UNCLASSIFIED

NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

TECHNICAL MEMORANDUM

REPORT NO: NAWCADPAX--98-156-TM

COPY NO. _________

HIGH INTENSITY RADIATED FIELD EXTERNAL ENVIRONMENTS FOR CIVIL AIRCRAFT OPERATING IN THE UNITED STATES OF AMERICA

Approved for public release; distribution is unlimited.

UNCLASSIFIED

DEPARTMENT OF THE NAVY
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

NAWCADPAX--98-156-TM

PREPARED BY:

____
FRED HEATHER / DATE

RELEASED BY:

____
JOHN L. DAWSON / DATE
Head, Electromagnetic Environmental Effects Division
Naval Air Warfare Center Aircraft Division

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(LEAVE BLANK)*	2. REPORT DATE December 1998	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE High Intensity Radiated Field External Environments for Civil Aircraft Operating in the United States of America	5. FUNDING NUMBERS
6. AUTHOR(S) Frederick W. Heather	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Air Warfare Center Aircraft Division 22347 Cedar Point Road Unit #6 Patuxent River, Maryland 20670-1161	8. PERFORMING ORGANIZATION REPORT NUMBER NAWCADPAX--98-156-TM
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Federal Aviation Administration William J. Hughes Technical Center Flight Safety Research Section, AAR-421 Atlantic City International Airport, NJ 08405	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The William J. Hughes Technical Center COTR is Peter Saraceni

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

NAWCAD Patuxent River, Maryland, was tasked by the FAA to determine the High Intensity Radiated Field (HIRF) levels for civil aircraft operating in the U.S. The electromagnetic field survey will apply to civil aircraft seeking FAA certification under Federal Aviation Regulations (FAR's) Parts 23, 25, 27, and 29. The HIRF survey determined the Rotorcraft Severe, Fixed Wing Severe, Certification, and Normal Environments that civil aircraft may be exposed to while operating in the continental U.S. and its territories. The HIRF survey was accomplished by accessing EME data bases, technical manuals, and phone contact with emitter operators to determine the HIRF drivers, analyze the severity, and provide a U.S. composite environment. These HIRF environments were subsequently provided to the EEHWG for harmonization with the European HIRF environment. The harmonized environment is known as the International HIRF environments that are planned to be used in the FAR advisory material and other supporting documents. The International HIRF environments are also shown in this report for completeness.

14. SUBJECT TERMS HIRF, EMC, Aircraft, Rotorcraft, Environments	15. NUMBER OF PAGES 139
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unclassified

CONTENTS

Page No.

List of Tables

Page No.

List of Figures

Page No.

1. INTRODUCTION

1.1 TASKING

NAWCAD Patuxent River, Maryland, was tasked by the FAA through reference 1 to determine the High Intensity Radiated Field (HIRF) levels for civil aircraft operating in the U.S. The electromagnetic field survey will apply to civil aircraft seeking FAA certification under Federal Aviation Regulations (FAR's) Parts 23, 25, 27, and 29.

1.2 PURPOSE

The purpose of the HIRF survey was to determine the Rotorcraft Severe, Fixed Wing Severe, Certification, and Normal Environments that civil aircraft may be exposed to while operating in the continental U.S. and its territories.

1.3 SCOPE

The HIRF survey was accomplished by accessing EME data bases, technical manuals, and phone contact with emitter operators to determine the HIRF drivers, analyze the severity, and provide a U.S. composite environment.

1.4 RESULTS

Identified in this report are the Rotorcraft Severe, Fixed Wing Severe, Certification, and Normal Environments that aircraft may see while operating in the continental U.S. and its territories. For each environment, the driving emitters are identified, and the emitter data used to predict the HIRF field levels are provided. Also detailed are the analysis methods used to calculate the fields. These HIRF environments were subsequently provided to the Electromagnetic Effects Harmonization Working Group (EEHWG) for harmonization with the European HIRF environment. The harmonized environment is known as the International HIRF environments that will be used in the advisory material and other supporting documents. The International HIRF environments are also shown in this report for completeness.

THIS PAGE INTENTIONALLY LEFT BLANK

2. BACKGROUND

2.1 SAE AND EUROCAE EFFORTS

On 10 February 1988 (reference 2), the Society of Automotive Engineering (SAE) was requested to develop guidance for designers aircraft, aircraft engine, and electronics components on how to maximize protection of airborne avionics and electronic systems from the adverse effects of high energy RF fields through which aircraft may fly. The SAE created under the AE4 EMC Committee the AE4R Radiated Environments Subcommittee. The AE4R was organized into three panels. Panel 1 was set up to analyze and validate the HIRF environment that the FAA had developed. Panel 2 was set up to write the high level advisory material that would support the FAA's HIRF rule making efforts. Panel 3 was set up to write an SAE Aerospace Recommend Practices (ARP) document that provided design and certification methods, later known as the HIRF User's Guide/Manual.

Concurrently with the FAA efforts, the JAA in Europe had gone to the European Organization for Civil Aviation Equipment (EUROCAE) with a similar request. EUROCAE set up a similar organization under a group called Working Group 33, HIRF. In an early effort to get international agreement on the technical efforts, the EUROCAE members participated in numerous AE4 meetings held in the U.S.

The Panel 1 effort was the forerunner of the HIRF environment survey of this report. The FAA had contracted the DOD Electromagnetic Compatibility Analysis Center (ECAC) in 1987 to research and define the U.S. high energy RF field environmental envelope to be used for type certification of aircraft and aircraft engines and for the technical standards orders (TSO) authorization of electronic equipment. Panel 1 reviewed the environment data, methods for calculating field strength, and assumptions. Panel 1 published several iterations of the HIRF environment and documented some of their findings in the SAE AE4R meeting minutes. The SAE AE4R Panel 1 effort ended with the freezing of the Part 25 Severe Certification and Normal Environments and their corresponding assumptions. The frozen HIRF environments and assumptions were incorporated into a final draft of the advisory circular in 1992. At this point in time, the FAA and JAA had decided that the HIRF rule needed further international harmonization before it could be used in the FAA rule making process. The FAA tasked the Aviation Rulemaking Advisory Committee (ARAC), at the end of 1992, to harmonize the rule and make the necessary adjustment to the supporting documents.

The only activity that was on going after this point in the SAE AE4R Panel 1 was a small subpanel that was trying to define the rotorcraft environment. The SAE AE4R Panel 1 Rotorcraft Subpanel and their corresponding group in EUROCAE WG-33 continued to work together to define the assumptions, review emitter data, and propose HIRF environments for rotorcraft. These groups worked closely with the ARAC group to provide a harmonized environment that was completed in June 1997.

2.2 EEHWG EFFORTS

The EEHWG was established in 1993 by the ARAC Transport Airplane and Engine Subcommittee (TAES) in response to the public announcement by the FAA in the Federal Register, Vol. 57, No. 239, December 1992. The EEHWG was chartered with making recommendation to the TAES concerning the FAA disposition of the HIRF and Lightning requirements. The HIRF task involved the development of new requirements for aircraft exposed to HIRF as related to FAR Parts 23.1317, 25.1317, 27.1317, 29.1317, 33, and 35, as appropriate. This task supplemented the efforts by RTCA, SAE, EUROCAE, and FAA/JAA during the period of 1987 to 1992. The EEHWG took the reports prepared by SAE and EUROCAE and converted them into a harmonized Advisory Circular/Advisory Material Joint (AC/AMJ 20.1317) and User's Manual/User's Guide. The EEHWG also took the FAA Notice of Proposed Rule Making (NPRM) and the Joint Aviation Authority (JAA) Notice of Proposed Amendment (NPA) HIRF materials and converted them into a harmonized NPRM/NPA document.

The EEHWG need to create harmonized NPRN/NPA documents for each part of the FAR, drove a need for expanding the scope of the HIRF environments from just Part 25 to Parts 23, 25, 27, and 29. The FAA had tasked NAWCAD in 1994 to conduct this HIRF Electromagnetic Field Survey study which complemented the efforts of the EEHWG and the SAE AE4R Rotorcraft Subcommittee. The frozen environment needed to be updated to include Part 23 commuter and general aviation airplanes and Parts 27 and 29 for rotorcraft. The assumptions for the various types of fixed wing aircraft and rotorcraft had to be adjusted for the inclusion of VFR's and the corresponding flight envelope of the aircraft (i.e., hovering and vertical landing/takeoff).

The EEHWG concentrated all its effort on harmonizing the various documents. The environments remained frozen up until June 1997. The EEHWG did evaluate the unique area of reducing the HIRF levels by considering probability of encounter for aircraft operating near land-based and ship-based HIRF emitters. The FAA contracted the support of Electromagnetics Applications Inc. (EMA) to analyze this concept and conduct statistical studies for land-based emitters. The results are published in reference 3. It was the conclusion of the EEHWG that probability of encounter could not be used to predict the HIRF environments for land-based emitters. Pat Scott of Honeywell was tasked by the EEHWG to analyze the ship-based emitters. The EEHWG reviewed his study (reference 4) and made changes to the assumptions that resulted in the ship to aircraft separation changing from 300 to 500 ft. At the meeting in Bridgeport, Connecticut, the FAA/JAA proposed the final International HIRF environments and assumption. The International HIRF environment ended up with following environments:

- Rotorcraft Severe Environment.
- Fixed Wing Aircraft Severe HIRF Environment.
- Aircraft Certification HIRF Environment.
- Aircraft Normal HIRF Environment.

These HIRF environments and assumptions were incorporated into the joint NPRN/NPA and AC/AMJ material and distributed at the November 1997 meeting of EEHWG.

2.3 RELATED VALIDATIONS

Early in the efforts of the SAE, there were requests for flight validation of some of the levels being predicted. To this end, the FAA conducted several studies to investigate the phenomena and document the exposure seen. The following three studies were felt by the SAE AE4R to validate the levels contained in the HIRF environments.

2.3.1 OHIO UNIVERSITY FLIGHTS

The FAA Technical Center contracted Ohio University Avionics Engineering Center to provide limited measurements of the field strength to be encountered by aircraft flying near certain specified transmitters. For each transmitter to be measured, the ECAC was tasked to estimate independently the field strength at a point on the flight test profile. Ohio University then flew test flights in DC-3 aircraft equipped with RF field strength measurement equipment. The four sites measured in 1988 were:

- 100 kHz: Loran-C, Carolina Beach, North Carolina.
- 15.195 and 11.939 MHz: Voice of America, HF Broadcast, Greenville, North Carolina.
- 21.5 MHz: Over-the-Horizon Radar (OTH-B), Moscow, Maine.
- 3 GHz: TPS-75 Radar, Baltimore, Maryland.

It was concluded from the study that HIRF levels do exist and modeling techniques should continue to be used to estimate the HIRF levels.

2.3.2 NASA FLIGHTS

NASA, under the fly-by-light, powered-by-wire program, flew a 757 near several sites to compare modeling and flight test results. No external field measurements were made. The cockpit and EE bays were instrumented for field measurements. The data collected for the cockpit area agreed with the modeling done using finite difference time domain based simulation software. Descriptions of the flight test efforts are provided in references 5, 6 and 7.

2.3.3 FAA TECHNICAL CENTER FLIGHTS

The FAA Technical Center arranged to conduct several flight tests with their S-76 helicopter. The purpose of the flights was to evaluate the practicality of performing aircraft level HIRF tests, determine the effects of HIRF on a specific rotorcraft with the potential to obtain information on rotorcraft in general, and evaluate the effects of exposure to “real world” HIRF emitters. The results of the flight tests are detailed in references 8, 9, and 10.

THIS PAGE INTENTIONALLY LEFT BLANK

3. ASSUMPTIONS

The EME exists due to the manmade transmissions of electrical energy into free space. This energy is radiated from radar, radio, television, and other sources. The transmitters are ground-based, ship-based, or airborne.

In calculating the environment, numerous assumptions were made. Most are documented in the NPRN/NPA or AC/AMJ. The guideline used early in the process contains some basic assumptions. Finally, there are some assumptions that are considered common or ordinary. This section will try to detail all possible assumptions that were used in the development of the U.S. HIRF environments.

3.1 NPRN/NPA ASSUMPTIONS

The assumptions from the NPRN/NPA and AC/AMJ are reprinted in appendix A. The environment was divided into 17 frequency bands. For each band, table 1 summarizes the assumptions detailed in appendix A (direct and slant illumination are defined on pages 30-31, paragraphs 4.4.4 and 4.4.5 respectively).

TABLE 1
NPRN/NPA ASSUMPTIONS SUMMARY

Source	U.S. Rotorcraft Severe Distance (ft)	U.S. Fixed Wing Severe Distance (ft)	U.S. (All Aircraft) Certification Distance (ft)	U.S. (All Aircraft) Normal Distance (ft)
Airport/Heliport/Off Shore Platforms				
Fixed:				
Air route/Airport surveillance radar	300 slant	500 slant	500 slant	500 slant
All other	100 direct	250 slant < 5 miles	250 slant < 5 miles	250 slant < 5 miles
Mobile:				
Aircraft’s weather radar	150 direct	150 direct	150 direct	250 direct
All others	50 direct	50 direct	50 direct	50 direct
Non-Airport/Heliport/Off Shore Platforms				
HIRF Special Use Airspace (SUA’s)	Edge of SUA	Edge of SUA	Edge of SUA	Edge of SUA
All others (radial from facility)				
>0-3 nmi	100 direct	500 slant	500 slant	500 slant
3-5 nmi	100 direct	500 slant	1000 slant	1000 slant
5-10 nmi	100 direct	500 slant	1000 slant	1500 slant
10-25 nmi	100 direct	500 slant	1000 slant	2500 slant
>25 nmi	100 direct	500 slant	1000 slant	1000 slant
Ship-Based Transmitters				
All Ships	500 direct	500 slant	1000 slant	not applicable
Air to Air				
Interceptor	not applicable	500 direct	500 direct	not applicable
All others	not applicable	100 direct	100 direct	not applicable

3.1.1 OTHER ASSUMPTIONS

The following is a list of other assumptions that were made during the development of the HIRF environments. Although most of these assumptions are very basic, they are provided to document all possible assumptions for the reader:

1. The maximum electric field strength that an aircraft may be exposed to is evaluated over the range from the minimum allowable separation distance between aircraft and RF emitter and infinity. The minimum distance is the worst-case distance that is determined by the scenario (severe, certification, or normal) being considered and the environment within that scenario.

2. All calculations consider only freespace loss between the emitter and the aircraft (i.e., no losses for atmospheric effects).

3. The airport environment consists of fixed and mobile emitters located on an airport. The airport included an area defined by a 5 nmi radius from the geographic center of the airport. This differs from the approach used by the Europeans which uses a 5 mile airspace wedge from the end of the runways.

4. The fixed airport environment consists of all fixed emitters located on an airport. In general, the minimum distance between a fixed emitter and the taxiway or runway is defined by regulations. This minimum distance is used as the minimum separation distance between the aircraft and the fixed airport environment. The typical fixed emitters in the U.S. airport environments are:

Marker Beacon	Ground Controlled Approach Radar
Localizer	Distance Measuring Equipment
VOR	Microwave Landing Systems
Glide Slope	Airport Surveillance Radar
TACAN	Air Route Surveillance Radar
Weather Radar	VHF and UHF Communication
Telemetry	ATCRBS Interrogator

   Not all of these emitters are located on every airport, but they are located on some airports in the U.S. Based on FAA regulations, fixed emitters are located no closer to an airport runway or taxiway than 250 ft. This was the basis for the use of 250 ft for fixed emitters at airports.

5. Mobile emitters in the airport environment consist of all emitters that are not in a fixed location. Emitters, such as commercial VHF radios on ground support vehicles, are part of the mobile environment. Emitters, such as the aircraft’s HF and UHF communications, TACAN, Doppler Navigation Radars, radio altimeters, weather radars, and ATCRBS beacons, are also included in the mobile airport environment. These aircraft emitters may be operating while the aircraft is on the ground and waiting to take off.

6. The aircraft to aircraft environment consists of emitters aboard other aircraft at distance much closer than normal in-flight separation. The emitters on civil aircraft are included already in the mobile airport environment. Therefore, only military aircraft need to be considered in the aircraft to aircraft environment.

   The military aircraft fall into two categories: interceptor and non-interceptor aircraft. An interceptor aircraft may approach as close as 50 ft to an unidentified commercial aircraft while attempting to establish the identity of, and provide instruction to, the aircraft. It can be assumed that very high powered emitters such as ECM systems and fire control radars will not be operating at this close visual range. Non-interceptor aircraft would not intentionally approach closer than 500 ft from another aircraft but may be operating weather radars. Aircraft with unique missions such as early warning radars would never operate their primary radar with aircraft closer than 1 mile. These guidelines form the basis for the air to air portion of the HIRF environment.

7. The emitters located on the ground are the largest population of systems since it includes all fixed and ground mobile emitters that are not located on airports. The typical ground based emitters in the U.S. environments are:

Sounders	Troposcatter
Submarine Communication	AM Broadcast
Radar Astronomy	HF Broadcast
Land Mobile	FM Broadcast
Test and Training Equipment	TV Broadcast
Weather Radar	Air Route Surveillance Radars
National Defense Radars	VHF and UHF Communication
Loran and Omega Navigation	Satellite Up Links

   The International Civil Aviation Organization (ICAO) aircraft minimum obstruction clearance for VFR is 500 ft AGL. Therefore, the minimum distance used for fixed wing aircraft was set at 500 ft.

8. The operator guidelines for rotorcraft advise a two rotor-blade separation from ground obstacles when operating below the ICAO 500 ft minimum. After an extensive survey of rotorcraft sized, it was determined that the typical distance resulted in a 100 ft separation.

9. The Part 25 Transport aircraft are always operating under the IFR once they are clear of the airport. The IFR required a 1,000 ft minimum altitude. This criteria led to the uses of 1,000 ft for the Certification and Normal Environments.

10. The shipboard environment includes emitters on commercial and military ships that may be located in harbors near airports or at sea. The typical shipboard emitters in the U.S. environments are:

Air Search Radars	Weather Radar
Fire-Control Radars	Surface Search Radars
Satellite Communications	Microwave Landing Systems
HF Communication	VHF and UHF Communication
TACAN	ATCRBS Interrogator

    In addition, the EEHWG considered probability as detailed in Section 2.2. The shipboard separation was determined to be 1,000 ft slant.

11. The heliport and off-shore platform environment includes emitters on commercial facilities on land or at sea. The typical emitters in the U.S. heliport and off-shore platform environments are:

Satellite Communications	Weather Radar
HF Communication	Surface Search Radars
VOR Navigation	Microwave Landing Systems
Homing Beacons	VHF and UHF Communication

    Rotorcraft operating off of heliports and off-shore platforms were determined to be operating under VFR; therefore, the separation distance was set at 100 ft.

12. Antenna heights above ground due to antenna towers that are not part of the basic equipment package were not considered. Flat earth is assumed, i.e., terrain was not included.

13. Emitter data were extracted from authorized transmitters as of 1997.

14. Emitter data for the U.S. EME included contiguous United States (CONUS), Alaska, Hawaii, and Puerto Rico.

15. Modulation was not considered for the nonpulsed emitters; therefore, peak field strength and average field strengths were set to be the same.

16. High impedance fields ($E>120\pi H$) were found to exist in the frequency range of 10 to 100 kHz. These fields were excluded from the HIRF envelopes because they do not propagate and are more likely to be a problem on airframes which are predominantly nonconducting. However, a note has been added stating the HIRF strength values for these frequency regions and is for information only.

17. The peak field strength is based on the maximum authorized power level of the transmitter and antenna gain for the frequency range. The average field strength is based on the maximum average field strength (peak output power of the transmitter times the maximum duty cycle times the antenna gain) for the frequency range. The field

strengths used in the environments for peak and average may or may not be from the same driver emitter.

18. The antenna pattern and rotation rate were not used for any of the calculations.

19. The maximum antenna gain was taken from the 3 dB bandwidth.

20. The units used to define the field strength of the HIRF environment are in terms of root mean square (rms). All measurements or calculations of the field strength are derived in terms of the power density, either peak or average, then converted to volts per meter (V/m_{rms}). The rms units for electric field strength or power density are to be omitted, since they are assumed to be understood without restatement in the units. The true electrical peak will not be used for expressing the field strength.

21. Pulse modulated signals, such as from a radar, have differences between peak and average power density. The ratio between the peak and average values is the duty cycle for pulse modulated or gated signals. The maximum duty cycle is to be used to calculate the environment. For pulsed emitters when the signal is on, the peak field is the value of the electric field for the time that the signal is on. When the signal is off, the field strength is zero.

THIS PAGE INTENTIONALLY LEFT BLANK

4. ANALYSIS METHODS

4.1 DATA COLLECTION AND REDUCTION METHODOLOGY

The methodology used to collect and reduce the data for the U.S. HIRF environment is shown in figure 1.

The refinement of the HIRF environment for this study began with the data collected by Joint Spectrum Center (formerly ECAC) for the first HIRF environment study. This data was emitter data extracted from three data bases. The FRS data base contains emitter data for all Federal Communications Commission (FCC) authorized transmitters. The FRS data include systems such as Radio and TV broadcast, terrestrial radars, satellite uplinks, and navigation systems. The Government Master File (GMF) data base contains emitter data for all government owned and operated transmitters. The predominate data in the GMF data base is the DOD emitters. The ECS contains general technical information about government transmitters both operating and nonoperating. A complete description of the data bases is described in Section 4.2.

The Joint Spectrum Center first study extracted data from these data bases for all emitters that exceeded 100 W. Joint Spectrum Center also did a second data extraction of all emitters associated with six major airports in the U.S. The six major airports were: New York Kennedy Airport, New York, Chicago O'Hare, Illinois, Dallas Fort Worth Airport, Texas, Los Angeles Airport, California, St. Louis Lambert Field, Missouri, and Boston Logan Airport, Massachusetts. This latter study was used to support the development of the normal HIRF environment. All this data is contained in large format computer printouts that are stored at Joint Spectrum Center contractor IITRI in Annapolis, Maryland.

This study reviewed Joint Spectrum Center's data then requested another data extraction to update the emitter information to reflect the most current license or authorized transmitters. Also, the data extraction included transmitters with effective radiated power (ERP) greater than 1 kW and transmitters greater than 100 W. The data were collected on magnetic tape and eventually downloaded to a PC Fox Pro data base. The Fox Pro data base was used to create a subset data base that contained data licensing information and equipment descriptions on the top 25 highest emitters in each of the 17 HIRF frequency ranges. The Fox Pro subset data base was brought to Patuxent River and used to update the HIRF environment. The 1995 Fox Pro source data base remained archived at IITRI.

NAWCAD Patuxent River collated the assumptions that had evolved since 1992 when the HIRF environment was frozen. All the assumptions that were applicable are documented in Section 3 of the report. Using the assumptions, the emitter data in each of the 17 frequency bands were analyzed to locate the top 5 highest ERP drivers in each band.

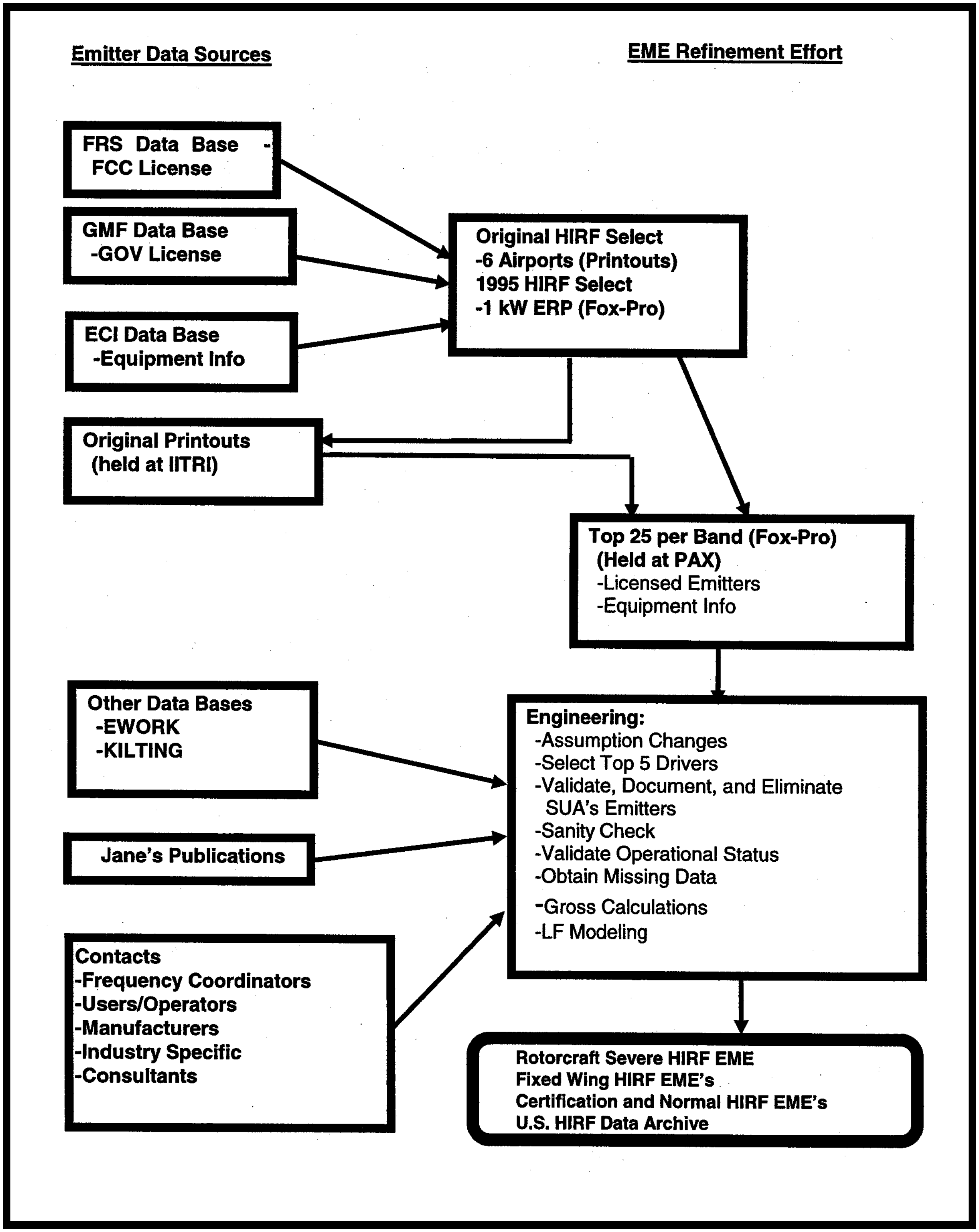

FIGURE 1
U.S. HIRF EME DEVELOPMENT PROCESS

If an emitter was determined to be a possible driver, its location was plotted on a low altitude aeronautical map to determine if it was located in a Special Use Airspace (SUA) or near an airport. If it was in an SUA, it was noted and removed as a driver and replaced by the next lower ERP emitter.

The complete list of five emitters was checked to determine if there is common knowledge about other possible high power source in that band or if the emitter data appeared to have unreasonable characteristics. When either of these conditions occurred, the data source was consulted to locate the needed data. It was this step that led to the inclusion of various broadcasts to the emitters and correction of emitter data.

Each of the five driver emitters per band was validated as operational. In some cases, it was necessary to contact the facility to verify it was still authorized to transmit and capable of emitting. In most cases, the driver emitters were obviously operating such as the air route surveillance radars.

The task of locating sufficient data to permit calculation of the field strength level began after the five driver emitters per band were validated as operational emitters. The major data missing was usually the antenna type and size. This data was essential to calculation of the near-field strengths. Source for this information started with other emitter data bases used for EW such as Ework and Kilting. Next, Jane's book series on military systems was consulted. When necessary, the contact was made with the manufacturer, user, or consultants to complete the emitter data for the five band drivers.

The final effort involved modeling and calculating the HIRF environments. The calculations were done as described in the following sections of this report. An Excel spread sheet was used to estimate the field strengths. The large LF emitters required special array modeling to derive the field strengths. No finite element or finite difference modeling was made of the antenna system because the emitter data base contained insufficient information to allow this kind of detailed modeling. The emitter that produced the highest field strength was then used to compile the environment.

This process was iterated for the assumptions for Rotorcraft Severe, Fixed Wing Severe, Certification, and Normal HIRF Environments. The peak and average field strengths were tabulated and graphed for presentation. The raw data for this report have been archived at Patuxent River and a copy with the FAA.

4.2 DATA BASES

4.2.1 ECS

The Equipment Characteristics and Space (ECS) contains detailed technical characteristics of communications, radar, EW, and space systems equipment. The data base is developed and maintained by the Joint Spectrum Center (JSC) in Annapolis, Maryland. The JSC extracts data from technical manuals, J/F-12 Applications for Frequency Allocation, JSC project activities, manufacturers' brochures, and similar documents. The ECS includes a summary description of each communications electronics (C-E) system and provides selected detailed technical parameters of each subsystem and component that, together, composes the system and establishes its overall technical characteristics. Data are primarily on U.S. military systems. Limited information is also available on commercial systems. The data base contains technical characteristics on approximately 25,000 terrestrial systems.

The ECS also contains characteristics on over 360 satellites and orbital characteristics of over 1,600 individual satellites. However, none of this satellite data is relevant to HIRF.

4.2.2 FRRS

The Frequency Resource Record System (FRRS) contains information on DOD frequency assignments used throughout the world that are controlled by the Unified Commands and the Military Departments (MILDEP's). It provides a centralized record depository for all permanent frequency assignments of 90 days or longer duration. All data are maintained at the JSC central computing facility in Annapolis. The data base also provides the interface for processing frequency assignment actions between DOD organizations and the National Telecommunications and Information Administration (NTIA). Each record contains administrative and technical data such as the type of assignment, organizational information, and the equipment location. The data base contains over 181,000 frequency assignment records and is updated weekly.

