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BACKGROUND STUDY ON EFFICIENT USE OF THE 2700-2900 MHz BAND

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ABSTRACT

In early 1980, NTIA, through the Interdepartment Radio Advisory Committee (IRAC) Spectrum Planning Subcommittee (SPS), became cognizant of several new major radar systems being developed by Government agencies in the 2700-2900 MHz band. In light of the long history of EMC problems in this band, NTIA recommended to the IRAC that several tasks be undertaken to ensure that the new systems are engineered properly to enhance their accommodation in the 2700-2900 MHz band. The associated tasks identified by NTIA were assigned by the IRAC to the IRAC Technical Subcommittee (TSC) and in turn were referred to the TSC Working Group 1.

This report provides background information and summarizes the findings on the referred tasks. Equipment characteristics, radar deployment patterns, usage of the band based on Radio Spectrum Measurement System (RSMS) van measurements, and projected usage of the band in the 1980's were discussed. Also the accommodation of new systems planned for the band was studied. Based on the projected growth in the band and present and projected radar deployment patterns, recommendations were made to the IRAC which would enhance the accommodation of new systems planned for the band.

KEY WORDS

2700-2900 MHz Band
Radar Spectrum Engineering Criteria (RSEC)
Interference

ACKNOWLEDGEMENT

The completion of this investigation of tasks assigned by the Interdepartment Radio Advisory Committee (IRAC) required the contributions of many individuals. The investigation was conducted by the IRAC Technical Subcommittee (TSC) Working Group 1. Members of TSC Working Group 1 consisted of representatives from the following Government agencies: NTIA, FAA, DOC, Army, Navy and Air Force.

In addition, this investigation could not have been as detailed without the support given by Robert Matheson, John Smilley, Frank Saunders and Vincent Lawrence of NTIA's Radio Spectrum Measurement System (RSMS) van team. They conducted the RSMS measurements contained herein, coordinated the location and scope of the measurements with appropriate Government field personnel, and reduced the measured data to a form usable for analysis.

SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the radio spectrum allocated to the U.S. Federal Government. Part of NTIA's responsibility is to: "...establish policies concerning spectrum assignment, allocation and use, and provide the various Departments and agencies with guidance to assure that their conduct of telecommunications activities is consistent with these policies" (Department of Commerce, 1980). In support of these requirements, the guidance provided by NTIA with the assistance of the Interdepartment Radio Advisory Committee (IRAC) encompasses the areas of: utilizing spectrum, identifying existing and/or potential Electromagnetic Compatibility (EMC) problems between systems of various departments and agencies, providing recommendations for resolving any compatibility conflicts, and recommending changes to improve spectrum management procedures.

In early 1980, NTIA, through the IRAC Spectrum Planning Subcommittee (SPS), became cognizant of several new major radar systems being developed by Government agencies in the 2700-2900 MHz band. In light of the long history of EMC problems in this band, NTIA recommended to the IRAC (IRAC Doc. 21452) that several tasks be undertaken to ensure that the new systems are engineered properly to enhance their accommodation in the 2700-2900 MHz band. The associated tasks identified by NTIA were assigned by the IRAC to the IRAC Technical Subcommittee (TSC) (IRAC Doc. 21572) and in turn were referred to the TSC Working Group 1. This report summarizes the findings on the tasks referred to the TSC Working Group 1 and includes recommendations and radar system performance guidelines which should enhance the accommodation of new radar systems in the 2700-2900 MHz band.

Concern over potential EMC problems in the 2700-2900 MHz band were first brought to the attention of the IRAC by the Federal Aviation Administration (FAA) in 1971 (IRAC Doc. 14312). During the period of August 1971 through April 1973, the IRAC had under study the accommodation of Department of Defense (DoD), Federal Aviation Administration (FAA), and Department of Commerce (DOC) radar operations in the band 2700-2900 MHz. A series of meetings were held between the agencies (Summary Minutes of the First (October 1972) and Second (December 1972) OTP Meetings) to determine if the FAA ASR-8 air traffic control radars could be accommodated in this band without degrading their performance, and what impact these radars would have on the performance of existing radars in the band. An initial assessment of the problem (Maiuzzo, 1972) determined that the addition of new radars to the band could create a potential problem.

The Office of Telecommunications Policy (OTP)* subsequently tasked the Office of Telecommunications (OT)* to perform a spectrum resource assessment of the 2700-2900 MHz band. The intent of this assessment was to provide a quantitative understanding of potential problems in the band as well as to identify options available to spectrum managers for dealing with these problems.

*OTP and OT have been reorganized into the National Telecommunications and Information Administration (NTIA) within the Department of Commerce.

Three major tasks related to the spectrum resource assessment of the 2700-2900 MHz band were completed. These tasks encompassed:

1. A detailed measurement and model validation program in the Los Angeles and San Francisco areas. The objective of this task was to validate models and procedures used to predict radar-to-radar interference, and assess the capability of predicting band congestion. This task was completed and the findings given in a report by Hinkle, Pratt and Matheson (1976).

2. Investigation of the signal processing properties of primary radars in the 2700-2900 MHz band and the Automated Radar Terminal System (ARTS-IIIA) to assess the capability of the radars to suppress asynchronous interference and the trade-offs in suppressing asynchronous signals. This task was completed and the findings given in a report by Hinkle, Pratt and Levy (1979).

3. Investigation of the feasibility of deploying Limited Surveillance Radar (LSR) systems in the Los Angeles and San Francisco Areas. This task was completed and the findings given in a report by Hinkle (1980).

The last of these reports identified the possibility of potential problems occurring in accommodating the FAA Airport Surveillance Radar (ASR-9) and the joint FAA, National Weather Service (NWS) and Air Force next generation weather radar (NEXRAD) in certain congested areas and under collocated conditions. The ASR-9 and NEXRAD radars are scheduled for deployment in 1986.

OBJECTIVE

The objectives of the TSC Working Group 1 were:

1. Perform the tasks assigned to the TSC Working Group 1 by the IRAC. The IRAC tasks were:

   a. Identify Government agency plans for use of the 2700-2900 MHz band to satisfy their future requirements.

   b. Describe the theoretical environmental signal characteristics (pulsewidth, pulse repetition frequency, and expected signal levels) which new radars in the 2700-2900 MHz band may have to contend with in performing their operational requirements.

   c. Review the current Radar Spectrum Engineering Criteria (RSEC, Part 5.3 of the NTIA Manual) as to their appropriateness in light of the existing radars and those planned in the future in the 2700-2900 MHz band.

2. Determine radar system performance guidelines for use by Government agencies in the early phases of planning and design specifications of new systems. The performance guidelines are intended to enhance the accommodation of new radar systems in congested areas and collocated conditions, and to eliminate the costly case-by-case engineering of radar deployments which may require changes in system design and hardware already fabricated.

3. Make recommendations to the IRAC on the assigned tasks, and determine procedures for implementing the recommended action by the IRAC Spectrum Planning Subcommittee (SPS) and Frequency Assignment Subcommittee (FAS).

APPROACH

In order to accomplish the tasks assigned to the TSC Working Group 1, the following approach was taken.

For IRAC Task "a":

1. Request information from each Government agency on projected plans for deploying radar systems in the 2700-2900 MHz band through calendar year 1989.

2. Establish band usage trends based on identified future requirements.

For IRAC Task "b":

1. Identify equipment characteristics (peak output power, pulse width, pulse repetition frequency, antenna gain, etc.) for radar systems presently operating and planned for the 2700-2900 MHz band.

2. Calculate expected signal levels at the RF input of deployed radar system based on typical operational distance separations and nominal radar system equipment characteristics.

3. Use the information obtained in 1 and 2 above to describe the environmental signal characteristics with which new radar systems may have to contend in performing their operational requirements.

For IRAC Task "c":

1. Identify operational deployment patterns of radars presently operating in the band in terms of typical distance separations between radars.

2. Develop frequency-distance separation relationships based on the RSEC and other more stringent emission spectrum bound levels using characteristics of future planned systems.

3. Determine emission spectrum characteristics of radars presently operating in the band using the Department of Commerce Radio Spectrum Measurement System (RSMS) van, and the current state-of-the-art emission spectrum characteristics of crossed-field and linear-beam tubes.

4. Determine whether the RSEC is adequate to ensure an acceptable degree of electromagnetic compatibility among radars presently in the band and planned for the band based on typical distance separations between radars in the band and identified frequency-distance separation requirements.

The information obtained pursuant to IRAC Tasks "a," "b," and "c" was then used to identify radar system performance guidelines which would enhance the accommodation of new radar systems in the band. This information was then used to recommend changes to the RSEC.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

This section contains a summary of the conclusions and recommendations resulting from the investigation of IRAC tasks (IRAC Doc. 21512) related to the 2700-2900 MHz band which were assigned to the IRAC Technical Subcommittee. A detailed investigation into the feasibility of accommodating new systems planned for the 2700-2900 MHz band was conducted by the TSC Working Group 1. Information was obtained on the present and projected usage of the 2700-2900 MHz band through calender year 1989. Other areas investigated by the Working Group pertaining to the 2700-2900 MHz band included:

1. Rules and regulations.

2. Identification of heavily used areas and radar distance separation statistics.

3. Nominal radar equipment characteristics of existing and future planned systems.

4. Frequency-distance separation criteria for new systems planned for the band.

5. Emission spectrum characteristics of various transmitter output tube devices.

6. Adequacy of the RSEC in light of existing and future planned systems.

7. Environment signal characteristics (pulse width, pulse repetition frequency, and expected signal levels) which new radars may have to contend with in performing their operational requirements.

The above areas are discussed in detail in Sections 3 through 6 of this report.

CONCLUSIONS

Present Environment

The following are conclusions on the present environment in the 2700-2900 MHz band:

1. There are approximately 627 radars in the 2700-2900 MHz band. The major users of the band are the Air Force and FAA with 35.4 and 35.2 percent, respectively. Other users of the band are the Department of the Navy and Department of Commerce with 11.6 and 10.8 percent, respectively. The distribution of the radars by service are: 61.9 percent Aeronautical Radionavigation, 11.3 percent Meteorological Aids and 16.3 percent Radiolocation. Experimental stations account for 10.3 percent.

2. There are certain areas in the United States where it is difficult to accommodate new radars in the 2700-2900 MHz band. Areas where there are numerous radar deployments are the East coast megalopolis (Boston, Massachusetts to Washington, D.C.) and West coast areas of San Francisco, Los Angeles, and San Diego, California. Other areas which are heavily used include: Oklahoma City, Oklahoma and St. Louis, Missouri. Also large metropolitan areas near military bases are heavily used, such as: Miami, Jacksonville, and Pensacola, Florida; Millington, Tennessee; Norfolk, Virginia and Phoenix, Arizona. Figure 8 shows the designated heavily used areas. Approximately 35 percent of the radar assignments are in the designated heavily used areas.

3. An investigation into separation distances between radars revealed that 25 percent of the radars in the band have at least one radar within two statute miles (collocated condition). Also 55 percent of the radars in the band have at least one radar within 15 statute miles. These radar separation distance statistics indicate the need for well designed radar systems in order to accommodate new Government agency requirements in the band.

Future Environment

The following are conclusions on the future environment in the 2700-2900 MHz band projected for the 1980's:

1. The number of radar systems operating in the 2700-2900 MHz band will not increase in the 1980's. However, the number of radar systems transmitting on dual channels simultaneously may increase from 85 to 242 resulting in an approximate 22% increase in the number of operating channels by 1989.

2. The Air Force and the Navy plan to replace many of their Ground Control Approach (GCA) radars in the 1980's. GCA nomenclatures planned for full or partial replacement include: AN/CPN-4; AN/FPN-47, 48, and 55; and AN/MPN-11, 13, and 14. These GCA radars are scheduled to be replaced by the Air Force AN/GPN-20 and Navy AN/GPN-27 radars. The AN/GPN-20 and AN/GPN-27 are versions of the FAA ASR-7 and ASR-8 radars respectively.

3. There are two major new radar systems planned for the 2700-2900 MHz band in the 1980's. The FAA plans to replace all 96 of the ASR-4, ASR-5, and ASR-6 radars with ASR-7/8 or new ASR-9 radar systems which are scheduled to be deployed in 1986. The National Weather Service (NWS) of the Department of Commerce plans to replace their weather radars (WSR-57 and WSR-74s) with the NEXRAD radar system beginning in 1986. The FAA and Air Force also plan to deploy the NEXRAD radar system. By 1990, 135 NEXRAD systems are projected to be deployed by the NWS, FAA and Air Force.

4. The ASR-9 and NEXRAD system can be collocated (less than two mile separation distance) if waveguide filters are used and the radars can be separated in frequency by approximately 60 MHz. There are presently 18 radar sites in the United States where FAA and NWS radars are collocated.

5. The receivers of the ASR-9 and NEXRAD radar systems will use doppler processing and adaptive thresholding techniques. These types of receiver signal processing may be more susceptible to interference from other radars. However, the use of interference suppression circuitry can mitigate this susceptibility to interference.

Radar Spectrum Engineering Criteria (RSEC)

The current RSEC was reviewed as to its appropriateness in light of the existing radars and those planned for the future in the 2700-2900 MHz band. Also measurements of conventional magnetron, coaxial magnetron and klystron transmitter emission spectrum characteristics were made with the Radio Spectrum Measurement Systems (RSMS). Investigations of these areas led to the following conclusions related to the current RSEC:

1. Based on frequency-distance calculations and radar separation distance statistics, it was concluded that the current RSEC is adequate in some situations, but not adequate for approximately 55 percent of the assignments. These difficulties occur in heavily used areas and under collocated conditions. It should be noted that this does not imply that 55 percent of the radars in the band are presently receiving interference. This finding is based on the RSEC emission spectrum bounds, and an INR = 0 criterion (No Interference). As a result of this finding, the opinion of the Working Group was that appropriate changes to the current RSEC would enhance the accommodation of new radar systems in the 2700-2900 MHz band.

2. A conventional magnetron tube cannot meet the current RSEC Column B criteria without using a waveguide filter due to the inherent frequency pulling characteristics of the tube during the risetime of the modulating pulse.

3. The coaxial magnetron and klystron can meet the present RSEC column B criteria.

4. The noise floor level specified in the RSEC is approximately 60 dB down for typical parameters of radars in the 2700-2900 MHz band. The measured noise floor level of conventional and coaxial magnetron is approximately 70-75 dB down from the fundamental level, and the noise floor level of a klystron is approximately 110-115 dB down from the fundamental level. Therefore, for radars in the 2700-2900 MHz band the present RSEC noise floor level of 60 dB is conservative.

Spectrum Efficiency

More efficient use of the 2700-2900 MHz band can be achieved by incorporating Electromagnetic Compatibility (EMC) provisions in the design of the radar systems. For example:

1. Waveguide filters can be used to achieve more efficient use of the 2700-2900 MHz band. Narrower emission spectrum with lower spurious characteristics than the present RSEC can be achieved by the use of waveguide filters. Waveguide filters can be used with conventional magnetrons, coaxial magnetrons or klystrons to achieve up to an 80 dB per decade fall-off from the present RSEC 40 dB bandwidth.

2. The klystron transmitter output tube has significantly cleaner emission spectrum characteristics than the conventional magnetron or coaxial magnetron; thus permitting more efficient use of the band. Also it is easier to change the transmitter output power level in klystrons to permit more efficient use of the band.

3. The use of receiver interference suppression circuitry in radar systems will permit more efficient use of the band. Electromagnetic environmental signal characteristics to be considered in the design of receiver interference suppression circuitry of radar systems deployed in designated heavily used area and under collocated conditions are:

   Peak Interference-to-Noise Ratio at IF Output: $\leq$ 50 dB
   Pulse width: 0.5 to 4.0 us
   PRF : 100 to 2000 pps

The use of waveguide filters, variable transmitter power and receiving interference suppression circuitry may result in trade-offs in system performance such as: probability of detection, desired signal sensitivity, target azimuth shift, target resolution, etc. However, these trade-offs are generally minimal when the interference suppression circuitry is initially designed into the system.

Environmental Factors

In addition to the number of equipments in designated heavily used areas, there are environmental factors which contribute to the congestion of the 2700-2900 MHz band. Environmental factors which contribute to congestion are propagation anomalies such as ducting and multipathing. The following are conclusions related to these propagation anomalies, and how they affect the utilization of the band:

1. The ducting of microwave energy can complicate the problem of electromagnetic compatibility between radar systems by enhancing potential interfering signal levels. Several of the designated heavily used areas are in areas where the occurrence of elevated ducts is greater than 30 percent for all hours of the year. In some of the coastal areas, ducting occurs 50-60 percent for all hours of the worst month.

2. The FAA regional frequency managers take into consideration ducting in making frequency assignments in the 2700-2900 MHz band. In areas where ducting occurs frequently, the frequency separation is increased.

3. The major effect of multipathing is to cause stretching of the interfering radar pulse width, and additional interfering pulses when the difference in distance between the direct and reflected paths exceeds the distance that a signal can travel in one pulse width. Thus multipath propagation adds to the severity of potential interference between pulsed radars.

RECOMMENDATIONS

The following are recommendations by TSC Working Group 1 based on the technical findings contained in this report. Any action to implement these recommendations will be accomplished under separate correspondence by modifications of established rules, regulations or procedures. TSC Working Group 1 recommends that:

1. The Interdepartment Radio Advisory Committee (IRAC) approve the recommended Radar Spectrum Engineering Criteria (RSEC) contained in Appendix C of this report. The recommended RSEC changes are applicable to new fixed radars planned for the 2700-2900 MHz band, and will enhance the accommodation of new systems in designated heavily used areas and for collocated operation.

2. If the IRAC approves the proposed RSEC for fixed radars in the 2700-2900 MHz band contained in Appendix C of this report, the following action should be taken by the IRAC Frequency Assignment Subcommittee (FAS):

   a) Incorporate the designated heavily used area map (See Figure 8 and TABLE 22) in Annex D of the NTIA Manual as an aid in identifying areas where accommodation of new radar systems in the 2700-2900 MHz band may be difficult.

   b) Assign a Special-Note to frequency assignments in designated heavily used areas or for collocated operation when the additional EMC capabilities stated in the proposed RSEC are not installed in the initial deployment of the radar. This S-note should read as follows:

SXXX-This assignment, in the 2700-2900 MHz band, is for operation in a designated heavily used area or for collocated operation (see Annex D of the NTIA Manual). This equipment has the capability of implementing the additional Electromagnetic Compatibility (EMC) provisions of RSEC Criteria D under Section 5.3 of the NTIA Manual. Implementation of this capability may be necessary at a later date.

3. The effects of pulsed radar interference on doppler and adoptive threshold radar signal processing should be investigated.

SECTION 3

RULES AND REGULATIONS

INTRODUCTION

This section presents a discussion of the international and national allocation rules pertaining to spectrum usage of the 2700-2900 MHz band, the U.S. Government technical standards pertaining to equipment operating in the band, and the procedure for selection and coordination of the use of radio frequencies in the 2700-2900 MHz band.

INTERNATIONAL ALLOCATIONS

The service allocated internationally to the 2700-2900 MHz band, by the Final Acts of the WARC-79, are presented in TABLE 1. All International Telecommunication Union (ITU) regions are allocated to the Aeronautical Radionavigation Service on a primary basis, and to the Radiolocation Service on a secondary basis. The use of 2700-2900 MHz band by the aeronautical radionavigation is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in the band and only when actuated by radars operating in the band (Footnote 717). Ground-based radars used for meteorological purposes are authorized by footnote 770 to operate on a basis of equality with stations of the Aeronautical Radionavigation Service. All international footnotes pertaining to the 2700-2900 MHz band are listed in TABLE 1.

NATIONAL ALLOCATIONS

In the United States, the 2700-2900 MHz is allocated for exclusive Government services as indicated in TABLE 1. The Government allocates this band to the Aeronautical Radionavigation and Meteorological Aids Services on a primary basis, and to the Radiolocation Service on a secondary basis. The radiolocation usage is limited to the military services (footnote G2). All military service radiolocation assignments must be fully coordinated with the Meteorological Aids and Aeronautical Radionavigation Services (footnote G15). Non-Government operations are permitted in the band (US18). However, non-Government operations are mainly limited to frequency assignments required for the development of radiodetermination systems for Government agencies or other countries. All national footnotes pertaining to the 2700-2900 MHz band are listed in TABLE 1.

TECHNICAL STANDARDS

The following discussion of the technical standards applicable to systems operating in the 2700-2900 MHz band is based on the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management (NTIA,1980) and appropriate military standards. Chapter 5 of the NTIA Manual contains the technical standards, minimum performance requirements and design objectives that are applicable to telecommunication equipments used in Government radio stations. These standards normally take precedence within the Federal Government. However, any Government agency may promulgate more stringent standards for its own use.

TABLE 1

SUMMARY OF FREQUENCY ALLOCATIONS FOR THE 2700-2900 MHz BAND
BASED ON RESULTS OF WARC-79

INTERNATIONAL			UNITED STATES				
Region 1 MHz	Region 2 MHz	Region 3 MHz	Band MHz	National Provisions	Government Allocation	Non-Government Allocation	Remarks
2700 - 2900	AERONAUTICAL RADIONAVIGATION 717 Radiolocation 770 771		2700-2900	717 770 US18	AERONAUTICAL RADIONAVIGATION METEOROLOGICAL AIDS Radiolocation G2 G15		

FOOTNOTES:

717 - The use of the bands 1300 - 1350 MHz, 2700 - 2900 MHz and 9000 - 9200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these band and only when actuated by radars operating in the same band.

770 - In the band 2700 - 2900 MHz, ground-based radars used for meteorological purposes are authorized to operate on a basis of equality with stations of the aeronautical radionavigation service.

771 - Additional allocation: in Canada, the band 2850 - 2900 MHz is also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars.

US18 - Navigation aids in the US and possessions in the bands 9-14 kHz, 90-110 kHz, 190-415 kHz, 510-535 kHz, and 2700-2900 MHz are normally operated by the U.S. Government. However, authorizations may be made by the FCC for non-Government operation in these bands subject to the conclusion of appropriate arrangements between the FCC and the Government agencies concerned and upon special showing of need for service which the Government is not yet prepared to render.

G2 - In the bands 261-225, 420-450 (except as provided by US217), 890--902, 928-942, 1300-1400, 2300-2450, 2700-2900, 5650-5925, and 9000-9200 MHz, the Government radiolocation is limited to the military services.

G15 - Use of the band 2700-2900 MHz by the military fixed and shipborne air defense radiolocation installations will be fully coordinated with the meteorological aids and aeronautical radionavigation services. The military air defense installations will be moved from the band 2700-2900 MHz at the earliest particable date. Until such time as military air defense installations can be accommodated satisfactorily elsewhere in the spectrum, such operations will, insofar as paracticable, be adjusted to meet the requirements of the aeronautical radionavigation service.

