code. This code shall be transmitted at intervals equal to sixty-four (64) dot lengths.

b. Compass Locator (COMLO). COMLO's shall transmit a two-letter identification code derived from the identification code of the instrument landing system (ILS) with which it is associated. The identification code shall be transmitted at intervals equal to forty-eight (48) dot lengths.

c. NDB's That Are Not Part of the NAS. With NDB's that are not a part of the NAS, it is permissible to add one digit to the standard three-letter identification code. This four-character code (three letters, one number) shall be transmitted at intervals equal to eighty (80) dot lengths.

d. Code Suppression. The NDB identification code shall not be suppressed during voice transmissions.

e. Absence of Identification. The absence of an identification code shall serve as an indication that the NDB is unusable or out of service.

31. STATION VOICE TRANSMISSIONS. The NDB can be used as an outlet for automated weather observing system and other weather system broadcasts until an alternate method of disseminating this information becomes available. However, the primary purpose of NDB's is to provide navigational aid and, therefore, NDB's should not be retained solely to satisfy voice broadcast requirements. The quality of voice transmission from an NDB can be a problem because of antenna bandwidth limitations and susceptibility to noise from manmade and natural sources. When installed, NDB voice coverage will be usable to at least two-thirds of the rated service volume.

32. AIRBORNE COMPONENTS. Airborne components of the system consist of ADF equipment which conforms to the requirements of chapter 4 of this order.

33. NDB/ADF-BEARING ACCURACY. The basic purpose of an NDB is to allow an ADF-equipped aircraft to fly from point A to point B and to stay within a defined airspace in the process. For terminal and transition NDB's, this airspace is the obstacle clearance zone. This zone is based on NDB- and ADF-bearing accuracy. The total system accuracy is approximately ±10 degrees. (See appendix 2).

34. USE OF OTHER THAN NDB GROUND STATIONS. In addition to NDB's, ADF receivers can also receive and process signals from amplitude modulation (AM) broadcast stations, maritime radio beacons, and several other types of stations. Pilots have used such stations as aids during a visual flight rules (VFR) flight for a long time. However, these stations are neither flight inspected nor a part of the NAS. A VFR flight using such ground stations as a sole means of navigation is uncertified; pilots fly at their own risk. An IFR flight using such ground stations shall not be permitted.

35. EN ROUTE USE OF NDB'S. Except as noted in subparagraphs a, b, and c, NDB's will not be used as en route navigation aids.

a. NDB's may be used as en route aids in Alaska when other NAVAID's are unavailable. Airspace protection shall be increased to compensate for the accuracy limitations in such cases.

b. NDB's may be used on a temporary basis as substitute NAVAID's to support an air route when a Very High Frequency Omnidirectional Radio Range is out of service.

c. NDB's may be used together with Distance Measuring Equipments for the air route structure system. This may include terminal approaches in Alaska.

36. USE OF AN NDB AS A COMLO. When an NDB is colocated with a marker beacon and used in conjunction with an ILS, it is commonly referred to as a COMLO. Where a COMLO is used as a supplement to an ILS, it should be located at the outer marker beacon site. Due to the frequency congestion in the LF and medium frequency bands, use of a COMLO at the middle marker, in addition to one at the outer marker, is not recommended.

37. NONPRECISION APPROACH, NDB LOCATION. Where an NDB serves as a final approach fix in the absence of an ILS, the NDB should be located at a site equivalent to an outer marker site. Site selection shall take into account the appropriate obstacle clearance requirements.

38. FLAGS AND WARNINGS. Unlike most navigation aids, the NDB/ADF System generally does not provide a warning or a flag if the received signal is deficient in level or quality. The pilot must determine whether the received signal is reliable by listening to the identification and observing the needle movements. The reception of two different identification signals simultaneously or the lack of any identification means that the ADF bearing is unreliable. Similarly, unusual needle variations are also an indication of unreliable bearing. Since the NDB/ADF System provides no other warning or flag, the pilot must monitor both station identification and ADF needle variation while making use of the NDB/ADF System.