4.2.3 GMF

The GMF contains records of the frequencies assigned to all U.S. Federal Government agencies in the U.S. and its possessions. The JSC obtains data daily from NTIA, and the master file is updated weekly. Over 330,000 frequency assignment records are currently in this data base.

4.2.4 FCC

The FCC data base contains the records of frequencies assigned by the FCC to state and local government agencies and the private sector. The source of the data is the FCC via the JSC. The data receives a major update annually, with minor updates quarterly. There are over 3,157,000 frequency assignment records in this data base.

4.3 SOURCES

4.3.1 JANE'S

The Jane's books are series of technical information on numerous telecommunication electronics devices. The books available are:

- Jane's Avionics - Design features, functions, modifications, applications, customers, frequency, power output, display, sensors, antennas, contractor lists, manufacturers index, and 2,000 photographs and drawings. The technical details and illustrations cover 3,000 airborne and avionics systems for civil and military aviation worldwide.

- The Jane's Radar and Electronics Warfare Systems Book is an unclassified description of over 2,000 surveillance and countersurveillance systems in use around the world. It compares targeting, control intelligence gathering, and self-protection for air-defense, Communications Intelligence (COMINT), ELNT, and electronic countermeasures (ECM), plus radar system and EW simulation, and monitors old equipment and new programs in development in an 800 page book.

4.4 ELECTROMAGNETIC FIELD ENGINEERING ANALYSIS

The analysis of the electromagnetic field produced by an emitter was done using classical antenna propagation theory. The area surrounding an antenna is generally divided into three regions. The following definitions of these three regions have been taken from the IEEE Standards Definitions of Terms for Antennas (reference 11):

- **Reactive Near-Field Region** - That region of the field immediately surrounding the antenna wherein the reactive field predominates.
- **Radiating Near-Field Region** - That region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon the distance from the antenna. For an antenna focused at infinity, the radiating near-field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology. If the antenna has a maximum overall dimension, which is not large compared to the wavelength, this field region may not exist.
- **Far-Field Region** - That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. If the antenna has a maximum overall dimension "D", which is large compared to the wavelength, the far-field region is commonly taken to exist at distances from the antenna greater than the quality two times the square of the maximum dimension all divided by the wavelength. For an antenna focused at infinity, the far-field region is sometimes referred to as the Fraunhoffer region on the basis of analogy to optical terminology.

Figure 2 shows the various approximate field regions for an aperture antenna with an aperture much greater than a wavelength (λ). "D" is the largest linear dimension of the aperture, r is the range or distance from the antenna.

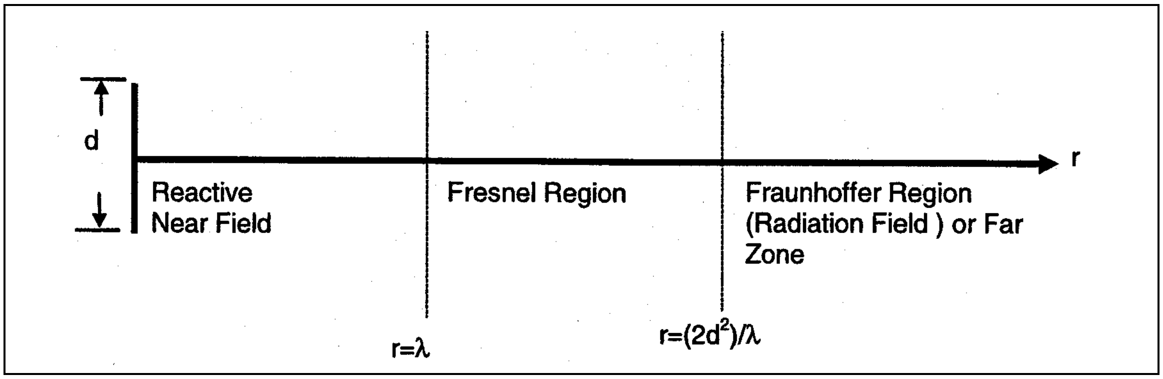

FIGURE 2
ANTENNA FIELD REGION

4.4.1 PROPAGATION LOSS CALCULATION

In the Fraunhoffer region, the radiation is in a diverging beam shape, where the density is maximum at the beam center and decreases away from the beam center as the angle of divergence increases. If the aperture is made larger or the antenna illumination is made more uniform, the radiated beam is made narrower and the beam center power density is made higher. The power density at the beam center in the far field is given by equation 1.

Equation 1

$$P_D = \frac{P_T G}{4\pi r^2}$$

Where:
P_D = Power Density (watts/meter^2)
P_T = Transmitter Output Power (watts)
G = Antenna Gain (unitless)
r = Distance or Range from Antenna (meters)
π = The constant Pi (3.1415…)

All power densities in the far-field region are estimated by equation 1 and have the following properties:

- The electromagnetic field produced by a distant source is of the spherical wave type.
- For the given direction of radiation, the EM radiation behaves like a plane wave.
- The ratio of the amplitude of the electric field and the amplitude of the magnetic field are constant and equal to 377 ohms. The electric field is perpendicular to the magnetic field and both are perpendicular to the direction of propagation.
- The amplitude of the power density (electric and magnetic fields) is proportional to the inverse of the distance to the source.
- No large obstacle intervened between the antenna and the estimated point in space along an optical line of sight.

- No alternate transmission path is followed by a substantial fraction of the radiated energy (i.e., multipath).
- The intervening atmosphere has a constant index of refraction, so no bending of the wave occurs or absorption of the energy from the wave at the frequency used.

Equation 2

$$r > \frac{2d^2}{\lambda}$$

Where:
d = Maximum Antenna Dimension (meter)
λ = Wavelengths (meters)
r = Distance or Range from Antenna (meters)

Equation 1 was used for all types of emitter antennas when the emitter's antenna to aircraft separation was determined to be in the far field of the emitter's antenna. To be in the far field, the separation distance had to meet the criteria shown in equations 2 or 4.

Equation 3

$$\lambda = \frac{c}{f}$$

Where:
c = Speed of Light = 300 (mega-meters/second)
f = Frequency (MHz)
λ = Wavelength (meters)

Equation 4 (substituting equation 3 in equation 4)

$$r > \frac{2\,d^2\,f}{300}$$

Where:
d = Maximum Antenna Dimension (meter)
f = Transmitter Carrier Frequency (MHz)
r = Distance or Range from Antenna (meters)

4.4.2 NEAR-FIELD MODELING

The near-field region of an emitter does not have the above properties. In the near-field region, the gain is a function of the linear distance from the antenna and aperture type; consequently, the antenna performance must be evaluated using special considerations.

The power densities in the near field are calculated using the far-field equation 1 and a near-field gain reduction factor χ as shown in equation 5.

Equation 5

$$P_D = \frac{P_T G \chi}{4\pi r^2}$$

Where:
P_D = Power Density (watts/meter^2)
P_T = Transmitter Output Power (watts)
G = Antenna Gain (unitless)
χ = Near-Field Gain Reduction Factor (unitless)
r = Distance or Range from Antenna (meters)
π = The Constant Pi (3.1415…)

All emitter antennas were classified as having one of the following apertures: a rectangular aperture, circular aperture, or a linear aperture. Phase array antennas are treated as rectangular or circular apertures. Elliptical or crossed polarized antennas are treated as either circular or rectangular antennas depending upon the ratio of the elliptical wave.

The methods presented in the following section of this report for calculating near-field gain reduction factors were initially proposed by Alexander Gross of Joint Spectrum Center. SAE AE4R and EUROCAE extensively reviewed, validated, and adopted these methods as the way near-field reduction would be estimated. These unique near-field models became known within the HIRF community as the “Gross” method.

4.4.2.1 Linear Apertures

A linear aperture has maximum overall dimensions which are not large compared to the wavelength. As given in the definition at the beginning of this section, the radiating near-field region does not exist. Therefore, no near-field correction is used. Typical antennas that meet this requirement are dipoles and monopoles. Equation 6 is used to determine if the antenna is a linear antenna and does not have a near field.

Equation 6

$$d <= \lambda = \frac{300}{f}$$

Where:
d = Largest Antenna Dimension (meter)
f = Transmitter Carrier Frequency (MHz)
λ = Wavelength (meters)

All linear antennas use equation 1 to determine the power density at the criteria separation distance.

4.4.2.2 Rectangular Apertures

Rectangular apertures are horns or partial dish antennas (so-called orange peel antennas). A rectangular aperture antenna may not have the same vertical and horizontal axis illumination taper. Therefore, the gain reduction for each axis is independently determined. The near-field reduction for either axis is given in table 2 and shown in figure 3. The gain reduction is given in dB for a uniform power distribution and for several illumination distributions from $\cos^1$ to $\cos^4$ as a function of the near-field distance.

TABLE 2
RECTANGULAR APERTURE NEAR-FIELD REDUCTION

Δ_h or Δ_v	Uniform	$\cos^1$	$\cos^2$	$\cos^3$	$\cos^4$
0.010	20.3	16.0	14.0	12.6	11.5
0.015	17.6	14.0	12.4	11.0	9.8
0.020	17.3	13.2	11.2	9.7	8.6
0.025	15.3	12.2	10.2	8.8	7.8
0.030	15.3	11.4	9.5	8.0	7.0
0.035	14.4	10.8	8.8	7.4	6.4
0.040	14.2	10.2	8.2	6.8	5.8
0.050	13.0	9.2	7.2	5.8	4.8
0.060	12.4	8.4	6.6	5.0	4.0
0.070	12.0	7.6	5.8	4.4	3.4
0.080	10.4	7.0	5.3	3.8	2.8
0.090	9.3	6.6	4.7	3.4	2.4
0.100	9.2	6.1	4.2	3.0	2.1
0.150	10.0	4.3	2.6	1.6	1.2
0.200	7.0	3.0	1.6	0.9	0.6
0.250	5.2	2.0	1.1	0.6	0.4
0.300	4.0	1.5	0.8	0.4	0.3
0.350	3.0	1.1	0.6	0.2	0.2
0.400	2.2	0.8	0.4	0.2	0.2
0.500	1.8	0.5	0.2	0.0	0.0
0.600	1.5	0.4	0.2	0.0	0.0
0.700	1.1	0.2	0.1	0.0	0.0
0.800	0.8	0.2	0.0	0.0	0.0
0.900	0.6	0.1	0.0	0.0	0.0
1.000	0.3	0.0	0.0	0.0	0.0

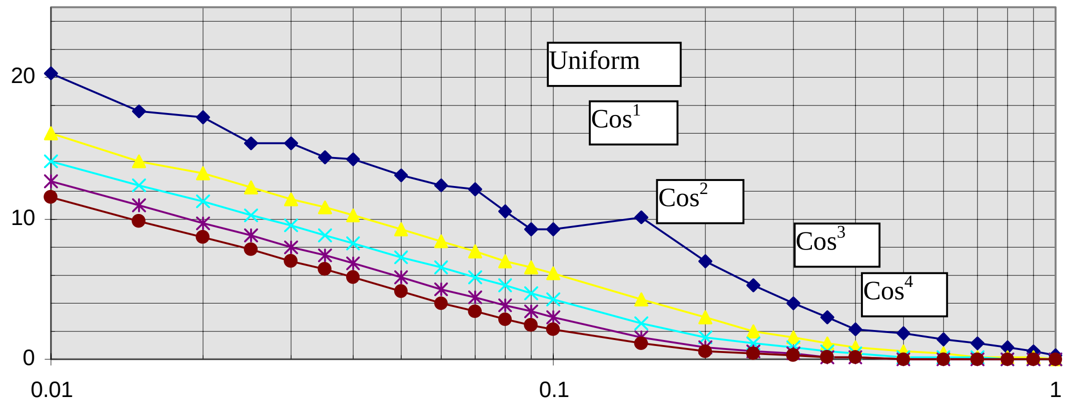

FIGURE 3
NEAR-FIELD CORRECTION FACTORS FOR RECTANGULAR APERTURE

To determine the type of illumination distribution, it must be given as part of the antenna data or it can be calculated from the antenna dimensions and beamwidth using equation 7. Illuminations above $\cos^4$ are omitted since the gain reduction in the near field would be almost negligible. When I_d is found to be border line between the two orders of illumination, the higher order is used since the power density in the near field will be greater and, therefore, more conservative. Once the value for the illumination distribution constant is calculated, use table 3 to estimate the corresponding illumination type.

Equation 7

$$I_d = (5.8384 \times 10^{-5})\, f\, B\, d$$

Where:
- I_d = Constant for estimating Illumination Distribution
- d = Largest Dimension (meter)
- f = Transmitter Carrier Frequency (MHz)
- B = Beamwidth of antenna at the 3 dB points (degrees)

TABLE 3
ILLUMINATION DISTRIBUTION FOR RECTANGULAR APERTURES

Limits of I_d			Estimated Illumination
0.088	-	1.2	Uniform
1.2	-	1.45	$\cos^1$
1.45	-	1.66	$\cos^2$
1.66	-	1.93	$\cos^3$
1.93	-	2.03	$\cos^4$

Equations 8 and 9

$$\Delta_h = \frac{r\,f}{d_h^2\, 300}$$

$$\Delta_v = \frac{r\,f}{d_v^2\, 300}$$

Where:
- Δ_h = Horizontal Axis Normalized Distance (unitless)
- r = Separation Distance or range (meters)
- f = Transmitter Carrier Frequency (MHz)
- d_h = Horizontal Axis Dimension (meters)
- Δ_v = Vertical Axis Normalized Distance (unitless)
- d_v = Vertical Axis Dimension (meters)

Next, the distance from the antenna must be normalized by dividing by the far-field boundary for each axis. The normalized distance for each axis is determined using equation 8 for the horizontal axis and equation 9 for the vertical axis.

From table 2, find the near-field gain reduction factors (either χ_h or χ_v) using the axis illuminations type (determined by using equation 7 and table 3) and the normalized distances from equations 8 and 9 (Δ_h and Δ_v). The total near-field gain reduction is the sum of the gain reduction in dB converted to a numeric factor as given in equation 10.

Equation 10

$$\chi = 10^{-[(\chi_h + \chi_v)/10]}$$

Where:
χ = Total Near-Field Reduction Factor (unitless)
χ_h = Horizontal Near-Field Reduction Factor (dB)
χ_v = Vertical Near-Field Reduction Factor (dB)

The total near-field reduction factor (χ) is used in equation 5 to obtain the power density.

4.4.2.2.1 Derivation of Antenna Size

As can be deduced from the discussion on determining the near-field power density, it becomes important to know the emitter antenna aperture size. However, in some situations, such as during the early stages of evaluating emitters, the antenna aperture size may not be given in the data bases. Several techniques were used to estimate the size of the antenna from the available data. After using these techniques, the emitter was compared to the other possible drivers. If it determined that the emitter was close or was the driver, then further research was conducted to determine the exact size of the aperture. The following discussion provides the details on how the antenna size was derived for the early analysis.

In some cases, the antenna gain, frequency, and basic description are given. Equation 11 was used to estimate the size.

Equation 11

$$d_v = d_h = \left[\frac{f^2 G}{4\pi^2 \sigma \Gamma 300^2} \right]^{1/2}$$

Where:
d_v = Antenna Vertical Dimension (meters)
d_h = Antenna Horizontal Dimension (meters)
f = Transmitter Carrier Frequency (MHz)
G = Antenna Gain (unitless)
σ = Antenna Efficiency (unitless)
Γ = Antenna Factor (unitless)
π = The Constant Pi (3.1415…)

Equation 11 is derived from the classical formula used for determining the antenna gain, but solved for the antenna area. For a rectangular aperture, the horizontal and vertical axes are assumed equal; therefore, the square root is taken of the antenna area resulting in the equal ordinate dimensions. The antenna efficiency (σ) used in equation 11 is a rating of how well the antenna emits the input power. Antenna efficiency is usually between 0.5 and 0.99, with a typical value of 0.55. For the estimated antenna size, the antenna efficiency value assumed was 0.55, unless the antenna data provided further information. Also, equation 11 uses antenna gain factor (Γ) which is linked to the antenna illumination. table 4 gives the gain factors possible for rectangular apertures illumination. Again, uniform illumination is assumed, unless the antenna data provide further information.

TABLE 4
GAIN FACTORS FOR RECTANGULAR ANTENNAS

Illumination	Gain Factor (Γ)
Uniform	1.0
$\cos^1$	0.81
$\cos^2$	0.67
$\cos^3$	0.0575
$\cos^4$	0.0515

Equation 12

$$d = \frac{f \ \kappa}{\phi 300}$$

Where:
- d = Antenna Dimension (meters)
- f = Transmitter Carrier Frequency (MHz)
- κ = Aperture Illumination Constant (unitless)
- ϕ = Antenna Beamwidth (degrees)

Another approach to estimating the antenna dimension is based on beamwidth and frequency. The antenna dimension to half-power beamwidth and frequency are given in equation 12.

A constant (κ) is used which corresponds to the aperture illumination as given in table 5. A uniform illumination is assumed unless the emitter antenna data provide further information.

TABLE 5
APERTURE ILLUMINATION CONSTANT

Illumination	Illumination Constant (κ)
Uniform	57.3
$\cos^n$	70.0

The horizontal or vertical antenna dimensions are estimated using the corresponding azimuth and elevation beamwidth. When appropriate, the ordinate dimension could be divided into the area of equation 11 to determine the unknown ordinate dimension. The aperture size estimated by these methods would be iterated until a reasonable size was derived for use in the near-field estimates.

There are other techniques that could be used to estimate beamwidth and gain. However, this never was necessary because the data source almost always had antenna gain and beamwidth. In a few situations, effective radiated power (ERP, r = 0) was given with no further antenna data. This was the situation for broadcast TV and radio. In these situations, the gain was assumed to be 1 and, later in the study, the sizes of typical antenna systems were determined and used for the HIRF calculation. The specific characteristics for each emitter driver are described in appendix D.

4.4.2.3 Circular Aperture

Circular apertures refer to transmission line to space wave couplers that are truly a circle in shape. Examples of such aperture are parabolic dish, circular planar array, log spirals, and circular horns. The near-field reduction for either axis is given in table 6 and shown in figure 4. The gain reduction is given as linear factors for a uniform power distribution and for several illumination distributions as a function of the aperture curvature (ρ).

TABLE 6
CIRCULAR APERTURE NEAR-FIELD CORRECTION

Δ_c	Uniform	$(1-\rho^2)^1$	$(1-\rho^2)^2$	$(1-\rho^2)^3$
0.01	26	27.7	59.0	103.5
0.02	26	28.1	59.2	102.5
0.03	26	30.1	59.4	102.0
0.04	26	31.9	59.7	102.0
0.05	26	33.5	60.7	101.0
0.06	26	35.0	62.6	98.0
0.07	26	37.0	63.7	92.0
0.08	26	39.0	63.5	84.0
0.09	26	40.0	61.0	77.0
0.10	26	40.7	56.0	69.0
0.15	24	29.0	32.0	35.0
0.20	18	19.5	20.1	22.0
0.30	9.5	10.5	10.5	11.0
0.40	5.5	6.0	6.0	6.0
0.50	3.5	3.9	3.9	3.5
1.00	1	1.0	1.0	1.0

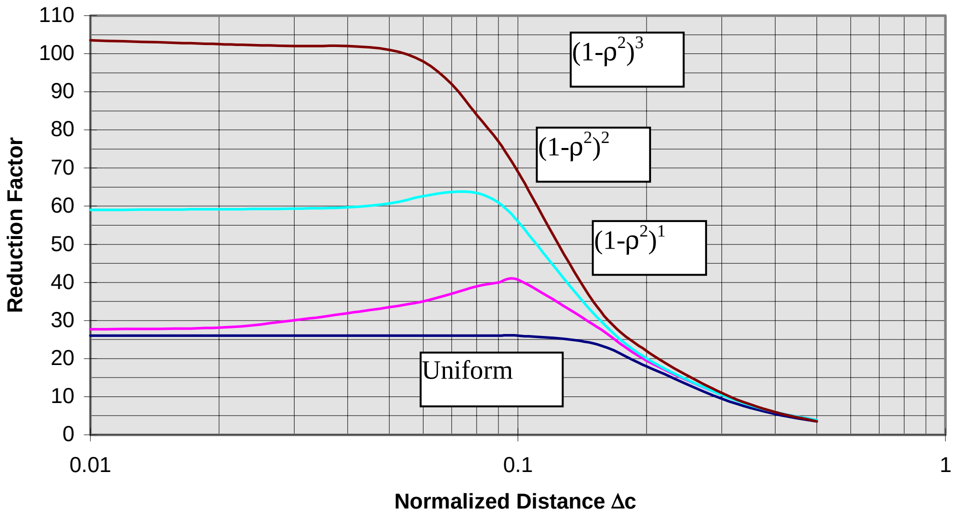

FIGURE 4
NEAR-FIELD CORRECTION FACTORS FOR CIRCULAR APERTURES

Equation 13

$$I_d = (5.8384 \times 10^{-5})\, f\, B\, d_c$$

Where:
- I_d = Constant for Estimating Illumination Distribution
- d_c = Circular Aperture Diameter (meter)
- f = Transmitter Carrier Frequency (MHz)
- B = Beamwidth of Antenna at the 3 dB Points (degrees)

To determine the type of illumination distribution, it must be given as part of the antenna data or it can be calculated from the antenna diameter and beamwidth using equation 13. Illumination tapers above $(1-\rho^2)^3$ are omitted since the gain reduction in the near field would be almost negligible. When I_d is found to be border line between the two orders of illumination, the higher order is used since the power density in the near field will be greater and, therefore, more conservative. Once the value for the illumination distribution constant is calculated, use table 7 to estimate the corresponding illumination type.

TABLE 7
ILLUMINATION DISTRIBUTION FOR CIRCULAR APERTURE

Limits of I_d	Estimated Illumination
1.02-1.27	Uniform
1.27-1.47	$(1-\rho^2)^1$ Taper
1.47-1.65	$(1-\rho^2)^2$ Taper
1.65-1.81	$(1-\rho^2)^3$ Taper

Next, the distance from the antenna must be normalized by dividing by the far-field boundary for the given diameter of the circular aperture. The normalized distance (Δ_c) is determined by using equation 14.

Equation 14

$$\Delta_c = \frac{r\, f}{2 d_c^2\, 300}$$

Where:
- Δ_c = Circular Aperture Normalized Distance (unitless)
- r = Separation Distance or Range (meters)
- f = Transmitter Carrier Frequency (MHz)
- d_c = Circular Aperture Diameter (meters)

From table 6, find the near-field gain reduction factor (χ_c) using the illuminations type (determined by using equation 13 and table 7) and the normalized distance from equation 14 (Δ_c).

To calculate the near-field power density, equation 5 is used, where the value "r" is set at the far-field boundary using equation 4 and the circular's near-field reduction factor (χ_c) as determined above. The resulting equation is shown in equation 15.

Equation 15

$$P_D = \frac{300^2 P_t G \chi_c}{16\pi d_c^4 f}$$

Where:
P_D = Power Density (watts/meter^2)
P_t = Transmitter Output Power (watts)
G = Antenna Gain (unitless)
χ_c = Near-Field Gain Reduction Factor (unitless)
d_c = Circular Aperture Diameter (meters)
π = The Constant Pi (3.141592…)
f = Frequency of Transmitter (MHz)

4.4.2.3.1 Derivation of Antenna Size

The diameter of circular apertures is the most critical parameter in determining the near-field power density as it was with rectangular apertures. In some situations, during the evaluation of the emitter, the antenna size may not be given in the data bases. The following techniques were used to estimate the size of the antenna from the available data in a manner similar to rectangular apertures. After using these techniques, the emitter was compared to the other possible drivers. If it was determined that the emitter was close or was the driver, then further research was conducted to determine the exact size of the aperture. The following discussion provides the details on how the antenna size was derived for the early analysis.

Equation 16

$$d_c = 2\left[\frac{f^2 G}{8\pi^3 \sigma\Gamma 300^2}\right]^{1/2}$$

Where:
d_c = Antenna Diameter (meters)
f = Transmitter Carrier Frequency (MHz)
G = Antenna Gain (unitless)
σ = Antenna Efficiency (unitless)
Γ = Antenna Factor (unitless)
π = The Constant Pi (3.1415…)

For the cases where the antenna gain, frequency, and basic description are given, equation 16 was used to estimate the size.

Equation 16 is derived from the classical formula used for determining the antenna gain, but solved for the antenna area. For a circular aperture, the diameter is determined by substituting in the formula for the area of a circle (Area=$2\pi r^2$) then doubling the radius to get the diameter. The antenna efficiency (σ) used in equation 16 is a rating of how well the antenna emits the input power. Antenna efficiency is usually between 0.5 and 0.99, with a typical value of 0.55. For the antenna size, estimating the antenna efficiency value assumed was 0.55, unless the antenna data provide further information. Also, equation 16 uses antenna gain factor (Γ) which is linked to the antenna illumination. Table 8 gives the gain factors possible for rectangular apertures illumination. Again, uniform illumination is assumed, unless the antenna data provide further information.

TABLE 8
GAIN FACTORS FOR CIRCULAR ANTENNAS

Illumination	Gain Factor (Γ)
Uniform	1.0
$(1-\rho^2)^1$	0.75
$(1-\rho^2)^2$	0.56
$(1-\rho^2)^3$	0.44

The approach to estimating the antenna diameter is based on beamwidth and frequency. The antenna diameter as a function of half-power beamwidth and frequency is given in equation 17.

Equation 17

$$d_c = \frac{f\kappa}{\phi 300}$$

Where:
d_c = Antenna Diameter (meters)
f = Transmitter Carrier Frequency (MHz)
κ = Aperture Illumination Constant (unitless)
ϕ = Antenna Beamwidth (degrees)

The constant (κ) is used which corresponds to the aperture illumination given in table 9. A uniform illumination is assumed unless the emitter antenna data provide further information.

TABLE 9
APERTURE ILLUMINATION CONSTANT

Illumination	Illumination Constant (κ)
Uniform	57.3
$(1-\rho^2)^n$ Taper	65

The aperture size estimated by these methods would be iterated until a reasonable size was derived for use in the near-field estimates.

There are other techniques that could be used to estimate beamwidth and gain. However, this never was necessary because the data source almost always had antenna gain and beamwidth. The specific characteristics used for each emitter driver are described in appendix D.

4.4.2.4 Beam Forming Antennas and Arrays

Beam forming antennas and arrays may come as rectangular or circular antennas. The purpose of this section is to aid in understanding how antenna systems were analyzed.

4.4.2.4.1 Slotted Arrays

Slotted array may be made in a rectangular matrix or in a circular planar array. In either case, the size of the antenna was taken from the overall size of the rectangular matrix or circular array.

4.4.2.4.2 Circular Dish

Dish antennas may be illuminated by a horn, dipoles, or log periodic. The antennas then directly or indirectly reflect to a reflector that is circular with some curvature. The size of this antenna aperture is based solely on the diameter of the reflector. None of the other components were considered.

4.4.2.4.3 Dipole Arrays

Dipole arrays are used for everything from broadcast curtain array antennas to radar antennas. The radar antennas that use dipole arrays have their aperture dimension based on the overall size of the dipole array. HF broadcast curtain array antennas are unique in that the size of the antenna is based on the active portion of the antenna. Typically, the physical antenna is constructed of three or more bands of antennas, erected serially next to each other. Furthermore, within a given band, the operator of the antenna may elect to transmit on select dipole elements in the array, further complicating determining the size of the antenna. The vertical size has an additional factor in that reflected image of the antenna is also part of the vertical size. Therefore, rather than using the physical size of the antenna, it is better to use the horizontal and vertical beamwidth data and derive the electrical equivalent sizes. Using this approach to determining the size of the antenna, the gain to be used for HF dipole arrays already include the constructive interference of the reflected wave.

4.4.3 AVERAGE AND PEAK POWER

The emitter characteristics were analyzed to determine the average and peak power densities. As detailed in the assumption for systems using AM, FM, or PCM modulations, such as AM, FM, and TV broadcast, the peak power was set at the transmitters CW output rating, and average power was set equal to peak power. In radar application, the equipment modulation characteristics are used. The simplest way is to know the transmitter duty cycle (or duty in %). Peak and average transmitter power outputs are related as shown in equation 18.

Equation 18

$$P_{Ta} = P_{Tp} D$$

Where:
- D = Duty Cycle (unitless, duty/100)
- P_{Tp} = Transmitter Peak Output (watts)
- P_{Ta} = Transmitter Average Output (watts)

If the duty cycle is not known, then the pulse width and pulse repetition rate are used to determine the duty cycle using equation 19.

Equation 19

$$D = T_W F_R$$

Where:
- D = Duty Cycle (unitless)
- T_W = Transmitter Pulse Width (msec)
- F_R = Transmitter Pulse Repetition Frequency (kHz)

4.4.4 DIRECT ILLUMINATION

Direct illumination of an emitter occurs when an aircraft can be in the main beam of the antenna. Rotorcraft were almost always possible of being illuminated by the main beam of the antenna because the separation distance from the emitter was a bubble of a 100 ft radius from the ground up and around the emitter. Fixed wing aircraft would encounter this situation when the emitter has no restriction where it could radiate its main beam of energy. The power density used is as calculated above using the gain of the antenna at the 3 dB point. The power density is not increased for the maximum possible gain.

4.4.5 SLANT ILLUMINATION

The slant illumination is the result of an emitter having a maximum elevation angle that the main beam of the antenna can be raised to. The fixed wing aircraft are limited to minimum emitter ground separations of 500 ft and higher. This situation is illustrated in figure 5.