Radar Spectrum Engineering Criteria

The Radar Spectrum Engineering Criteria (RSEC) applies to all Government radar systems. RSEC specifications are contained in Part 5.3 of the NTIA Manual. The RSEC specifies certain equipment characteristics to ensure an acceptable degree of electromagnetic compatibility among radar systems, and between such systems and those of other radio services sharing the frequency spectrum. While the specific technical requirements of RSEC are omitted herein, the following list identifies the radar characteristics that are considered:

(1) Emission bandwidth
(2) Emission levels
(3) Antenna pattern
(4) Frequency tolerance
(5) Tunability
(6) Image and Spurious rejection
(7) Local-oscillator radiation

Military Standards

The Department of Defense also uses Military Standards 461B and 469 for guidance in developmemt of its radar systems. MIL-STD-461B entitled "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference" sets forth engineering design criteria to:

(a) Ensure that interference control is considered and incorporated into the design of equipments and subsystems; and

(b) Provide a basis for evaluating the electromagnetic characteristics of equipments and subsystems, as well as for inputs to analyses of the electromagnetic compatibility and effectiveness of systems in a complex electromagnetic environment.

MIL-STD-469 entitled "Radar Engineering Design Requirements, Electromagnetic Compatibility" sets forth engineering design criteria to control the spectral characteristics of all new radar systems operating between 100 MHz and 40 GHz.

COORDINATION PROCEDURES

The NTIA Manual of Regulations and Procedures for Radio Frequency Management (NTIA,1979) Annex D sets forth the procedure for field level selection and coordination of the use of radio frequencies in the 2700-2900 MHz band. The purpose of this procedure is to provide for the local selection of frequencies and to minimize, through effective coordination, the possibility of harmful interference in certain bands and geographical areas. This coordination procedure is applicable to the use of frequencies in the 2700-2900 MHz band by U.S. Government radio stations within the U.S. and Possessions.

In the 2700-2900 MHz band, the Federal Aviation Administration (FAA) has the authority for field level selection and coordination of the use of radio frequencies. Figure 1 shows the FAA frequency management regions for the U.S. and Possessions. Annex D of the NTIA Manual identifies the regional office locations and FAA frequency manager for each region.

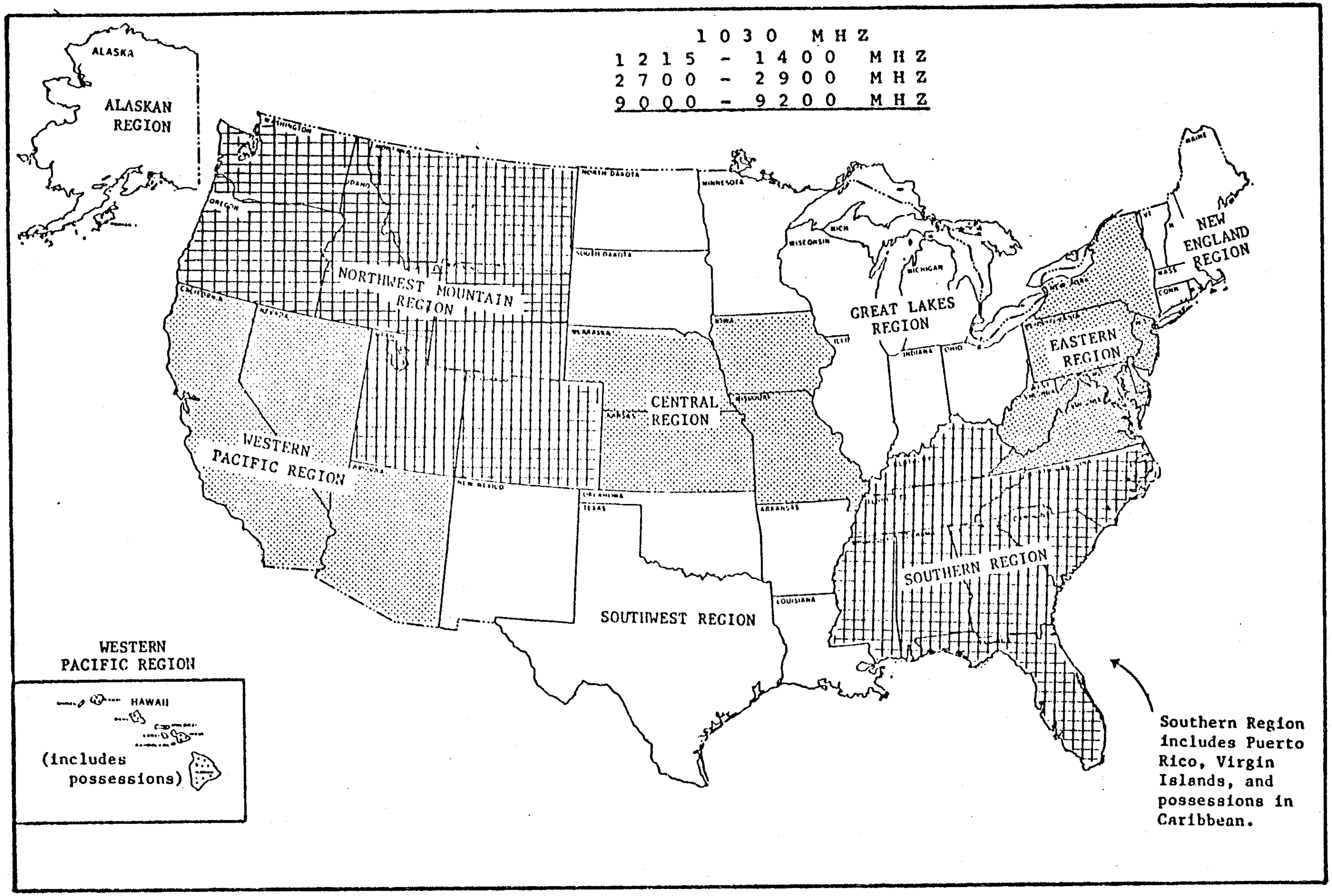


Figure 1. FAA Frequency Management Regions

SECTION 4

SPECTRUM USAGE AND EQUIPMENT CHARACTERISTICS OF SYSTEMS IN THE 2700-2900 MHz BAND

INTRODUCTION

This section contains a description of the radiodetermination environment in the 2700-2900 MHz band. The present usage of the band by the various Government agencies and projected band usage through calendar year 1989 are discussed. Nominal equipment characteristics of radiodetermination stations operating in the 2700-2900 MHz band are also provided.

Because of concern over congestion in the 2700-2900 MHz band, a detailed investigation of present and future planned use of the band was conducted. The purpose of this investigation was to determine if the character of the 2700-2900 MHz band will change, and to identify future usage trends. New systems planned for the band were identified along with the new technology and signal processing techniques to be used by the new systems.

This information was obtained to aid in determining if future planned systems for the 2700-2900 MHz band can be accommodated, and to aid in identification of radar system performance guidelines which will enhance the accommodation of planned new systems.

SPECTRUM USAGE

Present Environment

TABLE 2 shows the distribution of Government equipments in the 2700-2900 MHz band by agency and station class. This data was based on the Government Master File (GMF), October 1980, and information obtained from the frequency management offices of the various Government agencies. The information given in TABLE 2 indicates the number of radiodetermination equipments authorized to operate in the band, and not the number of frequency assignments authorized to operate on. As of October 1980, the number of equipments authorized to operate in the 2700-2900 MHz band is 627. Figure 2 shows the location of all the equipments authorized to operate in the band. The difference between the number of equipments authorized to operate in the band and the number of frequencies authorized to operate on is due to the fact that several radiodetermination systems in the band have the capability to operate on two channels, and in many cases the A and B channels of the system operate on two different frequencies. Whether both channels of a system are operated on a single frequency, or on two frequencies, and the frequency distance between channels is determined through coordination with the FAA regional frequency coordinators.

The major users of the band are the Air Force and FAA with 35.2 percent and 35.4 percent of the equipments respectively. Figures 3 and 4 show the locations of the Air Force and FAA radars respectively. Other users of the band with a significant number of equipments are the Navy and Department of Commerce (DoC) with 11.6 and 10.8 percent respectively. The locations of the Navy and DoC radars are shown in Figures 5 and 6 respectively. The Army has approximately 2.7 percent of the equipments in the band. Most of the Army radars are on the White Sands Missile Test Range in New Mexico (see Figure 7).

TABLE 2

USAGE OF THE 2700-2900 MHz BAND

AGENCY/SERVICE	STATION CLASS										NUMBER OF EQUIPMENTS	PERCENTAGE OF EQUIPMENTS
	RLS	RL	LR	MOB	MR	WXD	XC	XD	XR	XT		
FAA	208	8	5	0	0	0	0	0	0	0	221	35.2
AIR FORCE	100	24	63	1	3	0	5	2	2	22	222	35.4
NAVY	17	26	8	0	1	0	0	0	0	21	73	11.6
ARMY	5	0	10	0	2	0	0	0	0	0	17	2.7
COMMERCE	0	0	0	0	0	68	0	0	0	0	68	10.8
NSF	1	0	0	0	0	2	0	0	0	0	3	0.5
NASA	0	0	10	0	0	1	0	0	0	0	11	1.8
Non-Government	0	0	0	0	0	0	3	5	4	0	12	2.0
Number of Assignments	331	58	96	1	6	71	8	7	6	43	TOTAL 627	
Percentage of Assignments	52.7	9.2	15.3	0.2	1.0	11.3	1.3	1.1	1.0	6.9		

RLS - Surveillance Radar Station
RL - Radionavigation Land Station
LR - Radiolocation Land Station
MOB - Radio Beacon Mobile Station
MR - Radiolocation Mobile Station

WXD - Meteorological Radar Station
XC - Experimental Contract Developmental Station
XD - Experimental Developmental Station
XR - Experimental Research Station
XT - Experimental Testing Station