39. PILOT MONITORING DURING USE. ADF navigation requires that the pilot monitor the audio output of the ADF receiver (i.e., the NDB identification and all other received signals including background noise) and the needle action of the bearing indicator. Whenever there is a question as to the reliability of the NDB signal, the pilot should switch to another form of navigation. There are some potential problems of which the pilot should be aware such as, RF interference from other NDB's, skywave interference (paragraph 25), and adverse weather and precipitation static (p-static). Adverse weather and p-static can affect the reception of NDB signals. This is caused primarily by thunderstorms; frictional charging from neutral snow, ice, dust, or particles in the atmosphere; and engine charging. The duration of these effects can be momentary or they can last for the duration of the flight.

40.-59. RESERVED.

# CHAPTER 3. OPERATIONAL CHARACTERISTICS OF NDB GROUND STATIONS

60. INTRODUCTION. This chapter identifies signal characteristics and tolerances of the NDB ground station. This chapter represents performance that shall be provided throughout the operational service volume.

61. EMISSION CHARACTERISTICS. The mean power of any unwanted emissions supplied to the antenna transmission line, as compared with the mean power of the fundamental, shall be in accordance with the following:

a. On any frequency removed from the assigned frequency by more than 100 percent, up to and including 150 percent of the authorized bandwidth, at least 25 dB attenuation.

b. On any frequency removed from the assigned frequency by more than 150 percent, and up to and including 300 percent of the authorized bandwidth, at least 35 dB attenuation.

c. On any frequency removed from the assigned frequency by more than 300 percent of the authorized bandwidth, for transmitters with mean power of 5 kilowatts or greater, at least 80 dB attenuation; and for transmitters with mean power less than 5 kilowatts, at least 43 plus 10 $\log_{10}$ (mean power of the fundamental in watts) dB attenuation; i.e., 50 microwatts absolute level.

62. FREQUENCY TOLERANCE. The frequency tolerance of the NDB carrier shall comply with the following:

a. The RF carrier of all stations shall be within 0.01 percent of the assigned frequency.

b. With dual carrier NDB's, the requirements of this paragraph refer to the continuous carrier as opposed to the keyed carrier that provides the station identification.

63. FIELD STRENGTH.

a. Minimum Field Strength. Throughout the operational coverage volume, the minimum field strength shall not be less than 50 microvolts per meter (uv/m), which is the minimum value allowed at the alarm point. This is equivalent to 70 uv/m at peak power. (50 uv/m = 34 dBuv/m; 70 uv/m = 37 dBuv/m). dBuv/m are dB's with respect to one microvolt.

b. Flight Inspection Guidance. Minimum field strength settings will be based on flight inspection guidance. Correlation of flight inspection results will be made with the measurements of antenna current and impedance made by the maintenance technician during routine checks of the facility. Also, the selection of airborne locations and times that the field strength is measured is important in order to avoid abnormal results for the locality concerned; locations on air routes in the area around the beacon are operationally most significant.

64. POWER LIMITATIONS. NDB radiated power shall not exceed by more than 2 dB that power which is necessary to provide a field strength of 70 uv/m, at peak power, throughout the operational service volume (see paragraph 63a).

65. SINGLE CARRIER NDB'S. A "single carrier" NDB is a double sideband system. It radiates a continuous wave (CW) carrier on the assigned frequency. The identification signal is provided by keyed AM of the carrier frequency. The emission designator is 2K04A2A for a single carrier NDB with 1020 Hz modulation. The emission designator is 800HA2A for a single carrier NDB with 400 Hz modulation.

66. DUAL CARRIER NDB'S. A "dual carrier" NDB is a single sideband system (full carrier). It radiates a CW carrier on the assigned frequency. The identification signal is provided by on/off keying of a second carrier. This second carrier is transmitted at a frequency equal to the carrier frequency plus the frequency of the modulation tone. For example, at a carrier frequency of 200 kHz, the second carrier would be approximately 200.4 kHz (400 Hz identification) or 201.02 kHz (1020 Hz identification). The emission designator is 1K12XXA for a dual carrier NDB with 1020 Hz modulation. The emission designator is 500HXXA for a dual carrier NDB with 400 Hz modulation.