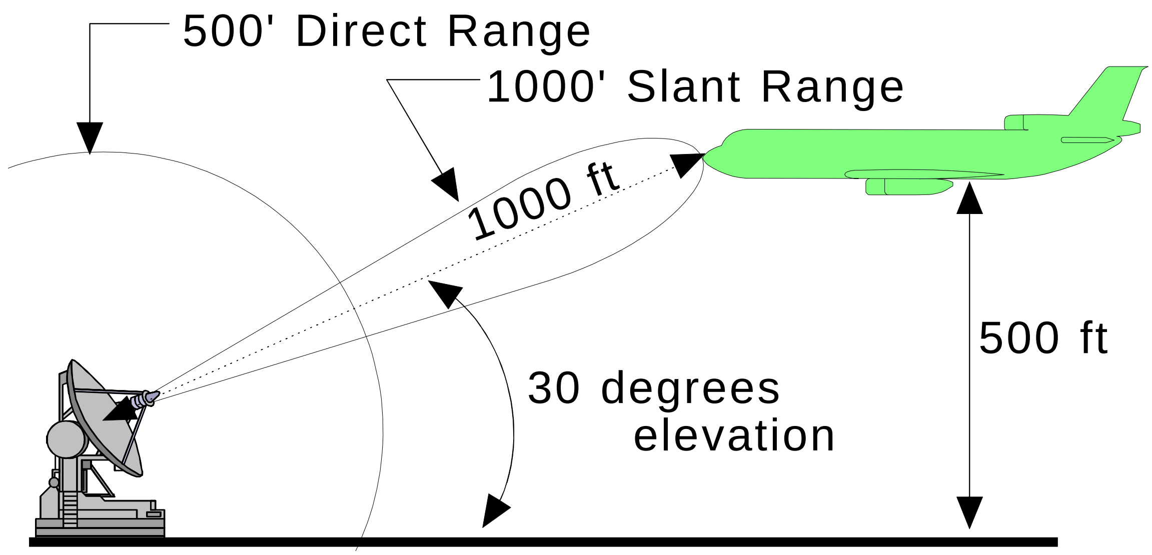

FIGURE 5
ILLUSTRATION OF SLANT ILLUMINATION

In the above situation, the aircraft is flying 500 ft above the ground based emitter (the height of the emitter is assumed to be insignificant). The emitter antenna main beam elevation is limited to a maximum angle of 30 deg. At 1,000 ft from the emitter, the aircraft encounters the maximum illumination (main beam) of the emitter's antenna. As it flies closer, the aircraft will only encounter much lower side lobe illuminations. The distance at which the aircraft encounters the maximum illumination from an elevation limited antenna main beam is called slant range.

Many ground based emitters have limited elevation angles. For all these emitters, it was appropriate to use the slant range from the emitter (rather than 500 ft direct illumination) to estimate the power densities.

4.4.6 OVERHEAD ILLUMINATIONS

Another aspect of elevation limited antennas is the possibility of a higher overhead power density than experienced at the slant range. Figure 6 illustrates an exaggerated version of this situation.

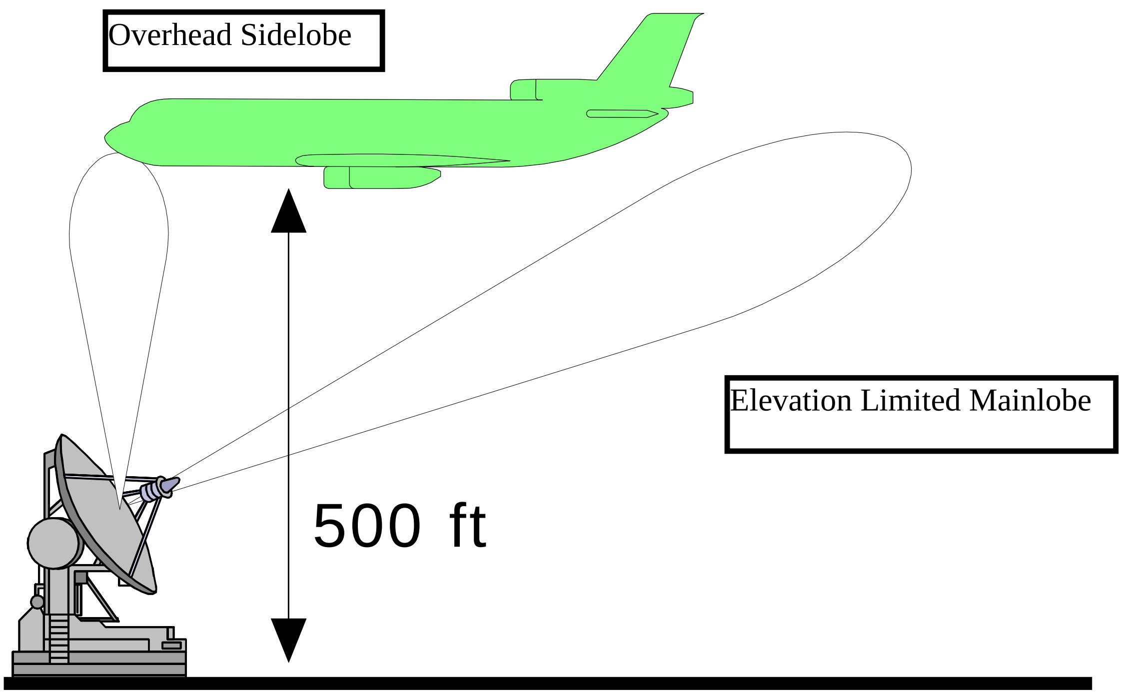

FIGURE 6
ILLUSTRATION OF OVERHEAD ILLUMINATION

In the illustration, the aircraft is now over the top of an emitter who main beam (main lobe) is limited in elevation. The aircraft to emitter separation is at the minimum separation distance, in the example it is 500 ft. In these situations, the aircraft will be exposed to the side lobe of the antenna. If the side lobe level was known for an emitter, it was used. The default value if unknown was set to 15 dB below the main lobe.

The power density for overhead illumination was estimated for each elevation limited emitter using these methods.

4.4.7 POWER DENSITY TO FIELD STRENGTH

The last step in the HIRF calculation was the conversion to field intensity. Each of the power densities (peak, average, overhead, etc.) were converted to equivalent field strength values using the impedance of free space air (120π or 377 ohms) as shown in equation 20.

Equation 20

$$E = (P_d Z)^{(1/2)}$$

Where:
- E = Electric Field Intensity (volts/meter)
- P_d = Power Density (watts/meter)
- Z = Impedance of free space air (120π or 377 ohms)

The narrative on power density to field strength conversions excerpted from the HIRF user's manual is provided in appendix A. It is provided for additional reference on electric field intensity conversion and background on rms engineering conventions.

The resulting electric field intensities were used to find the highest driver emitter for peak field intensity and the highest emitter driver for the average field intensity for each of the 17 bands.

4.4.8 NEAR-FIELD ANALYSIS

In the near field, the field may actually be higher further out. This effect occurs because the field is going in and out of constructive phasing as it develops into a plane wave. To determine if this was of concern for an emitter, the near-field correction values and near-field intensities were evaluated from the minimum separation distance out to the far field. Figures 7 and 8 are examples of where this analysis is used.

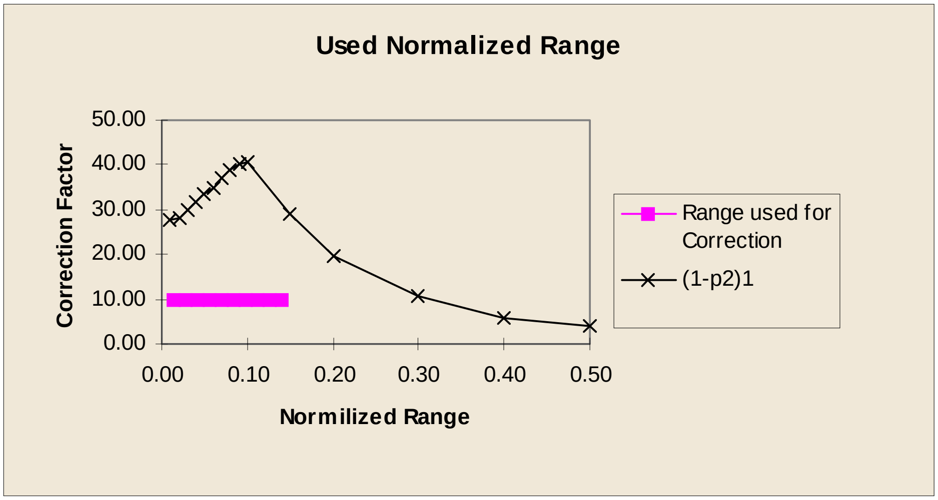

FIGURE 7
EXAMPLE OF NEAR-FIELD CORRECTION FACTOR

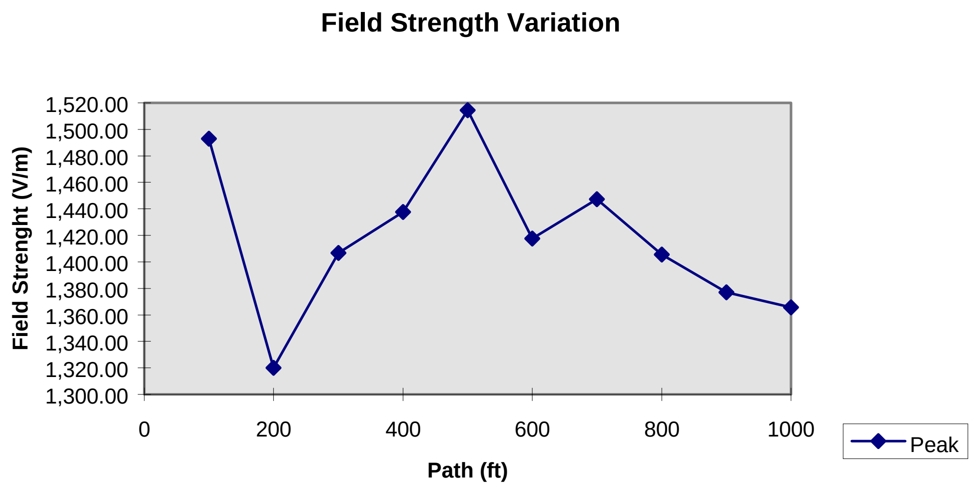

FIGURE 8
EXAMPLE OF NEAR-FIELD STRENGTH

Notice that in figure 7 the near-field correction peaks at 0.1 normalized range. This indicates the possibility of a higher field farther away than the minimum range. Figure 8 would be analyzed to see if the variation in the near-field correction value resulted in an anomaly in the fall off of the field intensity. These examples were taken from the Terminal Doppler Weather Radar operating in the 4 to 6 GHz range, the field intensity at 100 ft was 1,493 V/m then proceeded to decrease, then increase to a higher value of 1,514 V/m at 500 ft. Therefore, the distance for the Rotorcraft Severe Environment used the field intensity at the 500 ft distance number instead of the field at the minimum distance set by the assumptions of 100 ft. This analysis was performed on all emitters.

THIS PAGE INTENTIONALLY LEFT BLANK

5. U.S. HIRF ENVIRONMENTS

This section presents the results of the HIRF survey. The resulting U.S. Rotorcraft Severe, Fixed Wing Severe, Certification, and Normal Environments are presented. A discussion follows each environment on the emitters considered for each emitter, the drivers, and other relevant study results. Provided in Section 6 are the higher power emitters that were eliminated from consideration because they were excluded by the assumptions or are recommended to be identified in a Special Use Airspace in Aeronautical Charts.

5.1 U.S. ROTORCRAFT SEVERE ENVIRONMENT

The U.S. Rotorcraft Severe HIRF Environment is a worst case estimate of the electromagnetic field strength levels in the airspace in which rotorcraft flight operations are permitted. The assumptions for this environment were detailed in Section 3. The study determined the five highest possible drivers and the resulting maximum peak and average EME.

5.1.1 DRIVERS

This study identified the emitters listed in table 10 as the five peak drivers and table 11 as the average five drivers for the band of the U.S. Rotorcraft Severe Environment. Where possible, other lower power emitter drivers analyzed are listed. However, duplicate drivers are shown to indicate that there are several locations which operate the driver and alternates were not considered. The path, range, and comment are also provided in the tables for each emitter analyzed. The number one driver characteristics and analysis are presented in appendix D.

TABLE 10
EMITTER DRIVERS FOR THE PEAK FIELD INTENSITY
U.S. ROTORCRAFT SEVERE ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-87	FRT-3
Peak Field Strength (V/m)	127	127	127	127	127
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FPN-45A	FRT-87	FPN-42	FPN-44	FPN-64
Peak Field Strength (V/m)	180	143	127	127	114
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 10 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Peak Field Strength (V/m)	67	67	67	67	67
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	TPS-71
Peak Field Strength (V/m)	318	318	318	318	218
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Peak Field Strength (V/m)	71	71	71	71	71
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Peak Field Strength (V/m)	82	82	82	82	82
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Peak Field Strength (V/m)	140	140	140	140	140
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Peak Field Strength (V/m)	140	140	140	140	140
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Peak Field Strength (V/m)	402	402	402	402	402
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 10 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
700 MHz to 1 GHz	SPS-49	SPS-49	SPS-49	SPS-49	TV Ch 52-69 (701-806 MHz)
Peak Field Strength (V/m)	430	430	430	430	402
Path (ft)	500	500	500	500	100
Comment	Ship System, direct	Ship System, direct	Ship System, direct	Ship System, direct	Non Airport, direct
1 GHz to 2 GHz	ARSR-1D	ARSR-3	FPS-64	FPS-65	FPS-66
Peak Field Strength (V/m)	6,057	5,080	5,037	4,596	3,820
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 GHz to 4 GHz	WSR-88	WSR-88	CIMERON	SPS-48	SPY-1
Peak Field Strength (V/m)	3,351	3,351	2,759	2,404	2,204
Path (ft)	430	430	450	500	500
Comment	Airport, direct	Airport, direct	Non Airport, direct	Ship System, direct	Ship System, direct
4 GHz to 6 GHz	FPS-16V	FPS-16	TDWR	TDWR	TDWR
Peak Field Strength (V/m)	9,179	9,179	1,514	1,514	1,514
Path (ft)	100	100	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Peak Field Strength (V/m)	125	125	125	125	125
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	TPQ-39	NIKE-HURCLES	WECTRGTTR CKNGRDR	GPN-22	TPN-25
Peak Field Strength (V/m)	7,430	7,103	6,720	2,318	2,318
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Airport Fixed other, direct	Airport other, direct
12 GHz to 18 GHz	SAT BUS SYS	HAC6531	ASDE-3	ASDE-3	ASDE-3
Peak Field Strength (V/m)	578	558	232	232	232
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

TABLE 10 (continued)

18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Peak Field Strength (V/m)	1,008	1,008	1,008	1,008	1,008
Path (ft)	100	100	100	100	100
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

TABLE 11
EMITTER DRIVERS FOR THE AVERAGE FIELD INTENSITY
U.S. ROTORCRAFT SEVERE ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-31	FRT-3	FRT-64	FRT-72
Average Field Strength (V/m)	127	127	127	127	57
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FRT-87	FRT-72B	FRT-72	FRT-72	FRT-72
Average Field Strength (V/m)	143	57	57	57	57
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Average Field Strength (V/m)	67	67	67	67	67
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast
Average Field Strength (V/m)	318	318	318	318	218
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Average Field Strength (V/m)	71	71	71	71	71
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 11 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Average Field Strength (V/m)	82	82	82	82	82
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Average Field Strength (V/m)	140	140	140	140	140
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Average Field Strength (V/m)	140	140	140	140	140
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Average Field Strength (V/m)	402	402	402	402	402
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	SPS-49
Average Field Strength (V/m)	402	402	402	402	79
Path (ft)	100	100	100	100	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Ship System, direct
1 GHz to 2 GHz	FPS-64	FPS-66	FPS-66A	FPS-65	ARSR-3
Average Field Strength (V/m)	232	232	174	152	137
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 GHz to 4 GHz	SPS-48	WSR-88	WSR-88	CIMERON	SPY-1
Average Field Strength (V/m)	291	127	127	100	65
Path (ft)	500	100	100	100	500
Comment	Ship System, direct	Airport, direct	Airport, direct	Non Airport, direct	Ship System, direct

TABLE 11 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
4 GHz to 6 GHz	FPS-16V	FPS-16V	TDWR	TDWR	TDWR
Average Field Strength (V/m)	116	116	70	70	70
Path (ft)	100	100	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Average Field Strength (V/m)	76	76	76	76	76
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	TPQ-39	GPN-22	TPN-18	NIKEHURCLE S	FSC-79
Average Field Strength (V/m)	266	99	99	79	73
Path (ft)	100	250	250	100	100
Comment	Non Airport, direct	Airport other, direct	Airport other, direct	Non Airport, direct	Non Airport, direct
12 GHz to 18 GHz	SAT BUS SYS	HAC6531	SAT BUS SYS	SAT BUS SYS	SAT BUS SYS
Average Field Strength (V/m)	558	558	558	558	558
Path (ft)	100	100	100	100	100
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Average Field Strength (V/m)	18	18	18	18	18
Path (ft)	100	100	100	100	100
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

5.1.2 PEAK AND AVERAGE DATA

The recommended maximum peak and average field intensities as a function of the HIRF bands for the U.S. Rotorcraft Severe Environment are listed in table 12.

TABLE 12
PEAK AND AVERAGE FIELD INTENSITIES FOR THE U.S. ROTORCRAFT SEVERE ENVIRONMENT

Range	Peak	Average
10 kHz to 100 kHz	127	127
100 kHz to 500 kHz	180	143
500 kHz to 2 MHz	67	67
2 MHz to 30 MHz	318	318
30 MHz to 70 MHz	71	71
70 MHz to 100 MHz	82	82
100 MHz to 200 MHz	140	140
200 MHz to 400 MHz	140	140
400 MHz to 700 MHz	402	402
700 MHz to 1 GHz	430	402
1 GHz to 2 GHz	6,057	232
2 GHz to 4 GHz	3,351	291
4 GHz to 6 GHz	9,179	116
6 GHz to 8 GHz	125	76
8 GHz to 12 GHz	7,430	266
12 GHz to 18 GHz	578	558
18 GHz to 40 GHz	1,008	18

5.1.3 PEAK AND AVERAGE PLOTS

The recommended U.S. Rotorcraft Severe Environment are visually plotted in figure 9 for peak field intensities and figure 10 for the average field intensities.

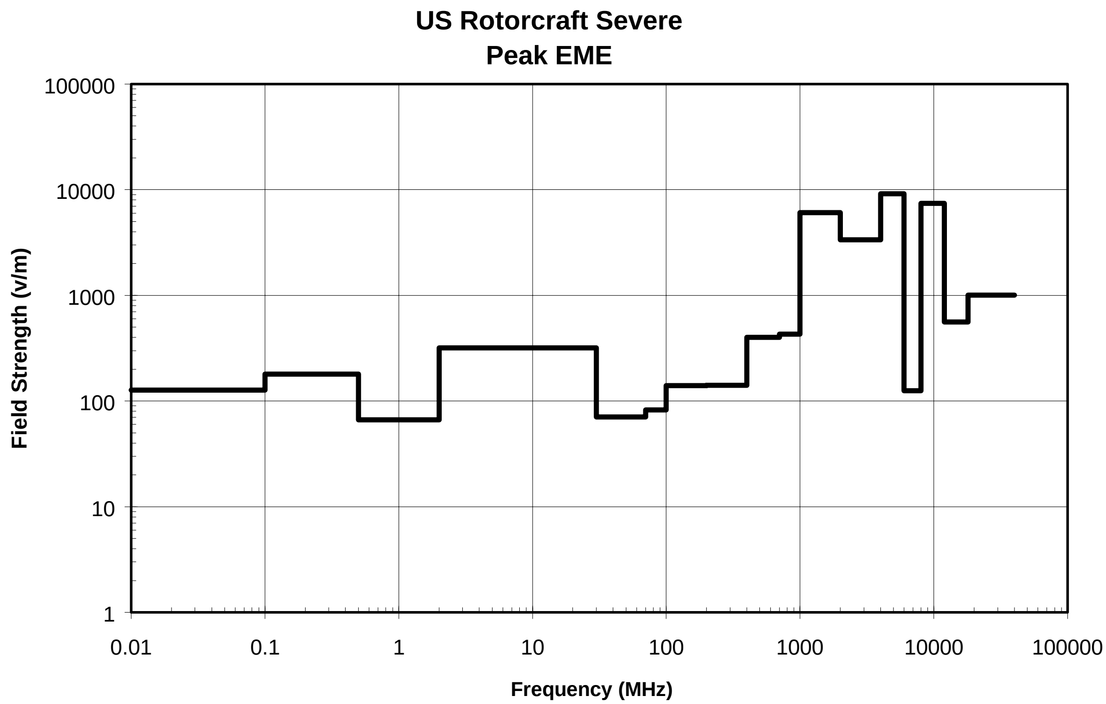

FIGURE 9
PEAK U.S. ROTORCRAFT SEVERE ENVIRONMENT

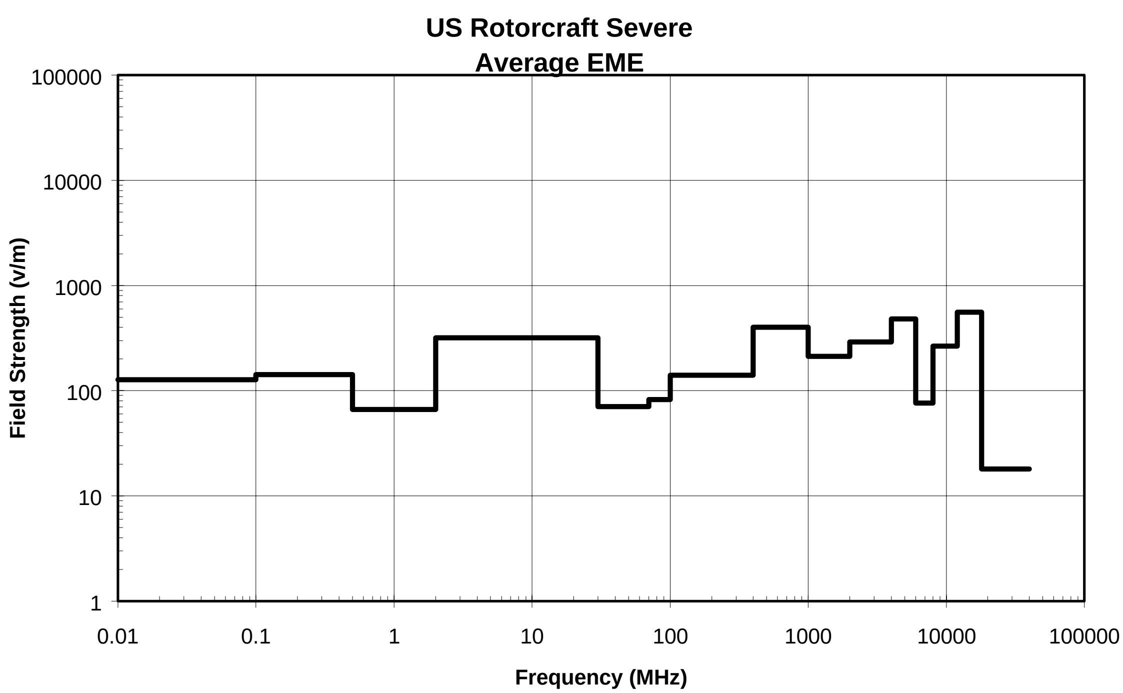

FIGURE 10
AVERAGE U.S. ROTORCRAFT SEVERE ENVIRONMENT

5.2 U.S. FIXED WING SEVERE ENVIRONMENT

The U.S. Fixed Wing Severe HIRF Environment is a worst case estimate of the electromagnetic field strength levels in the airspace in which fixed wing flight operations are permitted. The assumptions for this environment were detailed in Section 3. The study determined the five highest possible drivers and the resulting maximum peak and average EME.

5.2.1 DRIVERS

This study identified the emitters listed in table 13 as the five peak drivers and table 14 as the five average drivers for the band of the Fixed Wing Severe Environment. Where possible, other lower power emitter drivers analyzed are listed. However, duplicate drivers are shown to indicate that there are several locations which operate the driver and alternates were not considered. The number one driver characteristics are presented in appendix D.

TABLE 13
EMITTER DRIVERS FOR THE PEAK FIELD INTENSITY
U.S. FIXED WING SEVERE ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-87	FRT-3
Peak Field Strength (V/m)	25	25	25	25	25
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FPN-45A	FRT-87	FPN-44	FPN-42	FPN-64
Peak Field Strength (V/m)	36	29	25	25	16
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Peak Field Strength (V/m)	27	27	27	27	27
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	TPS-71
Peak Field Strength (V/m)	187	187	187	187	13
Path (ft)	500	500	500	500	500 (9584)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, slant
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Peak Field Strength (V/m)	16	16	16	16	16
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 13 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Peak Field Strength (V/m)	18	18	18	18	18
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Peak Field Strength (V/m)	29	29	29	29	29
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Peak Field Strength (V/m)	29	29	29	29	29
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Peak Field Strength (V/m)	80	80	80	80	80
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	SPS-49
Peak Field Strength (V/m)	80	80	80	80	67
Path (ft)	500	500	500	500	500 (3,206)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Ship System, slant
1 GHz to 2 GHz	ARSR-3	FPS-64	ARSR-1	FPS-65	ARSR-2
Peak Field Strength (V/m)	781	407	384	372	371
Path (ft)	500 (1.002)	500 (3,842)	500 (3,842)	500 (3,842)	500 (3,842)
Comment	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, slant
2 GHz to 4 GHz	WSR-88D	WSR-88D	CIMERON	SPS-48	SPY-1
Peak Field Strength (V/m)	3,002	3,002	2,783	2,275	2,204
Path (ft)	500 (578)	500 (578)	500	500 (553)	500
Comment	Airport Fixed radar, slant	Airport Fixed radar, slant	Non Airport, direct	Ship System, slant	Ship System, direct
4 GHz to 6 GHz	FPS-16V	FPS-16	TDWR	TDWR	TDWR
Peak Field Strength (V/m)	5,449	5,449	1,442	1,442	1,442
Path (ft)	500	500	500 (578)	500 (578)	500 (578)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, slant	Airport Fixed radar, slant	Airport Fixed radar, slant

TABLE 13 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Peak Field Strength (V/m)	125	125	125	125	125
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	TPQ-39	NIKE-HURCLES	WECTRGTTR CKNGRDR	GPN-22	TPN-25
Peak Field Strength (V/m)	2,198	2,019	2,002	1,954	1,954
Path (ft)	500	500	500	250 (289)	250 (289)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Airport fixed other, slant	Airport fixed other, slant
12 GHz to 18 GHz	SAT BUS SYS	HAC6531	ASDE-3	ASDE-3	ASDE-3
Peak Field Strength (V/m)	343	343	188	188	188
Path (ft)	500	500	250	250	250
Comment	Non Airport, direct	Non Airport, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Peak Field Strength (V/m)	688	688	688	688	688
Path (ft)	250	250	250	250	250
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

TABLE 14
EMITTER DRIVERS FOR THE AVERAGE FIELD INTENSITY
U.S. FIXED WING SEVERE ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-31	FRT-64
Average Field Strength (V/m)	25	25	25	25	25
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FRT-87	FRT-72B	FRT-72	FRT-72	FRT-72
Average Field Strength (V/m)	29	11	11	11	11
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 14 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Average Field Strength (V/m)	27	27	27	27	27
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast
Average Field Strength (V/m)	187	187	187	187	187
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Average Field Strength (V/m)	16	16	16	16	16
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Average Field Strength (V/m)	18	18	18	18	18
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Average Field Strength (V/m)	29	29	29	29	29
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Average Field Strength (V/m)	29	29	29	29	29
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Average Field Strength (V/m)	80	80	80	80	80
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	SPS-49
Average Field Strength (V/m)	80	80	80	80	12
Path (ft)	500	500	500	500	500 (3,206)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Ship System, slant

TABLE 14 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
1 GHz to 2 GHz	ESI11160	LOEARTS	ARSR-3	FPS-64	ASR4
Average Field Strength (V/m)	73	73	21	19	19
Path (ft)	500	500	500 (1,003)	500 (3,842)	500 (1,003)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, slant	Non Airport, slant	Non Airport, slant
2 GHz to 4 GHz	SPS-48	WSR-88	WSR-88	CIMERON	SPY-1
Average Field Strength (V/m)	275	135	135	100	65
Path (ft)	500 (553)	500 (578)	500 (578)	500	500
Comment	Ship System, slant	Airport Fixed radar, slant	Airport Fixed radar, slant	Non Airport, direct	Ship System, direct
4 GHz to 6 GHz	FPS-16V	FPS-16	TDWR	TDWR	TDWR
Average Field Strength (V/m)	69	69	66	66	66
Path (ft)	500	500	500 (578)	500 (578)	500 (578)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, Slant	Non Airport, Slant	Non Airport, Slant
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Average Field Strength (V/m)	76	76	76	76	76
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	TPQ-39	GPN-22	TPN-18	FSC-79	FSC-79
Average Field Strength (V/m)	84	83	83	73	73
Path (ft)	500	250 (289)	250 (289)	500	500
Comment	Non Airport, direct	Airport fixed other, slant	Airport fixed other, slant	Non Airport, direct	Non Airport, direct
12 GHz to 18 GHz	SAT BUS SYS	HAC6531	SAT BUS SYS	SAT BUS SYS	SAT BUS SYS
Average Field Strength (V/m)	343	343	343	343	343
Path (ft)	500	500	500	500	500
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Average Field Strength (V/m)	12	12	12	12	12
Path (ft)	250	250	250	250	250
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

5.2.2 PEAK AND AVERAGE DATA

The recommended maximum peak and average field intensities as a function of the HIRF bands for the U.S. Fixed Wing Severe Environment are listed in table 15.