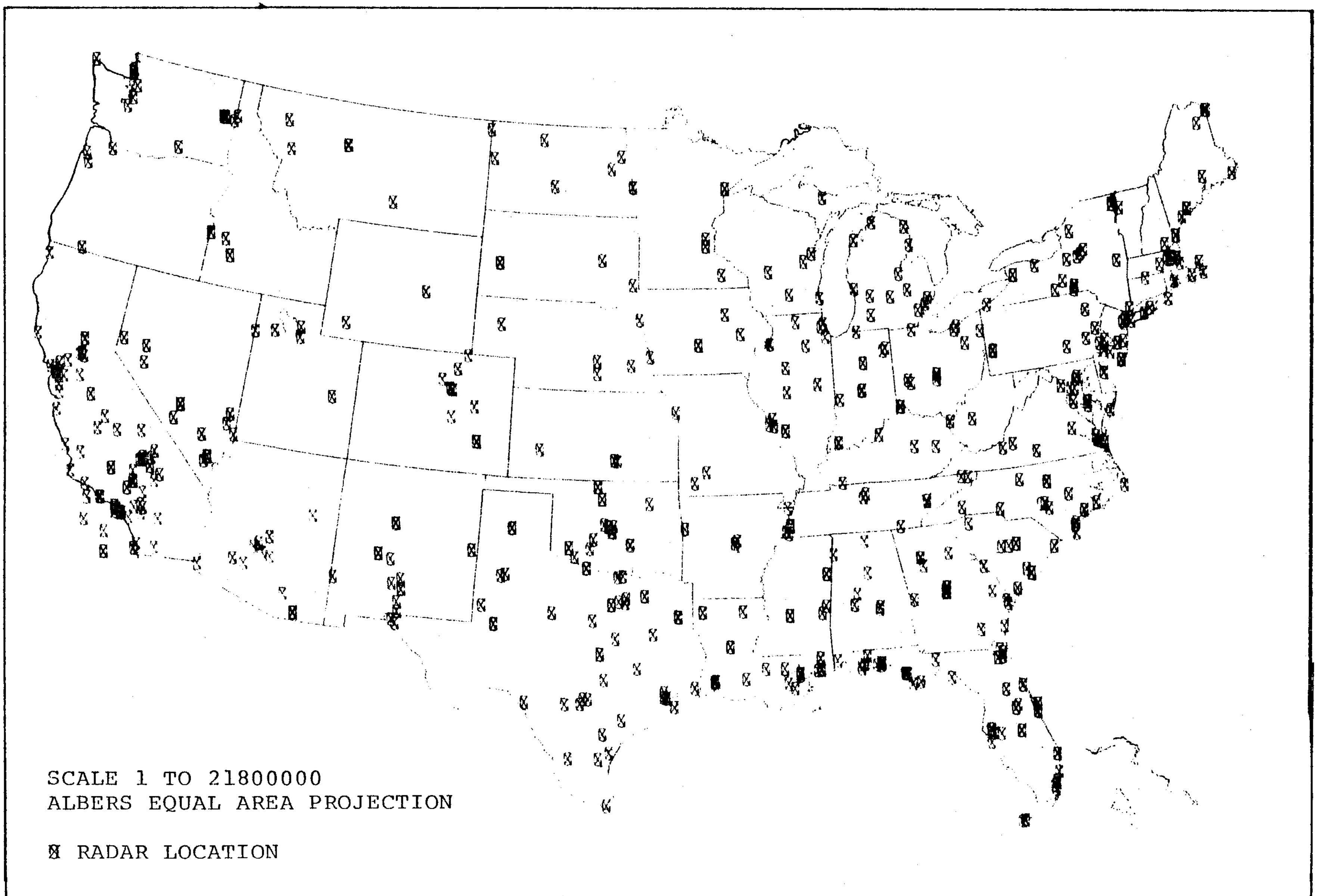


Figure 2. Radar Locations in the 2700-2900 MHz Band

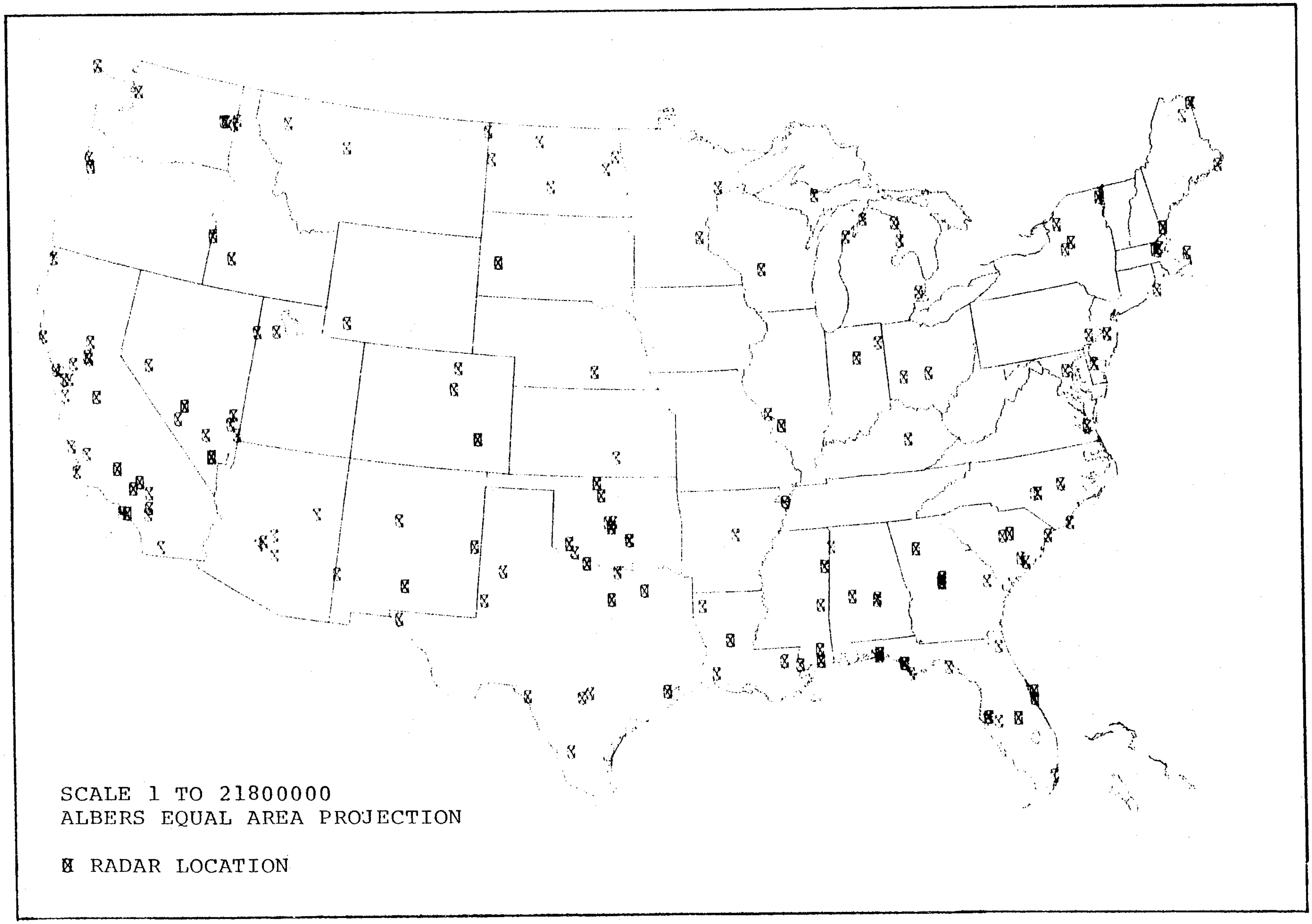


Figure 3. Air Force Radar Location in the 2700-2900 MHz Band

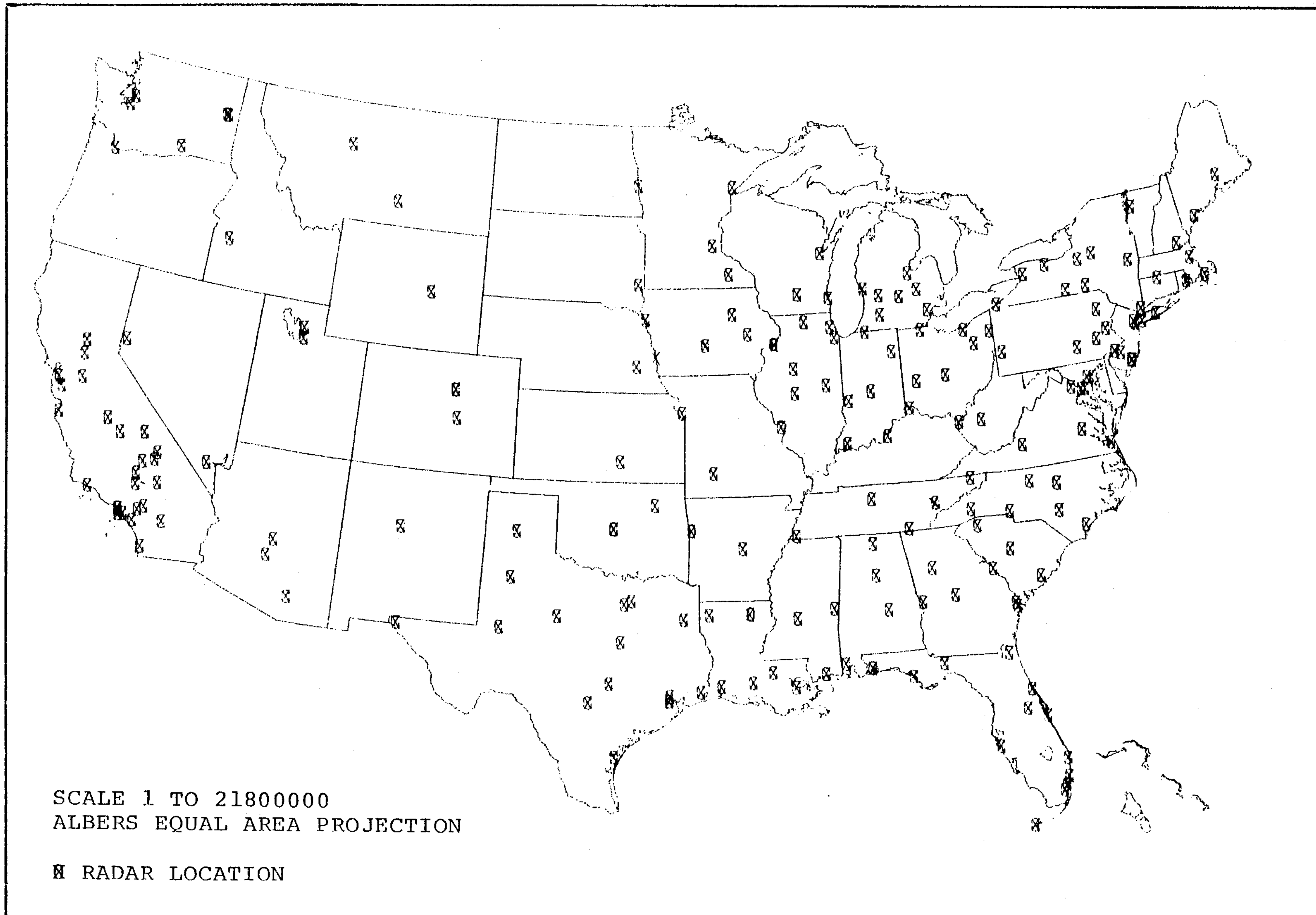


Figure 4. FAA Radar Locations in the 2700-2900 MHz Band

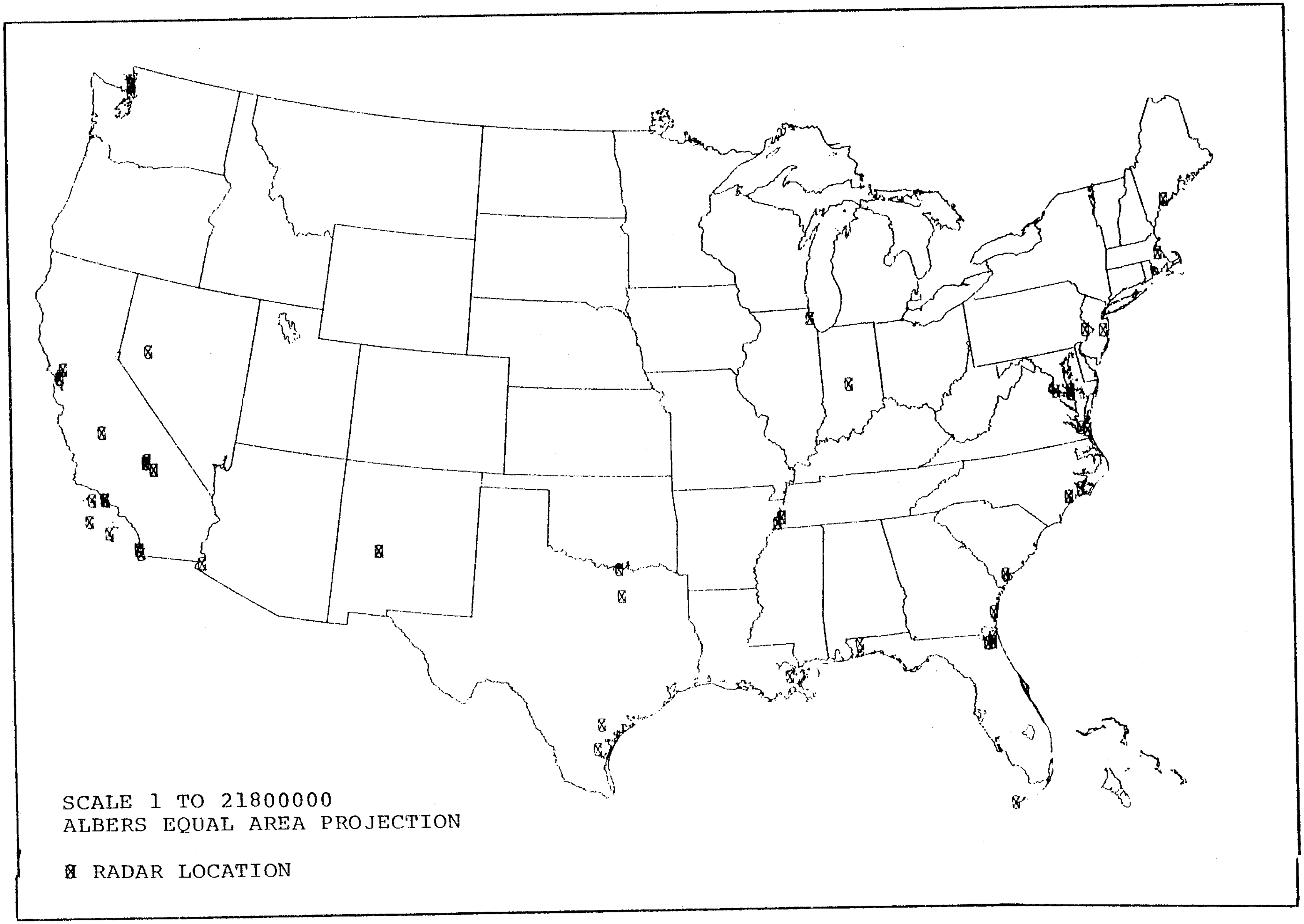


Figure 5. Navy Radar Locations in the 2700-2900 MHz Band

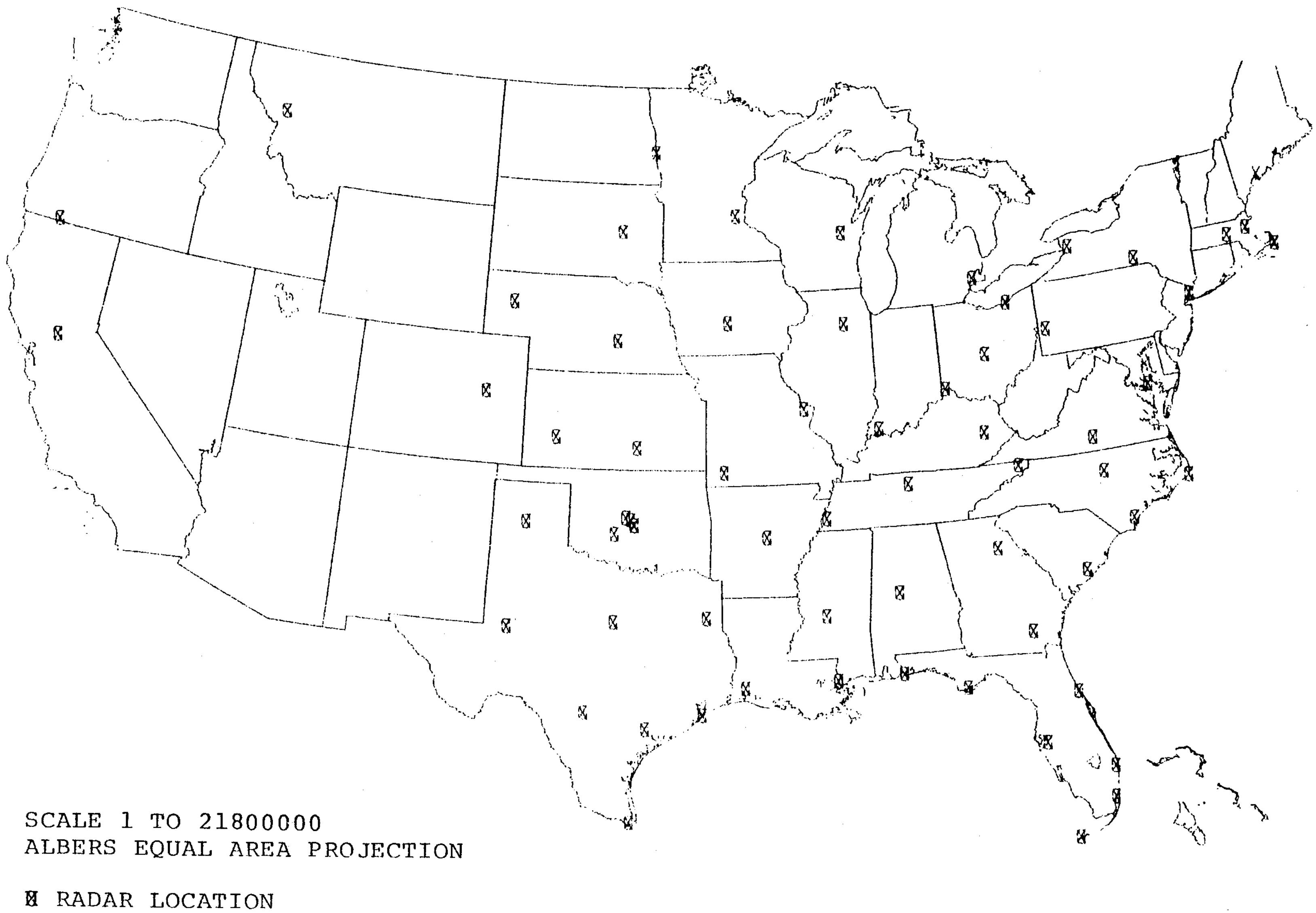


Figure 6. Department of Commerce Radar Locations in the 2700-2900 MHz Band

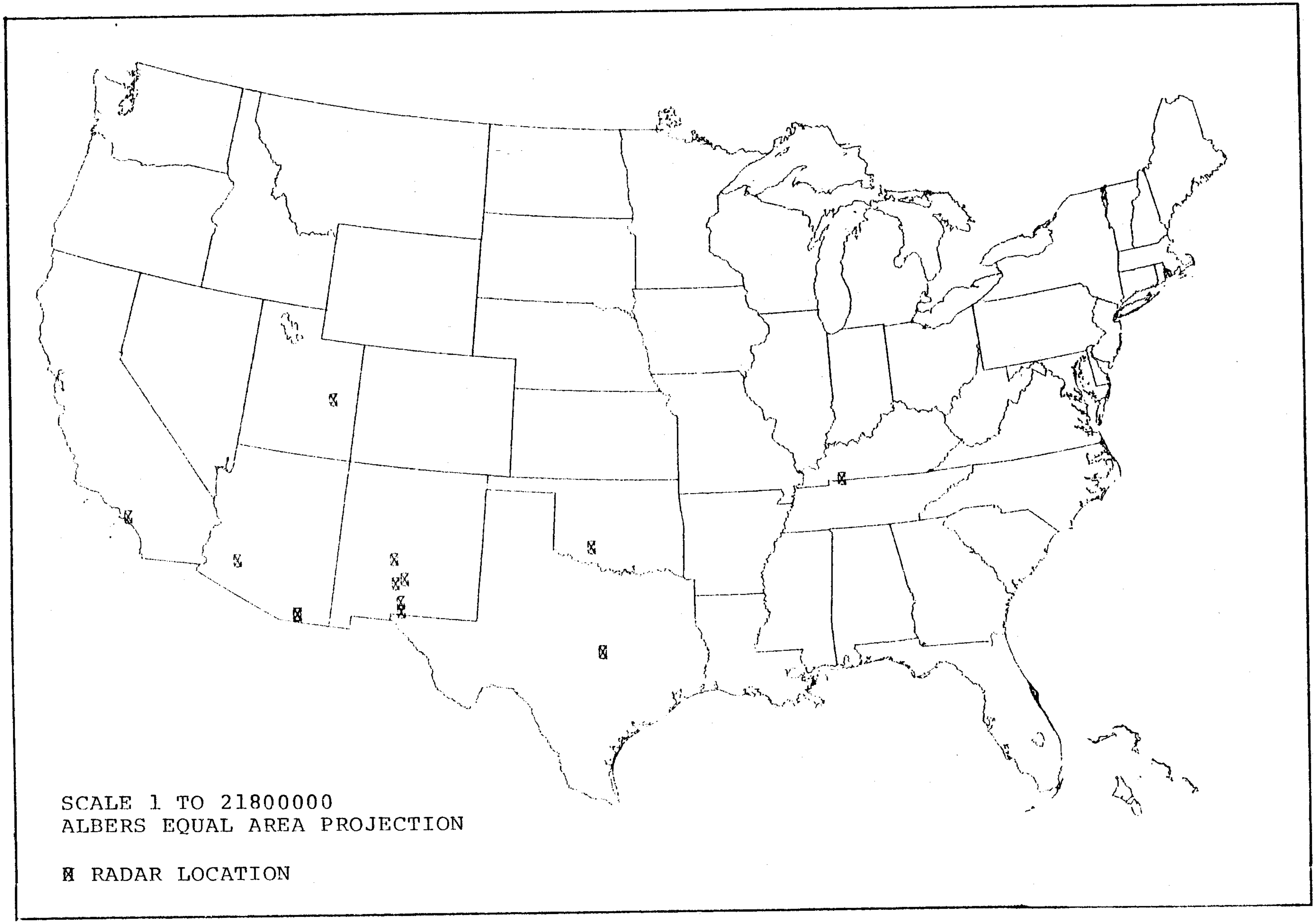


Figure 7. Army Radar Locations in the 2700-2900 MHz Band

TABLE 2 also shows that approximately 61.9 percent of the equipments in the 2700-2900 MHz band are in the Aeronautical Radionavigation Service (Station Classes RLS and RL). Therefore, a large majority of the radars in the band are aeronautical radionavigation radar systems. The aeronautical radionavigation radar systems in the band are the FAA Airport Surveillance Radars (ASR's) and the military Ground Control Approach (GCA) radars. Approximately 11.3 percent of the equipments in the band are in the Meteorological Aids Service (Station Class WXD). Sixty-eight of the seventy-one equipments in the Meteorological Aids Service belong to the DoC National Weather Service (NWS). Approximately 16.3 percent of the equipments in the band are in the secondary Radiolocation Service (Station Classes LR and MR). Approximately 10.3 percent of the equipments in the band are experimental radar stations (Station Classes XC, XD, XR, and XT).

Future Environment

In order to determine if the major new systems planned for the 2700-2900 MHz band can be accommodated, it was necessary to identify the projected use of the band by all Government agencies. Information on projected use of the band through calendar year 1989 was obtained from the frequency management offices of the various Government agencies.

The projected radar inventory for the FAA, Army, Navy, Air Force, DoC, National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF) are shown in TABLES 3 through 9. The NEXRAD system deployment is projected for the DoC, FAA, and Air Force through calendar year 1990. For each agency, except the Army, Navy and Air Force, the tables show the number of expected systems operational for each nomenclature in a particular calendar year. The expected total number of system deployments for each year is shown at the bottom of each table. TABLES 3 and 7 through 9 also show the radar systems presently operating in the 2700-2900 MHz band that are planned for replacement by new radar systems.

The FAA plans to replace the Airport Surveillance Radar (ASR) nomenclatures ASR-4, ASR-5, and ASR-6 with ASR-7/8 or the new ASR-9 radar system (see TABLE 3). Deployment of the ASR-9 system is scheduled to begin in 1986 and be completed in 1990. The projected number of ASR-9 systems is 101.

The National Weather Service (NWS) of the Department of Commerce plans to replace the WSR-57 and WSR-74(s) radars with the NEXRAD radar system (see TABLE 7). Deployment of the NEXRAD radar system is scheduled to begin in 1986. The FAA and Air Force also plan to deploy the NEXRAD radar system. By 1990, it is projected that 135 NEXRAD radar systems will be deployed by the NWS, FAA, and Air Force.

The Navy and the Air Force also plan to replace many of their Ground Control Approach (GCA) radars in the 1980's. GCA nomenclatures planned for replacement include: AN/CPN-4; AN/FPN-47, 48 and 55; and AN/MPN-11, 13, and 14. These GCA radars are scheduled to be replaced by the AN/GPN-20 and AN/GPN-27 radars. The AN/GPN-20 and AN/GPN-27 are similar to the FAA ASR-7 and ASR-8 radars. In fact, the ASR-7, ASR-8, AN/GPN-20 and AN/GPN-27 radar systems are all manufactured by the same contractor. By the end of 1986, the Navy plans to replace all their GCA radars with the AN/GPN-27 or remote radar information via

TABLE 3

PROJECTED RADAR INVENTORY FOR FAA FOR CALENDAR YEARS 1980-1989
IN 2700-2900 MHz BAND

	CALENDAR YEAR									
NOMENCLATURE	80	81	82	83	84	85	86	87	88	89
ASR-2	1	1	0	0	0	0	0	0	0	0
ASR-4	34	34	34	34	34	34	34	14	0	0
ASR-5	37	37	37	37	37	37	37	37	22	0
ASR-6	24	24	24	24	24	24	24	24	24	12
ASR-7	40	40	40	40	40	40	40	40	40	40
ASR-8	76	76	76	76	76	76	76	76	76	76
ASR-9**	0	0	0	0	0	0	3	24	50	86
AN/CPN-4A	1	1	1	1	1	1	1	1	1	1
AN/FPN-47	2	2	2	2	2	2	2	2	2	2
AN/FPS-6	3	3	3	3	3	3	3	3	3	3
AN/FPS-90	3	3	3	3	3	3	3	3	3	3
NEXRAD*	0	0	0	0	0	0	0	2	12	25
TOTAL	221	221	220	220	220	220	223	226	233	248

*Projected FAA NEXRAD System Deployments for 1990 is 30.
**Projected ASR-9 System Deployments for 1990 is 101.

TABLE 4

PROJECTED RADAR INVENTORY FOR ARMY FOR CALENDAR YEARS 1980-1989
IN 2700-2900 MHz BAND

	CALENDAR YEAR									
NOMENCLATURE	80	81	82	83	84	85	86	87	88	89
TOTAL	17	17	17	17	17	17	17	17	17	17

TABLE 5

PROJECTED RADAR INVENTORY FOR NAVY FOR CALENDAR YEARS 1980-1989
IN 2700-2900 MHz BAND

	CALENDAR YEAR									
NOMENCLATURE	80	81	82	83	84	85	86	87	88	89
TOTAL	73	71	70	67	66	66	66	66	66	66

TABLE 6

PROJECTED RADAR INVENTORY FOR AIR FORCE FOR CALENDAR YEARS 1980-1989
IN 2700-2900 MHz BAND

	CALENDAR YEAR									
NOMENCLATURE	80	81	82	83	84	85	86	87	88	89
TOTAL	222	252	230	207	190	183	183	183	186	196

*Projected Air Force NEXRAD Systems Deployments for 1990 is 20.

TABLE 7

PROJECTED RADAR INVENTORY FOR DoC FOR CALENDAR YEARS 1980-1989 IN 2700-2900 MHz BAND

NOMENCLATURE	CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89
WSR-57	56	56	56	56	56	56	54	48	31	6
WSR-74S	8	8	8	8	8	8	8	8	8	8
AN/FPS-18	2	2	2	2	2	2	2	2	2	2
WDS-73	1	1	1	1	1	1	1	1	1	1
WDR-73	1	1	1	1	1	1	1	1	1	1
NEXRAD*	0	0	0	0	0	0	2	8	25	50
TOTAL	68	68	68	68	68	68	68	68	68	68

* Projected DoC NEXRAD System Deployments for 1990 is 85.

TABLE 8

PROJECTED RADAR INVENTORY FOR NASA FOR CALENDAR YEARS 1980-1989 IN 2700-2900 MHz BAND

NOMENCLATURE	CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89
SPANDAR	1	1	1	1	1	1	1	1	1	1
REVLRT-2 VERLORT	2	2	2	2	2	2	2	2	2	2
AN/FPS-18	1	1	1	1	1	1	1	1	1	1
AN/MPS-19	6	6	6	6	6	6	6	6	6	6
ASR-7	1	1	1	1	1	1	1	1	1	1
TOTAL	11	11	11	11	11	11	11	11	11	11

TABLE 9

PROJECTED RADAR INVENTORY FOR NSF FOR CALENDAR YEARS 1980-1989 IN 2700-2900 MHz BAND

NOMENCLATURE	CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89
AN/FPS-18	2	2	2	2	2	2	2	2	2	2
AN/MPS-19	1	1	1	1	1	1	1	1	1	1
TOTAL	3	3	3	3	3	3	3	3	3	3

microwave link. The Navy AN/GPN-27 procurement specification is identical to the FAA ASR-8 radar systems. In general, military procurement of GCA radar systems in recent years have been similar to radars developed by the FAA.

The Army, NASA and NSF did not project any change in radar system deployments in the 2700-2900 MHz band. At the present time there are no known planned replacements for existing radiolocation systems in the band. The Air Force AN/FPS-116 is essentially an up-grade package for the AN/FPS-6 and AN/FPS-90 height-finder radars.

A summary of the projected radar inventory in the 2700-2900 MHz band for calendar years 1981 through 1989 for all agencies is shown in TABLE 10. The information in TABLE 10 indicates that the projected number of radar systems in the 2700-2900 MHz band will not change that significantly in the 1980's. However, the number of systems deployed in the band does not give a true indication of the spectrum usage of the band. In order to estimate the usage of the band, it is also necessary to take into consideration if radar systems operate with more than one channel on simultaneously (dual channel operation). There are several radar nomenclatures presently operating in the band which operate dual channels simultaneously. The ASR-8, AN/GPN-20 and AN/GPN-27 all have a frequency diversity capability. Also, the present projected requirement for the NEXRAD system is for two channels to operate simultaneously. One channel for reflectivity information, and one for doppler information. The FAA, DoC, Navy, and Air Force plan to significantly increase in the 1980's their number of systems which operate dual channels simultaneously. A summary of projected dual channel systems in the 2700-2900 MHz band for calendar years 1980 through 1989 is shown in TABLE 11. TABLE 11 shows a projected increase in dual channel systems from 85 to 242 systems which is a 184 percent increase

The projected numbers of operating channels for calendar years 1980 through 1989 in the 2700-2900 MHz band is shown in TABLE 12. The information in TABLE 12 was obtained by taking into consideration the total number of systems projected for the band (see TABLE 10), and adding the number of projected dual channel radars planned for the band (see TABLE 11). TABLE 12 shows that in the 1980's there will be a significant increase in the number of operating channels in the 2700-2900 MHz band. In fact, there is a projected increase of 22 percent in the number of operating channels in the 2700-2900 MHz band for the 1980's. However, the number of systems deployed in the band will remain fairly constant in the 1980's.

EQUIPMENT CHARACTERISTICS

The following is a summary of equipment characteristics of radar systems presently operating and planned for the 2700-2900 MHz band. A survey of nominal radar system equipment characteristics of presently operating and planned radar systems in the 2700-2900 MHz band was conducted using information from technical manuals and system characteristics provided in the IRAC Systems Review process.

The nominal radar system characteristics of radars presently operating in the band as of October 1980 are listed in TABLE 13 by service type, and the nominal radar system characteristics of new radar systems planned for the band (ASR-9 and NEXRAD) are listed in TABLE 14 by service type. TABLE 13 does not include the characteristics of all the experimental assignments in the band

TABLE 10

SUMMARY OF PROJECTED RADAR INVENTORY FOR CALENDAR YEARS 1980-1989
IN 2700-2900 MHz BAND

AGENCY	80	81	82	83	84	85	86	87	88	89
	CALENDAR YEAR									
FAA	221	221	220	220	220	220	223	226	233	248
DoC	68	68	68	68	68	68	68	68	68	68
ARMY	17	17	17	17	17	17	17	17	17	17
NAVY	73	71	70	67	66	66	66	66	66	66
AIR FORCE	222	252	230	207	190	183	183	183	186	196
NASA	11	11	11	11	11	11	11	11	11	11
NSF	3	3	3	3	3	3	3	3	3	3
TOTAL	615	643	619	593	575	568	571	574	584	609

TABLE 11

SUMMARY OF PROJECTED DUAL CHANNEL SYSTEMS FOR CALENDAR YEARS 1980-1989
IN 2700-2900 MHz BAND

AGENCY	80	81	82	83	84	85	86	87	88	89
	CALENDAR YEAR									
FAA	76	76	76	76	76	76	76	78	88	101
DoC	0	0	0	0	0	0	2	8	25	50
NAVY	4	10	16	24	32	37	44	44	44	44
AIR FORCE	5	25	28	32	32	32	32	34	37	47
TOTAL NUMBER DUAL CHANNEL SYSTEMS	85	111	120	132	140	145	154	164	194	242

NOTES:

1. The total number of dual channel opeating systems assumes that all ASR-8, AN/GPN-20, AN/GPN-27 and NEXRAD radars will operate dual channel.

TABLE 12

SUMMARY OF PROJECTED NUMBER OF OPERATING CHANNELS FOR CALENDAR YEARS 1980-1989 IN 2700-2900 MHz BAND

	CALENDAR YEAR									
	80	81	82	83	84	85	86	87	88	89
TOTAL NUMBER OF SYSTEMS IN BAND (TABLE 10)	615	643	619	593	575	568	571	574	584	609
TOTAL NUMBER OF DUAL OPERATING SYSTEMS 1 (TABLE 11)	85	111	120	132	140	145	154	164	194	242
TOTAL NUMBER OF OPERATING CHANNELS	700	754	739	765	715	713	725	738	778	851

NOTES:

1. The total number of dual channel operating systems assumes that all ASR-8, AN/GPN-20, AN/GPN-27 and NEXRAD radars will operate dual channel.

TABLE 13

SYSTEM CHARACTERISTICS OF RADARS PRESENTLY OPERATING IN THE 2700-2900 MHz BAND

Aeronautical Radionavigation

Peak Power:	0.4-1.4 MW	
Pulse Width:	0.5-0.83 μs	
PRF:	700-1500 pps	
Antenna Gain:	31-34 dBi	(cosecant squared)
Sensitivity:	-112 to -104 dBm	
Noise Figure:	2.5-4.75 dB	

Meteorological Aids

Peak Power:	0.5-0.56 MW	
Pulse Width:	0.5-1.0 μs	(short pulse)
	4.0 μs	(long pulse)
PRF:	545-658	(short pulse)
	164	(long pulse)
Antenna Gain:	38 dBi	(parabolic dish)
Sensitivity:	-108 to -100 dBm	
Noise Figure:	4.0 dB	

Radiolocation

Peak Power	.250-3.5 MW
Pulse Width:	.8 - 2.0 μs
PRF:	300-1200 pps
Antenna Gain:	30-39 dBi
Sensitivity:	-110 to -106 dBm
Noise Figure:	4.0-8.0 dB

TABLE 14

SYSTEM CHARACTERISTICS OF RADARS PLANNED FOR THE 2700-2900 MHz BAND

Aeronautical Radionavigation

Peak Power:	1.32 MW
Pulse Width:	1.05 μs
PRF:	700-1200 pps
Antenna Gain:	32-34 dBi
Sensitivity:	-108 dBm
Noise Figure:	4.5 dB

Meteorological Aids

Peak Power:	1.0 MW
Pulse Width:	1.0 μs
PRF:	300-1300 pps
Antenna Gain:	45.1 dBi
Sensitivity:	-110 dBm
Noise Figure:	4.0 dB

The range of peak transmitter output power of Aeronautical Radionavigation and Meteorological Aids radars is between 0.4 and 1.4 MW. The majority of the Radiolocation radars have a peak transmitter output power of approximately 3.5 MW. The range of radar transmitter pulse widths of existing and planned radars operating in the 2700-2900 MHz band is 0.5 to 4.0 μs. The replacement of the WSR-57 and WSR-74(s) radars will remove all the 4.0 μs pulse width radars. After the WSR radars are removed, all the radars in the band will have pulse widths between 0.5 and 2.0 μs. The Pulse Repetition Frequency (PRF) of existing radar and radars planned for the band range between 100 and 1500 pulses per second. At the present time there are no known radars operating or planned for the band which employ chirped (FM) or phase coded pulses.