67. IDENTIFICATION CODE MODULATIONS. The characteristics of the identification code shall conform to the following:

a. Modulation Frequency. The modulation frequency shall be either 400 $\pm$25 Hz or 1020 $\pm$50 Hz.

b. Depth of Modulation. The depth of modulation of the carrier of an NDB should be as great as possible. Ninety-five percent modulation, as measured at the transmitter, should be a goal. This goal is dependent upon the antenna systems frequency bandwidth, frequency of the modulation signal, and the condition of the antenna. With these constraints considered, the modulation level should be as great as practical without distorting the navigation or identification signal.

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

69. GROUNDING. Frequency planning is done on the assumption that the field strength and the equivalent isotropic radiated power (EIRP) will be maintained within the proper tolerances. If the grounding resistance is high (due to insufficient grounding), the radiation efficiency will be lower and the EIRP will have an increased sensitivity to changes in climatic conditions and other factors. Consequently, in all cases, the grounding system should be the best possible, taking into account local circumstances.

70.-89. RESERVED.

# CHAPTER 4. OPERATIONAL CHARACTERISTICS FOR ADF COMPONENTS

90. INTRODUCTION. This chapter specifies the functional capability and performance characteristics required of the ADF component. The term "component" describes the complete aircraft installation. This includes the antenna and its transmission line, the receiver, electrical power source(s), identification signal reproduction devices, and the bearing indicator. Airborne components used in IFR operations must meet all Federal Aviation Regulation requirements. For non-IFR operations, the requirements are limited to those of paragraphs 91 through 96. Components should be capable of performing as specified throughout the operational service volume. The applicable performance requirements should be met when the ground stations are operating in accordance with this order.

91. RECEIVER SENSITIVITY. Based on the field strength specified in paragraph 63, the airborne component shall provide the sensitivity necessary to display the bearing information with the accuracy specified. Clear and distinct reproduction of the identification signal shall be provided in the mode used for navigation. Greater sensitivity is not recommended. Excessive sensitivity makes the receiver unnecessarily susceptible to electromagnetic interference. It also encourages use of the NDB's beyond their operational service volume, where the airspace is not flight inspected and where frequency protection is not guaranteed.

92. RECEIVER SELECTIVITY. The selectivity of the airborne component shall be sufficient to assure adequate rejection of undesired signals. Currently, the frequency assignment process provides protection to airborne components that meet or exceed the selectivity of figure 4-1. Future airborne components shall be designed to meet the improved selectivity of figure 4-2.

FIGURE 4-1. CURRENT ADF RECEIVER SELECTIVITY

| Frequency Difference | One-Signal Selectivity | Two-Signal Selectivity |
|---|---|---|
| 0 kHz | 0 dB | +12 dB |
| ±1 kHz | 0 dB | +11 dB |
| ±2 kHz | - 3 dB | + 7 dB |
| ±3 kHz | -15 dB | - 5 dB |
| ±4 kHz | -29 dB | -19 dB |
| ±5 kHz | -42 dB | -32 dB |
| ±6 kHz | Less than -48 dB | Less than -38 dB |

NOTE: Two-signal selectivity defines the minimum desired to undesired signal ratio (D/U ratio) for which an ADF shall be able to provide satisfactory navigation information.

FIGURE 4-2. FUTURE ADF RECEIVER SELECTIVITY

| Frequency Difference | One-Signal Selectivity | Two-Signal Selectivity |
|---|---|---|
| 0 kHz | 0 dB | +12 dB |
| ±1 kHz | 0 dB | +10 dB |
| ±1.5 kHz | -6 dB | + 4 dB |
| ±2 kHz | -12 dB | - 2 dB |
| ±3 kHz | -27 dB | -17 dB |
| ±4 kHz | -42 dB | -32 dB |
| ±5 kHz | -57 dB | -47 dB |
| ±6 kHz | -72 dB | -62 dB |
| ±7 kHz | Less Than -80 dB | Less Than -70 dB |

93. STATION IDENTIFICATION. In the navigation mode, the airborne component shall provide the pilot with positive identification of the ground component.