TABLE 15
PEAK AND AVERAGE FIELD INTENSITIES FOR THE U.S. FIXED WING SEVERE ENVIRONMENT

Range	Peak	Average
10 kHz to 100 kHz	25	25
100 kHz to 500 kHz	36	29
500 kHz to 2 MHz	27	27
2 MHz to 30 MHz	187	187
30 MHz to 70 MHz	16	16
70 MHz to 100 MHz	18	18
100 MHz to 200 MHz	29	29
200 MHz to 400 MHz	29	29
400 MHz to 700 MHz	80	80
700 MHz to 1 GHz	80	80
1 GHz to 2 GHz	781	73
2 GHz to 4 GHz	3,002	275
4 GHz to 6 GHz	5,449	69
6 GHz to 8 GHz	125	76
8 GHz to 12 GHz	2,198	83
12 GHz to 18 GHz	343	343
18 GHz to 40 GHz	668	12

5.2.3 PEAK AND AVERAGE PLOTS

The recommended U.S. Fixed Wing Severe Environment are visually plotted in figure 11 for peak field intensities and figure 12 for the average field intensities.

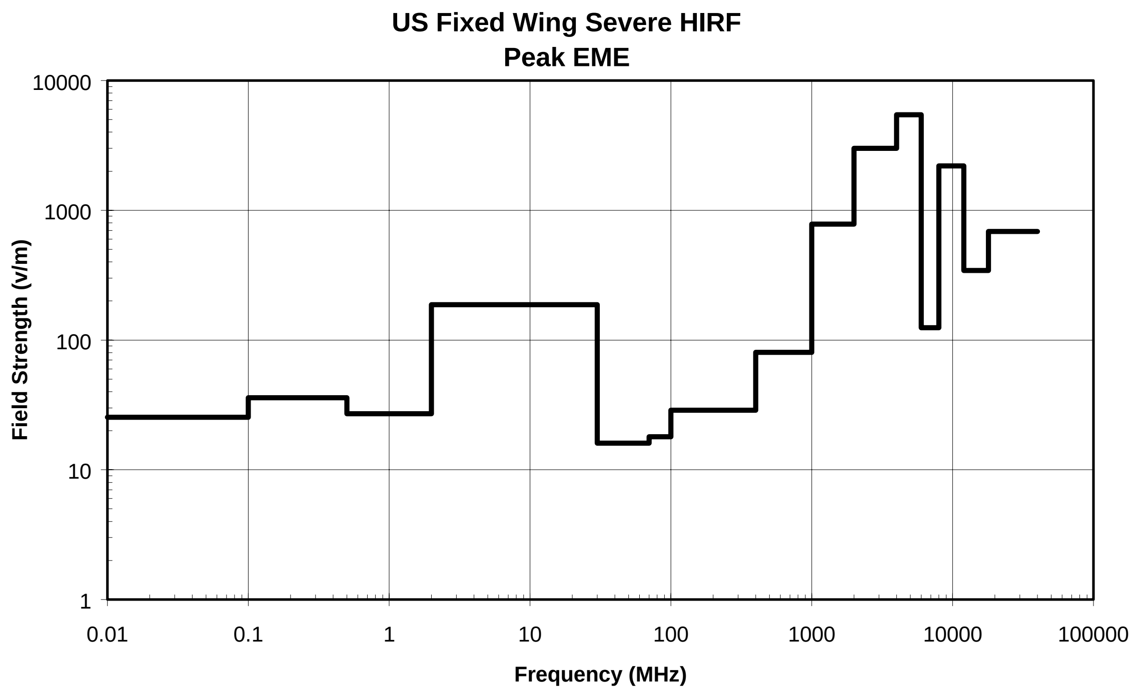

FIGURE 11
PEAK U.S. FIXED WING SEVERE ENVIRONMENT

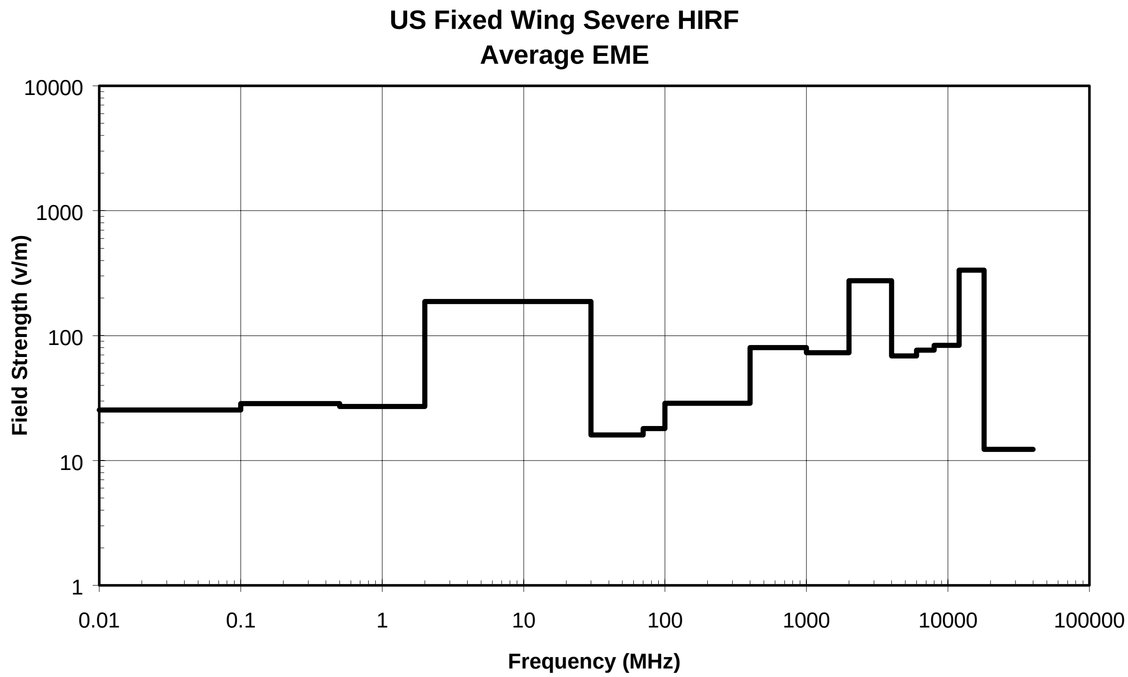

FIGURE 12
AVERAGE U.S. FIXED WING SEVERE ENVIRONMENT

5.3 U.S. AIRCRAFT CERTIFICATION ENVIRONMENT

The U.S. Certification HIRF Environment is an estimate of the electromagnetic field strength levels in the airspace in which flight operations are permitted. The assumptions for this environment were detailed in Section 3. The study determined the five highest possible drivers and the resulting maximum peak and average EME.

5.3.1 DRIVERS

This study identified the emitters listed in table 16 as the five peak drivers and table 17 as the five average drivers for the band of the U.S. Certification Environment applicable to both rotorcraft and fixed wing aircraft. When the same emitter is listed for more than one driver, this is because there are more than one to five or more of that emitter. The number one driver characteristics are presented in appendix D.

TABLE 16
EMITTER DRIVERS FOR THE PEAK FIELD INTENSITY
U.S. CERTIFICATION ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-31	FRT-64
Peak Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FPN-45A	FRT-87	FPN-44	FPN-42	FPN-64
Peak Field Strength (V/m)	18	14	8	8	8
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Peak Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	TPS-71
Peak Field Strength (V/m)	113	113	113	113	65
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Peak Field Strength (V/m)	8	8	8	8	8
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 16 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Peak Field Strength (V/m)	9	9	9	9	9
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Peak Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Peak Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Peak Field Strength (V/m)	40	40	40	40	40
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	SPS-49
Peak Field Strength (V/m)	40	40	40	40	34
Path (ft)	1,000	1,000	1,000	1,000	1,000 (6,412)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Ship System, slant
1 GHz to 2 GHz	ARSR-3	FPS-64	ARSR-1	FPS-65	ARSR-2
Peak Field Strength (V/m)	406	203	192	186	185
Path (ft)	1,000 (2,006)	1,000 (7,208)	1,000 (7,685)	1,000 (7,688)	1,000 (7,685)
Comment	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, slant
2 GHz to 4 GHz	WSR-88	WSR-88	SPY-1	CIMERON	SPS-48
Peak Field Strength (V/m)	3002	3002	2204	1,940	1,589
Path (ft)	500 (578)	500 (578)	1,000	1,000	1,000 (1,105)
Comment	Airport, slant	Airport, slant	Ship System, direct	Non Airport, direct	Ship System, slant
4 GHz to 6 GHz	FPS-16V	FPS-16	TDWR	TDWR	TDWR
Peak Field Strength (V/m)	2,800	2,800	1,341	1,341	1,341
Path (ft)	1,000	1,000	1,000(1,157)	1,000(1,157)	1,000(1,157)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, slant	Non Airport, slant	Non Airport, slant

TABLE 16 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Peak Field Strength (V/m)	125	125	125	125	125
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	GPN-22	TPN-25	TPQ-39	WECTRGTTR CKNGRDR	NIKE-HURCLES
Peak Field Strength (V/m)	1,954	1,954	1,240	1,174	1,137
Path (ft)	250 (289)	250 (289)	1,000	1,000	1,000
Comment	Airport fixed other, slant	Airport Fixed radar, slant	Non Airport, direct	Non Airport, direct	Non Airport, direct
12 GHz to 18 GHz	ASDE-3	ASDE-3	ASDE-3	SAT BUS SYS	HAC6531
Peak Field Strength (V/m)	188	188	188	176	176
Path (ft)	250	250	250	1,000	1,000
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Non Airport, direct	Non Airport, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Peak Field Strength (V/m)	688	688	688	688	688
Path (ft)	250	250	250	250	250
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

TABLE 17
EMITTER DRIVERS FOR THE AVERAGE FIELD INTENSITY
U.S. CERTIFICATION ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-31	FRT-64
Average Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FRT-87	FRT-72B	FRT-72	FRT-72	FRT-72
Average Field Strength (V/m)	14	6	6	6	6
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 17 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Average Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast
Average Field Strength (V/m)	113	113	113	113	113
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Average Field Strength (V/m)	8	8	8	8	8
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Average Field Strength (V/m)	9	9	9	9	9
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Average Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Average Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Average Field Strength (V/m)	40	40	40	40	40
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	SPS-49
Average Field Strength (V/m)	40	40	40	40	6
Path (ft)	1,000	1,000	1,000	1,000	1,000 (6,413)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Ship System, slant

TABLE 17 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
1 GHz to 2 GHz	ESI-11160	LOEARTS	ARSR-3	ARSR-4	FPS-64
Average Field Strength (V/m)	53	53	11	10	9
Path (ft)	1,000	1,000	100 (2,006)	1,000 (2,006)	1,000 (7,685)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, slant	Non Airport, slant	Non Airport, slant
2 GHz to 4 GHz	SPS-48	WSR-88	WSR-88	CIMERON	SPY-1
Average Field Strength (V/m)	192	135	135	70	33
Path (ft)	1,000 (1,105)	500 (578)	500 (578)	1,000 (2,933)	1,000
Comment	Ship System, slant	Airport Fixed radar, slant	Airport Fixed radar, slant	Non Airport, slant	Ship System, Direct
4 GHz to 6 GHz	TDWR	TDWR	TDWR	FPS-16	FPS-16
Average Field Strength (V/m)	62	62	62	35	35
Path (ft)	1000 (1,157)	1000 (1,157)	1000 (1,157)	1,000	1,000
Comment	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, direct	Non Airport, direct
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Average Field Strength (V/m)	76	76	76	76	76
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	GPN-22	TPN-18	FSC-79	FSC-79	TPQ-39
Average Field Strength (V/m)	83	83	73	73	44
Path (ft)	250 (289)	250 (289)	1,000	1,000	1,000
Comment	Airport fixed other, slant	Airport fixed other, slant	Non Airport, direct	Non Airport, direct	Non Airport, direct
12 GHz to 18 GHz	SAT BUS SYS	HAC6531	SAT BUS SYS	SAT BUS SYS	SAT BUS SYS
Average Field Strength (V/m)	176	176	176	176	176
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Average Field Strength (V/m)	12	12	12	12	12
Path (ft)	250	250	250	250	250
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

5.3.2 PEAK AND AVERAGE DATA

The recommended maximum peak and average field intensities as a function of the HIRF bands for the U.S. Certification Environment are listed in table 18.

TABLE 18
PEAK AND AVERAGE FIELD INTENSITIES FOR THE U.S. CERTIFICATION ENVIRONMENT

Range	Peak	Average
10 kHz to 100 kHz	13	13
100 kHz to 500 kHz	18	14
500 kHz to 2 MHz	13	13
2 MHz to 30 MHz	113	113
30 MHz to 70 MHz	8	8
70 MHz to 100 MHz	9	9
100 MHz to 200 MHz	14	14
200 MHz to 400 MHz	14	14
400 MHz to 700 MHz	40	40
700 MHz to 1 GHz	40	40
1 GHz to 2 GHz	406	53
2 GHz to 4 GHz	3,002	192
4 GHz to 6 GHz	2,800	62
6 GHz to 8 GHz	125	76
8 GHz to 12 GHz	1,954	83
12 GHz to 18 GHz	188	176
18 GHz to 40 GHz	688	12

5.3.3 PEAK AND AVERAGE PLOTS

The recommended U.S. Certification Environment are visually plotted in figure 13 for peak field intensities and figure 14 for the average field intensities.

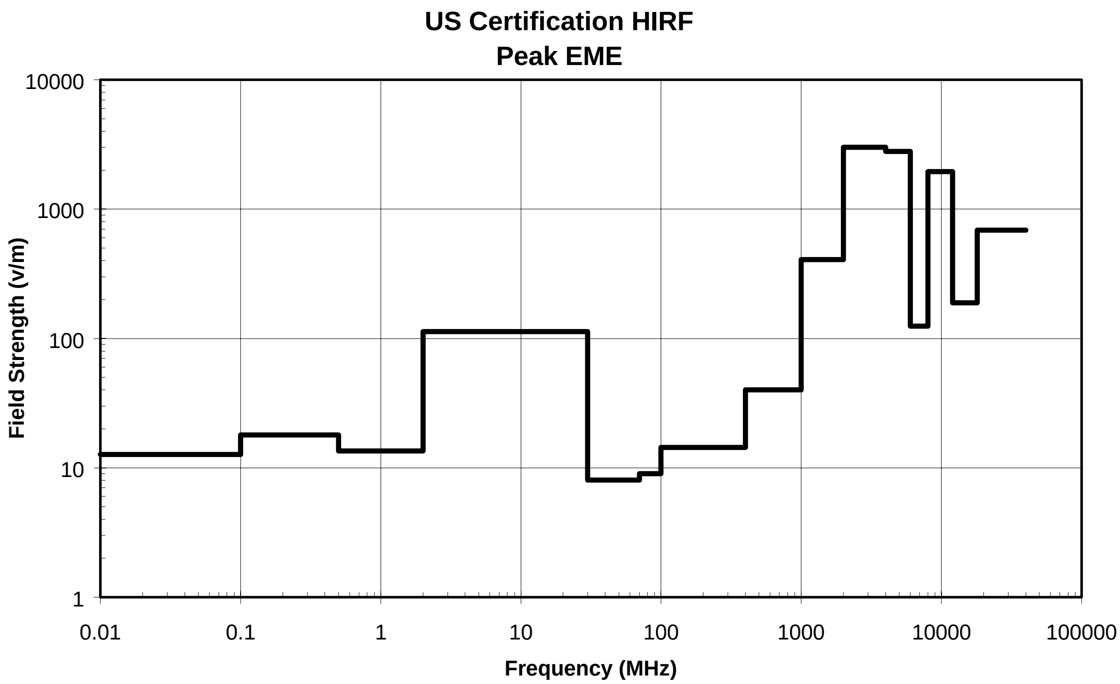

FIGURE 13
PEAK U.S. CERTIFICATION ENVIRONMENT

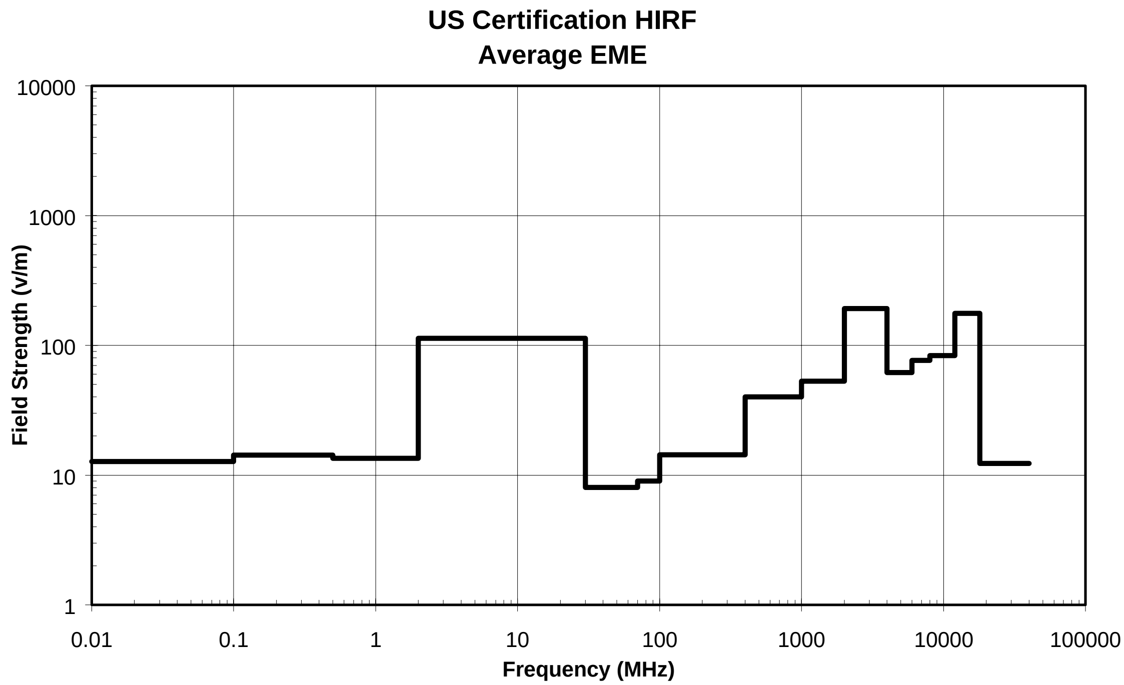

FIGURE 14
AVERAGE U.S. CERTIFICATION ENVIRONMENT

5.4 U.S. AIRCRAFT NORMAL ENVIRONMENT

The U.S. Normal HIRF Environment is an estimate of the electromagnetic field strength levels in the airspace in which normal flight operations are permitted. The assumptions for this environment were detailed in Section 3. The study determined the five highest possible drivers and the resulting maximum peak and average EME.

5.4.1 DRIVERS

This study identified the emitters listed in table 19 as the five peak drivers and table 20 as the five average drivers for the band of the U.S. Normal Environment applicable to both rotorcraft and fixed wing aircraft. When the same emitter is listed for more than one driver, this is because there are more than one to five or more of that emitter. The number one driver characteristics are presented in appendix D.

TABLE 19
EMITTER DRIVERS FOR THE PEAK FIELD INTENSITY
U.S. NORMAL ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-31	FRT-64
Peak Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FPN-45A	FRT-87	FPN-44	FPN-42	FPN-64
Peak Field Strength (V/m)	18	14	8	8	8
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Peak Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	TPS-71
Peak Field Strength (V/m)	113	113	113	113	65
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Peak Field Strength (V/m)	8	8	8	8	8
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 19 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Peak Field Strength (V/m)	9	9	9	9	9
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Peak Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Peak Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Peak Field Strength (V/m)	40	40	40	40	40
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	NOAA1
Peak Field Strength (V/m)	40	40	40	40	12
Path (ft)	1,000	1,000	1,000	1,000	1,000 (5,776)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, slant
1 GHz to 2 GHz	ARSR-3	FPS-64	ARSR-1	FPS-65	ARSR-2
Peak Field Strength (V/m)	406	203	192	186	185
Path (ft)	1,000 (2,006)	1,000 (7,685)	1,000 (7,685)	1,000 (7,685)	1,000 (7,685)
Comment	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, slant	Non Airport, slant
2 GHz to 4 GHz	WSR-88	WSR-88	WSR-88	CIMERON	GPN-20
Peak Field Strength (V/m)	3,003	3,003	3,003	1,940	802
Path (ft)	500 (578)	500 (578)	500 (578)	1,000	250 (501)
Comment	Airport Fixed radar, slant	Airport Fixed radar, slant	Airport Fixed radar, slant	Non Airport, direct	Airport, slant
4 GHz to 6 GHz	FPS-16V	FPS-16	TDWR	TDWR	TDWR
Peak Field Strength (V/m)	2,800	2,800	1,341	1,341	1,341
Path (ft)	1,000	1,000	1,000 (1,157)	1,000 (1,157)	1,000 (1,157)
Comment	Non Airport, direct	Non Airport, direct	Non Airport slant	Non Airport slant	Non Airport slant

TABLE 19 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Peak Field Strength (V/m)	125	125	125	125	125
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	GPN-22	TPN-25	TPQ-39	WECTRGTTR CKNGRDR	NIKE-HURCLES
Peak Field Strength (V/m)	1,954	1,954	1,240	1,174	1,137
Path (ft)	250 (289)	250 (289)	1,000	1,000	1,000
Comment	Airport fixed other, slant	Airport fixed other, slant	Non Airport, direct	Non Airport, direct	Non Airport, direct
12 GHz to 18 GHz	ASDE-3	ASDE-3	ASDE-3	SAT BUS SYS	HAC6531
Peak Field Strength (V/m)	188	188	188	176	176
Path (ft)	250	250	250	1,000	1,000
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Non Airport, direct	Non Airport, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Peak Field Strength (V/m)	688	688	688	688	688
Path (ft)	250	250	250	250	250
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

TABLE 20
EMITTER DRIVERS FOR THE AVERAGE FIELD INTENSITY
U.S. NORMAL ENVIRONMENT

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
10 kHz to 100 kHz	FRT-87	FRT-3	FRT-31	FRT-31	FRT-64
Average Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 kHz to 500 kHz	FRT-87	FRT-72B	FRT-72	FRT-72	FRT-72
Average Field Strength (V/m)	14	6	6	6	6
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 20 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
500 kHz to 2 MHz	AM Radio	AM Radio	AM Radio	AM Radio	AM Radio
Average Field Strength (V/m)	13	13	13	13	13
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
2 MHz to 30 MHz	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast	VOA/SW Broadcast
Average Field Strength (V/m)	113	113	113	113	113
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
30 MHz to 70 MHz	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)	TV Ch 2-6 (47-68 MHz)
Average Field Strength (V/m)	8	8	8	8	8
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
70 MHz to 100 MHz	FM Radio	FM Radio	FM Radio	FM Radio	FM Radio
Average Field Strength (V/m)	9	9	9	9	9
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
100 MHz to 200 MHz	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)	TV Ch 7-11 (174-198 MHz)
Average Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
200 MHz to 400 MHz	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)	TV Ch 11-13 (204-216 MHz)
Average Field Strength (V/m)	14	14	14	14	14
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
400 MHz to 700 MHz	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)	TV Ch 14-52 (470-698 MHz)
Average Field Strength (V/m)	40	40	40	40	40
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
700 MHz to 1 GHz	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)	TV Ch 52-69 (701-806 MHz)
Average Field Strength (V/m)	40	40	40	40	40
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct

TABLE 20 (continued)

Range	Driver #1	Driver #2	Driver #3	Driver #4	Driver #5
1 GHz to 2 GHz	ESI11160	LOEARTS	ARSR-3	ARSR-4	FPS-64
Average Field Strength (V/m)	53	53	11	10	9
Path (ft)	1,000	1,000	1,000 (2,006)	1,000 (2,006)	1,000 (7,685)
Comment	Non Airport, direct	Non Airport, direct	Non Airport, slant	Non Airport, slant	Non Airport, slant
2 GHz to 4 GHz	WSR-88	WSR-88	WSR-88	CIMERON	GPN-20
Average Field Strength (V/m)	135	135	135	70	25
Path (ft)	500 (578)	500 (578)	500 (578)	1,000	250 (501)
Comment	Airport Fixed radar, slant	Airport Fixed radar, slant	Airport Fixed radar, slant	Non Airport, direct	Airport fixed other, slant
4 GHz to 6 GHz	FPS-16	CP-3	TDWR	TDWR	FPS-16
Average Field Strength (V/m)	142	88	64	64	41
Path (ft)	1,000	1,000 (1157)	500 (578)	500 (578)	1,000
Comment	Non Airport, direct	Non Airport, slant	Airport Fixed radar, slant	Airport Fixed radar, slant	Non Airport, direct
6 GHz to 8 GHz	FSC-79	FSC-79	FSC-79	FSC-79	FSC-79
Average Field Strength (V/m)	76	76	76	76	76
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
8 GHz to 12 GHz	GPN-22	TPN-18	FSC-79	FSC-79	TPQ-39
Average Field Strength (V/m)	83	83	73	73	44
Path (ft)	250 (289)	250 (289)	500	500	1,000
Comment	Airport fixed other, slant	Airport fixed other, slant	Non Airport, direct	Non Airport, direct	Non Airport, direct
12 GHz to 18 GHz	SAT BUS SYS	HAC6531	SAT BUS SYS	SAT BUS SYS	SAT BUS SYS
Average Field Strength (V/m)	176	176	176	176	176
Path (ft)	1,000	1,000	1,000	1,000	1,000
Comment	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct	Non Airport, direct
18 GHz to 40 GHz	ADSE-2	ADSE-2	ADSE-2	ADSE-2	ADSE-2
Average Field Strength (V/m)	12	12	12	12	12
Path (ft)	250	250	250	250	250
Comment	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct	Airport fixed other, direct

5.4.2 PEAK AND AVERAGE DATA

The recommended maximum peak and average field intensities as a function of the HIRF bands for the U.S. Normal Environment are listed in table 21.

TABLE 21
PEAK AND AVERAGE FIELD INTENSITIES FOR THE U.S. NORMAL ENVIRONMENT

Range	Peak	Average
10 kHz to 100 kHz	13	13
100 kHz to 500 kHz	18	14
500 kHz to 2 MHz	13	13
2 MHz to 30 MHz	113	113
30 MHz to 70 MHz	8	8
70 MHz to 100 MHz	9	9
100 MHz to 200 MHz	14	14
200 MHz to 400 MHz	14	14
400 MHz to 700 MHz	40	40
700 MHz to 1 GHz	40	40
1 GHz to 2 GHz	406	53
2 GHz to 4 GHz	3,002	135
4 GHz to 6 GHz	2,800	62
6 GHz to 8 GHz	125	76
8 GHz to 12 GHz	1,954	83
12 GHz to 18 GHz	188	176
18 GHz to 40 GHz	688	12

5.4.3 PEAK AND AVERAGE PLOTS

The recommended U.S. Normal Environment are visually plotted in figure 15 for peak field intensities and figure 16 for the average field intensities.

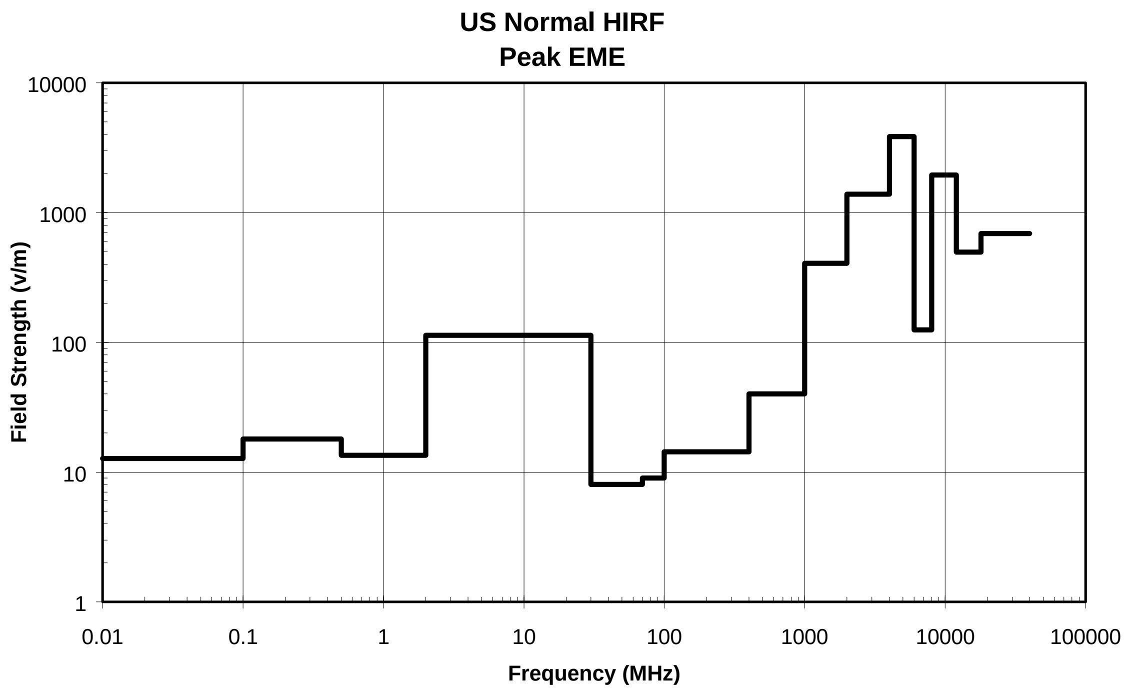

FIGURE 15
PEAK U.S. NORMAL ENVIRONMENT

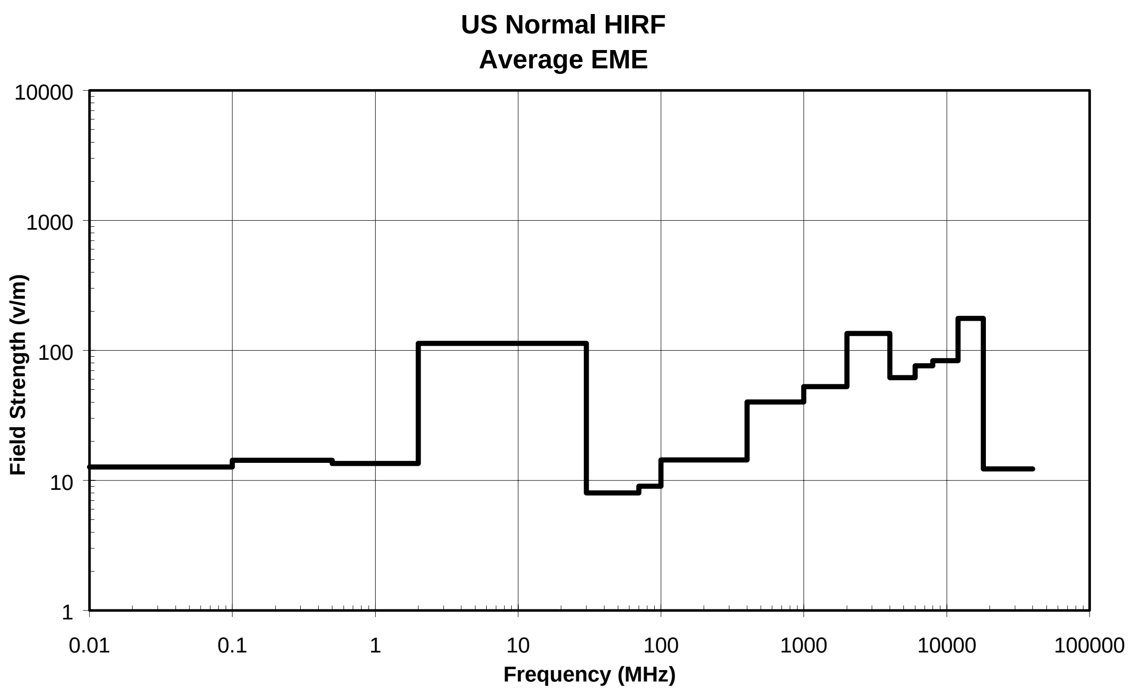

FIGURE 16
AVERAGE U.S. NORMAL ENVIRONMENT

THIS PAGE INTENTIONALLY LEFT BLANK

6. RECOMMEND SPECIAL USE AIRSPACE EMITTERS

In Section 5, the driver emitters were identified. However, there were many emitters that were higher than the drivers. The assumptions to developing the environment allowed for elimination of these higher power emitters if they met certain criteria, such as an emitter located in an SUA. The following sections will identify those high power emitters that were eliminated and recommend appropriate action based on the assumptions.