Several different types of antennas are used by radars in the 2700-2900 MHz band. All the Aeronautical Radionavigation radars use a shaped beam reflector which produces a cosecant-squared elevation pattern. The antenna gain of the Aeronautical Radionavigation radars range between 31 and 34 dBi. The Meteorological radars have parabolic dish antennas with pencil beams, and a gain of 32 to 45.1 dBi. The type of Radiolocation radar antennas is varied with antenna gains between 32 and 39 dBi. Some of the later model radars have antennas with several feed horns.

The receivers of radar systems presently operating and planned for the band have sensitivities between -112 and -100 dBm, and noise figures between 2.5 and 8 dB. The receiver system of radars presently operating in the 2700-2900 MHz band use conventional normal, log normal and Moving Target Indicator (MTI) signal processing techniques. New systems, ASR-9 and NEXRAD, planned for the band will use doppler signal processing with inphase and quadrature (I and Q) channels. The FAA ASR-9 radar will also use adaptive thresholding techniques. The receiver signal processing techniques used in these new radars will be more susceptible to interference than the conventional normal and MTI channel signal processing used in radars presently operating in the 2700-2900 MHz band.

In summary, the system characteristics of radars in the band are homogeneous in nature with no complex wave forms (chirped or phase coded pulse) used. For more detailed radar system characteristic information, Appendix D contains a compendium of system characteristics by nomenclature for the major systems presently operating and planned for the 2700-2900 MHz band.

SECTION 5

RADAR DEPLOYMENT PATTERNS

INTRODUCTION

This section contains information on typical separation distances between radars operating in the 2700-2900 MHz band. Typical separation distances are obtained for use in determining the necessary transmitter emission spectrum bounds to enhance the accommodation of new systems planned for the band. Heavily used areas where it is difficult to accommodate additional radars in the 2700-2900 MHz band are identified, and measurements made with the NTIA Radio Spectrum Measurement System (RSMS) van in certain designated heavily used areas are analyzed to assess band occupancy and environmental signal characteristics. Also discussed are environmental factors (propagation anomalies) which contribute to congestion in heavily used areas.

SEPARATION DISTANCES

Separation distances between radars in the 2700-2900 MHz band were obtained using the October 1980 Government Master File (GMF). For each radar in the 2700-2900 MHz band, the number of radars operating within the following separation distances were counted: 0-2 statute miles, 2-5 statute miles, 5-10 statute miles, 10-15 statute miles, and 15-30 statute miles.

TABLE 15 shows a sample of the radar separation distance data obtained for radar equipments deployed in the state of Florida. The Government agency, station class, city, state, of each radar, and number of radars within the specified separation distances are shown in TABLE 15. A complete set of radar distance separation data similar to TABLE 15 for all radars in the 2700-2900 MHz band in the United States is contained in Appendix B. TABLE B-1 in Appendix B lists the radar locations in the 2700-2900 MHz band in order by state, and TABLE B-2 in Appendix B lists for convenience radar locations in order by Government agency and state. TABLE B-3 in Appendix B identifies the agency and station class abbreviations used in TABLE 15.

The radar separation distance information shown in TABLE 15 can be used to identify collocated radar deployments. For example, the Commerce radar at Key West has one radar within two miles, and one radar within 5-10 miles. The associated collocated radar (0-2 mile separation distance) is an FAA radar also located at Key West. The FAA radar located at Patrick AFB has three radars within two miles and two radars within 15-30 miles. The corresponding collocated radars with the FAA radar at Patrick AFB are the three Air Force radars at Patrick AFB.

Statistics on radar separation distances for the data given in Appendix B were calculated. The environmental separation distances for all radars operating in the 2700-2900 MHz band is shown in TABLE 16. TABLE 16 shows that there are 122 radar sites that have one radar within two miles, 26 radar sites that have two radars within two miles, and 24 radar sites that have three radars within two miles. Therefore, there are a total of 172 radar sites in the 2700-2900 MHz band which are collocated with other radars in the band. Thus approximately 32% of the radars in the 2700-2900 MHz band operate under collocated conditions. The statistics for radar separation distances of 2-5,

TABLE 15

EXAMPLE OF RADAR SEPARATION DISTANCE
DATA FOR STATE OF FLORIDA

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AF	LR	TYNDALL	FLA	1	3	0	0	1
AF	RLS	HOMESTED	FLA	0	0	1	0	2
AF	LR	JCKSNVLL	FLA	1	0	0	3	1
AF	LR	FTWLTNBC	FLA	0	0	3	1	0
AF	LR	CSANBLAS	FLA	0	0	0	0	3
AF	LR	EGLIN	FLA	2	0	1	1	0
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	RLS	EGLIN	FLA	2	0	1	1	0
AF	RLS	HURLBURT	FLA	0	0	1	3	0
AF	RLS	MACDILL	FLA	0	1	0	1	1
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	LR	MACDILL	FLA	0	1	1	0	1
AF	RLS	TYNDALL	FLA	2	2	0	0	0
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	MR	CCANAVRL	FLA	1	0	0	0	4
AF	LR	AVON PK	FLA	1	0	0	0	0
AF	RLS	TYNDALL	FLA	1	3	0	0	0
AF	LR	DUETTE	FLA	0	0	0	0	3
AF	LR	CROSS CY	FLA	0	0	0	0	0
C	WXD	DAYTNBCH	FLA	1	0	0	0	0
C	WXD	KEY W	FLA	1	0	1	0	0
C	WXD	PENSACOL	FLA	0	0	0	2	0
C	WXD	APALCHCL	FLA	0	0	0	0	1
C	WXD	TAMPA	FLA	0	0	0	2	2
C	WXD	MIAMI	FLA	0	0	1	1	2
C	WXD	WPALMBCH	FLA	1	0	0	0	0
FAA	RLS	MIAMI	FLA	0	0	1	1	2
FAA	RLS	PENSACOL	FLA	1	0	0	1	2
FAA	RLS	JCKSNVLL	FLA	0	0	1	0	4
FAA	RLS	ORLANDO	FLA	0	0	0	0	0
FAA	RLS	PALMBECH	FLA	1	0	0	0	0
FAA	RLS	FTLADRDL	FLA	0	0	0	0	2
FAA	RLS	TALLAHSS	FLA	0	0	0	0	0
FAA	RLS	DAYTNBCH	FLA	1	0	0	0	0
FAA	RLS	SARASOTA	FLA	0	0	0	0	1
FAA	RLS	PENSACOL	FLA	1	0	0	1	2
FAA	LR	TYNDALL	FLA	1	3	0	0	0
FAA	LR	MIAMI	FLA	0	0	1	2	0
FAA	LR	PATRICK	FLA	3	0	0	0	2
FAA	LR	KEY W	FLA	1	0	1	0	0
N	RL	KEY W	FLA	0	0	2	0	0
N	RL	JCKSNVLL	FLA	1	0	0	2	2
N	RLS	PENSACOL	FLA	0	0	0	0	0
AF	LR	AVON PK	FLA	1	0	0	0	0
N	RL	WHTNGFLD	FLA	0	0	0	0	2
N	RLS	MAYPORT	FLA	0	0	1	2	2
AF	MOB	EGLIN	FLA	2	0	1	1	0
N	RL	JCKSNVLL	FLA	1	0	0	3	1
AF	LR	CCANAVRL	FLA	1	0	0	0	4
AF	MR	TYNDALL	FLA	1	3	0	0	1

TABLE 16

ENVIRONMENTAL SEPARATION DISTANCES FOR RADARS OPERATING IN THE 2700-2900 MHz BAND

SEPARATION DISTANCES (STATUTE MILES)	NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES							
	1	2	3	4	5	6	7	8
0-2	122	26	24	0	0	0	0	0
2-5	26	5	4	1	0	0	0	0
5-10	34	14	4	1	0	0	0	0
10-15	56	18	13	3	2	4	0	1
15-30	114	46	16	16	5	0	0	0

TABLE 17

ENVIRONMENTAL SEPARATION DISTANCES FOR AIR FORCE RADARS OPERATING IN THE 2700-2900 MHz BAND

SEPARATION DISTANCES (STATUTE MILES)	NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES							
	1	2	3	4	5	6	7	8
0-2	65	20	9	0	0	0	0	0
2-5	10	1	3	1	0	0	0	0
5-10	22	5	2	0	0	0	0	0
10-15	29	3	7	3	1	1	0	1
15-30	49	17	6	8	1	0	0	0

TABLE 18

ENVIRONMENTAL SEPARATION DISTANCES FOR COMMERCE RADARS OPERATING IN THE 2700-2900 MHz BAND

SEPARATION DISTANCES (STATUTE MILES)	NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES							
	1	2	3	4	5	6	7	8
0-2	17	2	3	0	0	0	0	0
2-5	4	1	0	0	0	0	0	0
5-10	6	1	0	1	0	0	0	0
10-15	6	4	0	0	1	1	0	0
15-20	13	6	0	1	1	0	0	0

5-10, 10-15, and 15-30 miles are also shown in TABLE 16. For 10-15 miles separation distance, there is one site that has eight radars within 10-15 miles. That radar site is at Tinker AFB, Oklahoma (see TABLE B-1). The four radar sites that have six radars within 10-15 miles are at Oklahoma City, Oklahoma (see TABLE B-1). Two radar sites which have five radars within 10-15 miles are in the Los Angeles area.

Statistics on radar separations distances for radar sites were also calculated for each government agency. TABLES 17-21 show this information. The Air Force has the highest number of collocated radars (0-2 mile separation distance). The Air Force has 65 radar sites with one radar within two miles, 20 radar sites with two radars within two miles and nine radar sites with three radars within two miles. Commerce National Weather Service (NWS) has 22 radar sites which are collocated with other radars within two miles. Eighteen of the NWS collocated radar sites are at airports with FAA radars. NWS radar sites which are collocated with other radars can be identified in TABLE B-2. The FAA has 40 radar sites which operate collocated with other radars in the 2700-2900 MHz band.

In summary, the analysis of separation distances between radars in the 2700-2900 MHz band gave insight to typical deployment patterns in the band. This information was used to determine necessary transmitter emission spectrum bounds to enhance the accommodation of new radar systems planned for the band. (See Section 6 of this report.)

HEAVILY USED AREAS

There are certain areas in the United States where it is difficult to accommodate new radars in the 2700-2900 MHz band. The Working Group obtained information to identify designated heavily used areas to aid the IRAC Frequency Assignment Subcommittee (FAS) in making frequency assignments in the band. Heavily used areas in the United States were identified by the FAA Regional Frequency Managers. The FAA Frequency Engineering Branch (AAF 730) surveyed each of the FAA regional frequency managers to identify areas where the deployment of an additional ASR-8 radar would be difficult. The characteristics of the ASR-8 were identified as being most representative of the new systems (ASR-9 and NEXRAD) planned for the band.

Figure 2 shows the Radar locations in 2700-2900 MHz band for the United States. Areas where there are numerous radar deployments are the East coast megalopolis (Boston, Massachusetts to Washington, D.C.) and West coast areas of San Francisco, Los Angeles, and San Diego, California. Other areas which are heavily used include: Oklahoma City, Oklahoma and St. Louis, Missouri. Also large metropolitan areas near military bases are heavily used such as: Miami, Jacksonville, and Pensacola, Florida; Millington, Tennessee; St. Louis, Missouri; Norfolk, Virginia and Phoenix, Arizona. Figure 8 shows the designated heavily used areas in 2700-2900 MHz band identified by the FAA. Each area has been identified by a letter and four coordinates to facilitate the identification of these areas for the FAS in making new frequency assignments. TABLE 22 shows the coordinates of each designated heavily used area. The number of equipment each Government agency has in each area was obtained from the GMF. TABLE 23 shows this information for each area. The FAA and Air Force have the highest number of equipment in designated heavily used areas with 74 and 57 equipment respectively. Since the FAA radarsare used at airports in large metropolitan areas, it should be expected that the FAA would

TABLE 19

ENVIRONMENTAL SEPARATION DISTANCE FOR FAA RADARS OPERATING IN THE 2700-2900 MHz BAND

SEPARATION DISTANCES (STATUTE MILES)	NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES							
	1	2	3	4	5	6	7	8
0-2	30	2	8	0	0	0	0	0
2-5	7	3	1	0	0	0	0	0
5-10	17	6	2	1	1	0	0	0
10-15	15	6	4	1	0	2	0	0
15-30	37	15	9	6	1	0	0	0

TABLE 20

ENVIRONMENTAL SEPARATION DISTANCE FOR NAVY RADARS OPERATING IN THE 2700-2900 MHz BAND

SEPARATION DISTANCES (STATUTE MILES)	NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES							
	1	2	3	4	5	6	7	8
0-2	9	2	0	0	0	0	0	0
2-5	5	0	0	0	0	0	0	0
5-10	7	3	0	0	0	0	0	0
10-15	5	4	1	0	0	0	0	0
15-30	10	9	3	0	1	0	0	0

TABLE 21

ENVIRONMENTAL SEPARATION DISTANCES FOR ARMY RADARS OPERATING IN THE 2700-2900 MHz BAND

SEPARATION DISTANCES (STATUTE MILES)	NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES							
	1	2	3	4	5	6	7	8
0-2	2	1	4	0	0	0	0	0
2-5	0	0	0	0	0	0	0	0
5-10	1	0	0	0	0	0	0	0
10-15	0	0	0	0	0	0	0	0
15-30	3	0	3	0	1	0	0	0

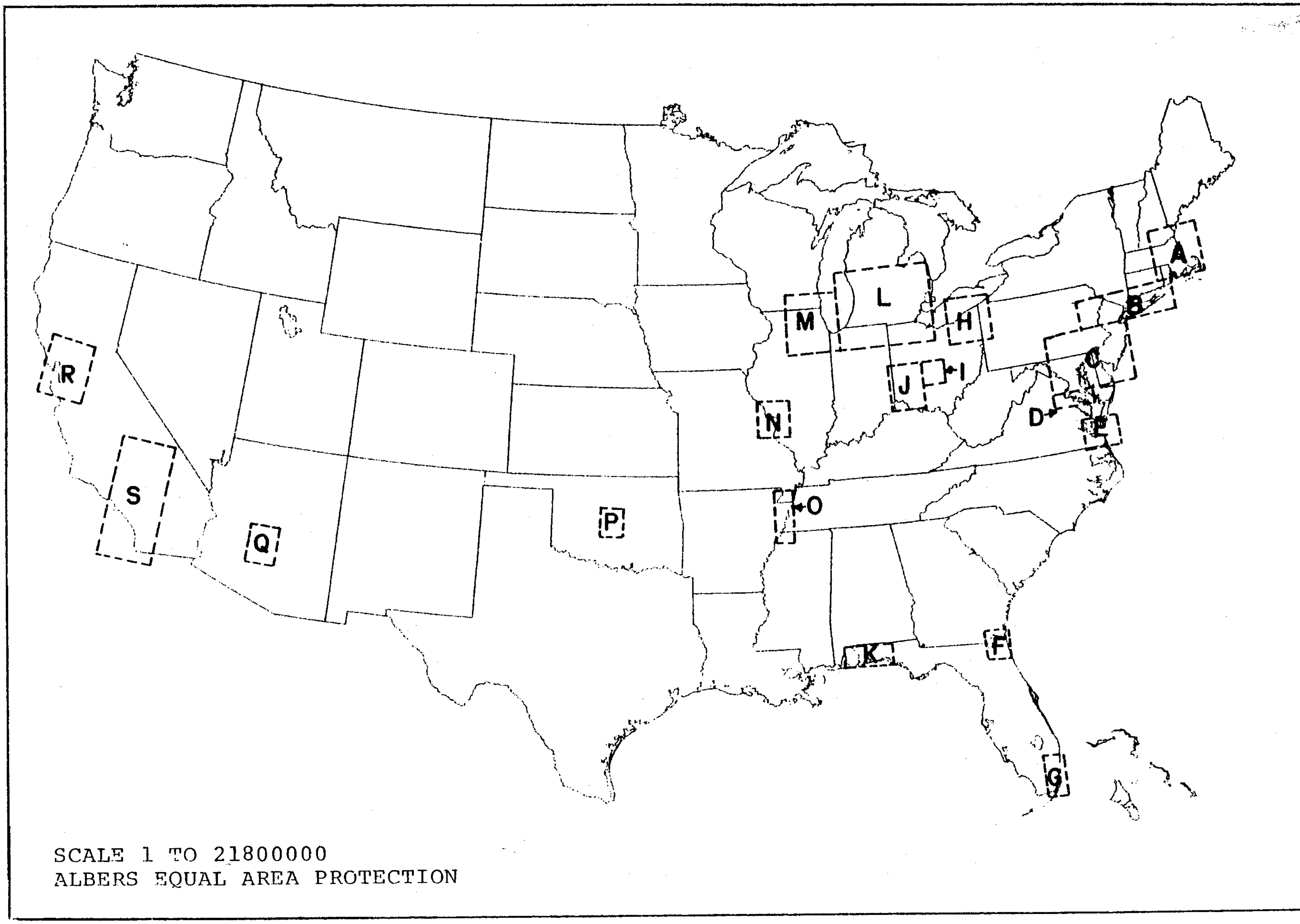


Figure 8. Designated Heavily Used Areas in the 2700-2900 MHz Band

TABLE 22

DESIGNATED HEAVILY USED AREAS

AREA	LATITUDE	LONGITUDE
A	41-30-00	69-45-00
	43-15-00	69-45-00
	43-15-00	72-00-00
	41-30-00	72-00-00
B	40-30-00	71-30-00
	41-30-00	71-30-00
	41-30-00	76-00-00
	40-30-00	76-00-00
C	38-30-00	74-00-00
	40-30-00	74-00-00
	40-30-00	77-45-00
	38-30-00	77-45-00
D	38-00-00	76-00-00
	38-30-00	76-00-00
	38-30-00	77-45-00
	38-00-00	77-45-00
E	36-30-00	75-15-00
	37-30-00	75-15-00
	37-30-00	76-45-00
	36-30-00	76-45-00
F	30-00-00	81-20-00
	31-00-00	81-20-00
	31-00-00	82-20-00
	30-00-00	82-20-00
G	25-00-00	80-00-00
	26-30-00	80-00-00
	26-30-00	80-45-00
	25-00-00	80-45-00
H	40-45-00	80-00-00
	42-20-00	80-00-00
	42-20-00	82-00-00
	40-45-00	82-00-00
I	39-30-00	82-30-00
	40-20-00	82-30-00
	40-20-00	83-30-00
	39-30-00	83-30-00

TABLE 22 CONTINUED

AREA	LATITUDE	LONGITUDE
J	38-45-00	83-30-00
	40-20-00	83-30-00
	40-20-00	85-00-00
	38-45-00	85-00-00
K	30-15-00	86-00-00
	31-00-00	86-00-00
	31-00-00	88-00-00
	30-15-00	88-00-00
L	41-00-00	82-40-00
	43-40-00	82-40-00
	43-40-00	87-00-00
	41-00-00	87-00-00
M	41-00-00	87-00-00
	43-00-00	87-00-00
	43-00-00	89-30-00
	41-00-00	89-00-00
N	38-15-00	89-40-00
	39-30-00	89-40-00
	39-30-00	91-00-00
	38-15-00	91-00-00
O	34-40-00	89-40-00
	36-30-00	89-40-00
	36-30-00	90-30-00
	34-40-00	90-30-00
P	35-00-00	97-00-00
	36-00-00	97-00-00
	36-00-00	98-00-00
	35-00-00	98-00-00
Q	33-00-00	111-30-00
	34-20-00	111-30-00
	34-20-00	112-40-00
	33-00-00	112-40-00
R	37-00-00	121-00-00
	39-00-00	121-00-00
	39-00-00	123-00-00
	37-00-00	123-00-00
S	32-15-00	116-30-00
	36-20-00	116-30-00
	36-20-00	118-45-00
	32-15-00	118-45-00

TABLE 23

NUMBER OF EQUIPMENT EACH AGENCY HAS IN DESIGNATED HEAVILY USED AREAS

AREA	AIR FORCE	ARMY	COMMERCE	FAA	NASA	NAVY	NSF
A	6	0	3	4	0	1	0
B	1	0	1	6	0	0	0
C	6	0	0	12	0	2	0
D	0	0	1	0	0	4	0
E	1	0	0	1	0	3	0
F	1	0	0	1	0	4	0
G	1	0	1	3	0	0	0
H	0	0	1	4	0	0	0
I	1	0	1	1	0	0	0
J	1	0	1	2	0	0	0
K	6	0	1	2	0	1	0
L	2	0	1	9	0	0	0
M	0	0	1	4	0	1	0
N	4	0	1	1	0	0	0
O	1	0	1	1	0	3	0
P	4	0	4	2	0	0	0
Q	4	0	0	2	0	0	0
R	7	0	1	4	0	3	0
S	11	1	0	15	1	11	0
TOTAL FOR EACH AGENCY	57	1	19	74	1	33	0
PERCENTAGE OF AGENCY EQUIPMENT IN HEAVILY USED AREAS	25	6	30	35	9	45	0

have the largest number of equipment in these areas. However, looking at the percentage of agency equipment each agency has in designated heavily used areas, the Navy has the highest percentage with 45. The FAA, Commerce and Air Force respectively have 35, 30, and 25 percent of their equipment in the designated heavily used areas.

The heavily used areas identified in Figure 8 and TABLE 22 are areas in the United States where it may be difficult to accommodate additional radars. This information was intended for utilization by the FAS to identify cases where detailed Electromagnetic Compatibility (EMC) studies may be required to determine if any new radar system can be accommodated.

Spectrum Usage Measurements in Heavily Used Areas

As part of the NTIA Frequency Assignment and Utilization program, measurements of selected Federal frequency bands have been performed to supply basic information on usage of the spectrum to Federal frequency managers. Measurements were performed using the Radio Spectrum Measurement System (RSMS) which is operated by NTIA. Because of concern over congestion in the 2700-2900 MHz band, spectrum occupancy measurements have been made in several designated heavily used areas since 1973. TABLE 24 lists the measurement location, date, and corresponding letter designators for each area (see Figure 8) where measurements have been made. Measurement and analysis capabilities of the RSMS van are given in a paper by Matheson (1977). The following is a discussion of measurements made with the RSMS van in San Diego and Los Angeles (Area S), and San Francisco (Area R). All measurements were made with a slant polarized omni antenna which has a gain of 0 dBi, and an IF bandwidth of 1.0 MHz which is approximately equal to the IF bandwidth to be used in the ASR-9 and NEXRAD radars.