94. BEARING INFORMATION. The airborne component shall display, in an unambiguous manner, the direction of arrival of the radio signal to which the receiver is tuned.

95. BEARING ACCURACY. The indicated bearing shall not differ from the direction of arrival of the radio signal to which the airborne component is tuned by more than 3 degrees. This shall apply at all bearing positions for tuned frequencies in the 190-535 kHz range. (Also see appendix 2).

96. RADIATION. Radiation from airborne components shall not result in degradation of operational use to other system users.

97. DEVELOPMENT OF FLAG AND WARNING FUNCTIONS. With today's technology, flag and warning functions can be added easily to the ADF receiver. Several receiver types have been marketed with this capability.

## APPENDIX 1. DEFINITIONS AND ACRONYMS

| | |
|---|---|
| ADF | Automatic Direction Finder |
| AGL | Above Ground Level |
| AM | Amplitude Modulation |
| AWOS | Automated Weather Observing System |
| COMLO | Compass Locator |
| CW | Continuous Wave |
| dB | Decibels |
| dBuv/m | Decibels with respect to one microvolt |
| DME | Distance Measuring Equipment |
| D/U Ratio | Desired to Undesired Signal Ratio |
| EIRP | Equivalent Isotropic Radiated Power |
| FAA | Federal Aviation Administration |
| FM | Frequency Modulation |
| ft | Feet |
| Hz | Hertz |
| ICAO | International Civil Aviation Organization |
| IFR | Instrument Flight Rules |
| ILS | Instrument Landing System |
| kHz | Kilohertz |
| km | Kilometer |
| LF | Low Frequency |
| LOM | Locator, Outer Marker |
| LMM | Locator, Middle Marker |

| | |
|---|---|
| m | Meter |
| MF | Medium Frequency |
| MSL | Mean Sea Level |
| NAS | National Airspace System |
| NAVAID | Navigation Aid |
| NDB | Nondirectional Beacon |
| nmi | Nautical Mile |
| NOTAM | Notice to Airmen |
| p-static | Precipitation Static |
| RF | Radiofrequency |
| RSS | Root-Sum-Square |
| (S+N/N) | Signal Plus Noise-to-Noise Ratio |
| TACAN | Tactical Air Navigation |
| TIS | Traveler's Information Service |
| uv/m | Microvolt Per Meter |
| VFR | Visual Flight Rules |
| VOR | Very High Frequency Omnidirectional Radio Range |

# APPENDIX 2. SYSTEM BEARING ACCURACY

1. SYSTEM ACCURACY. The accuracies described and quantified in paragraph 2 represent the normal error budget for an NDB/ADF System that includes basic avionics with analog indicators, a typical NDB ground station and an environment that does not include excessive environmental errors. Margin for pilot-induced flight technical error is also included.

2. COMBINED ERROR COMPONENT DEFINITION. The error terms are defined as follows:

a. Environmental Error (Ee). Environmental error is the error attributable to such factors as irregular terrain (mountain ridges, sharp discontinuities in ground conductivity, etc.) and atmospheric noise.

b. ADF Receiver Error (Ea). ADF receiver error is that error attributable to the inability of the airborne equipment to determine correctly the direction of signal arrival relative to the aircraft heading. This element embraces all factors in the ADF receiver which introduce errors in the information presented to the pilot.

c. Instrumentation Error (Ei). Instrumentation error is that error attributable to the inability of the airborne equipment to display correctly the bearing as determined by the ADF receiver.

d. Quadrantal Error (Eq). Quadrantal error is the angular error of a measured bearing caused by disturbances due to the characteristics of the aircraft.

e. Tilt Error (Et). Tilt error is the error which occurs as a function of the angle that an aircraft is banked during flight.