6.1 EXISTING SUA'S

The emitters in SUA's were eliminated from consideration as a driver from the HIRF environment since civil aircraft are restricted from flying in that airspace for some reason. In most cases, this was because the airspace is used for a special military purpose. It is recommended that the FAA update the following existing SUA, table 22, to include a note identifying that HIRF in excess of the safe civil aircraft HIRF levels exist within these SUA's.

TABLE 22
EXISTING SUA'S

Frequency Range	Emitter	Latitude and Longitude	SUA
100-200 MHz	SPS-28	39.20.52N -118.11.55W	R-4816S
100-200 MHz	NASA	37.55.46N - 075.28.22W	R-6604
200-400 MHz	RFCRF712	34.35.35N - 086-35-31W	R-2104
200-400 MHz	RATSCAT	32.54.30N - 106.24.30W	R-5107B
200-400 MHz	SAN ENVIRONMENTAL GEN	38.17.15N - 076.24.04W	R-4007
400-700 MHz	SPS-40	38.09.00N - 076.26.00W	R-4005
400-700 MHz	FPS-85	30.34.20N - 086.12.52W	R-2917
400-700 MHz	FPS-50	64.17.16N - 149.10.58W	R-2206
400-700 MHz	FPS-92	64.17.16N - 149.10.58W	R-2206
400-700 MHz	FPS-115	41.45.11N - 070.32.18W	R-4101
400-700 MHz	UNSWINDPROFILER	34.46.12N - 120.31.52W	R-2517
400-700 MHz	LILRSTER	22.08.02N - 159.43.42W	R-3101
700-1000 MHz	WEST III	30.29.05N - 086.50.19W	R-2915A
2-4 GHz	NASA	35.25.33N - 116.53.19W	R-2502N
2-4 GHz	SPANDAR	37.51.17N - 075.30.48W	R-6604
2-4 GHz	LOE LOAL CONIC	35.07.07N - 116.48.20W	R-2502E
2-4 GHz	NASA/JPL	35.20.25N - 116.52.27W	R-2502N
2-4 GHz	PD12M/FPN-66	35.02.50N - 079.19.45W	R-5311A
2-4 GHz	SPY-1	37.56.00N - 075.27.00W	R-6604
4-6 GHz	FPQ-14	28.25.29N - 080.39.52W	R-2932
4-6 GHz	FPQ-6	37.51.37N - 075.30.35W	R-6604
4-6 GHz	TPQ-18	34.39.57N - 120.34.49W	R-2517
4-6 GHz	FPQ-16	30.25.17N - 086.47.53W	R-2915C
4-6 GHz	FPS-16	34.07.17N - 119.09.01W	R-2519
4-6 GHz	TRC-170(V2)	31.34.34N - 110.24.26W	R-2303
4-6 GHz	FPS-16	32.54.04N - 106.05.55W	R-5107B
4-6 GHz	TRACKER RDR	28.28.53N - 080.34.36W	R-2932

TABLE 22 (continued)

Frequency Range	Emitter	Latitude and Longitude	SUA
4-6 GHz	TRC-132	33.01.14N - 114.25.09W	R-2306A
6-8 GHz	RADAR	37.18.07N - 116.46.17W	R-4807A
6-8 GHz	TPS-T1	40.09.34N - 113.20.59W	R-6402A
6-8 GHz	NASA DSN	35.25.19N - 116.53.11W	R-2502N
6-8 GHz	NASA DSN	35.20.00N - 116.50.00W	R-2502N
6-8 GHz	TWT/APS	35.14.18N - 116.46.44W	R-2502N
6-8 GHz	SAD SIV	30.25.26N - 086.46.18W	R-2915B
6-8 GHz	NASA DSN	35.20.19N - 116.53.11W	R-2502N
8-12 GHz	RADAR	37.18.50N - 116.47.29W	R-4807A
8-12 GHz	NASA	35.25.33N - 116.53.19W	R-2502N
8-12 GHz	MIDI RADAR	33.00.00N - 106.30.00W	R-5107B
8-12 GHz	RADAR	33.08.23N - 106.17.07W	R-5107B
8-12 GHz	SAD SX	30.29.00N - 086.45.00W	R-2915A
12-18 GHz	OA-3390/MPA	32.23.00N - 106.29.00W	R-5107B
12-18 GHz	SAD SVIII	30.23.33N - 086.44.45W	R-2915C
12-18 GHz	MPQ4A	37.01.40N - 077.56.00W	R-6602B,C
12-18 GHz	MSQT-12	40.09.34N - 113.20.59W	R-6402A
12-18 GHz	HUGTMTU	40.09.34N - 113.20.59W	R-6402A
12-18 GHz	GSG-11(V)2	32.04.26N - 106.09.07W	R-5103A
12-18 GHz	RATSCAT	32.54.30N - 106.24.30W	R-5107B
12-18 GHz	GPQ-11(V)1	39.19.21N - 118.13.27W	R-4816S
12-18 GHz	VITTASETSTYPEI	29.10.22N - 081.42.26W	R-2910
12-18 GHz	VITTASETSTYPEI	29.08.33N - 081.42.17W	R-2910
12-18 GHz	VITTASETSTYPEI	29.08.27N - 081.38.49W	R-2910
12-18 GHz	VITTASETSTYPEI	29.03.36N - 081.37.59W	R-2910
12-18 GHz	VITTASETSTYPEI	29.08.04N - 081.45.20W	R-2910
12-18 GHz	NIKEMISSLERDR	34.56.43N - 117.54.46W	R-2515
12-18 GHz	VPQ-1	64.43.11N - 146.31.18W	R-2205
18-40 GHz	GDE-22	32.55.00N - 106.03.00W	R-5107B
18-40 GHz	VIT RIR	37.50.28N - 075.29.08W	R-6604A
18-40 GHz	SPN-46	38.16.54N - 076.23.59W	R-24007

6.2 PROPOSED SUA'S

There were a few emitters that are not in SUA's. These emitters radiated extremely high intensity radiated fields. Rather than requiring aircraft to certify to function in the HIRF environment of these few emitters, it was decided by the HIRF community that they should be put in SUA's. These candidate SUA emitters were thereby eliminated as a driver to the HIRF environments. It is recommend that the FAA create the following SUA, table 23, to identify to aircraft operators that the emitters contained within have HIRF greater than the HIRF environment used to certify aircraft for safe operation.

TABLE 23
PROPOSED SUA'S

Frequency Range	Emitter	Latitude and Longitude	SUA (Radius, Altitude)
400-700 MHz	FPQ-16	48.43.33N - 097.54.00W	5 nmi, 30,000 ft
400-700 MHz	FPT-5	42.37.10N - 071.29.30W	4 nmi, 23,000 ft
400-700 MHz	FPS-115	32.34.49N - 083.34.09W	1 nmi, 6,000 ft
400-700 MHz	FPS-115	30.58.42N - 100.33.09W	1 nmi, 6,000 ft
400-700 MHz	FPS-115	39.08.15N - 121.26.47W	1 nmi, 6,000 ft
1-2 GHz	FPS-108	52.43.37N - 174.05.49E	45 nmi, unlimited ft
1-2 GHz	LIL LONGRNGETRKRDR	42.37.02N - 071.29.29W	0.5 nmi, 3,000 ft
4-6 GHz	FPQ-14	26.58.00N - 080.06.00W	1.0 nmi, 6000 ft
4-6 GHz	FPQ-14	28.13.34N - 080.35.58W	1.0 nmi, 6000 ft
4-6 GHz	FPQ-14	21.34.30N - 158.16.30W	1.0 nmi, 6000 ft

6.3 ELIMINATED EMITTERS

Emitters listed in table 24 were eliminated from the environment because they were excluded by the assumptions. Noted on the right column is the justification as to why the emitters were eliminated from the environment in accordance with the environment assumptions. It is recommended that, if an emitter should change its status such that it would not be eliminated from the environment, then the emitter should be placed in an SUA with a note to identify to aircraft operators that the emitters contained within have field strengths greater than the HIRF environment used to certify aircraft for safe operation.

TABLE 24
ELIMINATED EMITTERS

Frequency Range	Emitter	Latitude - Longitude	Justification
200-400 MHz	Gila River	33.32.47N - 098.45.46W	(Made of numerous low power emitters over a very large geographic area to achieve far field high gain)
200-400 MHz	WEST II	30.29.20N - 086.30.38W	Assumption # 14 Experimental
400-700 MHz	Lab made	38.18.00N - 097.13.00W	Assumption # 14 Experimental
400-700 MHz	SPS-40	36.36.00N - 121.51.00W	Assumption # 14 Experimental
1-2 GHz	TPS-63	34.07.00N - 116.02.00W	Assumption # 15 Mobile
4-6 GHz	RCAMIPIR/CAPRI	39.18.31N - 115.05.08W	Assumption # 14 Experimental
4-6 GHz	AND-F1	40.40.40N - 105.02.27W	Assumption # 14 Experimental
4-6 GHz	MPQ-53	(numerous)	Assumption # 15 Mobile
4-6 GHz	MPS-26	(numerous)	Assumption # 15 Mobile
6-8 GHz	HYBRIDSHF	37.43.58N - 121.52.41W	Assumption # 14 Experimental
8-12 MHz	SAN ENVIRONMENTAL GEN	38.20.29N - 077.03.07W	Assumption # 14 Experimental
12-18 GHz	ANDVERTEX4.57KPK	40.40.49N - 105.02.27W	Assumption # 14 Experimental
12-18 GHz	ROLANDTRACKRDR & HUGTRACKRDR	30.29.00N - 086.30.00W	Assumption # 14 Experimental
12-18 GHz	OA-3390/MPA	36.15.00N - 115.20.00W	Assumption # 15 Mobile
12-18 GHz	MPQ-51	(numerous)	Assumption # 15 Mobile
12-18 GHz	MSQT-43	(numerous)	Assumption # 15 Mobile
12-18 GHz	MPQ-4	(numerous)	Assumption # 15 Mobile
12-18 GHz	MPQ-51	(numerous)	Assumption # 15 Mobile

TABLE 24 (continued)

Frequency Range	Emitter	Latitude - Longitude	Justification
12-18 GHz	MPQ-37	(numerous)	Assumption # 15 Mobile
12-18 GHz	MSQT-43	(numerous)	Assumption # 15 Mobile
12-18 GHz	XM-42A	31.19.47N - 085.42.55W	Assumption # 14 Experimental
12-18 GHz	TPT-4	(numerous)	Assumption # 15 Mobile
12-18 GHz	MSQT-12	28.02.00N - 080.35.50W	Assumption # 15 Mobile
12-18 GHz	MPQ-50	36.46.32N - 119.45.59W	Assumption # 15 Mobile
12-18 GHz	APQ-170	(numerous)	Assumption # 14 Experimental
12-18 GHz	MK15MOD1	(numerous)	Assumption # 14 Experimental
12-18 GHz	SML66320-C10D20	28.22.35N - 081.04.55W	Assumption # 14 Experimental
18-40 GHz	TPQ-11	42.27.48N - 071.16.10W	Assumption # 15 Mobile
18-40 GHz	TPQ-11	41.39.30N - 070.31.18W	Assumption # 15 Mobile
18-40 GHz	SPN-42	(numerous)	Assumption # 14 Experimental

7. INTERNATIONAL HIRF ENVIRONMENTS

7.1 EUROPEAN HIRF ENVIRONMENTS

The EUROCAE Working Group 31 was responsible for the development of the European HIRF environment. The final version of the European environment was published at the EEHWG meeting held at Bridgeport in June 1997. The environments used the same assumptions as the U.S. HIRF environments. However, no emitters were placed in SUA's. The countries that primarily contributed to the development of the European HIRF environments were United Kingdom, France, Netherlands, Germany, and Sweden.

7.1.1 ROTORCRAFT SEVERE ENVIRONMENT

The European Rotorcraft Severe Environment data are provided in table 25 and graphed in figures 17 and 18.

TABLE 25
EUROPEAN ROTORCRAFT SEVERE ENVIRONMENT DATA

Range	Peak	Average
10 kHz to 100 kHz	150	150
100 kHz to 500 kHz	150	150
500 kHz to 2 MHz	300	300
2 MHz to 30 MHz	930	930
30 MHz to 70 MHz	75	75
70 MHz to 100 MHz	150	150
100 MHz to 200 MHz	300	105
200 MHz to 400 MHz	420	75
400 MHz to 700 MHz	1,020	200
700 MHz to 1 GHz	2,400	230
1 GHz to 2 GHz	7,000	250
2 GHz to 4 GHz	8,600	840
4 GHz to 6 GHz	7,700	900
6 GHz to 8 GHz	1,800	800
8 GHz to 12 GHz	8,000	500
12 GHz to 18 GHz	3,300	400
18 GHz to 40 GHz	1,800	700

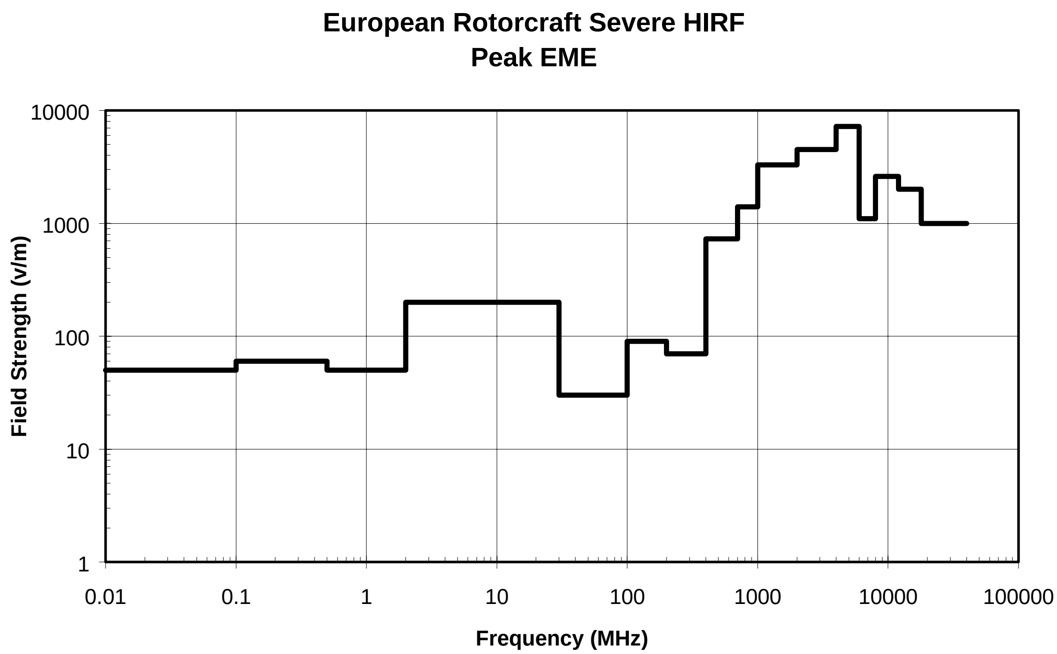

FIGURE 17
PEAK EUROPEAN ROTORCRAFT SEVERE ENVIRONMENT

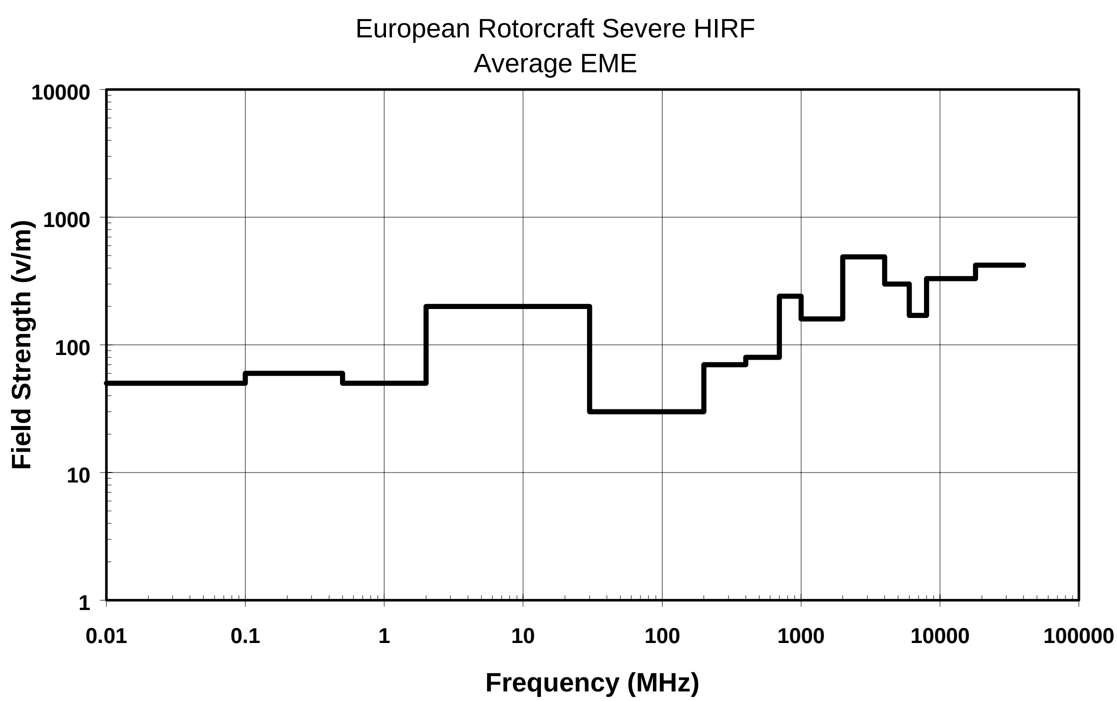

FIGURE 18
AVERAGE EUROPEAN ROTORCRAFT SEVERE ENVIRONMENT

7.1.2 FIXED WING SEVERE ENVIRONMENT

The European Fixed Wing Severe Environment data are provided in table 26 and graphed in figures 19 and 20.

TABLE 26
EUROPEAN FIXED WING SEVERE ENVIRONMENT DATA

Range	Peak	Average
10 kHz to 100 kHz	50	50
100 kHz to 500 kHz	60	60
500 kHz to 2 MHz	70	70
2 MHz to 30 MHz	200	200
30 MHz to 70 MHz	30	30
70 MHz to 100 MHz	30	30
100 MHz to 200 MHz	150	105
200 MHz to 400 MHz	70	75
400 MHz to 700 MHz	730	30
700 MHz to 1 GHz	2,400	80
1 GHz to 2 GHz	3,300	170
2 GHz to 4 GHz	6,000	820
4 GHz to 6 GHz	4,500	250
6 GHz to 8 GHz	1,800	330
8 GHz to 12 GHz	4,240	330
12 GHz to 18 GHz	3,300	510
18 GHz to 40 GHz	1,700	700

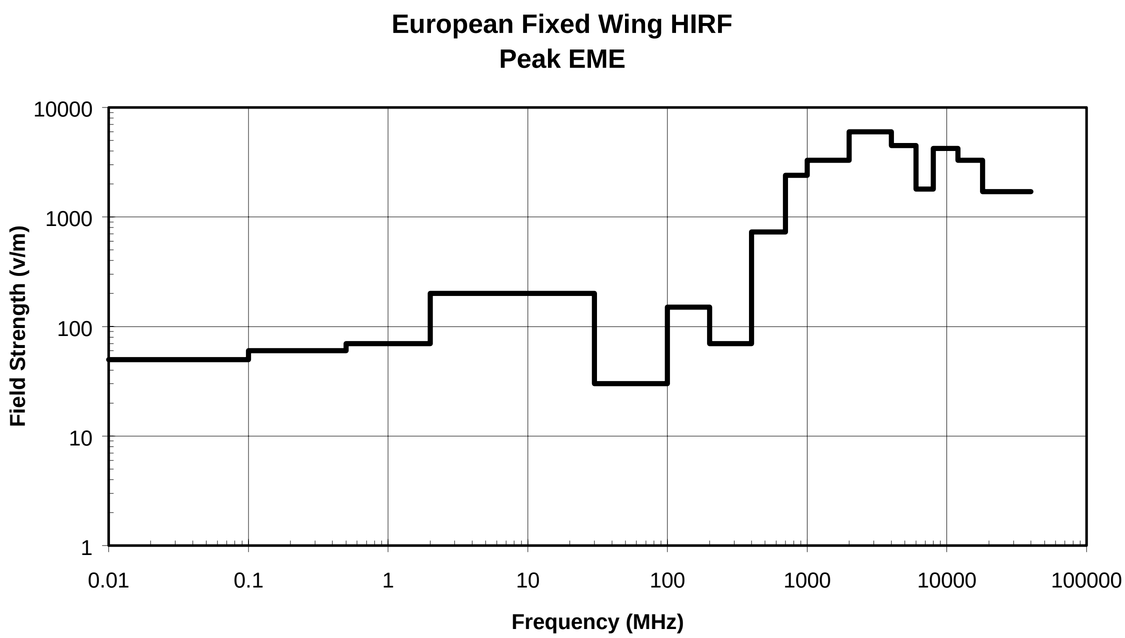

FIGURE 19
PEAK EUROPEAN FIXED WING SEVERE ENVIRONMENT

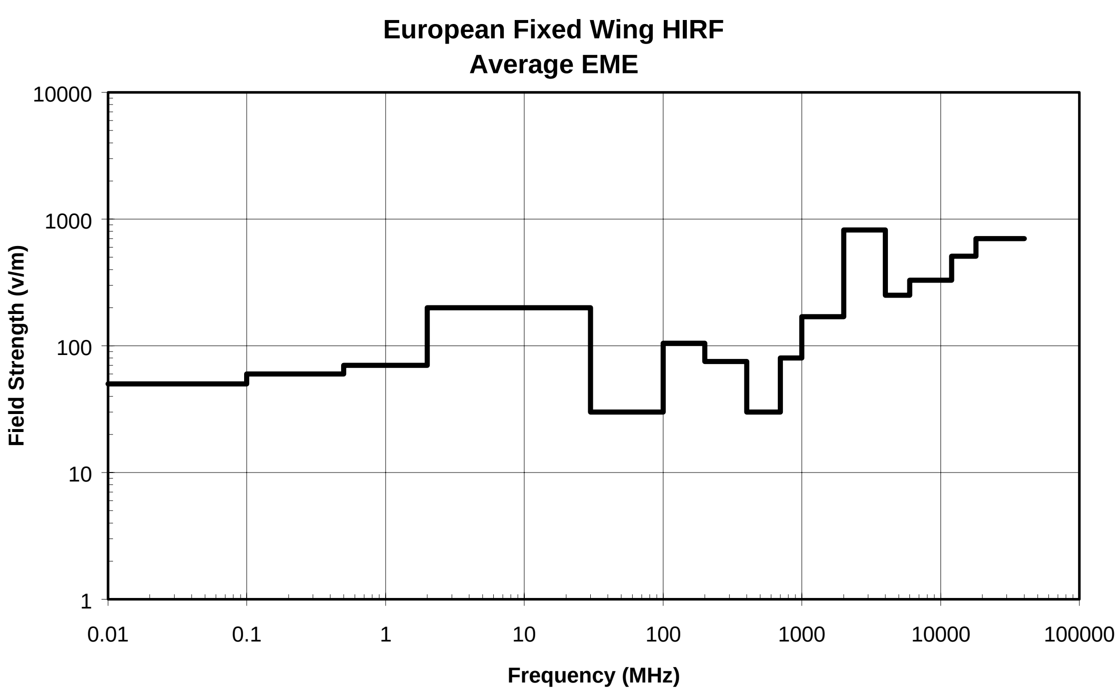

FIGURE 20
AVERAGE EUROPEAN FIXED WING SEVERE ENVIRONMENT

7.1.3 CERTIFICATION ENVIRONMENT

The European Certification Environment data are provided in table 27 and graphed in figures 21 and 22.