In May 1981, spectrum occupancy measurements were made in San Diego at Pt. Loma (32 40 29N, 117 14 37W). The site elevation at Pt. Loma is 419 feet. Figure 9 shows the measured spectrum occupancy at Pt. Loma. Radars operating in the 2700-2900 MHz band were identified using a pulse train separator, and radar PRF's listed in the GMF. Identified radars are also listed in Figure 9.

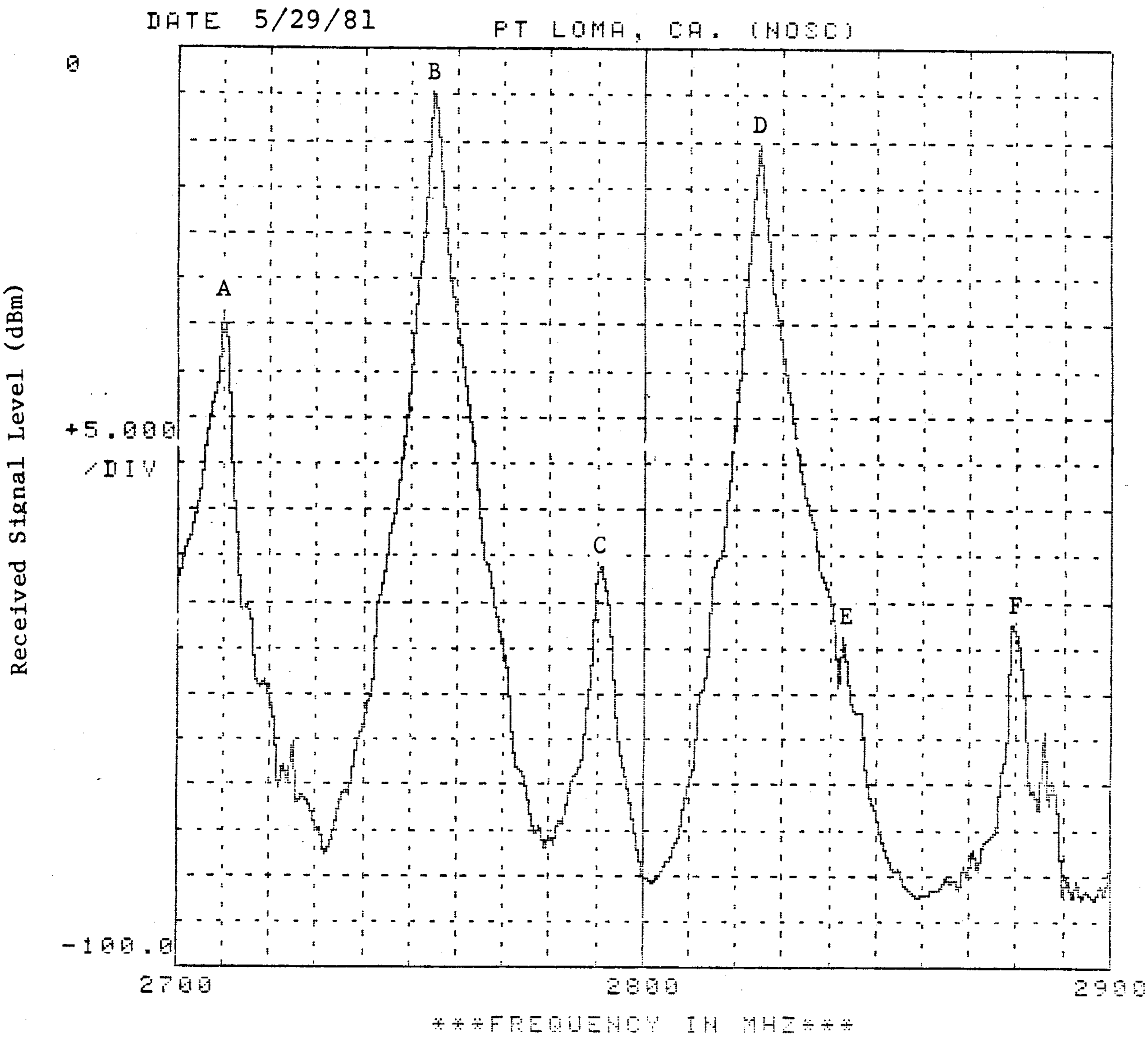
During July 1981, the FAA contracted with the NTIA Institute for Telecommunication Sciences to use the RSMS van to make spectrum occupancy and pulse count measurements in the 2700-3100 MHz band in Los Angeles (Area S). The purpose of these measurements was to obtain information for the NEXRAD Project Office on the electromagnetic environment in a heavily used area. The measurements were made to identify the environmental signal characteristics which the NEXRAD reciver may be subjected to in performing its operational mission. This information could then be taken into consideration in the design and development of signal processing circuitry or software to suppress asynchronous pulsed interference. Section 6 of this report contains additional information on environmental signal characteristics that have a bearing on radar receiver performance.

The FAA measurements were made at San Pedro Hill ($33^{\circ}44^{\circ}48$N, $118^{\circ}20^{\circ}09$W) which has a site elevation of 1480 feet, and in the Puente Hills north of Whittier ($34^{\circ}00^{\circ}04$N, 118° 00° 06W). The Whittier site elevation is 1260 feet. Figure 10 shows a sample of the spectrum occupancy measurements made at the Whittier site. The radars identified during the measurements are listed in the figure. Figure 10 shows the heavy use of the 2700-2900 MHz band in the Los Angeles basin area.

TABLE 24

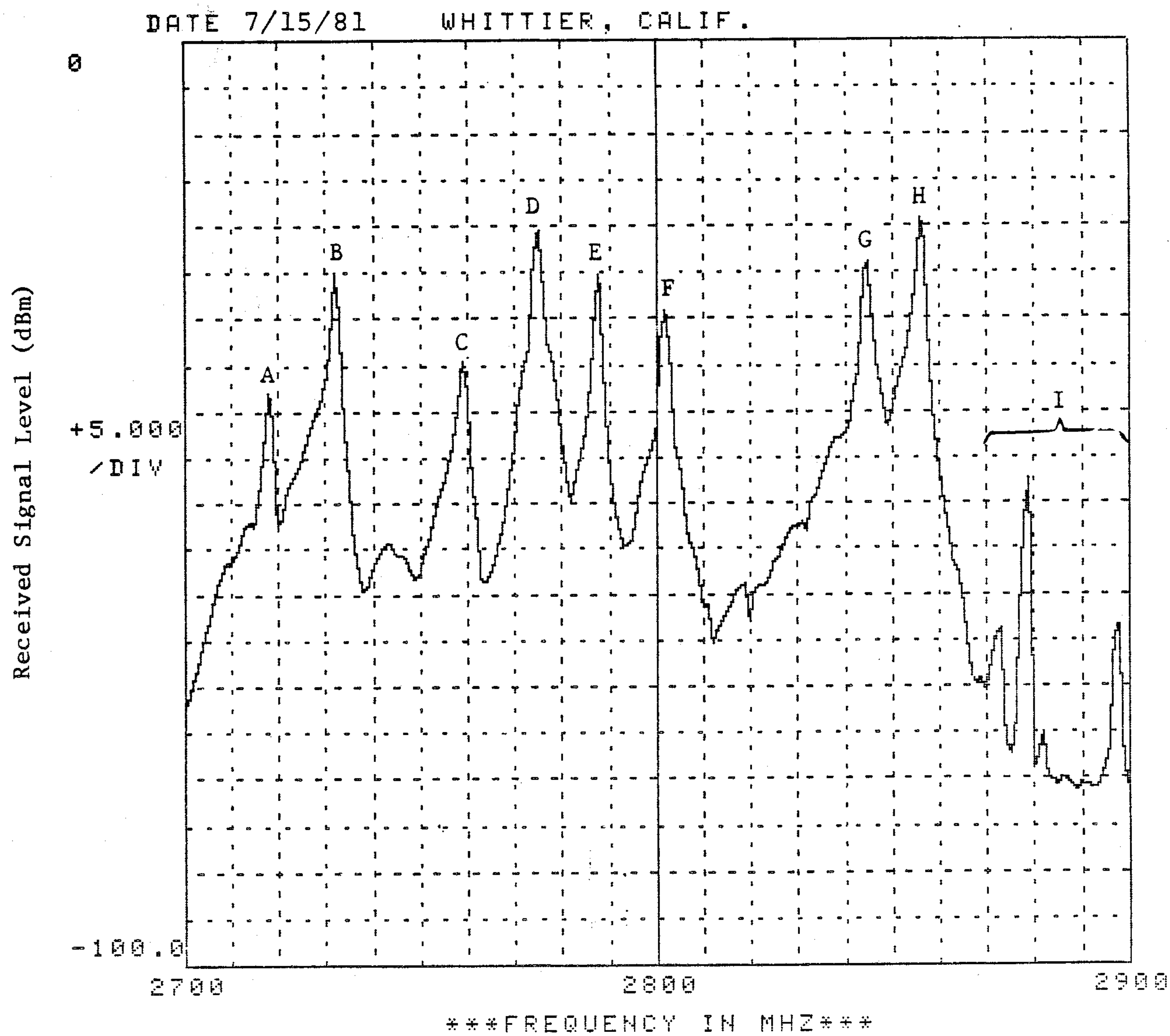
RSMS MEASUREMENTS IN THE
2700-2900 MHz BAND

LOCATION	DATE	HEAVILY USED AREA
Washington, D.C.	March-May 1974	C
Norfolk, VA	May-June 1974	E
Los Angeles, Calif.	December 1974-May 1975	S
San Francisco, Calif.	June-August 1975	R
Norfolk, VA.	March-April 1978	E
Washington, D.C.	July-August 1978	C
Boston, Mass.	May-July 1979	A
New York, N.Y.	October 1979	B
Los Angeles, Calif.	September-October 1980	S
San Diego, Calif.	April-May 1981	S
San Francisco, Calif.	August 1981	R



A. Miramar, ASR-5
B. North Island, ASR-8 (Channel B)
C. Imperial Beach, AN/CPN-4
D. North Island, ASR-8 (Channel A)
E. Mt. Laguna, AN/FPS-90
F. San Pedro, AN/FPS-90

Figure 9. 2700-2900 MHz Band Spectrum Occupancy in San Diego Area.



A. Miramar, ASR-5
B. El Toro, ASR-5
C. Los Angeles, ASR-4
D. Long Beach, ASR-8 (Channel B)
E. Burbank, ASR-6
F. Los Alamitos, AN/CPN-4
G. Long Beach, ASR-8 (Channel A)
H. Los Angeles, ASR-7
I. San Pedro, AN/FPS-90

Figure 10. 2700-2900 MHz Band Spectrum Occupancy in Los Angeles Area.

Pulse count measurements made from the Whittier site are shown in Figure 11-13. The Figures show the number of pulses counted in a five second period as a function of frequency. A five second period (dwell) was used since most of the radars in the 2700-2900 MHz band have an antenna rotation of 12 RPM or greater. Figures 11-13 are for pulse count thresholds of -90, -70 and -50 dBm respectively. The figures show statistics taken over several days. The maximum, average and minimum pulse count levels are shown. For the low threshold level of -90 dBm, the pulse count reached over 10,000 for a five second period. This is equivalent to 2000 pulses per second. The high pulse count for the low threshold is caused by multipathing of signals off mountains and buildings in the Los Angeles area and the use of the omni directional antenna on the RSMS van. Figure 11 shows that the average pulse count across the 2700-2900 MHz band varies between 150 and 10,000 pulses in a five second period which is equivalent to 30 to 2000 pulses per second. The minimum pulse density for the Whittier site occurs between the frequencies of 2810 to 2835 MHz. Figure 13, high threshold level of -50 dBm, only shows pulse counts which occur near the fundamental operating frequencies of radars in the Los Angeles basin. The measurements made by the FAA in the Los Angeles area in the 2700-2900 MHz band are documented in a report by Matheson, Smilley and Lawrence [1981].

The San Francisco (Area R) measurements were made at Mt. Diablo (36° 53° 30N, 121° 55° 00W) which has a site elevation of 3849 feet. Mt. Diablo is line-of-sight with the San Francisco Bay area and the Sacramento area. Figure 14 shows the spectrum occupancy measurements made from Mt. Diablo. The pulse count measurements made from Mt. Diablo are shown in Figure 15-17. During the pulse count measurements made at Mt. Diablo the Sacramento WSR-57 was not operational because of clear weather. Therefore, the pulse count is lower than normally expected in the 2880-2900 MHz band.

In summary, the spectrum occupancy and pulse count measurements made in designated congested areas R and S show that the 2700-2900 MHz band is heavily used. Although the measurements shown in Figures 9-17 are made from hill tops, the usage of the 2700-2900 MHz band in these areas indicates that even the location of a new radar in the valley or basin would require a detailed siting analysis to assure electromagnetic compatibility.

INFLUENCES OF ENVIRONMENTAL FACTORS ON SPECTRUM UTILIZATION

In addition to the number of equipments in the designated heavily used areas, there are environmental factors which contribute to the congestion of 2700-2900 MHz band. Environmental factors which contribute to congestion in the band are propagation anomalies such as ducting and multipathing. The following is a discussion of these propagation anomalies, and how they affect the utilization of the band.

Ducting

It has been determined (Dougherty and Dutton, 1981) that under the influences of climatological and synoptic weather processes such as subsidence, advection, or surface heating and radiative cooling, there is a tendency for the lower atmosphere to stratify. This stratification can take the form of refractivity layering (i.e., layers in which contrasting refractivity gradient

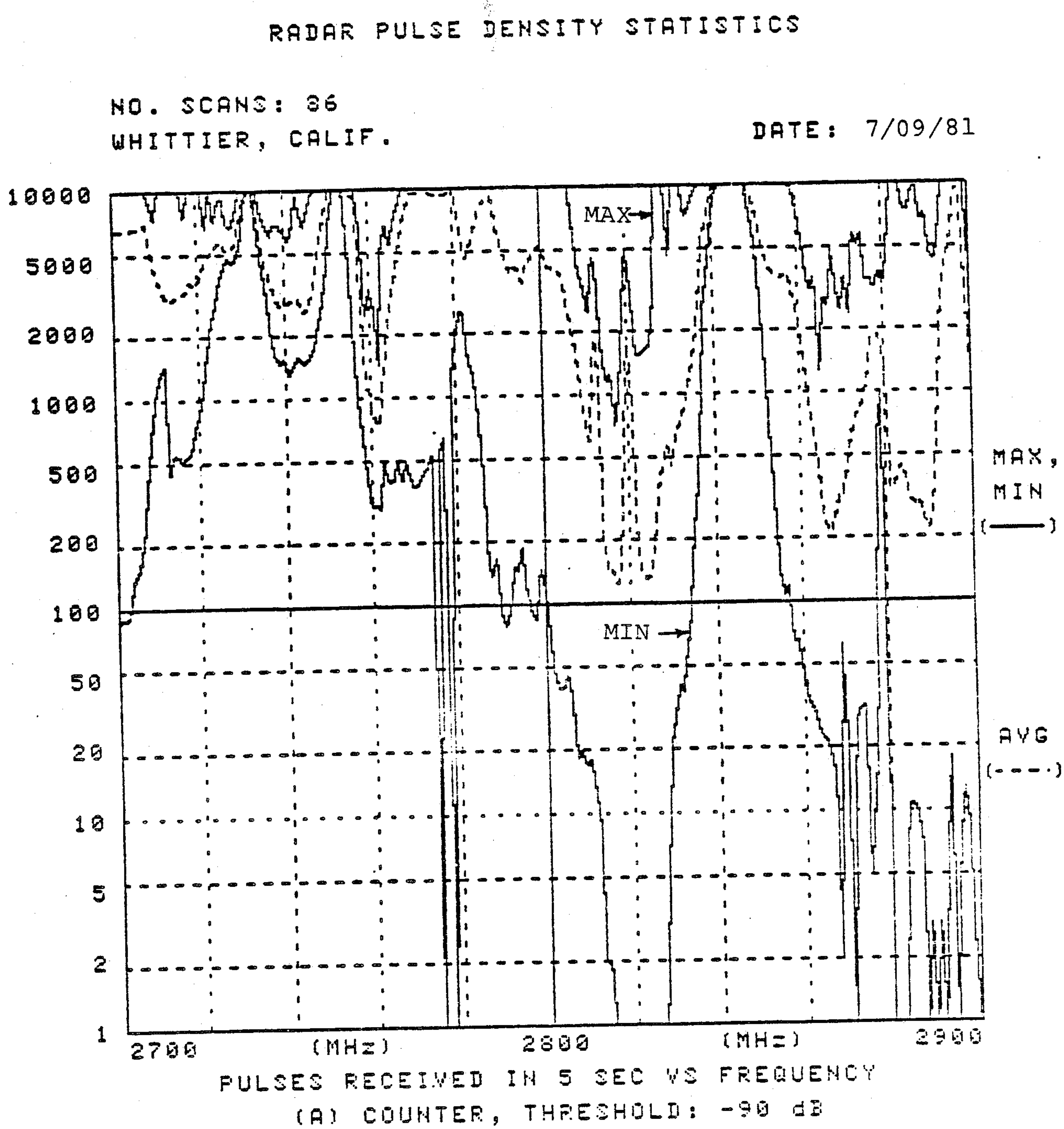


Figure 11. 2700-2900 MHz accumulated low threshold counter (A) pulse count scan.

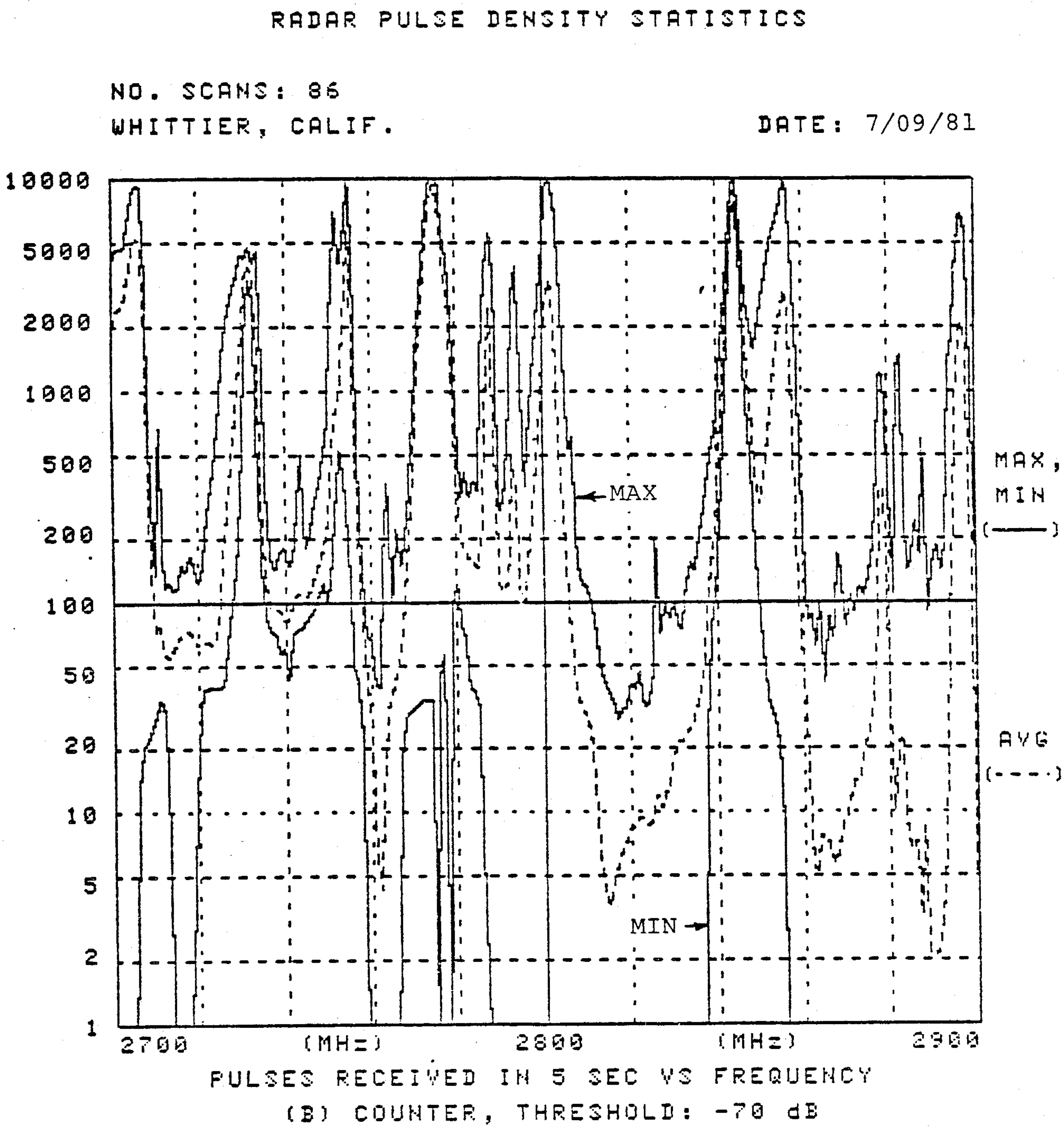


Figure 12. 2700–2900 MHz accumulated middle threshold counter (B) pulse count scan.