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

g. Combined Error (Es). Combined error is the total system error. It takes into account not only the environmental error but also all of the various types of errors attributable to the airborne equipment, the flight technical error, and the quadrantal error.

3. AIRBORNE BEARING ERROR DEFINITION. The term "airborne bearing error" will be considered to include airborne component error, instrumentation error, and quadrantal error.

4. ERROR COMBINATION. Based on the assumptions that the variable errors from the various sources are normally distributed and independent, they may be combined in Root-Sum-Squares (RSS) fashion. Thus, the static error standard deviations obtained from the various contributing sources may be combined geometrically rather than arithmetically by taking the square root of the sum of their squares.

a. Environmental Error (Ee). This component of error is basically uncontrollable. The FAA's only recourse is to flight check the facilities and to restrict them by NOTAM in any airspace where the combined error is unacceptable. If the combined error is unacceptable over an appreciable portion of the service volume, it may be appropriate not to commission the facility.

b. ADF Receiver Error (Ea). This component is estimated to be ±3 degrees.

c. Instrumentation Error (Ei). This component is estimated to be ±2 degrees.

d. Quadrantal Error (Eq). After compensation, this component is estimated to be ±5 degrees.

e. Tilt Error (Et). Tilt error is a function of the banking angle of the aircraft. Tilt error is not operationally significant.

f. Flight Technical Error (Ef). This component is estimated to be ±3 degrees. Although this error may not be completely independent of other errors, independence is assumed in this analysis.

g. Combined Error Determination. Figure 1 presents the RSS method for combining the previously mentioned errors. Based on this determination, the "variable" Environmental Error is fixed to a limit of ±7.28 degrees by the use of the other error values as fixed maximum limits.

FIGURE 1. COMBINED ERROR DETERMINATION

| | |
|---|---|
| Environmental Error (Ee): | Variable |
| ADF Receiver Error (Ea): | ±3 Degrees |
| Instrumentation Error (Ei): | ±2 Degrees |
| Quadrantal Error (Eq): | ±5 Degrees |
| Flight Technical Error (Ef): | ±3 Degrees |

Combined Error:

$$= (Ee^2 + Ea^2 + Ei^2 + Eq^2 + Ef^2)^{1/2}$$
$$= (Ee^2 + 9 + 4 + 25 + 9)^{1/2}$$
$$= (Ee^2 + 47)^{1/2}$$

Combined error shall be within ± 10 degrees.

5. <u>LIMITATIONS</u>. The accuracies described in this appendix are applicable to the 190-535 kHz frequency range. The frequencies 435 kHz to 510 kHz are not available for NDB assignment.

# APPENDIX 3. NDB FREQUENCIES

1. AERONAUTICAL RADIONAVIGATION. In the United States, NDB's operate in a band of the RF spectrum allocated, in parts, to the aeronautical radionavigation service. The FAA, in accordance with National and International agreements, allocates frequencies for NDB use from this band. These restrictions, as listed under Remarks, and the frequency band they apply to are presented as follows:

| Frequency (kHz) | Remarks |
|---|---|
| 190-200 | No voice transmissions permitted. |
| 200-275 | Voice transmissions may be permitted. |
| 275-285 | Maritime radionavigation is allowed on a secondary basis only. Voice transmissions may be permitted. |
| 285-325 | Aeronautical radionavigation allowed on a secondary basis only. No voice transmissions permitted. |
| 325-335 | Maritime radionavigation allowed on a secondary basis. Voice transmissions may be permitted. |
| 335-415 | Voice transmissions may be permitted. |
| 415-435 | Shared with the Maritime Mobile Service. No voice transmissions permitted. |
| 435-495 | Not available for NDB use. |
| 495-505 | Not available for NDB use. International Distress Frequency band. |
| 505-510 | Not available for NDB use. |
| 510-525 | Shared with Maritime Mobile Service. No voice transmissions permitted. |
| 525-535 | Shared with the Traveler's Information Service, 530 kHz. No voice transmissions permitted. |

NOTE: All voice transmissions are on a secondary basis; i.e., navigation takes precedence.