TABLE 27
EUROPEAN CERTIFICATION ENVIRONMENT DATA

Range	Peak	Average
10 kHz to 100 kHz	40	40
100 kHz to 500 kHz	40	40
500 kHz to 2 MHz	40	40
2 MHz to 30 MHz	100	100
30 MHz to 70 MHz	20	20
70 MHz to 100 MHz	20	20
100 MHz to 200 MHz	50	20
200 MHz to 400 MHz	70	70
400 MHz to 700 MHz	730	30
700 MHz to 1 GHz	690	70
1 GHz to 2 GHz	2,200	160
2 GHz to 4 GHz	3,500	240
4 GHz to 6 GHz	3,200	130
6 GHz to 8 GHz	800	170
8 GHz to 12 GHz	3,500	330
12 GHz to 18 GHz	1,700	210
18 GHz to 40 GHz	600	200

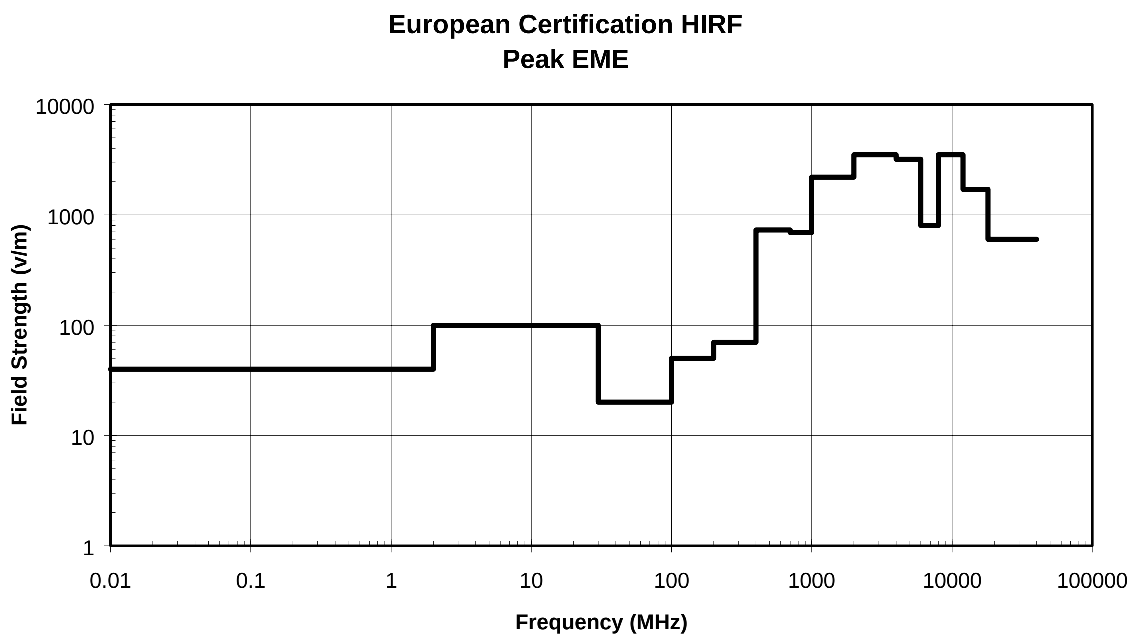

FIGURE 21
PEAK EUROPEAN CERTIFICATION ENVIRONMENT

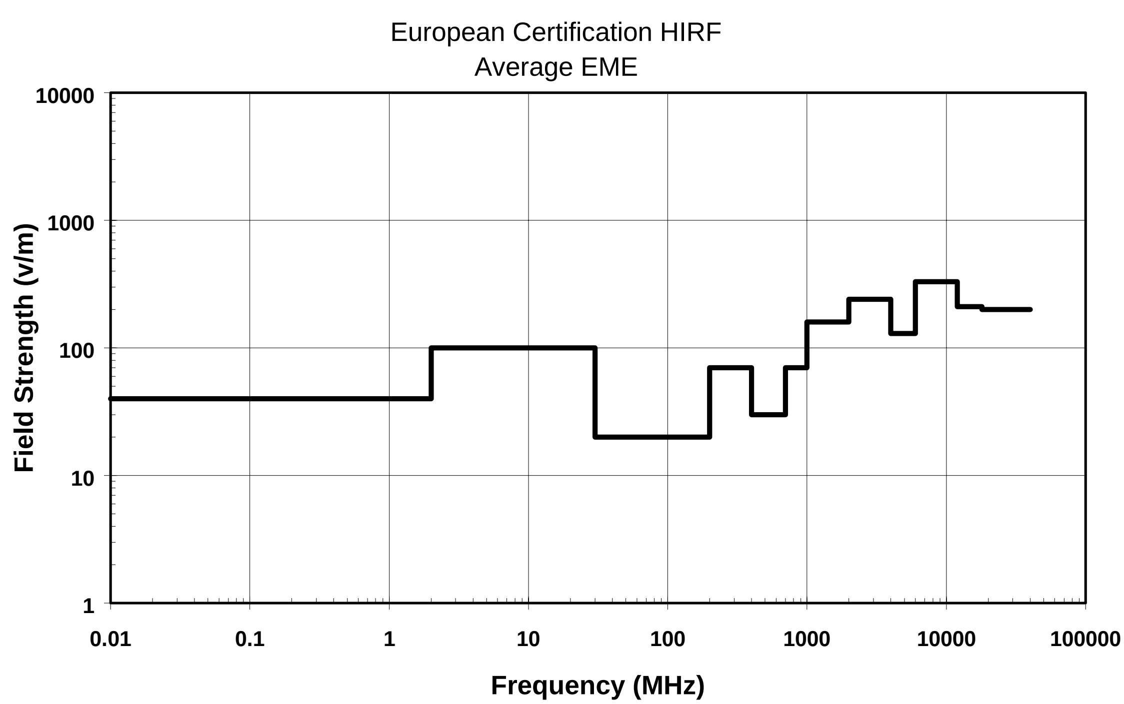

FIGURE 22
AVERAGE EUROPEAN CERTIFICATION ENVIRONMENT

7.1.4 NORMAL ENVIRONMENT

The European Normal Environment data are provided in table 28 and graphed in figures 23 and 24

TABLE 28
EUROPEAN NORMAL ENVIRONMENT DATA

Range	Peak	Average
10 kHz to 100 kHz	20	20
100 kHz to 500 kHz	20	20
500 kHz to 2 MHz	30	30
2 MHz to 30 MHz	40	40
30 MHz to 70 MHz	10	10
70 MHz to 100 MHz	10	10
100 MHz to 200 MHz	30	10
200 MHz to 400 MHz	10	10
400 MHz to 700 MHz	730	30
700 MHz to 1 GHz	690	30
1 GHz to 2 GHz	1,300	160
2 GHz to 4 GHz	3,000	120
4 GHz to 6 GHz	3,200	120
6 GHz to 8 GHz	400	170
8 GHz to 12 GHz	1,100	230
12 GHz to 18 GHz	730	120
18 GHz to 40 GHz	600	150

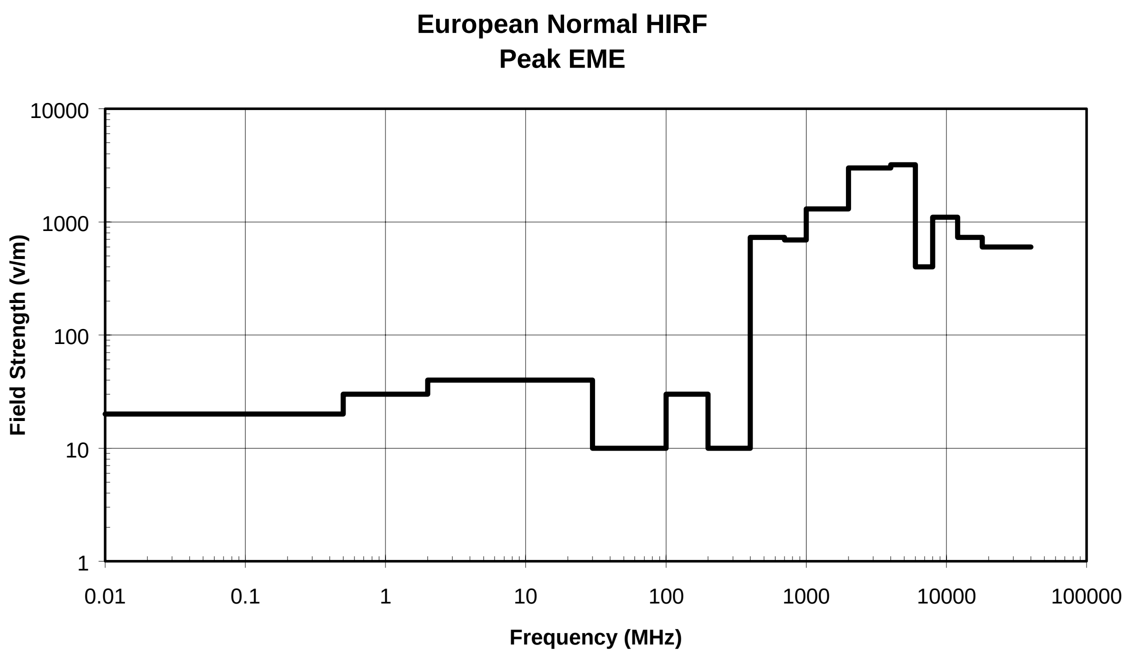

FIGURE 23
PEAK EUROPEAN NORMAL ENVIRONMENT

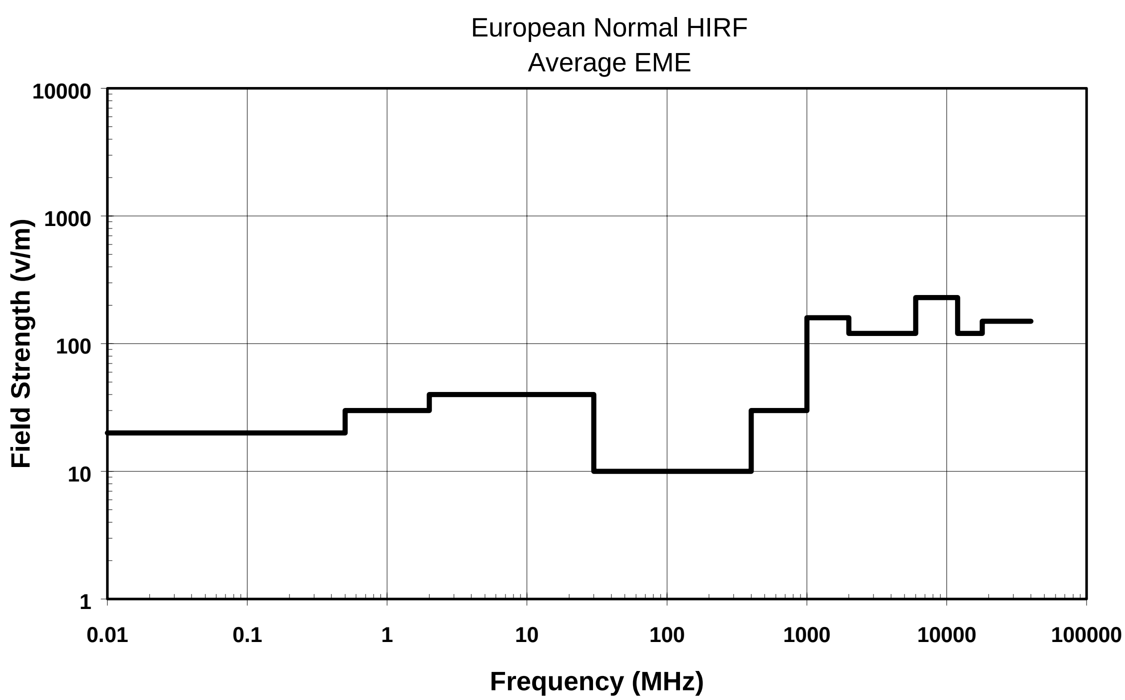

FIGURE 24
AVERAGE EUROPEAN NORMAL ENVIRONMENT

7.2 INTERNATIONAL HIRF ENVIRONMENT

The International HIRF Environment was developed at the EEHWG meeting at Bridgeport in June 1997 (reference 12). The U.S. and European HIRF environment data were used as the basis for the International HIRF Environments. The International HIRF Environment is a harmonized version of these environments with tailoring consideration as follows:

- The level maintained some relationship to 1997 and prior HIRF special conditions environments.
- Consolidation of frequency bands.
- High confidence that aircraft will not be affected by HIRF.
- Environments below 400 MHz were rounded to 50 or 100 V/m (this is where most EMI effects are observed in aircraft; therefore, high confidence is gained that the aircraft is protected).
- Environments above 1 GHz were rounded to the nearest 100 V/m with a maximum of 3,000 V/m or nearest 100 V/m average.
- Considered a test environment so it should not have to change every time a transmitter changes.
- Practicality of design and test levels.

The following sections detail the resulting environment.

7.2.1 INTERNATIONAL ROTORCRAFT SEVERE HIRF ENVIRONMENT

The International Rotorcraft Severe HIRF Environment data are provided in table 29 and graphed in figures 25 and 26. Noted in table 29 are the drivers used to harmonize the International Rotorcraft Severe HIRF Environment.

TABLE 29
INTERNATIONAL ROTORCRAFT SEVERE ENVIRONMENT DATA

Range	Peak	Driver	Average	Driver
10 kHz to 100 kHz	150	European	150	European
100 kHz to 500 kHz	200	U.S	200	European
500 kHz to 2 MHz	200	European	200	European
2 MHz to 30 MHz	200	European	200	European
30 MHz to 70 MHz	200	European	200	European
70 MHz to 100 MHz	200	European	200	European
100 MHz to 200 MHz	200	European	200	U.S.
200 MHz to 400 MHz	200	European	200	U.S.
400 MHz to 700 MHz	730	European	200	European
700 MHz to 1 GHz	1,400	European	240	U.S.
1 GHz to 2 GHz	5,000	U.S.	250	European
2 GHz to 4 GHz	6,000	European	490	European
4 GHz to 6 GHz	7,200	European	400	European
6 GHz to 8 GHz	1,100	European	170	European
8 GHz to 12 GHz	5,000	European	330	European
12 GHz to 18 GHz	2,000	European	330	European
18 GHz to 40 GHz	1,000	European	420	European

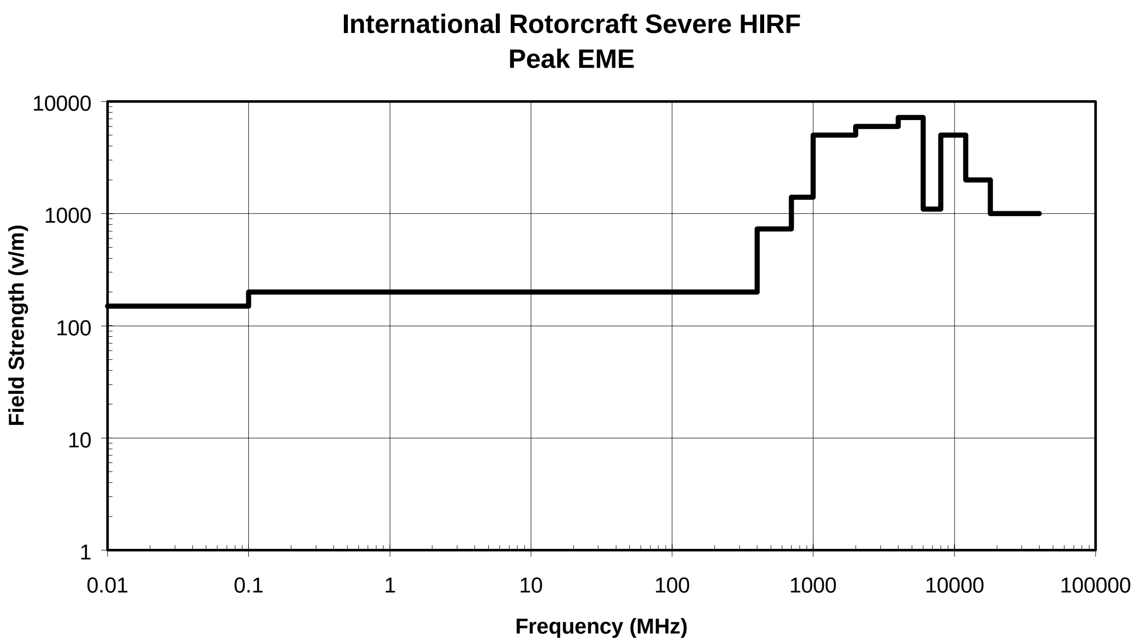

FIGURE 25
PEAK INTERNATIONAL ROTORCRAFT SEVERE ENVIRONMENT

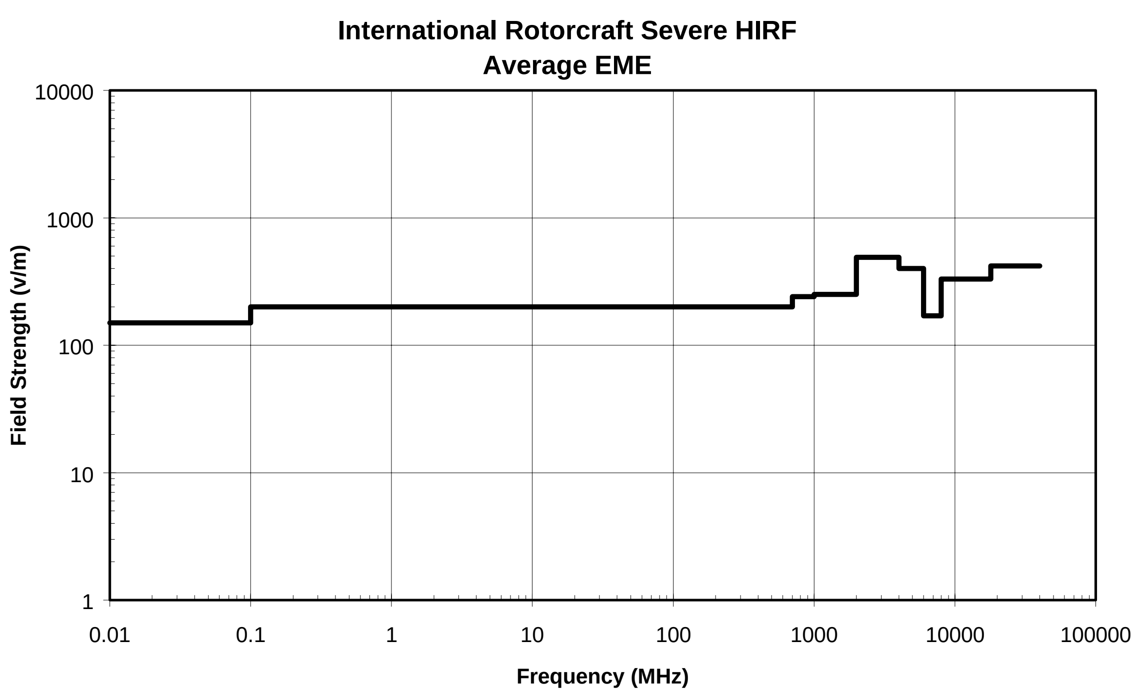

FIGURE 26
AVERAGE INTERNATIONAL ROTORCRAFT SEVERE ENVIRONMENT

7.2.2 INTERNATIONAL FIXED WING HIRF ENVIRONMENT

The International Fixed Wing Severe HIRF Environment data are provided in table 30 and graphed in figures 27 and 28. Noted in table 30 are the drivers used to harmonize the International Fixed Wing Severe HIRF Environment.

TABLE 30
INTERNATIONAL FIXED WING SEVERE ENVIRONMENT DATA

Range	Peak	Driver	Average	Driver
10 kHz to 100 kHz	50	European	50	European
100 kHz to 500 kHz	60	European	60	European
500 kHz to 2 MHz	70	European	70	European
2 MHz to 30 MHz	200	European	200	European
30 MHz to 70 MHz	30	European	30	European
70 MHz to 100 MHz	30	European	30	European
100 MHz to 200 MHz	90	European	30	European
200 MHz to 400 MHz	70	European	70	European
400 MHz to 700 MHz	730	European	80	U.S.
700 MHz to 1 GHz	1,400	European	240	U.S.
1 GHz to 2 GHz	3,300	European	160	European
2 GHz to 4 GHz	4,500	European	490	European
4 GHz to 6 GHz	7,200	U.S.	300	U.S.
6 GHz to 8 GHz	1,100	European	170	European
8 GHz to 12 GHz	2,600	European	330	European
12 GHz to 18 GHz	2,000	European	330	European
18 GHz to 40 GHz	1,000	European	420	European

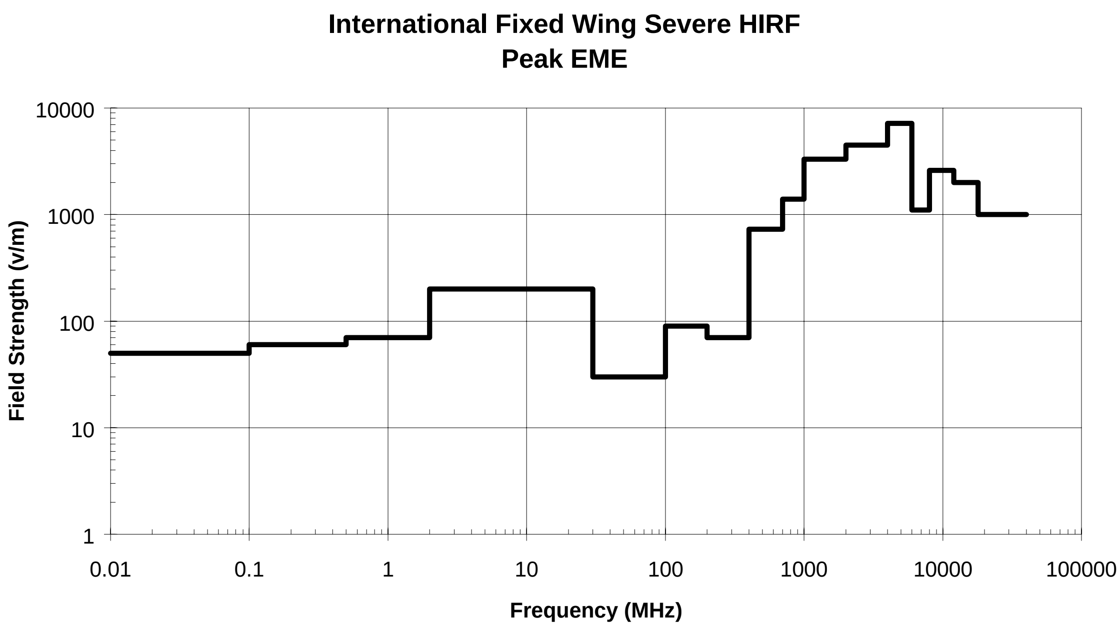

FIGURE 27
PEAK INTERNATIONAL FIXED WING SEVERE ENVIRONMENT

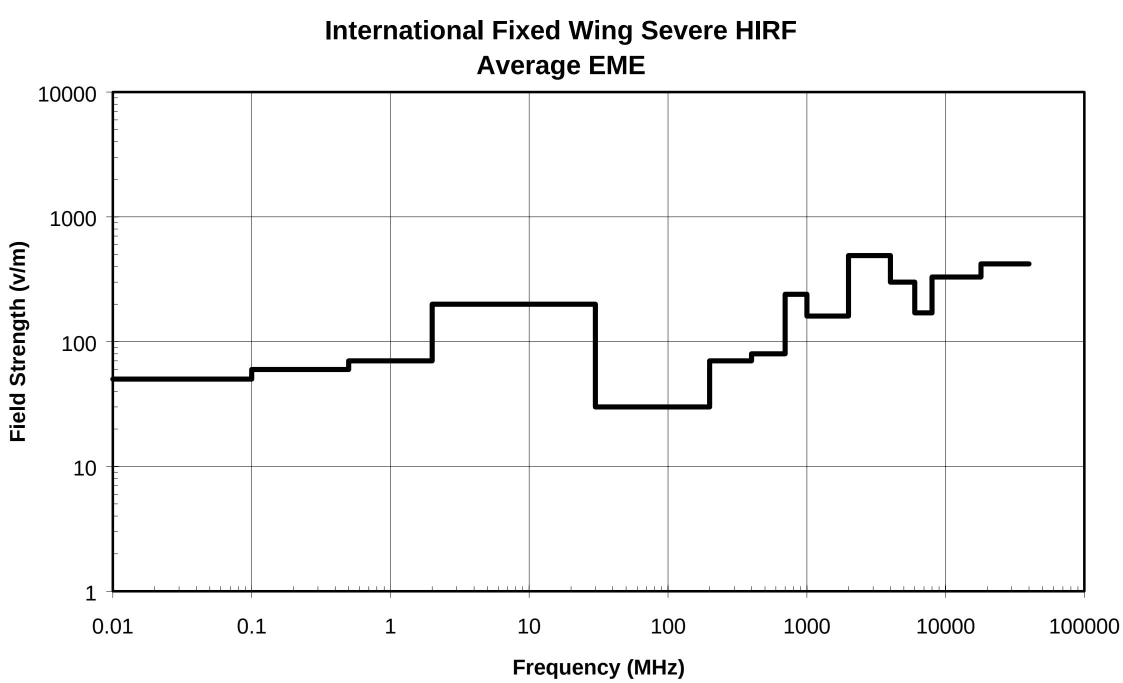

FIGURE 28
AVERAGE INTERNATIONAL FIXED WING SEVERE ENVIRONMENT

7.2.3 INTERNATIONAL CERTIFICATION HIRF ENVIRONMENT

The International Certification HIRF Environment data are provided in table 31 and graphed in figures 29 and 30. Noted in table 31 are the drivers used to harmonize the International Certification HIRF Environment.

TABLE 31
INTERNATIONAL CERTIFICATION ENVIRONMENT DATA

Range	Peak	Driver	Average	Driver
10 kHz to 100 kHz	50	European	50	European
100 kHz to 500 kHz	50	European	50	European
500 kHz to 2 MHz	50	European	50	European
2 MHz to 30 MHz	100	U.S.	100	U.S.
30 MHz to 70 MHz	50	European	50	European
70 MHz to 100 MHz	50	European	50	European
100 MHz to 200 MHz	100	European	100	European
200 MHz to 400 MHz	100	European	100	European
400 MHz to 700 MHz	700	European	50	U.S.
700 MHz to 1 GHz	700	European	100	European
1 GHz to 2 GHz	2,000	European	200	European
2 GHz to 4 GHz	3,000	European	200	European
4 GHz to 6 GHz	3,000	U.S.	200	U.S.
6 GHz to 8 GHz	1,000	European	200	European
8 GHz to 12 GHz	3,000	European	300	European
12 GHz to 18 GHz	2,000	European	200	European
18 GHz to 40 GHz	600	European	200	European

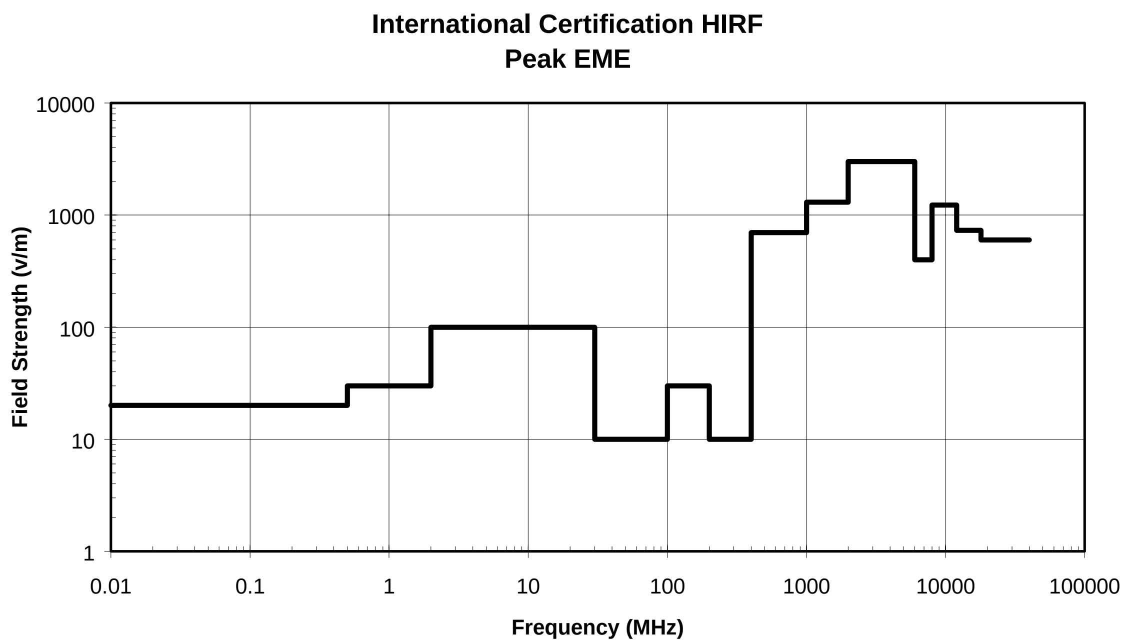

FIGURE 29
PEAK INTERNATIONAL CERTIFICATION ENVIRONMENT

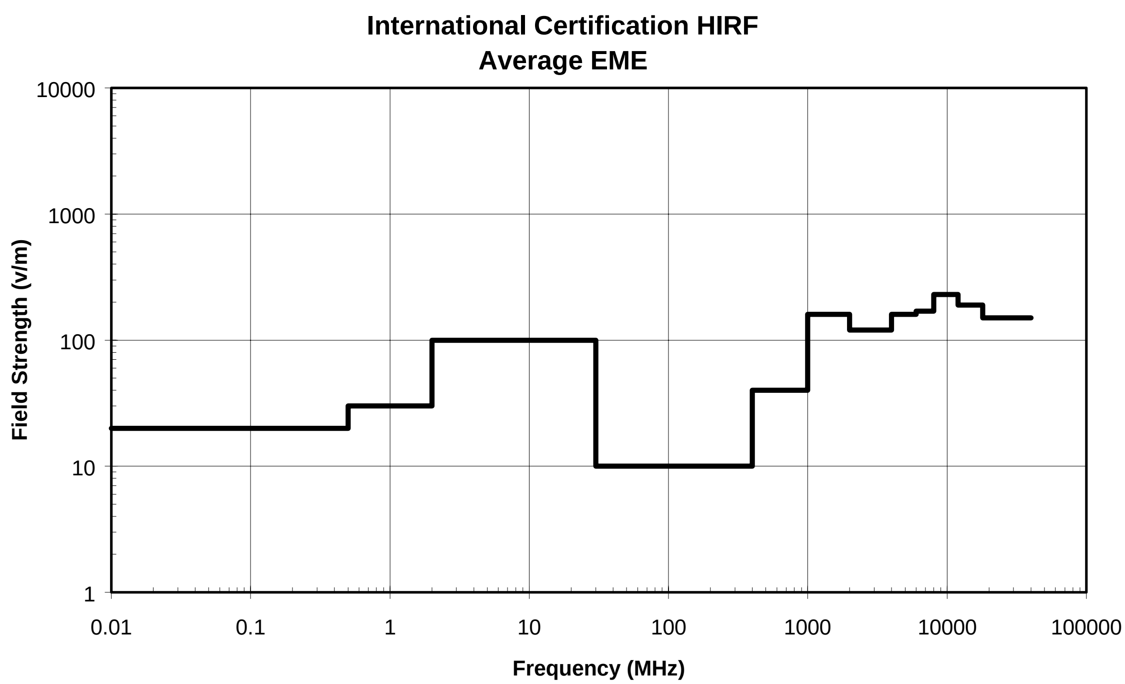

FIGURE 30
AVERAGE INTERNATIONAL CERTIFICATION ENVIRONMENT

7.2.4 INTERNATIONAL NORMAL HIRF ENVIRONMENT

The International Normal HIRF Environment data are provided in table 32 and graphed in figures 31 and 32. Noted in table 32 are the drivers used to harmonize the International Normal HIRF Environment.