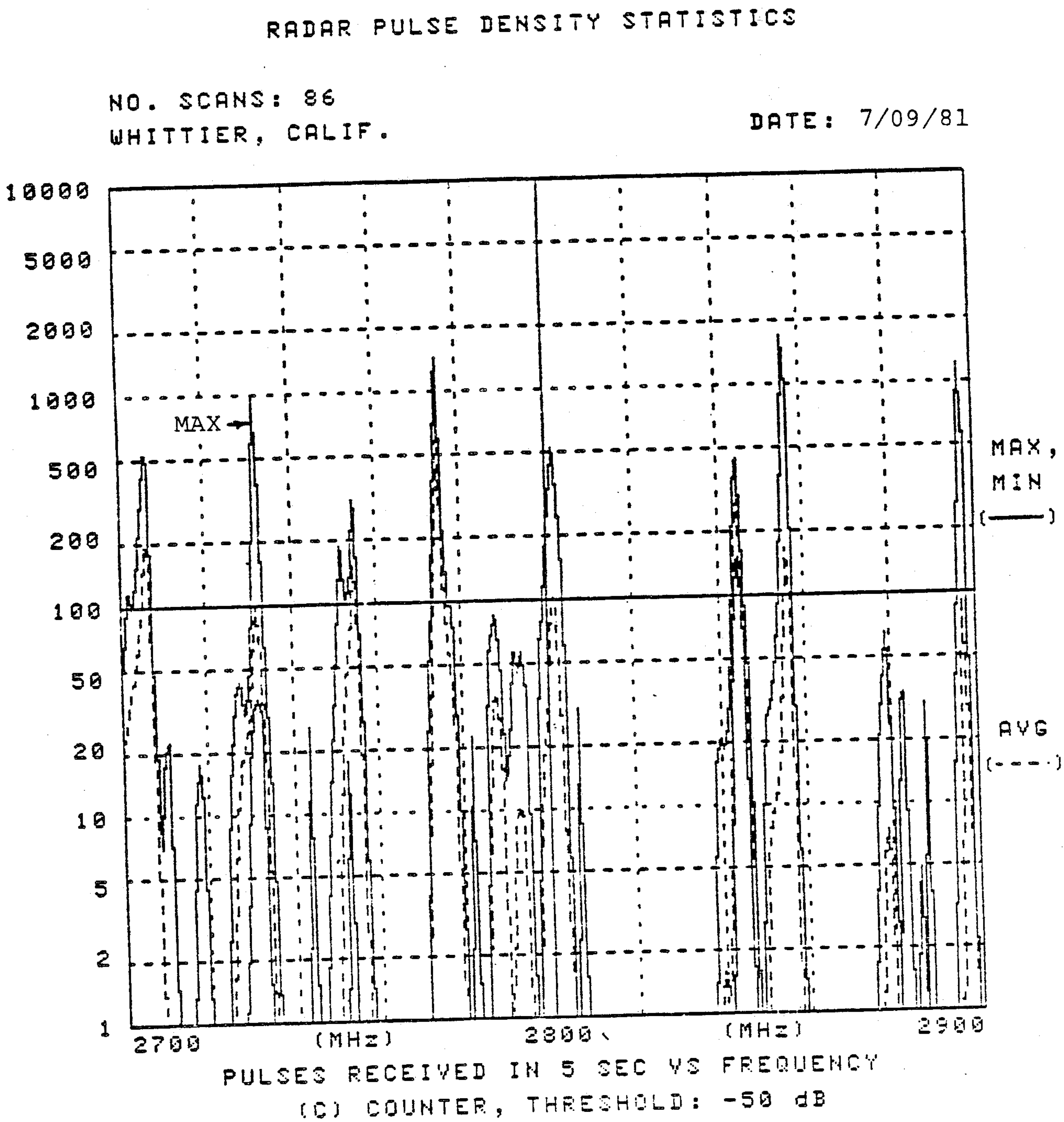
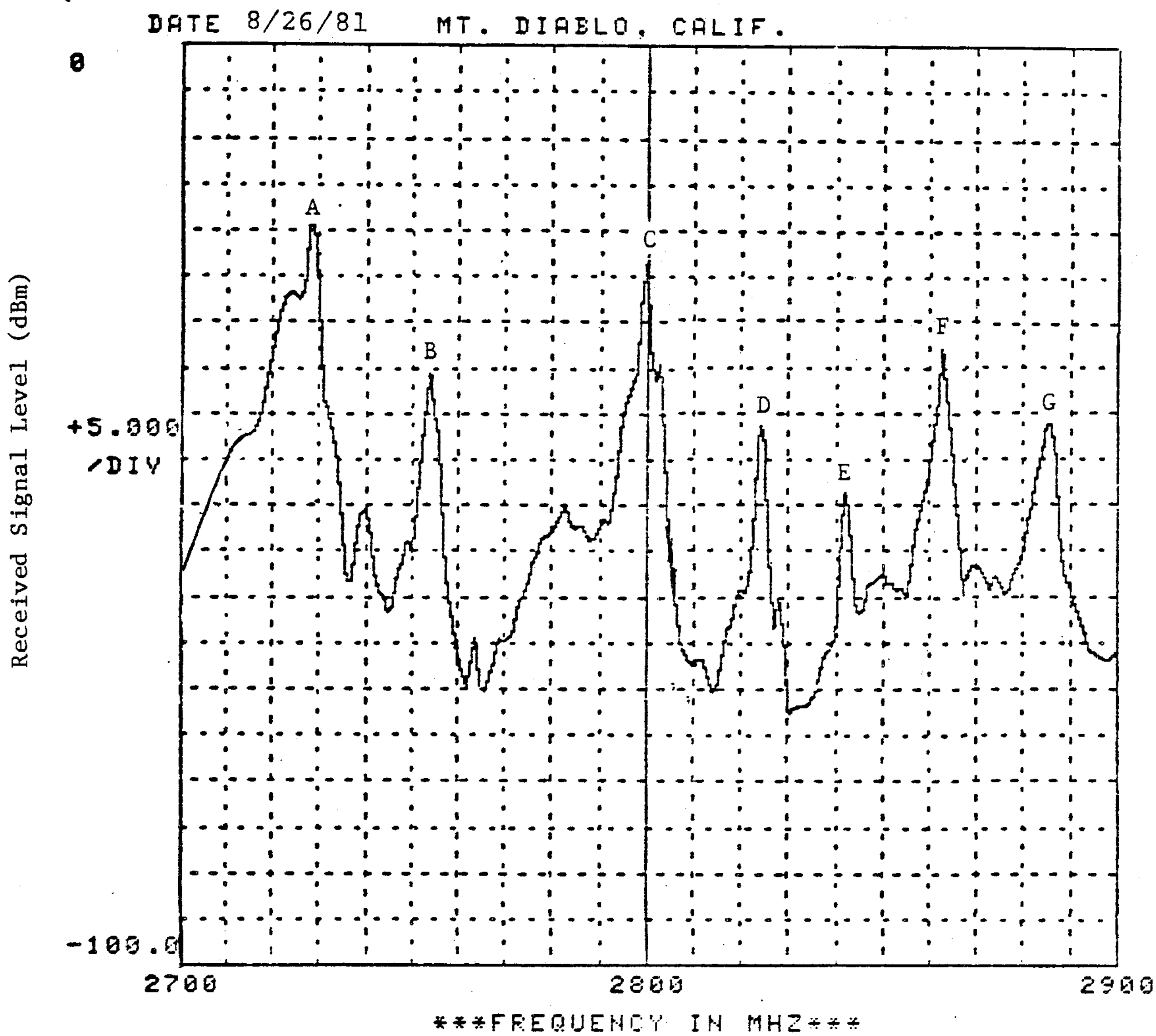


Figure 13. 2700-2900 MHz accumulated high threshold counter (C) pulse count scan.



A. Oakland, ASR-7
B. Mountain View, ASR-5
C. Travis AFB, AN/FPN-55
D. Mt. Tamalpais, AN/FPS-90
E. Maryville, ASR-5
F. Sacramento, ASR-4
G. Sacramento, WSR-57

Figure 14. 2700-2900 MHz Band Spectrum Occupancy in San Francisco Area.

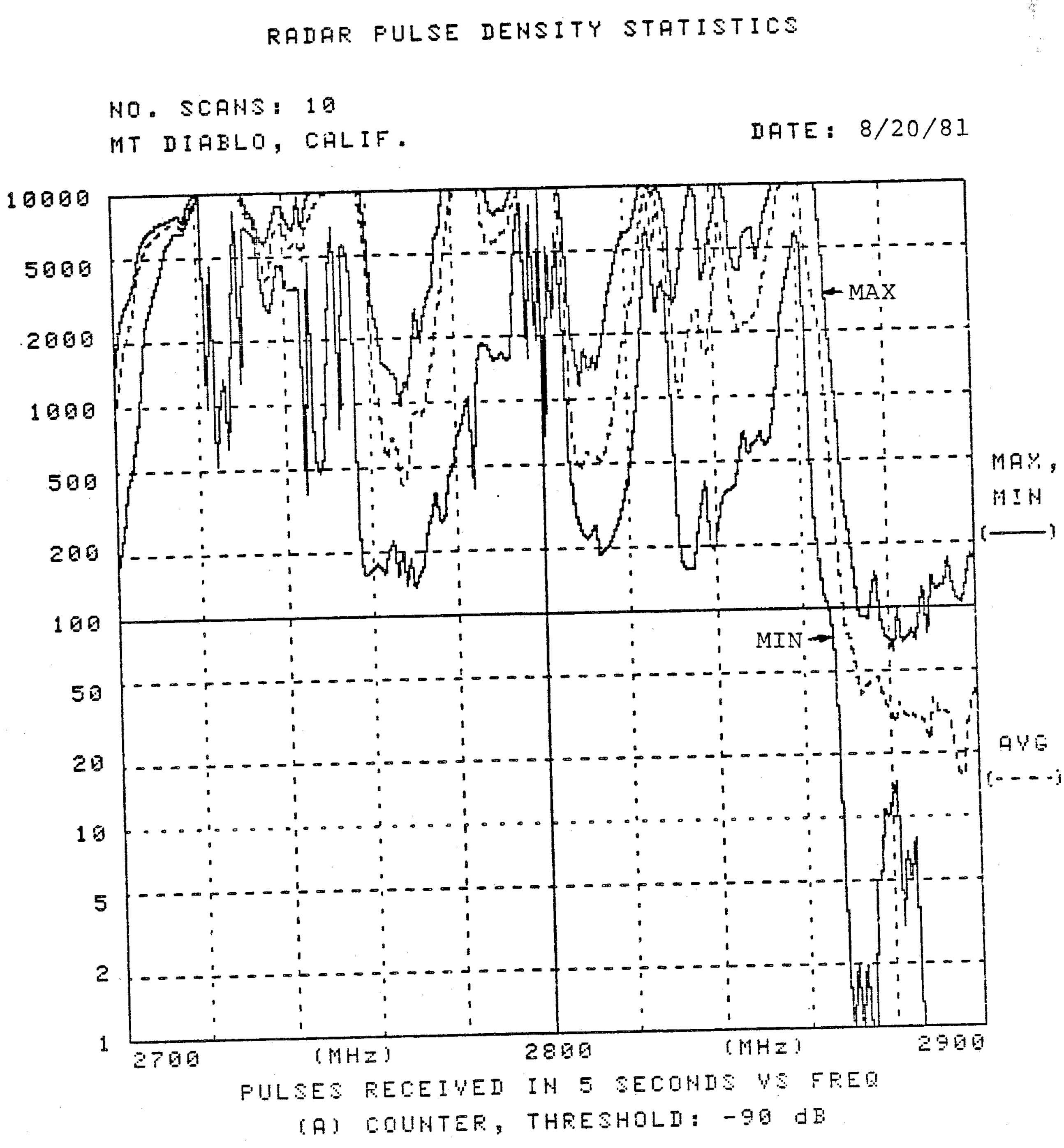


Figure 15. 2700-2900 MHz accumulated low threshold counter (A) pulse count scan.

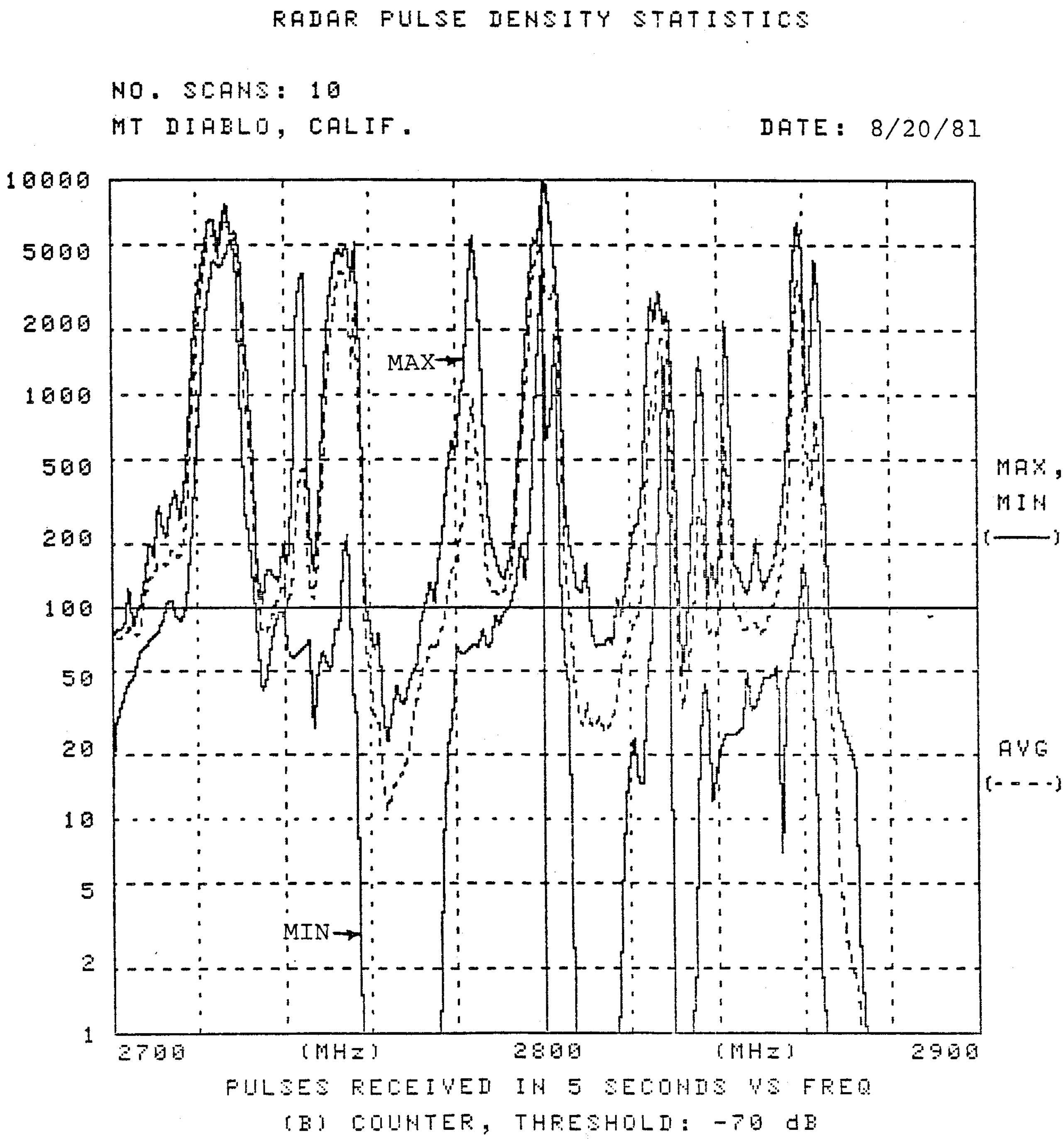


Figure 16. 2700-2900 MHz accumulated middle threshold counter (B) pulse count scan.

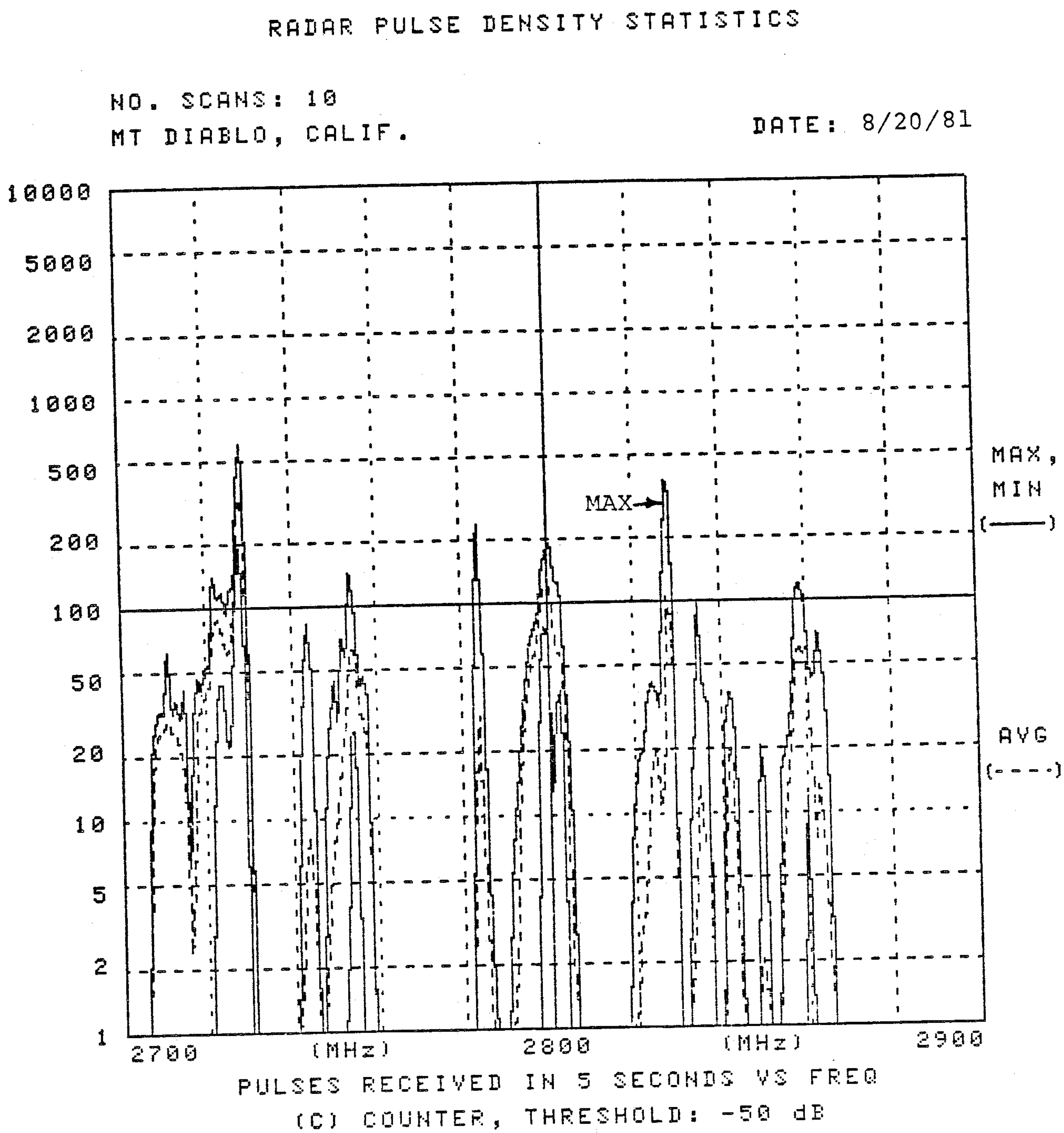


Figure 17. 2700-2900 MHz accumulated high threshold counter (C) pulse count scan.

occur) which create ducts which can refract microwave energy downward causing a ducting effect. The ducting of microwave energy can complicate the problem of electromagnetic compatibility between radar systems by enhancing potential interfering signal levels. Propagation of electromagnetic waves in ducts can vary from a near lossless situation relative to free space, to signal enhancement, (relative to free space) depending on the frequency and intensity of the duct. The intensity of the duct is most often described in terms of "duct height" which is defined as the height at which the modified refractivity is minimized.

Many researchers have investigated the ducting phenomenon in the Southern California area. Bean (1959) noted that during the summer months at San Diego and Oakland that an elevated duct is observed about 50 percent of the time. Rosenthal (1972, 1973) and Crain (1953) states that much of the coastal area of California is usually in a moist marine layer capped by a dry inversion layer. The inversion layer produces ducting conditions throughout the year and is most frequent in the summer months. Meterological parameters were measured by the Naval Electronics Laboratory Center (NELC) over a five year period, for all seasons and times of the day, in the off-shore San Diego area. These studies indicated that radar range enhancement occurs 30% of the time. Bean and Cahoon (1959) report rapid horizontal changes in refractive index associated with land-sea breezes, storms and frontal passages. Other researchers have noted large diurnal variations due to land-sea breeze circulation. In the Los Angeles area, Neiburger (1944) noted that the inversion layer undergoes significant diurnal changes in elevation. Edlinger (1959) also reported rapid changes in the marine layer with time of day.

Chang (1971) concludes that when both antennas are above or within the duct, the received field can be 10 to 20 dB above free space. When one or both terminals are below the duct, the field can be 10 to 25 dB below free space, even at distances up to 1200 km. Oversea paths are more likely to be affected by superrefraction and elevated layers than land paths, and thus may have greater variation in path loss. This may also apply to low, flat coastal regions in maritime zones such as the Los Angeles and San Diego Basins. Figure 18 shows the variation in transmission loss with effective distance for an oversea path in a maritime temperate climate (CCIR Report 238-3).

During measurements made in the Los Angeles and San Francisco areas in 1975 in the 2700-2900 MHz band [Hinkle, Pratt, Matheson, 1976], it was observed that in ducting conditions the measured propagation path loss was intermittently 40 dB less than the predicted median propagation loss, and sometimes approached 10 dB less than free space loss. These findings were in agreement with previous investigations and CCIR Report 238-3.