TABLE 32
INTERNATIONAL NORMAL ENVIRONMENT DATA

Range	Peak	Driver	Average	Driver
10 kHz to 100 kHz	20	European	20	European
100 kHz to 500 kHz	20	European	20	European
500 kHz to 2 MHz	30	European	30	European
2 MHz to 30 MHz	100	U.S.	100	U.S.
30 MHz to 70 MHz	10	European	10	European
70 MHz to 100 MHz	10	European	10	European
100 MHz to 200 MHz	30	European	10	U.S.
200 MHz to 400 MHz	10	U.S.	10	U.S.
400 MHz to 700 MHz	700	European	40	U.S.
700 MHz to 1 GHz	700	European	40	U.S.
1 GHz to 2 GHz	1,300	European	160	European
2 GHz to 4 GHz	3,000	European	120	European
4 GHz to 6 GHz	3,000	U.S.	160	U.S.
6 GHz to 8 GHz	400	European	170	European
8 GHz to 12 GHz	1,230	U.S.	230	European
12 GHz to 18 GHz	730	European	190	U.S.
18 GHz to 40 GHz	600	European	150	European

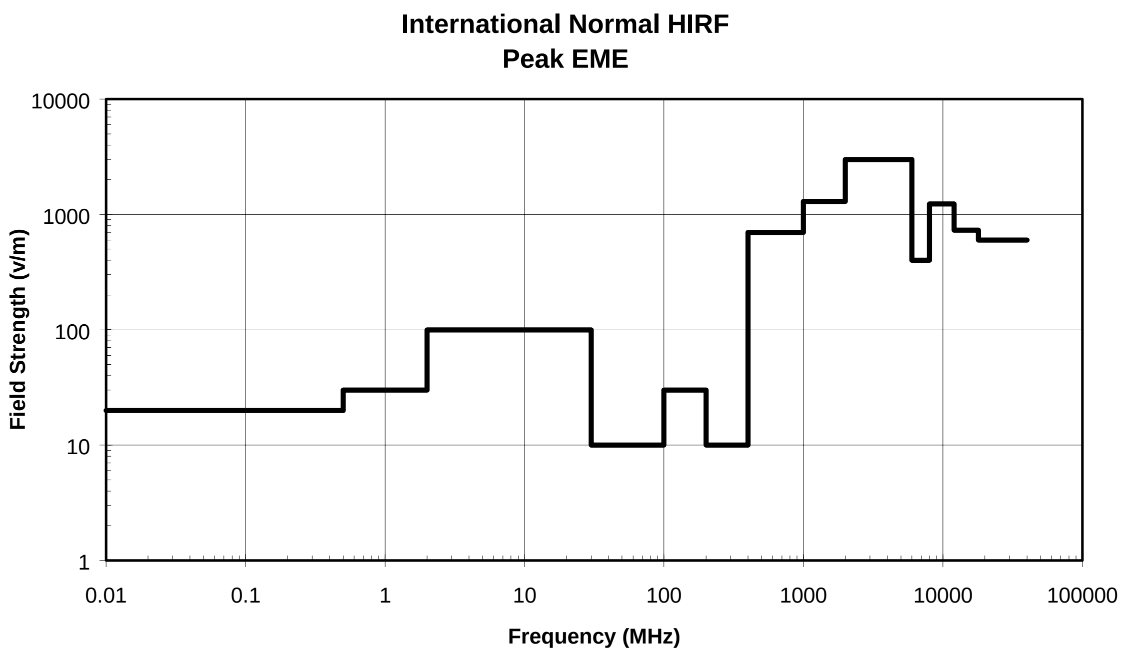

FIGURE 31
PEAK INTERNATIONAL NORMAL ENVIRONMENT

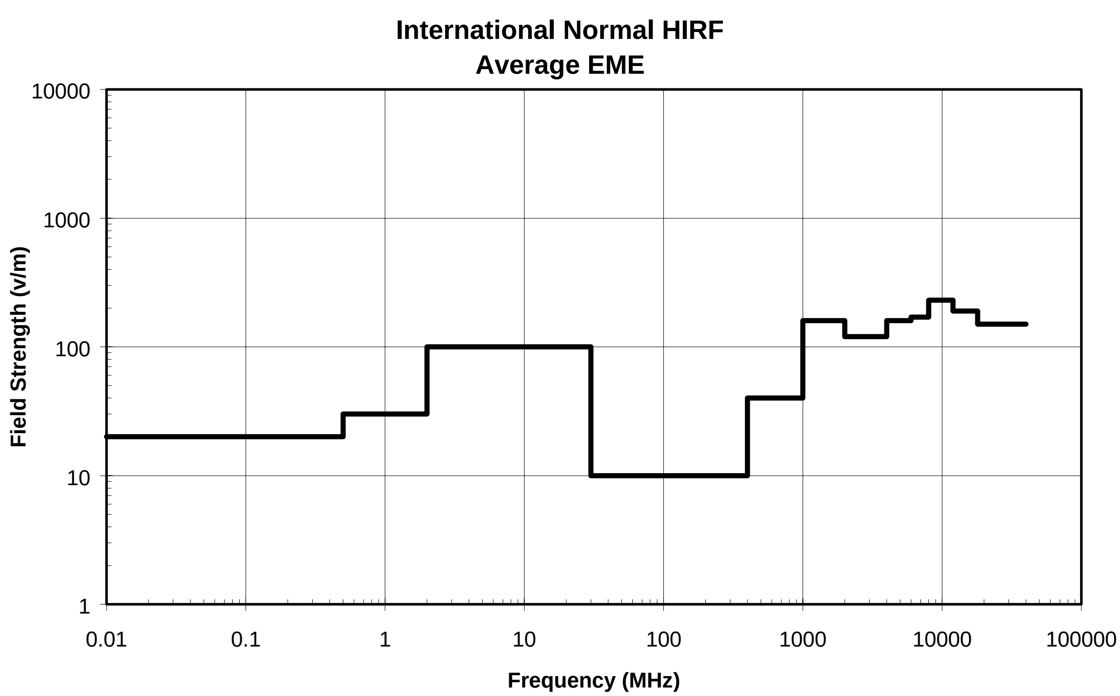

FIGURE 32
AVERAGE INTERNATIONAL NORMAL ENVIRONMENT

THIS PAGE INTENTIONALLY LEFT BLANK

REFERENCES

1. Interagency Agreement Number DTFA03-94-X-00008 Between Department of Transportation Federal Aviation Administration (FAA) FAA Technical Center and Naval Air Warfare Center Aircraft Division Patuxent River Flight Test and Engineering Group of 9 Jun 1994.

2. FAA Request Letter to Society of Automotive Engineering, AWS-120:N.Rasch:pod:11/16/87:267-9566 of 10 Feb 1988.

3. Electro Magnetic Applications Document No. WG-248, Statistical Analysis of Aircraft Motion with Respect to HIRF Emitter Locations - Update, of 23 Jun 1997.

4. Document No. WG-249, Ship Encounter Probability.

5. NASA Contractor Report 201636, "The NASA B-757 Test Series -Flight Test Results", Karl J. Moeller and Kenneth L. Dudley, of Dec 1996.

6. Digital Avionics Systems Conference Proceedings, "A Description of the Software Elements of the NASA EME Flight Test", Sandra V. Koppen, 1996.

7 Digital Avionics Systems Conference Proceedings, "A Description of the Hardware Elements of the NASA Flight Tests", Kenneth L. Dudley, 1996.

8. FAA Technical Center Final Report DOT/FAA/CT-93/5-I, S-76 High Intensity Radiated Fields: Volume I, of Oct 1993.

9. FAA Technical Center Final Report DOT/FAA/CT-93/5-II, S-76 High Intensity Radiated Fields: Volume II, of Oct 1993.

10. FAA Technical Center Final Report DOT/FAA/CT-93/5-III, S-76 High Intensity Radiated Fields: Volume III, of Oct 1993.

11. IEEE, "IEEE Standards Definitions of Terms for Antennas". 1-55937-317-2, 1993.

12. Electromagnetic Effects Harmonization Working Group Meeting #14 at Bridgeport, Connecticut, of 16 Jul 1997.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A - ASSUMPTIONS FROM NPRN/NPA AND AC/AMJ

1.1 GENERAL ASSUMPTIONS

The general assumptions are as follows:

1. The envelope was divided into the following frequency bands:

Ranges Above 10 kHz and Below 2 MHz	Ranges Above 2 MHz and Below 1 GHz	Ranges Above 1 GHz and Below 40 GHz
10-100 kHz	2-30 MHz	1-2 GHz
100-500 kHz	30-70 MHz	2-4 GHz
500 kHz-2 MHz	70-100 MHz	4-6 GHz
	100-200 MHz	6-8 GHz
	200-400 MHz	8-12 GHz
	400-700 MHz	12-18 GHz
	700 MHz-1 GHz	18-40 GHz

2. Main beam illumination by a transmitting antenna was used.
3. Maximum main beam gain of a transmitter antenna was used.
4. Modulation of a transmitted signal was not considered. However, the duty cycle was used to calculate the average power for pulsed transmitters.
5. Constructive ground reflections of HF signals, i.e., direct and reflected waves, were assumed to be in phase.
6. Noncumulative field strength was calculated. Simultaneous illumination by more than one antenna was not considered.
7. Near-field corrections for aperture and phased-array antennas were used.
8. Field strengths were calculated at minimum distances which were dependent upon the location of the transmitter and aircraft.
9. Field strength for each frequency band was the maximum for all transmitters within that band.
10. Peak and average:
    (a) Peak field strength was based on the maximum authorized peak power of the transmitter, maximum antenna gain, and system losses.

(b) Average field strength was based on the maximum authorized peak power of the transmitter, maximum duty cycle, maximum antenna gain, and system losses. Duty cycle is the product of pulse width and pulse repetition frequency. This applies to pulsed systems only.

(c) The field strength values are in volts per meter and were calculated from the power density.

11. The terms "direct range" and "slant range" are defined as follows:

Direct range is the "line-of-sight" distance between the transmitter and the aircraft.

Slant range is the distance between the transmitters and the aircraft taking into account the aircraft altitude and the maximum antenna elevation angle of the transmitter. If the maximum elevation angle was not available, 90 deg was assumed.

12. Transmitters located in Prohibited, Restricted, or Danger areas were not included in the environment.

13. From the U.S. element of the environment, selected high power transmitters were placed in SUA, which will be marked on the aeronautical charts. The size of an SUA would be derived from transmitter data and would therefore vary from transmitter site to transmitter site. The SUA size, as marked on the aeronautical charts, would be specified by altitude and radius. For transmitters located within an area of SUA, the transmitter field strength was assessed at the boundary of the SUA.

14. Transmitters with experimental licenses were excluded.

15. Nonairport mobile tactical military transmitters were excluded.

16. Transmitter cooperative operation with aircraft procedures were used to calculate illumination and power density.

17. The U.S. HIRF environment included estimated 3 dB transmitter losses into the antenna, unless transmitter data were available.

1.2 SPECIFIC ENVIRONMENT ASSUMPTIONS

The electromagnetic environment consists of the Rotorcraft Severe, Fixed Wing Severe, Certification, and Normal HIRF environments.

These environments are defined in the following paragraphs.

1.2.1 ASSUMPTIONS FOR THE CALCULATION OF THE ROTORCRAFT SEVERE HIRF ENVIRONMENT

The Rotorcraft Severe HIRF environment is a worst case estimate of the electromagnetic field strength levels in the airspace in which rotorcraft flight operations are permitted.

The Rotorcraft Severe environment considers transmitters in the following groups and rotorcraft to transmitter distances:

(a) Airport/Heliport Transmitters:

(i) 100 ft direct range for fixed transmitters within a 1 nmi boundary around the runway with the exception of airport surveillance radar and air route surveillance radar; for these two radar types, a 300 ft slant range distance was used.

(ii) 50 ft direct range for mobile transmitters, including transmitters on other aircraft, and 150 ft direct range for aircraft's weather radar.

(b) Nonairport/Nonheliport Ground Transmitters:

All transmitters, 100 ft direct range.

(c) Shipboard Transmitters:

300 ft direct range for all shipboard transmitters.

(d) Offshore Platforms:

100 ft direct range for all platform based transmitters.

(e) Air-to-Air Transmitters:

(i) Air-to-air interceptions of helicopters by fixed wing interceptors were not considered in the Rotorcraft Severe environment.

(ii) The scenario of air-to-air illumination of a helicopter by the airborne weather radar of an adjacent helicopter is covered in the Airport/Heliport transmitter group.

1.2.2 ASSUMPTIONS FOR THE CALCULATION OF THE FIXED WING SEVERE HIRF ENVIRONMENT

The Fixed Wing Severe HIRF environment is a worst case estimate of the electromagnetic field strength levels in the airspace in which fixed wing flight operations are permitted.

The Fixed Wing Severe environment considers transmitters in the following groups and aircraft to transmitter distances:

(a) Airport Environment:

(i) 250 ft slant range for fixed transmitters within a 5 nmi boundary around the runway with the exception of airport surveillance radar and air route surveillance radar. For these two radar types, a 500 ft slant range distance was used.

(ii) 50 ft direct range for mobile transmitters, including transmitters on other aircraft, and 150 ft direct range for aircraft's weather radar.

(b) Nonairport Ground Transmitters:

(i) 500 ft slant range for fixed transmitters beyond a 5 nmi boundary around the airport runway.

(ii) Aircraft were assumed to be at a minimum flight altitude of 500 ft above local terrain and avoiding all obstructions, including transmitter antennas, by 500 ft.

(c) Shipboard Transmitters:

A 2.4% gradient was used for the aircraft flightpath, with the subject aircraft clearing the antenna by 300 ft. The ship was assumed to be 2.5 nmi from the end of the runway. Slant range was computed using the maximum elevation angle. Where maximum antenna elevation angle was not available, 45 deg was used.

(d) Air-to-Air Transmitters:

(i) 500 ft direct range for noninterceptor aircraft with all transmitters operational.

(ii) 100 ft direct range for interceptor aircraft with only nonhostile transmitters operational.

1.2.3 ASSUMPTIONS FOR THE CALCULATION OF THE CERTIFICATION HIRF ENVIRONMENT

This Certification HIRF environment is derived from the Fixed Wing Severe HIRF environment. The Certification environment considered the same transmitter groups as the Fixed Wing Severe environment, the aircraft to transmitter distances were reassessed as follows:

(a) Airport/Heliport Transmitters:

(i) 250 ft slant range for all fixed, nonradar, transmitters within the airport boundary. Fixed radar transmitters within the airport boundary were assessed at a distance of 500 ft, using slant range.

(ii) The distance assumptions for all mobile transmitters and aircraft weather radar systems remained unchanged from those used in the Fixed Wing Severe environment.

(b) Nonairport/Nonheliport Ground Transmitters:

(i) 500 ft slant range for fixed transmitters within a wedge shaped area of airspace, originating at the departure and arrival end of the runway, over which aircraft would normally track, and extending for 3 nmi from the runway.

(ii) Aircraft were assumed to be at a minimum flight altitude of 1,000 ft above local terrain, except for takeoff and landing, and avoiding all obstructions, including transmitters, by 1,000 ft. Slant range was calculated using the maximum elevation angle for the transmitters. Where maximum elevation angle was not known, 45 deg was assumed.

(c) Shipboard Transmitters:

A study of the shipboard scenario of the severe environments concluded that, for routine flight operations, the most likely scenario was:

> The ship is assumed to be 2.5 nmi from the approach end of the runway, an aircraft established on the normal 3 deg ILS glideslope would pass over the ship at an altitude that would enable a slant range of 750 ft to be used as the distance criteria.

(d) Offshore Platforms:

This group of transmitters was not considered in the Certification environment.

(e) Air-to-Air Transmitters:

This group of transmitters was not considered in the Certification environment.

1.2.4 ASSUMPTIONS FOR THE CALCULATION OF THE NORMAL HIRF ENVIRONMENT

The Normal HIRF environment is the electromagnetic field strength level in the airspace on and about airports and/or heliports in which routine departure and arrival operations take place. The transmitter groups and the aircraft to transmitter distances considered in the Normal environment were as follows:

(a) Airport/Heliport Transmitters:

With the exception of the aircraft weather radar systems, the distance assumptions for both fixed and mobile transmitters located within the airport boundary remained unchanged from those used in the Severe environments and the Certification environment. For aircraft weather radar systems, a distance of 250 ft was used.

(b) Nonairport/Nonheliport Ground Transmitters:

Transmitters within a wedge shaped area of airspace, originating at each end of the runway, over which aircraft would normally track were assessed at differing slant ranges according to the transmitter distance from the runway as follows:

0-3 nmi	500 ft slant range
3-5 nmi	1,000 ft slant range
5-10 nmi	1,500 ft slant range
10-25 nmi	2,500 ft slant range

(c) Shipboard Transmitters:

This group of transmitters was not considered in the Normal environment.

(d) Offshore Platforms:

This group of transmitters was not considered in the Normal environment.

(e) Air-to-Air Transmitters:

This group of transmitters was not considered in the Normal environment.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B - DISCUSSION ON CALCULATION OF PEAK VERSUS AVERAGE AND CONVERSION BETWEEN POWER DENSITY AND FIELD STRENGTH

The emitter data bases, together with the designated minimum distances, were used to calculate the values of field strength for the environments. The peak field strength is based on the maximum authorized power level of the transmitter and antenna gain for the frequency range. The average field strength is based on the maximum average field strength (peak output power of the transmitter times the maximum duty cycle times the antenna gain) for the frequency range. The field strengths used in the environments for peak and average may or may not be from the same driver emitter.

For emitters that used amplitude modulation, such as AM Broadcast radio and TV, the continuous carrier output level (without modulation) was used for the calculation of both peak and average field strengths. Furthermore, for CW emitters, the duty cycle is unity and the peak and average powers are the same. It is more complex to define peak amplitudes when the signal is amplitude modulated (see figure B-1). The true peak field strength could be calculated from the product of continuous carrier output level, the percent of AM modulation, and the frequency of the modulation. In most cases, the percent of AM modulation and the modulation frequency vary greatly. Therefore, it was not used for HIRF calculations.

Pulse modulated signals, such as from a radar, have differences between peak and average power density. The ratio between the peak and average values is a function of the duty cycle with pulse modulated or gated signals. Although, in the case of the peak field, it is the value of the electric field for the time that the signal is on (figure B-2). When the signal is off, the field strength is obviously zero.

The antenna pattern and rotation rate were not used for any of the calculations. Only the 3 dB beamwidth gain was used.

The units used to define the field strength of the HIRF environment are in terms of rms. All measurements or calculations of the field strength are derived in terms of the power density, either average or peak, then converted to volts per meter (V/m_{rms}). The rms units for peak electric field or peak power density are usually omitted since they are assumed to be understood without restatement. In all cases, the rms values, as in all forms of electrical engineering, have always been true electrical peak divided by root 2.

The term known as peak rms is the normal parameter measured during equipment and aircraft EMC tests, and the way the HIRF environment is expressed. The measurement of modulated RF signals during HIRF testing and the terms peak and peak rms cause significant confusion. For all HIRF measurements of modulated signals, a peak detector must be used. By tradition, RF spectrum analyzers and measuring receivers are calibrated with a sine wave such that, in peak mode, a 1 V_{rms} sine wave input will give an indicated measurement of 1 V. This will not change if the signal is switched on and off, the peak reading will still be 1 V hence the term peak rms. Figure B-1 shows the relationship between peak and peak rms for an amplitude modulated sine wave. Figure B-2 shows the relationship between peak and peak rms for a pulse modulated or gated sine wave.

All measurements relating to HIRF are made using the peak detector function of the measuring receiver/spectrum analyzer. This is calibrated in terms of the equivalent rms value of a sine wave. What does this mean? When measuring a modulated signal, the bandwidth of the measuring receiver should be set wide enough to capture the total energy of the signal. The amplitude reading as measured by the peak detector function is noted. The unknown signal is disconnected and a sine wave signal at the same frequency fed in. Its amplitude is adjusted until the same reading is produced on the measuring receiver. This amplitude is expressed in terms of the rms value of the sine wave.

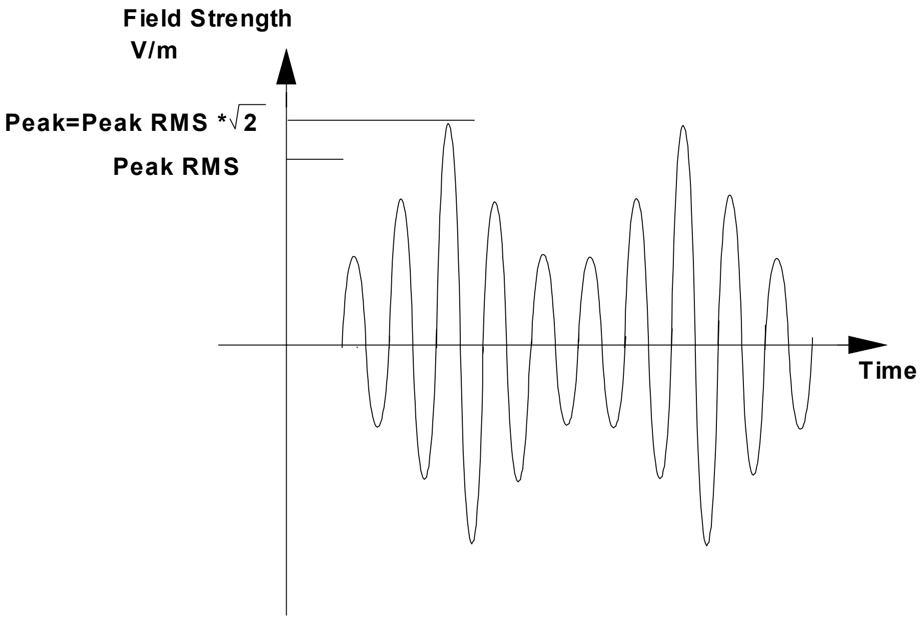

Figure B-1
AMPLITUDE MODULATED SIGNAL

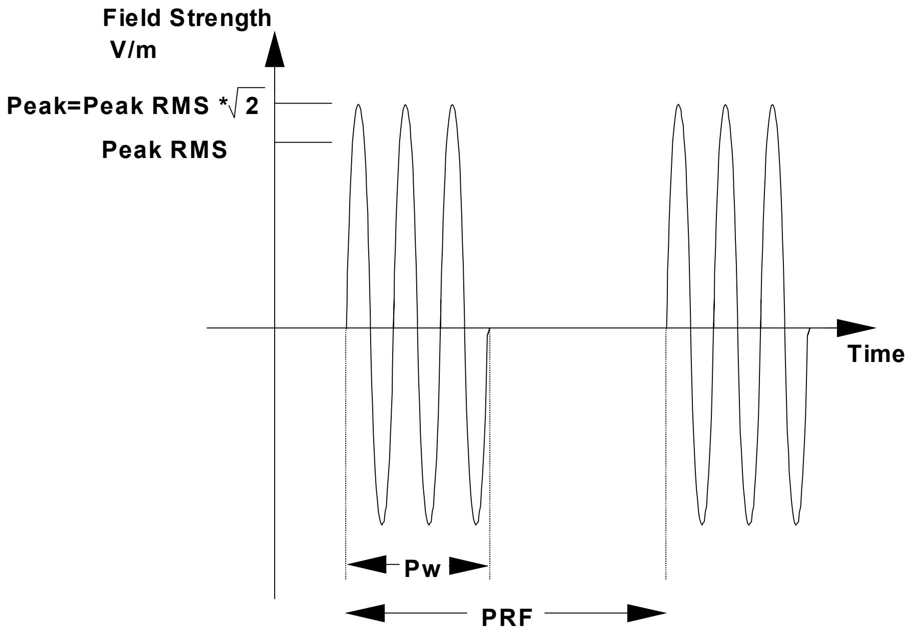

Figure B-2
PULSE MODULATED OR GATED SIGNAL

For calculating peak or average power, use the following engineering conventions:

- Start with the average output power of the emitter (usually measured with an average reading power meter):

  P_A = Average Power expressed in watts (rms)

  G = Gain of antenna system (including near-field correction factor), no units

  r = distance from antenna aperture expressed in meters

  From these values, the radiated power is calculated:

  Pd_A = Average Power Density expressed in watts/meter^2 (rms)

  $$Pd_A = (P_A * G)/(4 \pi r^2)$$

- For main beam illumination by simple pulse emitters, the peak power density is calculated:

  T_W = Pulse Width expressed in seconds

  F_R = Pulse Repetition Frequency (PRF) expressed in Hertz

  D = Duty cycle (ratio) = $T_W * F_R$

  Pd_p = Peak Power Density expressed in watts/meter^2 (rms) = Pd_A/D

- The power density is converted to electric field using the impedance of free space air (120π or 377 ohms):

  E_A = Average Electric Field Intensity expressed in Volts/meter (rms)

  $= (Pd_A * 377)^{(1/2)}$

  E_P = Peak Electric Field Intensity expressed in Volts/meter (rms)

  $= (Pd_P * 377)^{(1/2)}$ or

  $= E_A * D^{(-1/2)}$ or

  $= (377/4\pi)^{(1/2)} * (P_A * G)^{(1/2)}/r$ or

  $= (Pd_A * 377/D)^{(1/2)}$

- The true electric peak field (which is $E_T = E_P * 2^{(1/2)}$) is not used because it does not relate to common measurements.
- To convert from watts/meter^2 to mW/cm^2, a (10^3 W/mW) / (10^4 m^2/cm^2) conversion factor (1/10) is needed, e.g., 100 W/m^2 =10 mW/cm^2.

APPENDIX C - SAMPLE SPREAD SHEET

The HIRF environments were calculated using Microsoft Excel. Each emitter was set up on a separate workbook. The first spread sheet of the workbook contained the emitter data, transmitter characteristics, and antenna characteristics. The same spreadsheet then calculated the field intensity for ranges from 100 ft out to 1,000 ft or farther as necessary. The methods used to calculate the fields were described in Section 4 of this report. As a means to cross check the calculation, a parallel calculation is performed using the near-field analysis methods detailed in MIL-HBK-235. The handbook method predictions should produce field strengths within 3 dB of the “Gross” method adopted by the HIRF community. A macro function stored on module 1 extrapolates the near-field correction values based on range from another workbook containing the data tables for either rectangular or circular aperture illuminations.

The emitter workbook which predicted the highest field intensities for each HIRF range was manually linked to a workbook that tabularized the drivers and produced the HIRF field intensity graphs.

The following spread sheet is an example of the portion of the emitter workbook that predicted the field intensities for the ASDE-2.