Major parameters of interest on ducting to the frequency management community are percent occurrence of elevated ducts and minimum trapping frequency. Statistical information on these ducting parameters has been interpreted from radiosonde data taken over a five year period and have been analyzed by Ortenburg et.al. (1979), and Dougherty and Dutton (1981). The recent report by Dougherty and Dutton contain statistical information on the percent occurrence of elevated ducts and minimum trapping frequency for the United States. Figure 19 shows the occurrence of elevated ducts in percent of all hours of the year, and Figure 20 shows the occurrence of elevated ducts in percent of all hours of the worst month. Except for the California coast, the higher values of percent occurrence of elevated ducts is more common in the

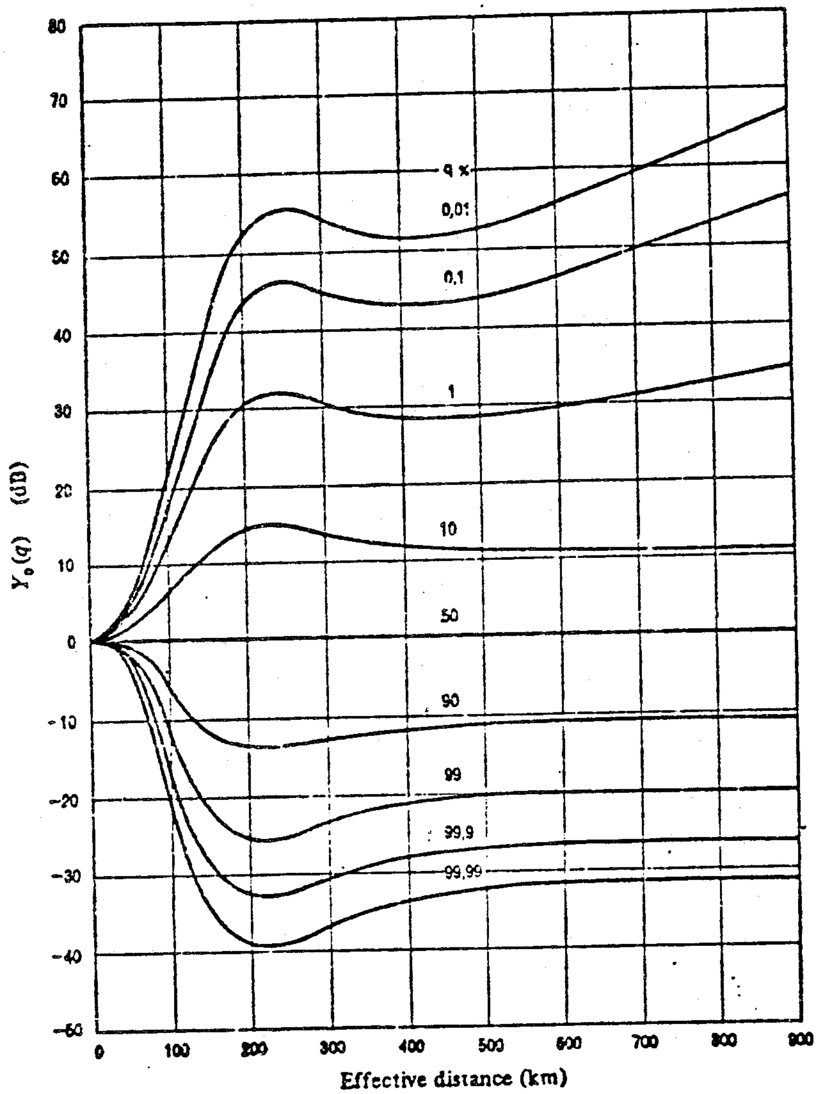


Figure 18. Variation of Propagation Loss With Effective Distance for an Oversea Path in a Maritime Temperate Climate (Ref. CCIR Report 238-3)

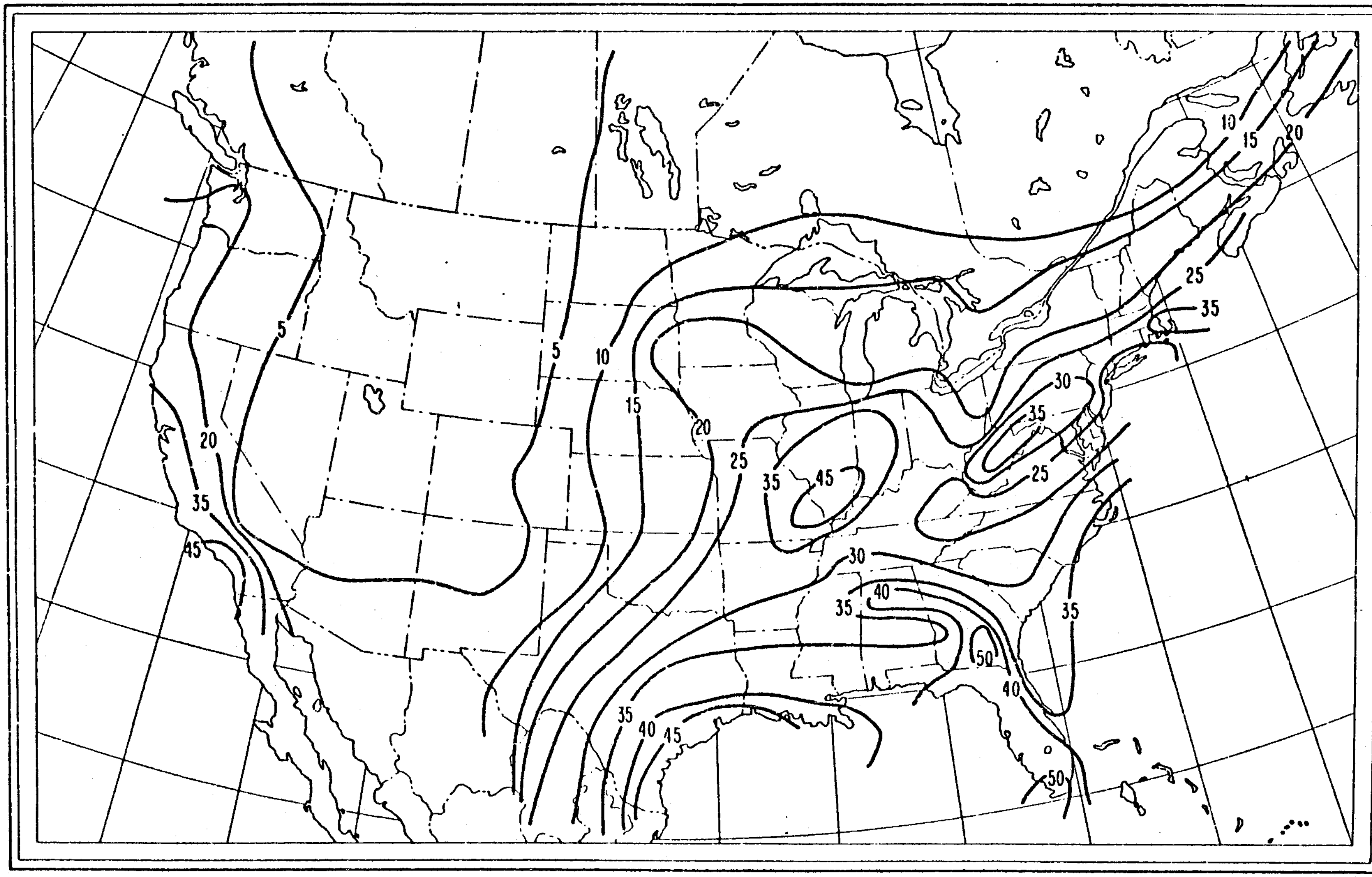


Figure 19. The occurrence of elevated ducts in percent of all hours of the year.

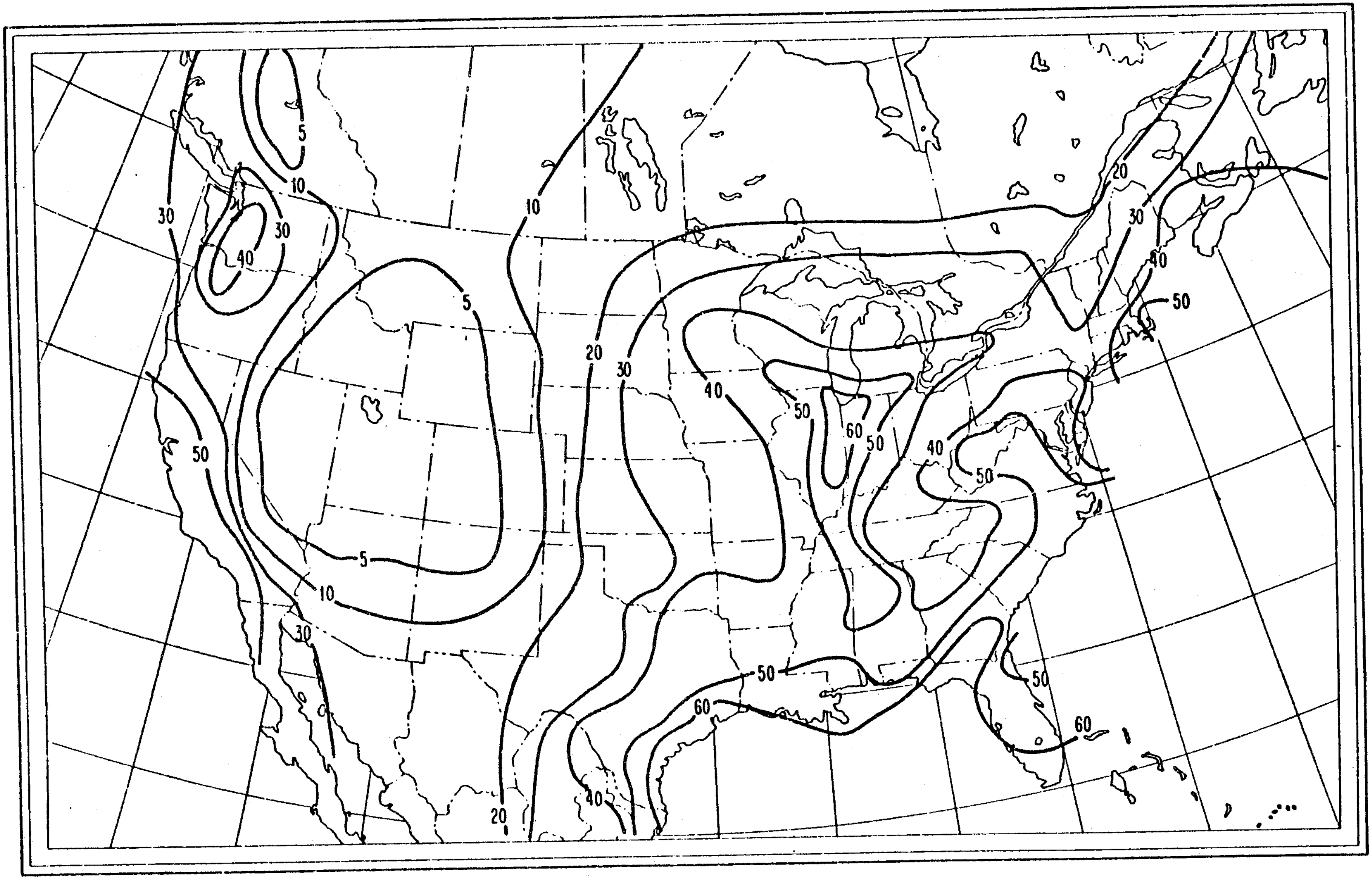


Figure 20. The occurrence of elevated ducts in percent of all hours of the worst month. For no month of the year would the expected occurrence of elevated ducts exceed the indicated values.

Eastern half of the United States. For most of the Nation, the worst month occurs in the summer, midsummer in West, late summer in the East. Along the Gulf Coast, the worst month occurs in the Spring. There are exceptions to these broad generalities. The worst month occurs in the Fall in the great basin (centered on Nevada and the desert portions of California, Arizona, and Utah) and in northwest Florida and the southern portions of Georgia, Alabama, and South Carolina.

Early work in duct propagation defined a minimum trapping (cut-off) frequency of propagation by an analogy to waveguide transmission (Kerr, 1951). However, experimental studies have demonstrated that the "cut-off" effect occurs over a range of frequencies rather than abruptly at a specific frequency. The upper bound for the minimum trapping frequency for the United States is shown in Figure 21. That is only for less than 10% of the elevated ducts would efficient trapping be limited to frequencies exceeding the indicated values in Figure 21. Figure 21 shows that the upper bound on the minimum trapping frequency is below 2900 MHz except in the Sierra Cascade, Great Basin and Rocky Mountain regions, and in the northern part of the United States. Therefore, the percent of occurrence of elevated ducts shown in Figures 19 and 20 should be representative of the occurrence of ducts in the 2700-2900 MHz band except in the areas in the United States where the upper bound for the minimum trapping frequency is greater than 2900 MHz (approximated by the 3000 MHz contour).

Information on the occurrence of surface ducts in percent and minimum trapping frequency is available (Ortenburger, 1978). However, this information is not available on contour maps of the United States.

Several of the designated heavily used areas (see Figure 8) are in areas in the United States where the occurrence of elevated ducts is greater than 30% for all hours of the year (see Figure 19). Therefore, ducting is likely to complicate and contribute to electromagnetic compatibility problems in many of the designated heavily used areas. The FAA takes into consideration ducting in coordinating frequency assignments in many of the FAA regions.

Multipathing

Propagation paths other than the great circle path between two radars occur often in the environment. These multipath propagation paths can be caused by terrain (hills and mountains), buildings and ducting. Propagation paths due to off-path reflections and diffraction through mountainous or hilly terrain may result in significant fluctuations from the loss measured on the great circle path.

Such multipath reflections were observed during measurements made in the Los Angeles area with the RSMS van. A detailed discussion on terrain multipath and procedures for taking it into account are given by Hinkle, Pratt, and Matheson (1976). In general, it was found that the off-path propagation loss was greater than the direct path loss. Only on one path (Ontario to Los Alamitos) was the measured multipath propagation loss less than the predicted propagation loss. For that path, the measured propagation path loss was 6 dB less than predicted. However, the 6 dB difference was within the variability of the propagation model.

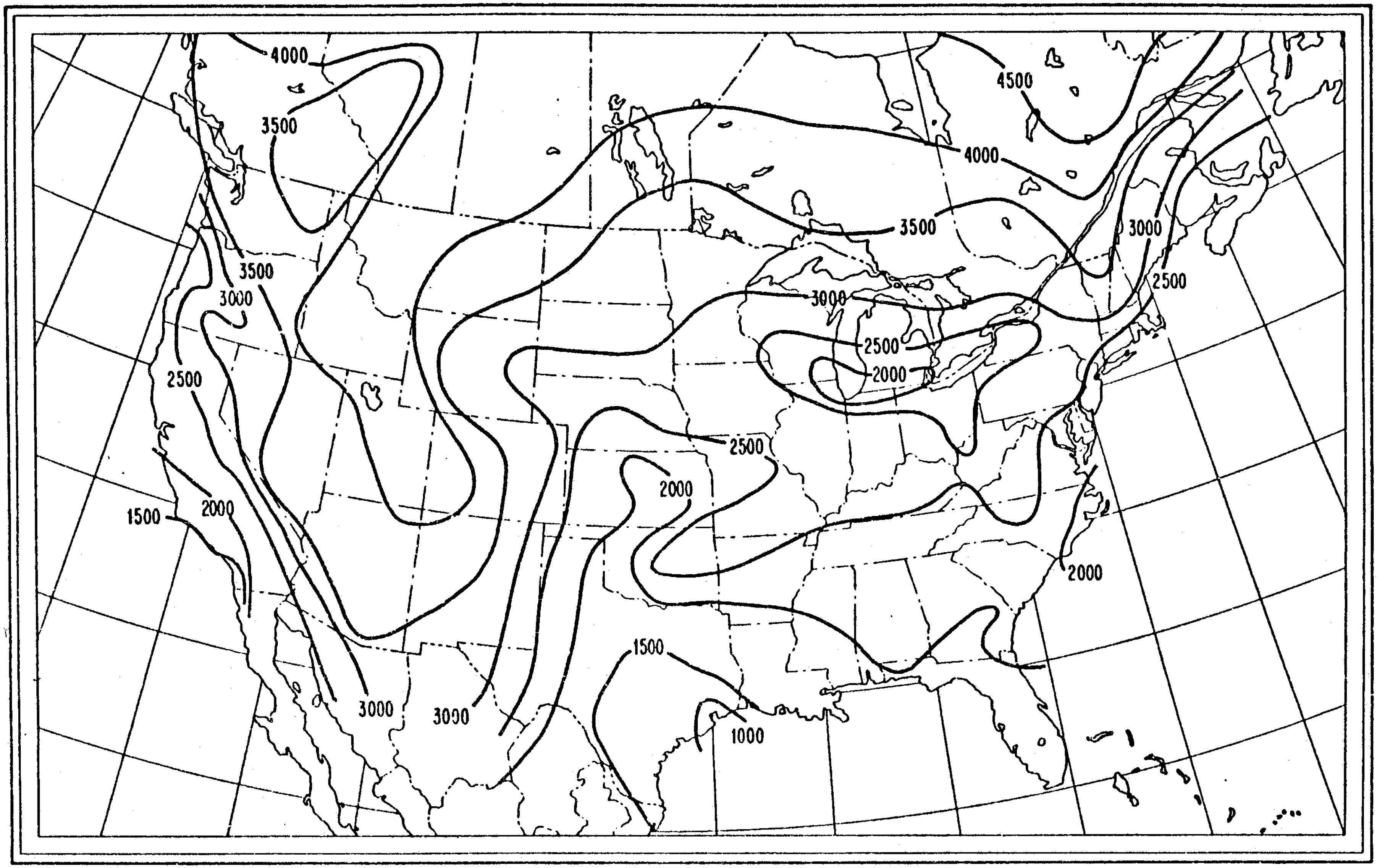


Figure 21. An upper bound for the minimum trapping frequency, $f_t(10\%)$ in megahertz. Only for less than 10% of elevated ducts would efficient trapping be limited to frequencies exceeding the indicated values.

The major effect of multipathing is to cause stretching of the interfering radar pulse width, and additional interfering pulses when the difference in distance between the direct and reflected path exceeds the distance that a signal can travel in one pulse width. Thus multipath propagation may add to the severity of interference from pulsed radars.

SECTION 6

RADAR SPECTRUM ENGINEERING CRITERIA

INTRODUCTION

This section contains recommended changes to the Radar Spectrum Engineering Criteria (RSEC) for radars which operate in the 2700-2900 MHz band. The appropriateness of the current RSEC is reviewed in light of present and future usage trends and radar deployment patterns in the 2700-2900 MHz band. Transmitter output emission spectrum characteristics are examined for several types of transmitter output tube devices and waveguide filters. Transmitter and receiver performance guidelines are identified which will improve the accommodation of new radar systems in the band. The identified performance guidelines are incorporated into proposed changes to the present RSEC.

REQUIRED TRANSMITTER EMISSION SPECTRUM BOUNDS

An investigation was made to determine if the emission spectrum bounds in the current RSEC are appropriate in light of present and future usage trends and radar deployment patterns in the 2700-2900 MHz band. Frequency-distance separation requirements were developed for the current RSEC and other more stringent emission spectrum bound levels based on characteristics of future planned systems. The frequency-distance separation requirements were then analyzed to determine whether or not the current RSEC is adequate to ensure an acceptable degree of electromagnetic compatibility among radars presently in the band and planned for the band.

Radar Spectrum Engineering Criteria

All radar systems presently operating in the 2700-2900 MHz band are subject to Criteria C of the current RSEC. (See Part 5.3.2 of the Manual of Regulations and Procedures for Federal Radio Frequency Management, NTIA 1980). Since new radar systems planned for the band procured after October, 1986 will have to meet the Column B Criteria of the current RSEC, the Column B Criteria were used in this investigation. The characteristics of the future planned systems used to determine the current RSEC emission spectrum bounds and more stringent emission spectrum bounds are shown in TABLE 14 in Section 4. The system characteristics given in TABLE 14 are representative of the ASR-9 and NEXRAD radars planned for the band.

Both the ASR-9 and NEXRAD radars are non-FM pulsed radars. Therefore the RSEC -40 dB bandwidth, B (-40 dB), is given by:

$$B(-40\ dB) = \frac{6.2}{\sqrt{t_r t}} \quad \text{or} \quad \frac{64}{t} \qquad (1)$$

whichever is less

where: B = Emission bandwidth, in MHz.
t = Emitted pulse duration in μs at 50% amplitude

t_r = Emitted pulse risetime in μs from the 10% to 90% amplitude points on the leveling edge.

For nominal pulse width (t) of 1.0 μs and risetime (t_r) of 0.1 μs (measured ASR-8 risetime), the -40 dB bandwidth is 19.6 MHz. From the -40 dB bandwidth, the emission spectrum fall off is given by:

$$\text{Suppression (dB)} = -20 \log \left| \frac{F - F_o}{\tfrac{1}{2}B(-40dB)} \right| -40 \qquad (2)$$

where: $\tfrac{1}{2}B(-40dB) \leq |F - F_o| \leq \tfrac{1}{2}B(-XdB)$

and: F_o = operating frequency in MHz. For non-FM pulse radars the peak of the power spectrum; for FM pulse radars the average of the lowest and highest carrier frequencies during the pulse.

The emission spectrum floor level (XdB) is given by:

$$X \text{ (dB)} = 60 \text{ dB, or}$$
$$X \text{ (dB)} = P_t + 30 \qquad (3)$$

whichever is the larger value.

The parameter P_t may be calculated from the following:

$$P_t = P_p + 20 \log (Nt) + 10 \log (PRR) - PG - 90 \qquad (4)$$

where: P_t = Maximum spectral level in dBm/kHz.
P_p = Peak power (dBm)
N = Total number of chips (subpulses) contained in the pulse. (N = 1 for non-FM and FM pulse radars).
t = Emitted pulse duration in u sec. at 50% amplitude (voltage) points.
PRR = Pulse repetition rate in pulses per second.
PG = Processing gain (dB) = 0 for non-FM (non-encoded) pulse radars, 10 log (d), for FM pulse radars; 10 log (N), for coded pulse radars.
and: d = Pulse compression ratio = emitted pulse duration compressed pulsed duration (at 50% amplitude points).

Using the nominal characteristics of future planned systems for the 2700-2900 MHz band (P_p = 90, t = 1.0, PRR = 1200, PG = 0), the value for P_t is 30.76. Therefore, the emission spectrum floor level (XdB) is 60.76 dB. Figure 22 shows plot of the current RSEC calculated for nominal characteristics of future planned systems. Also shown in Figure 22 are more stringent emission spectrum bounds for 40, 60 and 80 dB per decade fall-off from the -40 dB RSEC bandwidth. The more stringent emission spectrum bound curves are labeled RSEC -40, RSEC -60, and RSEC -80 for the 40, 60, and 80 dB per decade fall-offs respectively. The more stringent emission spectrum bound curves are used in developing frequency-distance separation curves for determining appropriate emission spectrum bounds for 2700-2900 MHz band radars.

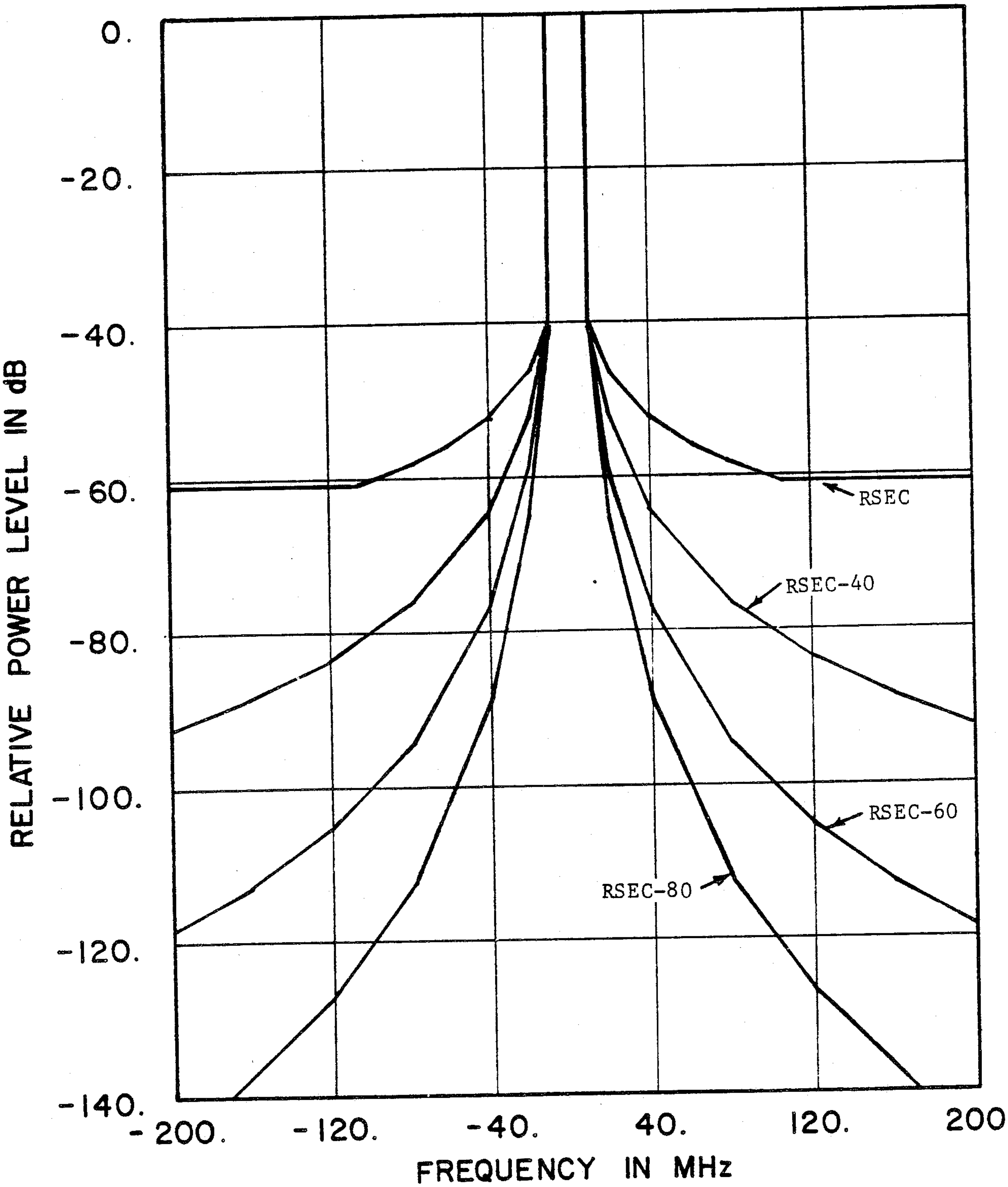


Figure 22. Emission Spectrum Bounds for RSEC and more Stringent Fall-Off Rates of 40, 60 and 80 dB per Decade from the RSEC 40 dB Bandwidth

Frequency-Distance Separation Requirements

Frequency-distance separation curves were calculated for the four emission spectrum bound curves shown in Figure 22. The frequency-distance curves were then examined to determine if the current RSEC is appropriate in light of present and future usage trends and radar deployment patterns in the 2700-2900 MHz band. The frequency-distance curves show graphically the relationship between the distance separation (d), and off-tuning or frequency separation (ΔF) necessary to limit the interference level at the receiver IF output to some specified value. The frequency-distance curves do not take into account signal processing circuitry, such as pulse integrators or sliding window detectors. Post processing may suppress asynchronous pulsed interference and permit closer frequency-distance separations than those given here. Appendix A contains information on receiver interference suppression circuitry. The frequency-distance separation relationships were obtained using the OFRCAL program (CCIR Report 654) which implements the following algorithm:

$$L(d) + FDR\ (\Delta F) = P_t + G_t + G_r - I_1 - INR - N \qquad (5)$$

where: L(d) = Median propagation path loss between receiving and interfering

FDR(ΔF) = Frequency-dependent-reflection, in dB

P_t = The peak transmitter power of the potential interfering radar, in dBm

G_t = The nominal mainbeam gain of the potential interfering radar minus correction for antenna tilt angle, in dBi

G_r = Receiving antenna median backlobe level, -13 dBi

I_1 = Waveguide and coupler insertion losses of both receiving and interfering radars. A 2 dB insertion loss was used at both ends (Offi and Herget, 1968).