Frequency Range	18-40 GHz
Description	Airport Surface Detection
Nomenclature	ADSE-2
Latitude	41.58.43N
Longitude	087.54.21W
Location	Chicago, Illinois, and other various locations
Antenna Description	Parabolic Reflector, Cosine Rectangular

Increment					150		50
		Peak	Average	Peak	Average	Peak	Average
	Units	100	ft Separation	250	ft Separation	300	ft Separation
Range	meters	30.49	30.49	76.22	76.22	91.46	91.46
	ft	100.00	100.00	250.00	250.00	300.00	300.00
Frequency	MHz	23,600.00	23,600.00	23,600.00	23,600.00	23,600.00	23,600.00
Pulse Width	μsec	0.02	0.02	0.02	0.02	0.02	0.02
PRF	Hz	14,500.00	14,500.00	14,500.00	14,500.00	14,500.00	14,500.00
Duty Cycle	#	0.00029	0.00	0.00	0.00	0.00	0.00
	%	0.03	0.03	0.03	0.03	0.03	0.03
Transmitter Peak	W	50,000.00	50,000.00	50,000.00	50,000.00	50,000.00	50,000.00
	dBm	76.99	76.99	76.99	76.99	76.99	76.99
Transmitter Average	W	15.95	15.95	15.95	15.95	15.95	15.95
	dBm	42.03	42.03	42.03	42.03	42.03	42.03
System Losses	dB	-2.36	-2.36	-2.36	-2.36	-2.36	-2.36
Antenna Gain	dB	45.00	45.00	45.00	45.00	45.00	45.00
Estimated Antenna Area	cm^2	0.291					
Estimated Antenna Size	meters	0.54					
Antenna Max x	meters	3.40	3.40	3.40	3.40	3.40	3.40
	ft	11.15	11.15	11.15	11.15	11.15	11.15
Antenna Max y	meters	0.30	0.30	0.30	0.30	0.30	0.30
	ft	0.98	0.98	0.98	0.98	0.98	0.98
Beam Width	deg	0.25	0.25	0.25	0.25	0.25	0.25
Antenna Max from BW	meters	3.31	3.31	3.31	3.31	3.31	3.31
	ft	10.84	10.84	10.84	10.84	10.84	10.84
Elevation Max	deg	3.00	3.00	3.00	3.00	3.00	3.00
Far Field from x	meters	909.39	909.39	909.39	909.39	909.39	909.39
	ft	2,982.79	2,982.79	2,982.79	2,982.79	2,982.79	2,982.79
Far Field from y	meters	7.08	7.08	7.08	7.08	7.08	7.08
	ft	23.22	23.22	23.22	23.22	23.22	23.22
Far Field from BW	meters	1,718.64	1,718.64	1,718.64	1,718.64	1,718.64	1,718.64
	ft	5,637.15	5,637.15	5,637.15	5,637.15	5,637.15	5,637.15
Far Field x used	meters	909.39	909.39	909.39	909.39	909.39	909.39
	ft	2,982.79	2,982.79	2,982.79	2,982.79	2,982.79	2,982.79
Far Field y used	meters	7.08	7.08	7.08	7.08	7.08	7.08
	ft	23.22	23.22	23.22	23.22	23.22	23.22
Hbk Far Field	meters	1,818.77	1,818.77	1,818.77	1,818.77	1,818.77	1,818.77

Illumination Estimator	#	1.17	1.17	1.17	1.17	1.17	1.17
Curve to Use	uniform	uniform	uniform	uniform	uniform	uniform	uniform
Normalized x value	#	0.03	0.03	0.08	0.08	0.10	0.10
Normalized y value	#	4.31	4.31	10.77	10.77	12.92	12.92
Handbook Normalized Range	#	0.0168	0.02	0.04	0.04	0.05	0.05
Near-Field Correction x	dB	14.65	14.65	10.01	10.01	9.25	9.25
Near-Field Correction y	dB	0.00	0.00	0.00	0.00	0.00	0.00
Total Near-Field Corr.	dB	14.65	14.65	10.01	10.01	9.25	9.25
Near-Field Correction Hbk	dB	14.24	14.24	9.55	9.55	8.48	8.48
Free Space Losses	dB	-40.67	-40.67	-48.63	-48.63	-50.22	-50.22
Power Density	dBm/m^2	64.31	29.35	60.99	26.03	60.16	25.20
	W/m^2	2,697.45	0.8605	1,255.47	0.40	1,037.13	0.33
	V/m	1,008.43	18.01	687.98	12.29	625.30	11.17
Handbook Power Density	dBm	64.72	29.76	61.44	26.48	60.94	25.97
	W/m^2	2,964.36	0.95	1,394.55	0.44	1,240.47	0.40
	V/m	1,057.15	18.88	725.08	12.95	683.85	12.21
Slant Path	meters	584.40	584.40	1,460.99	1,460.99	1,753.19	1,753.19
		1,916.82	1,916.82	4,792.06	4,792.06	5,750.47	5,750.47
Normalized Slant Path x	#	0.64	0.64	1.61	1.61	1.93	1.93
Normalized Slant Path y	#	82.54	82.54	206.36	206.36	247.63	247.63
Hbk Normalized Range	#	0.32	0.32	0.80	0.80	0.96	0.96
Near-Field Correction x		1.33	1.33	0.00	0.00	0.00	0.00
Near-Field Correction y		0.00	0.00	0.00	0.00	0.00	0.00
Slant Total Correction		1.33	1.33	0.00	0.00	0.00	0.00
Near-Field Correction Hbk	dB	0.63	0.63	0.00	0.00	0.00	0.00
Slant Range Power Den.	dBm/m^2	51.97	17.01	45.34	10.38	43.76	8.80
	W/m^2	157.44	0.05	34.24	0.01	23.77	0.01
	V/m	243.63	4.35	113.61	2.03	94.67	1.69
Hbk Slant Power Density	dBm/m^2	52.67	17.71	45.34	10.38	43.76	8.80
	W/m^2	185.10	0.06	34.24	0.01	23.77	0.01
	V/m	264.16	4.72	113.61	2.03	94.67	1.69
Overhead Losses	dB	20.00	20.00	20.00	20.00	20.00	20.00
Overhead Power Den. Pk	dBm/m^2	44.31	9.35	40.99	6.03	40.16	5.20
	W/m^2	26.97	0.01	12.55	0.00	10.37	0.00
	V/m	100.84	1.80	68.80	1.23	62.53	1.12
Hbk Overhead P. D.	dBm/m^2	44.72	9.76	41.44	6.48	40.94	5.97
	W/m^2	29.64	0.01	13.95	0.00	12.40	0.00
	V/m	105.71	1.89	72.51	1.30	68.39	1.22
Summary IAW Gross							
Direct Path	ft	100.00	100.00	250.00	250.00	300.00	300.00
Direct Field Strength	V/m	1,008.43	18.01	687.98	12.29	625.30	11.17
Slant Path	ft	1,916.82	1,916.82	4,792.06	4,792.06	5,750.47	5,750.47
Slant Field Strength	V/m	243.63	4.35	113.61	2.03	94.67	1.69
Overhead Path	ft	100.00	100.00	250.00	250.00	300.00	300.00
Overhead Field Strength	V/m	100.84	1.80	68.80	1.23	62.53	1.12

Minimum Normalized x		0.033526					
Summary IAW Handbook							
Direct Path	ft	100.00	100.00	250.00	250.00	300.00	300.00
Direct Field Strength	V/m	1,057.15	18.88	725.08	12.95	683.85	12.21
Slant Path	ft	1,916.82	1,916.82	4,792.06	4,792.06	5,750.47	5,750.47
Slant Field Strength	V/m	264.16	4.72	113.61	2.03	94.67	1.69
Overhead Path	ft	100.00	100.00	250.00	250.00	300.00	300.00
Overhead Field Strength	V/m	105.71	1.89	72.51	1.30	68.39	1.22
		Plotted Peak	Plot Average	Peak	Peak	Average	Average
Graph	Path	Field Strength	Field Strength	Gross	Handbook	Gross	Handbook
	100	1,008.43	18.01	1,008.43	1,057.15	18.01	18.88
	250	687.98	12.29	687.98	725.08	12.29	12.95
	300	625.30	11.17	625.30	683.85	11.17	12.21
	400	441.78	7.89	441.78	598.52	7.89	10.69
	500	388.56	6.94	388.56	553.86	6.94	9.89
	600	407.85	7.28	407.85	517.53	7.28	9.24
	700	400.72	7.16	400.72	479.20	7.16	8.56
	800	393.33	7.03	393.33	452.95	7.03	8.09
	900	384.71	6.87	384.71	434.41	6.87	7.76
	1000	373.20	6.67	373.20	412.68	6.67	7.37

APPENDIX D - DRIVER EMITTER CHARACTERISTICS

HIRF Ranges

Range	Range Number
10 kHz to 100 kHz	1
100 kHz to 500 kHz	2
500 kHz to 2 MHz	3
2 MHz to 30 MHz	4
30 MHz to 70 MHz	5
70 MHz to 100 MHz	6
100 MHz to 200 MHz	7
200 MHz to 400 MHz	8
400 MHz to 700 MHz	9
700 MHz to 1 GHz	10
1 GHz to 2 GHz	11
2 GHz to 4 GHz	12
4 GHz to 6 GHz	13
6 GHz to 8 GHz	14
8 GHz to 12 GHz	15
12 GHz to 18 GHz	16
18 GHz to 40 GHz	17

Drivers to HIRF EME Cross Reference (Numbers Correspond to HIRF Ranges)

Driver	Page	Peak Rotorcraft Severe EME	Average Rotorcraft Severe EME	Peak Fixed Wing Severe EME	Average Fixed Wing Severe EME	Peak Certification EME	Average Certification EME	Peak Normal EME	Average Normal EME
FRT-87 (100 kHz - 500 kHz)	105	1	1	1	1	1	1	1	1
FPN-45A	106	2		2		2		2	2
FRT-87 (100 kHz - 500 kHz)	107		2		2		2		2
AM Radio	108	3	3	3	3	3	3	3	3
VOA/SW	109	4	4	4	4	4	4	4	4
TV Ch 2-6	110	5	5	5	5	5	5	5	5
FM Radio	111	6	6	6	6	6	6	6	6
TV Ch 7-11	112	7	7	7	7	7	7	7	7
TV Ch 11-13	113	8	8	8	8	8	8	8	8
TV UHF Ch 14-51	114	9	9	9	9	9	9	9	9
SPS-49	115	10							
TV UHF Ch 52-69	116		10	10	10	10	10	10	10
ARSR-1	117	11							
ARSR-3	118			11		11		11	
FSP-64	119		11						
ESI-11160	120				11		11		11
SPS-48	121		12		12		12		
WSR-88	122	12		12		12		12	12
FPS-16V	123	13	13	13	13	13		13	
TDWR	124						13		13
FSC-79	125	14	14	14	14	14	14	14	14
TPQ-39	126	15	15	15	15				
GPN-22	127					15	15	15	15
ASDE-3	128	16		16		16		16	
SAT BUS	129		16		16		16		16
ADSE-2	130	17	17	17	17	17	17	17	17

FRT-87 (100 kHz - 500 kHz)

Frequency Range	100 kHz to 500 kHz
Description	Fixed, Submarine Communications
Nomenclature	AN/FRT-87 (Same as AN/FRT-3)
Latitude	38.59.00N
Longitude	076.27.00W
Location	Annapolis, Maryland and other various locations
Antenna Description	Linear (horizontal net)

Frequency	MHz	0.02
Pulse Width	µsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	1,000,000.00
	dBm	90.00
Transmitter Average	W	1,000,000.00
	dBm	90.00
System Losses	dB	-3.00
Antenna Gain	dB	0.00
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	0.00
	ft	0.00
Far Field y Used	meters	0.00
	ft	0.00
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

FPN-45A

Frequency Range	100 kHz to 500 kHz
Description	Fixed-LORAN
Nomenclature	AN/FPN-45A
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Linear

Frequency	MHz	0.10
Pulse Width	μsec	6.00
PRF	Hz	2,000.00
Duty Cycle	#	0.01
	%	1.20
Transmitter Peak	W	2,000,000.00
	dBm	93.01
Transmitter Average	W	24,000.00
	dBm	73.80
System Losses	dB	-3.00
Antenna Gain	dB	0.00
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	0.00
	ft	0.01
Far Field y Used	meters	0.00
	ft	0.00
Overhead Losses	dB	0.00

FRT-87 (100 kHz - 500 kHz)

Frequency Range	100 kHz to 500 kHz
Description	Fixed, Submarine Communications
Nomenclature	AN/FRT-87 (Same as AN/FRT-3)
Latitude	38.59.00N
Longitude	076.27.00W
Location	Annapolis, Maryland
Antenna Description	Linear (horizontal net)

Frequency	MHz	0.15
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	1,000,000.00
	dBm	90.00
Transmitter Average	W	1,000,000.00
	dBm	90.00
System Losses	dB	-3.00
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	0.00
	ft	0.01
Far Field y Used	meters	0.00
	ft	0.00
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

AM Radio

Frequency Range	500 kHz to 2 MHz
Description	Fixed-Broadcast
Nomenclature	AM Radio
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Monopole Array

Frequency	MHz	1.60
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	50,000.00
	dBm	76.99
Transmitter Average	W	50,000.00
	dBm	76.99
System Losses	dB	-3.00
Antenna Gain	dB	13.53
Antenna Max x	meters	140.63
	ft	461.25
Antenna Max y	meters	109.38
	ft	358.75
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	105.47
	ft	345.94
Far Field y Used	meters	63.80
	ft	209.27
Curve to Use		uniform
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

Parameteric Analysis of AM Radio Antenna Facilities

Freq	Elements	Hor Size	Ver Size	Field St.	Range	Facility
1600	4	609	100	6.55	100	KLIF
540	4	1805	296	2.43	100	
540	4	416	324	32	300	WHIS
1600	4	140	109	94	100	
540	3	370	555	4.89	500	WOWO
1600	3	125	187	14	200	
1600	3	44	89	28	100	KCBQ
540	3	419	131	9.66	100	
540	4	995	416	3.5	100	WJBK
1600	4	335	140	10.36	100	
1600	1	xx	xx	40	100	Omni

VOA/SW

Frequency Range	2 MHz to 30 MHz
Description	VOA/SW Broadcast
Nomenclature	Short wave
Latitude	Nationwide
Longitude	Nationwide
Location	Delano, California, Greenville, North Carolina
Antenna Description	Dipole Curtain Array

Frequency	MHz	17.80
Pulse Width	µsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	500,000.00
	dBm	86.99
Transmitter Average	W	500,000.00
	dBm	86.99
System Losses	dB	-3.00
Antenna Gain	dB	22.00
Antenna Max x	meters	68.47
	ft	224.58
Antenna Max y	meters	30.40
	ft	99.71
Beam Width	deg	16.00
Elevation Max	deg	90.00
Far Field x Used	meters	278.16
	ft	912.35
Far Field y Used	meters	54.83
	ft	179.85
Curve to Use		uniform
Overhead Losses	dB	0

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

Analysis of VOA Curtain Array Antennas

Hor. BW	Lenght	Ver BW	Height	V/M
38	53.4	2.5	812	66.6
32	51.6	2	826	67.54
36	30.4	2.5	438	72.03
31	29.1	2	451	88.7
36	30.4	3	365	90.72
30	30	2.5	361	87.56
39	42.37	2.5	661	90.21
31	41.1	2	637	78.05
31	41.1	10.5	121	158
36	30.4	16	68	318
48	66.6	12	266.4	100

TV Ch 2-6

Frequency Range	30 MHz to 70 MHz
Description	Fixed-Broadcast
Nomenclature	TV Ch 2-6 (47-68 MHz)
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Dipole Array

Frequency	MHz	88.00
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	60,000.00
	dBm	77.78
Transmitter Average	W	60,000.00
	dBm	77.78
System Losses	dB	0.00
Antenna Gain	dB	5.22
Antenna Max x	meters	20.45
	ft	67.09
Antenna Max y	meters	0.25
	ft	0.82
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	122.73
	ft	402.55
Far Field y Used	meters	0.02
	ft	0.06
Curve to Use		$\cos^2$
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

TV Antenna Analysis

Frequency MHz	Antenna Size meters	ERP dBm	Field Strength V/M	Range FT
88	20.5	83	70.6	100

FM Radio

Frequency Range	70 MHz to 100 MHz
Description	Fixed-Broadcast
Nomenclature	FM Radio
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Dipole Array

Frequency	MHz	107.00
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	63,000.00
	dBm	77.99
Transmitter Average	W	63,000.00
	dBm	77.99
System Losses	dB	0.00
Antenna Gain	dB	6.01
Antenna Max x	meters	16.82
	ft	55.18
Antenna Max y	meters	1.00
	ft	3.28
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	100.93
	ft	331.07
Far Field y Used	meters	0.36
	ft	1.17
Curve to Use		$\cos^2$
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

TV Ch 7-11

Frequency Range	100 MHz to 200 MHz
Description	Fixed-Broadcast
Nomenclature	TV Ch 7-11 (174-198 MHz)
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Dipole Array

Frequency	MHz	198.00
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	16,000.00
	dBm	72.04
Transmitter Average	W	16,000.00
	dBm	72.04
System Losses	dB	3.00
Antenna Gain	dB	13.01
Antenna Max x	meters	9.09
	ft	29.82
Antenna Max y	meters	0.30
	ft	0.98
Beam Width	deg	360.00
Elevation Max	deg	90.00
Far Field x Used	meters	54.55
	ft	178.91
Far Field y Used	meters	0.06
	ft	0.19
Curve to Use		$\cos^2$
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

TV Antenna Analysis

Frequency MHz	**Antenna Size meters**	**ERP dBm**	**Field Strength V/M**	**Range FT**
198	9.9	88	140.29	100

TV Ch 11-13

Frequency Range	200 MHz to 400 MHz
Description	Fixed-Broadcast
Nomenclature	TV Ch 11-13 (204-216 MHz)
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Dipole Array

Frequency	MHz	216.00
Pulse Width	µsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	16,000.00
	dBm	72.04
Transmitter Average	W	16,000.00
	dBm	72.04
System Losses	dB	3.00
Antenna Gain	dB	13.01
Antenna Max x	meters	8.33
	ft	27.33
Antenna Max y	meters	0.30
	ft	0.98
Beam Width	deg	360.00
Elevation Max	deg	3.00
Far Field x Used	meters	50.00
	ft	164.00
Far Field y Used	meters	0.06
	ft	0.21
Curve to Use		$\cos^2$
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

TV Antenna Analysis

Frequency MHz	**Antenna Size meters**	**ERP dBm**	**Field Strength V/M**	**Range FT**
216	8.3	88	140.5	100

TV UHF Ch 14-51

Frequency Range	400 MHz to 700 MHz
Description	Broadcast TV
Nomenclature	TV UHF Ch 14-51 (470-698 MHz)
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Dipole Array

Frequency	MHz	698.00
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	250,000.00
	dBm	83.98
Transmitter Average	W	250,000.00
	dBm	83.98
System Losses	dB	-2.15
Antenna Gain	dB	15.16
Antenna Max x	meters	2.58
	ft	8.46
Antenna Max y	meters	0.30
	ft	0.98
Beam Width	deg	360.00
Elevation Max	deg	3.00
Far Field x Used	meters	15.47
	ft	50.75
Far Field y Used	meters	0.21
	ft	0.69
Curve to Use		$\cos^2$
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

TV Antenna Analysis

Frequency MHz	**Antenna Size meters**	**ERP dBm**	**Field Strength V/M**	**Range FT**
470	7.7	97	397	100

SPS-49

Frequency Range	700 MHz to 1 GHz
Description	Air Traffic Surveillance
Nomenclature	AN/SPS-49
Latitude	Ship Based
Longitude	Ship Based
Location	All U.S. Ships (numerous land sites for testing too)
Antenna Description	Orange Peel

Frequency	MHz	850.00
Pulse Width	μsec	175.00
PRF	Hz	276.00
Duty Cycle	#	0.03450
	%	3.450
Transmitter Peak	W	360,000.00
	dBm	85.56
Transmitter Average	W	12,420.00
	dBm	70.94
System Losses	dB	-3.00
Antenna Gain	dB	29.00
Antenna Max x	meters	7.32
	ft	24.01
Antenna Max y	meters	4.34
	ft	14.01
Beam Width	deg	3.50
Elevation Max	deg	9.00
Far Field x Used	meters	151.82
	ft	497.96
Far Field y Used	meters	51.66
	ft	169.44
Curve to Use		$\cos^2$
Overhead Losses	dB	20.00

TV UHF Ch 52-69

Frequency Range	700 MHz to 1000 MHz
Description	Broadcast TV
Nomenclature	TV UHF Ch 52-69 (701-806 MHz)
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Dipole Array

Frequency	MHz	806.00
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00
	%	100.00
Transmitter Peak	W	250,000.00
	dBm	83.98
Transmitter Average	W	250,000.00
	dBm	83.98
System Losses	dB	-2.15
Antenna Gain	dB	15.16
Antenna Max x	meters	2.23
	ft	7.33
Antenna Max y	meters	0.30
	ft	0.98
Beam Width	deg	360.00
Elevation Max	deg	3.00
Far Field x Used	meters	13.40
	ft	43.95
Far Field y Used	meters	0.24
	ft	0.79
Curve to Use		$\cos^2$
Overhead Losses	dB	0.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

TV Antenna Analysis

Frequency MHz	**Antenna Size meters**	**ERP dBm**	**Field Strength V/M**	**Range FT**
806	2.2	97	401	100

ARSR-1

Frequency Range	1 GHz to 2 GHz
Description	Route tracking FAA
Nomenclature	ARSR-1D/E
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Orange peel parabolic reflector

Frequency	MHz	1,322.00
Pulse Width	μsec	2.00
PRF	Hz	370.00
Duty Cycle	#	0.000740
	%	0.074000
Transmitter Peak	W	5,000,000.00
	dBm	96.99
Transmitter Average	W	3,700.00
	dBm	65.68
System Losses	dB	-3.00
Antenna Gain	dB	34.30
Antenna Max x	meters	12.20
	ft	40.00
Antenna Max y	meters	3.35
	ft	11.00
Beam Width	deg	1.35
Elevation Max	deg	7.50
Far Field x used	meters	655.36
	ft	2,149.59
Far Field Y used	meters	49.56
	ft	162.56
Curve to use		$\cos^2$
overhead losses	dB	20.00

ARSR-3

Frequency Range	1 GHz to 2 GHz
Description	Route Tracking FAA
Nomenclature	ARSR-3
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Orange Peel (Slant range adjusted for 28 dB lookup gain)

Frequency	MHz	1,304.90
Pulse Width	μsec	2.00
PRF	Hz	365.00
Duty Cycle	#	0.000730
	%	0.073000
Transmitter Peak	W	6,500,000.00
	dBm	98.13
Transmitter Average	W	4,745.00
	dBm	66.76
System Losses	dB	-3.00
Antenna Gain	dB	34.50
Antenna Max x	meters	12.80
	ft	41.98
Antenna Max y	meters	6.89
	ft	22.63
Beam Width	deg	1.25
Elevation Max	deg	30.00
Far Field x Used	meters	712.65
	ft	2,337.49
Far Field y Used	meters	206.50
	ft	677.30
Curve to Use		$\cos^2$
Overhead Losses	dB	35.00

FPS-64A

Frequency Range	1 GHz to 2 GHz
Description	Search Radar
Nomenclature	AN/FPS-64A
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Orange Peel

Frequency	MHz	1,265.00
Pulse Width	μsec	6.00
PRF	Hz	355.00
Duty Cycle	#	0.002130
	%	0.213000
Transmitter Peak	W	5,000,000.00
	dBm	96.99
Transmitter Average	W	10,650.00
	dBm	70.27
System Losses	dB	-3.00
Antenna Gain	dB	34.80
Antenna Max x	meters	13.72
	ft	45.00
Antenna Max y	meters	5.79
	ft	19.00
Beam Width	deg	1.30
Elevation Max	deg	7.50
Far Field x Used	meters	793.68
	ft	2,603.28
Far Field y Used	meters	141.49
	ft	646.09
Curve to Use		$\cos^2$
Overhead Losses	dB	20.00

ESI-11160

Frequency Range	1 GHz to 2 GHz
Description	ESI-11160
Nomenclature	Satellite Communication
Latitude	34.49.24N
Longitude	120.31.54W
Location	Santa Barbara, CA and other various locations
Antenna Description	Circular Dish

Frequency	MHz	1,771.73
Pulse Width	µsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00000
	%	100.0000
Transmitter Peak	W	1,000.00
	dBm	60.00
Transmitter Average	W	1,000.00
	dBm	60.00
System Losses	dB	-3.00
Antenna Gain	dB	43.00
Antenna Max	meters	10.00
	ft	32.80
Beam Width	deg	1.15
Elevation Max	deg	85.00
Far Field Used	meters	1,181.15
	ft	3,874.18
Curve to Use		uniform
Overhead Losses	dB	20.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

SPS-48

Frequency Range	2 GHz to 4 GHz
Description	Search Radar
Nomenclature	AN/SPS-48
Latitude	Ship Based System
Longitude	Ship Based System
Location	U.S. Ships (also experimental land bases)
Antenna Description	Phased Array

Frequency	MHz	2,900.00
Pulse Width	μsec	27.00
PRF	Hz	541.00
Duty Cycle	#	0.01461
	%	1.46
Transmitter Peak	W	2,400,000.00
	dBm	93.80
Transmitter Average	W	35,056.80
	dBm	75.45
System Losses	dB	-3.00
Antenna Gain	dB	39.00
Antenna Max x	meters	5.65
	ft	18.53
Antenna Max y	meters	5.10
	ft	16.73
Beam Width	deg	1.60
Elevation Max	deg	65.00
Far Field x Used	meters	308.58
	ft	1,012.16
Far Field y Used	meters	251.43
	ft	824.69
Curve to Use		cos^2
Overhead Losses	dB	20.00

WSR-88

Frequency Range	2 GHz to 4 GHz
Description	NEXRAD Weather Radar
Nomenclature	UNSWSR-88D
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Circular Dish

Frequency	MHz	2,700.00
Pulse Width	μsec	4.50
PRF	Hz	452
Duty Cycle	#	0.006149
	%	0.614900
Transmitter Peak	W	1,000,000.00
	dBm	90.00
Transmitter Average	W	2,0034.00
	dBm	63.08
System Losses	dB	-3.00
Antenna Gain	dB	45.00
Antenna Max d	meters	8.54.30
	ft	28.01
Beam Width	deg	0.95
Elevation Max	deg	60.00
Far Field Used	meters	1,312.77
	ft	4,305.88
Curve to Use		$(1\text{-}r2)^1$
Overhead Losses	dB	25.00

TDWR

Frequency Range	2 GHz to 4 GHz
Description	Terminal Detection Weather Radar
Nomenclature	TDWR
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Circular Dish

Frequency	MHz	5,600.00
Pulse Width	μsec	1.10
PRF	Hz	1,930.50
Duty Cycle	#	0.00212
	%	0.2124
Transmitter Peak	W	250,000.00
	dBm	83.98
Transmitter Average	W	530.89
	dBm	57.25
System Losses	dB	-3.00
Antenna Gain	dB	50.00
Antenna Max d	meters	7.62
	ft	24.99
Beam Width	deg	0.55
Elevation Max	deg	60.00
Far Field used	meters	2,167.74
	ft	7,110.18
Curve to use		$(1-r^2)^2$
overhead losses	dB	40.00

FPS-16V

Frequency Range	4 GHz to 6 GHz
Description	Range Instrumentation Radar
Nomenclature	AN/FPS-16V
Latitude	30.29.00N
Longitude	086.30.00W
Location	Eglin AFB, FL and other various locations
Antenna Description	Circular Dish

Frequency	MHz	5,400.00
Pulse Width	µsec	0.50
PRF	Hz	320.00
Duty Cycle	#	0.0001600
	%	0.0160
Transmitter Peak	W	1,000,000.00
	dBm	90.00
Transmitter Average	W	160.00
	dBm	52.04
System Losses	dB	-3.00
Antenna Gain	dB	47.00
Antenna Max	meters	3.66
	ft	12.00
Beam Width	deg	1.20
Elevation Max	deg	90.00
Far Field Used	meters	482.24
	ft	1,581.75
Curve to Use		uniform
Overhead Losses	dB	20.00

FSC-79

Frequency Range	6 GHz to 8 GHz
Description	Spread Spectrum, Multiple Access,
Nomenclature	AN/FSC-79
Latitude	37.56.30N
Longitude	121.21.05W
Location	Stockton, CA and other various locations
Antenna Description	Circular Dish

Frequency	MHz	7,995.00
Pulse Width	μsec	375.00
PRF	Hz	1,000.00
Duty Cycle	#	0.37500
	%	37.5000
Transmitter Peak	W	8,000.00
	dBm	69.03
Transmitter Average	W	3,000.00
	dBm	64.77
System Losses	dB	-3.00
Antenna Gain	dB	62.00
Antenna Max	meters	18.30
	ft	60.02
Beam Width	deg	1.60
Elevation Max	deg	16.00
Far Field	meters	17,849.64
	ft	58,546.81
Curve to Use		uniform
Overhead Losses	dB	20.00

TPQ-39

Frequency Range	8 GHz to 12 GHz
Description	Range Tracking
Nomenclature	AN/TPQ-39
Latitude	37.25.00N
Longitude	121.06.00W
Location	Crows Landing, California, and other various locations
Antenna Description	Circular Dish

Frequency	MHz	9,000.00
Pulse Width	μsec	1.00
PRF	Hz	1,280.00
Duty Cycle	#	0.00128
	%	0.1280
Transmitter Peak	W	300,000.00
	dBm	84.77
Transmitter Average	W	384.00
	dBm	55.84
System Losses	dB	-3.00
Antenna Gain	dB	44.00
Antenna Max	meters	2.44
	ft	8.00
Beam Width	deg	1.50
Elevation Max	deg	90.00
Far Field Used	meters	357.22
	ft	1,171.67
Illumination Estimator	#	1.92
Curve to Use	p4	$(1-r^2)^3$
Overhead Losses	dB	20.00

GPN-22

Frequency Range	8 GHz to 12 GHz
Description	Precision Approach Radar (TPN-18, 19, and 25)
Nomenclature	AN/GPN-22
Latitude	41.07.00N
Longitude	095.55.00W
Location	Offutt AFB, NE and other various locations
Antenna Description	Phase Array

Frequency	MHz	9,020.00
Pulse Width	μsec	0.50
PRF	Hz	3,652.00
Duty Cycle	#	0.00183
	%	0.18
Transmitter Peak	W	250,000.00
	dBm	83.98
Transmitter Average	W	456.50
	dBm	56.59
System Losses	dB	-3.00
Antenna Gain	dB	42.00
Antenna Max x	meters	4.60
	ft	15.09
Antenna Max y	meters	3.98
	ft	13.05
Beam Width	deg	1.55
Elevation Max	deg	60.00
Far Field x Used	meters	636.21
	ft	2,086.77
Far Field y Used	meters	476.27
	ft	1,562.16
Curve to Use		$\cos^3$
Overhead Losses	dB	20.00

ASDE-3

Frequency Range	12 GHz to 18 GHz
Description	Airport Surface Detection Equipment, Fixed Airport
Nomenclature	ASDE-3
Latitude	Nationwide
Longitude	Nationwide
Location	Various
Antenna Description	Parabolic Reflector, Rectangular

Frequency	MHz	15,700.00
Pulse Width	μsec	0.04
PRF	Hz	33,250.00
Duty Cycle	#	0.001333
	%	0.133
Transmitter Peak	W	3,000.00
	dBm	64.77
Transmitter Average	W	3.87
	dBm	35.88
System Losses	dB	-3.00
Antenna Gain	dB	44.00
Antenna Max x	meters	5.08
	ft	16.66
Antenna Max y	meters	3.03
	ft	0.25
Beam Width	deg	0.25
Elevation Max	deg	2.0
Far Field x Used	meters	1,350.53
	ft	4,429.75
Far Field y Used	meters	215.66
	ft	707.37
Curve to Use		$\cos^2$
Overhead Losses	dB	22.00

SAT BUS

Frequency Range	12 GHz to 18 GHz
Description	Satellite Comm
Nomenclature	Sat Bus Sys
Latitude	39.16.38N
Longitude	104.48.25W
Location	Colorado Springs, CO, and other various locations
Antenna Description	Circular Dish

Frequency	MHz	14,000.00
Pulse Width	μsec	1,000.00
PRF	Hz	1,000.00
Duty Cycle	#	1.00000
	%	100.0000
Transmitter Peak	W	1,000.00
	dBm	60.00
Transmitter Average	W	1,000.00
	dBm	60.00
System Losses	dB	-6.00
Antenna Gain	dB	56.00
Antenna Max	meters	2.32
	ft	7.59
Beam Width	deg	0.50
Elevation Max	deg	60.00
Far Field Used	meters	500.29
	ft	1,640.94
Curve to Use		uniform
Overhead Losses	dB	20.00

Note: The analysis of this system used CW output with no modulation, therefore the PW and PRF are not representative of the actual modulation and are set so the duty cycle is 100%.

ADSE-2

Frequency Range	18 GHz to 40 GHz
Description	Airport Surface Detection
Nomenclature	ADSE-2
Latitude	41.58.43N
Longitude	087.54.21W
Location	Chicago, Illinois, and numerous airport nationwide
Antenna Description	Parabolic Reflector, Rectangular

Frequency	MHz	23,600.00
Pulse Width	μsec	0.02
PRF	Hz	14,500.00
Duty Cycle	#	0.00029
	%	0.03
Transmitter Peak	W	50,000.00
	dBm	76.99
Transmitter Average	W	15.95
	dBm	42.03
System Losses	dB	-2.36
Antenna Gain	dB	45.00
Antenna Max x	meters	3.40
	ft	11.15
Antenna Max y	meters	0.30
	ft	0.98
Beam Width	deg	0.25
Elevation Max	deg	3.00
Far Field x Used	meters	909.39
	ft	2,982.79
Far Field y Used	meters	7.08
	ft	23.22
Curve to Use		uniform
Overhead Losses	dB	20.00

UNCLASSIFIED