INR = Maximum allowable peak Interference-to-Noise Ratio at the receiver input to preclude performance degradation, INR=0

N = Receiver), inherent noise level referred to the RF input, (N = -114 + 10 log B(MHz) + NF), in dBm.

B = Receiving radar 3 dB IF bandwidth, in MHz, 1.1 MHz

NF = Receiving radar noise figure, 4 dB.

The principle of the frequency-distance computer model is that the parameters on the right hand side of Equation 5 are considered as constants and the parameters on the left hand side as variables. That is, the propagation loss, L(d), is a function of distance separation and frequency-dependent-rejection, FDR(ΔF) is a function of frequency separation between receiving and interfering radars. The left hand side of Equation 5 is essentially the required loss to obtain a specified INR at the receiver IF output.

The input parameters to the OFRCAL model include: transmitter emission spectrum, receiver IF selectivity, propagation model parameters, and required loss (Equation 5). The transmitter emission spectrum characteristics used were the RSEC and more stringent emission spectrum bounds of 40, 60 and 80 dB per decade fall-off from the -40 dB RSEC bandwidth (see Figure 22). The receiver selectivity characteristics used were similar to the specifications for the FAA ASR-9 radar. Since both the ASR-9 and NEXRAD radar may have approximately a 1.0 μs pulse width, the IF selectivity of both future planned systems should be similar. Figure 23 shows the receiver IF selectivity curve used in the OFRCAL model. The propagation model used in the OFRCAL program is the Integrated Propagation System (IPS) model (Baker, 1980). Figure 24 shows the propagation loss versus distance curve used in the OFRCAL model. The propagation parameters used in the IPS model are also shown in Figure 24.

Frequency-distance curves for two coupling conditions: 1) NEXRAD mainbeam coupled to ASR-9 backlobe, and 2) ASR-9 mainbeam coupled to NEXRAD backlobe are shown in Figures 25 and 26, respectively. Also shown in each figure are the parameter values for Equation 5, and statistics on separation distance occurrences discussed in Section 5 of this report. Since the frequency-distance curve shown in Figure 25 is for NEXRAD mainbeam coupling, the separation distance statistics are for Commerce NWS radars in the 2700-2900 MHz band and are taken from TABLE 18 in Section 5. The separation distance statistics shown in Figure 26 are for all radars operating in the 2700-2900 MHz band, and are taken from TABLE 16 in Section 5.

For the coupling conditions shown in Figures 25 and 26, the minimum radar separation distance for the present RSEC is 19.3 and 12.9 statute miles respectively. From the radar separation distance data given in Section 5 and Appendix B, approximately 55 percent of the radars in the 2700-2900 MHz band have at least one radar within 15 statute miles, and 25 percent of the radars in the band have at least one radar within two statute miles (collocated condition). It should be stated that this does not imply that 55 percent of the radars in the band presently have interference on the PPI display. It is shown later (see Figures 27 and 28) that even the sideband emission level of conventional magnetrons are 10-15 dB below the RSEC floor level.

Considering the frequency-distance separation curves and radar separation distance statistics shown in Figures 25 and 26, it was the consensus of the TSC Working Group 1 that the present RSEC is adequate in some situations, but is not adequate for approximately 55 percent of the assignments. These difficulties occur in heavily used areas and under collocated conditions. It should be noted that this does not imply that 55 percent of the radars in the band are presently receiving interference. This finding is based on the RSEC emissions spectrum bounds, and an INR=0 criterion (No Interference). As a result of this finding, it was the opinion of the Working Group that a few changes to the present RSEC would enhance the accommodation of new radar systems in the 2700-2900 MHz band.

Figures 25 and 26 were used to identify more appropriate emission spectrum bounds to be incorporated in the RSEC for radars in the 2700-2900 MHz band. It was the consensus of the Working Group that all new fixed radars in the band should have an emission spectrum level which, from the present RSEC 40 dB bandwidth, falls-off at 40 dB per decade to a fixed noise floor level of 80 dB. Also the new radars planned for the band should be designed and constructed to permit, without modification to the basic equipment, field incorporation of the

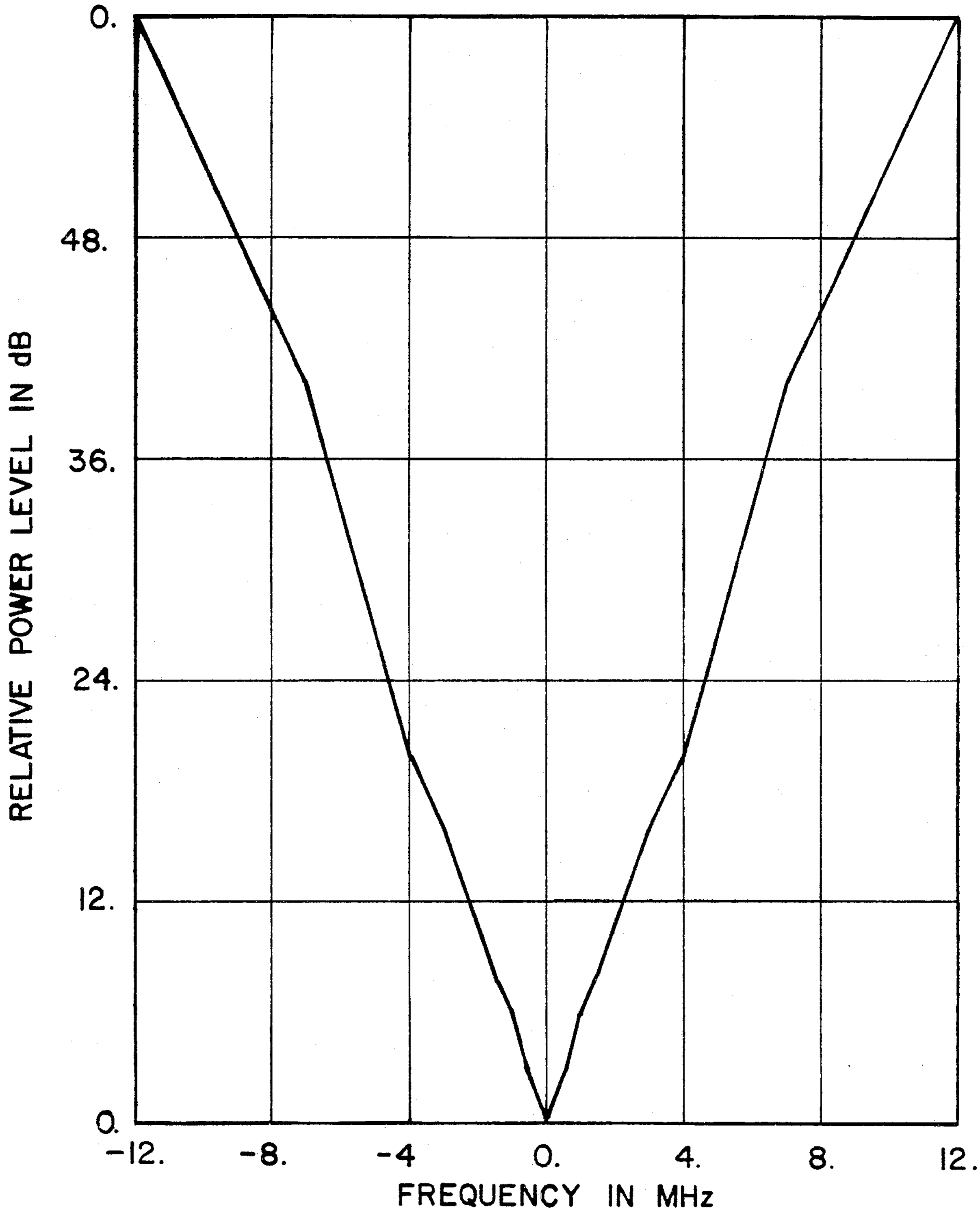


Figure 23. Modeled IF Selectivity

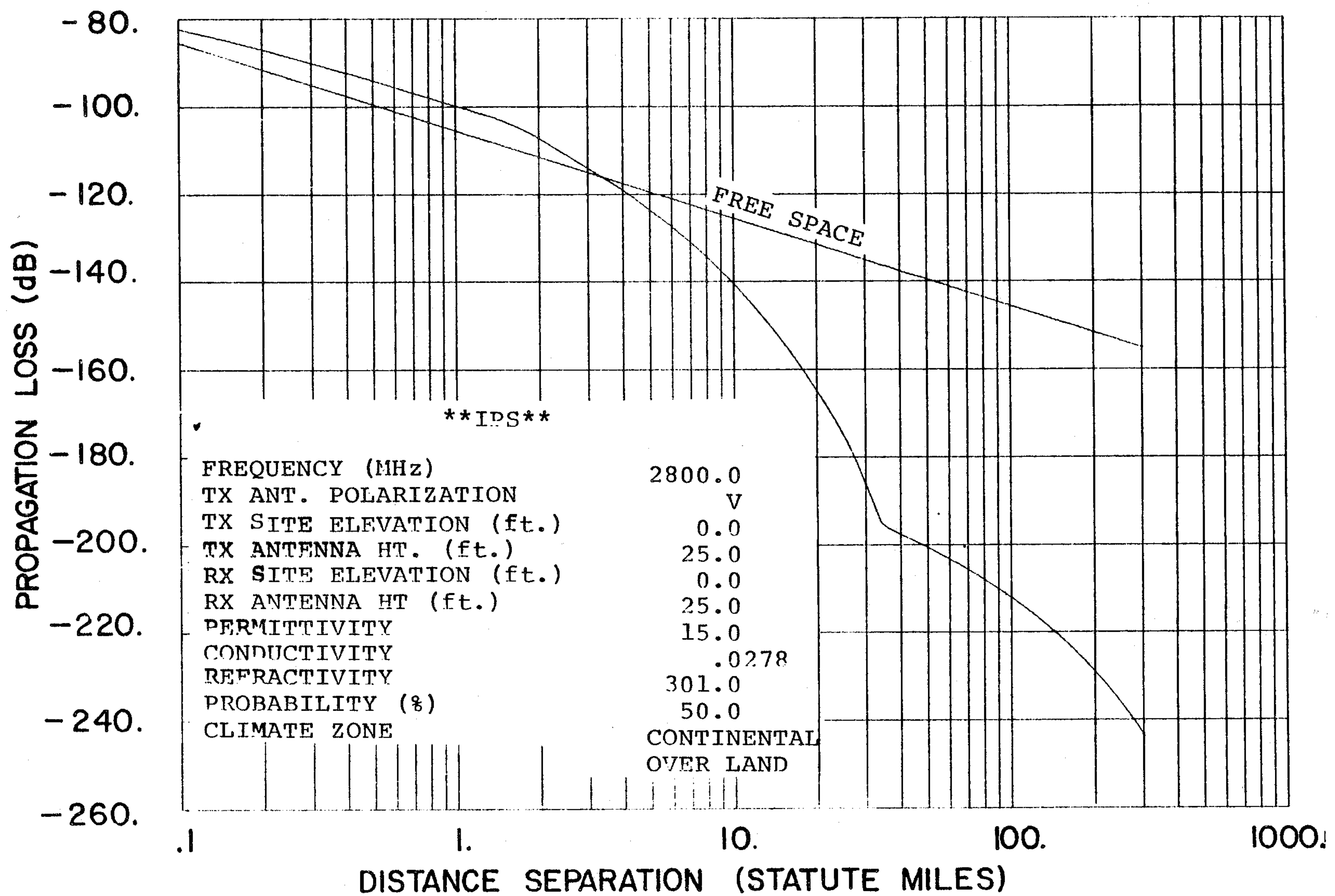
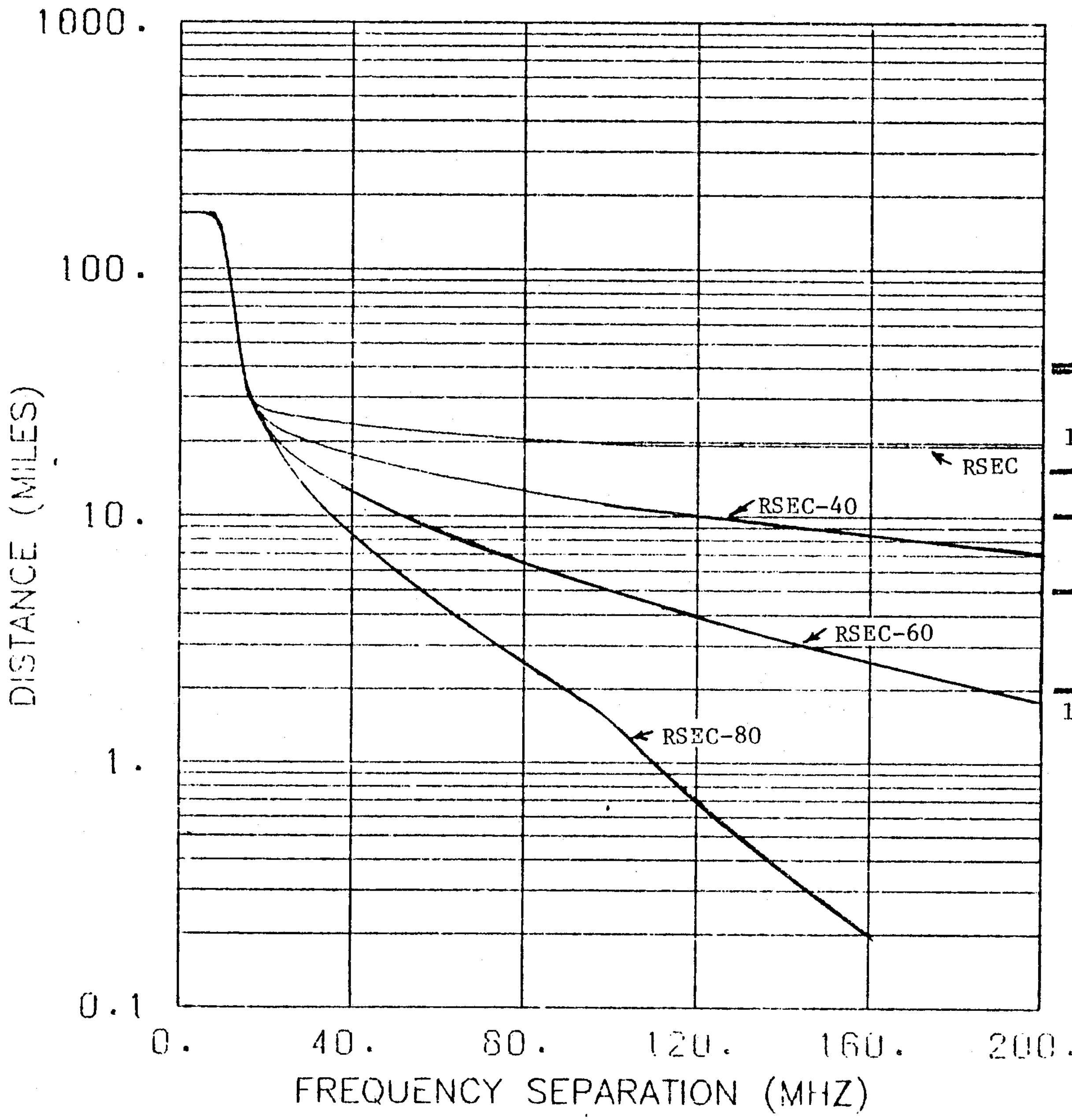


Figure 24. Propagation Loss Versus Distance Separation



NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES

1	2	3	4	5	6	7	8
13	6	0	1	1	0	0	0
6	4	0	0	1	1	0	0
6	1	0	1	0	0	0	0
4	1	0	0	0	0	0	0
17	2	3	0	0	0	0	0

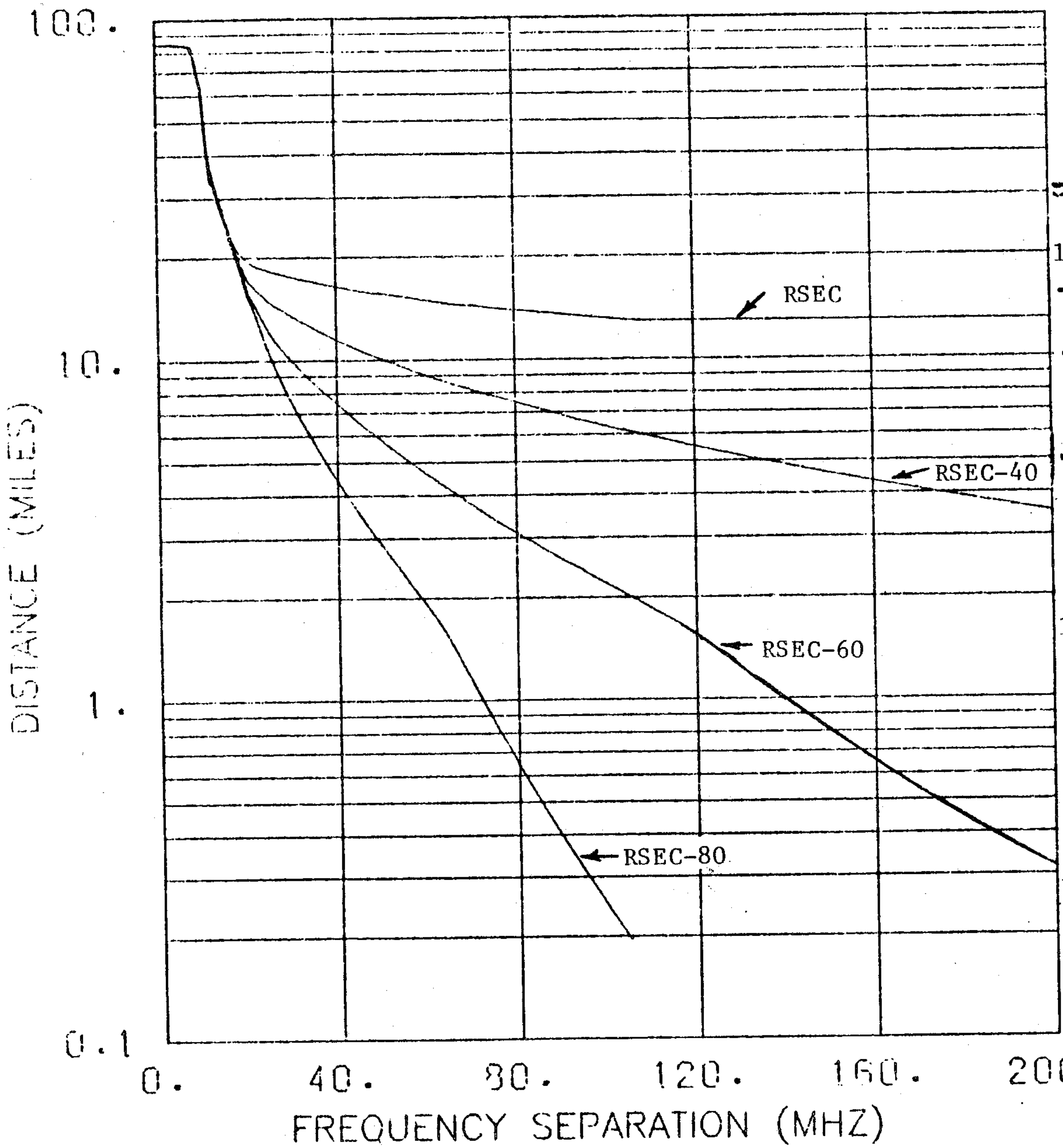
Parameter Values:

P_p = 90 dBm

G_t = 42 dBi (Mainbeam gain minus tilt angle)

L(d) = 225 dB

Figure 25. Frequency Distance Separation Requirements for NEXRAD Mainbeam to ASR-9 Backlobe



NUMBER OF RADARS WITHIN SPECIFIED SEPARATION DISTANCES

1	2	3	4	5	6	7	8
114	46	16	16	5	0	0	0
56	18	13	3	2	4	0	1
34	14	4	1	0	0	0	0
26	5	4	1	0	0	0	0
122	26	24	0	0	0	0	0

Parameters Values:

P_p = 90 dBm

G_t = 27 dBi (Mainbeam gain minus tilt angle)

L(d) = 210 dB

Figure 26. Frequency Distance Separation Requirements for ASR-9 Mainbeam to NEXRAD Backlobe

capability to meet an 80 dB per decade fall-off from the RSEC 40 dB bandwidth down to a noise floor level of 80 dB. The latter more stringent emission spectrum bounds would be used in designated congested areas (See Figure 8 and TABLE 22) and for collocated radar sites when required. It is shown later that the 80 dB per decade fall-off will require the use of waveguide filters which will result in the emission spectrum noise floor level to be over 100 dB down.

TRANSMITTER EMISSION SPECTRUM CHARACTERISTICS

In order to assure that the recommended changes to the present RSEC emission spectrum bounds are appropriate, transmitter emission spectrum characteristics for various transmitter output tube devices and waveguide filters were investigated. The objectives of this investigation were to:

1. Determine the emission spectrum characteristics relative to the present RSEC of various transmitter output tube devices with and without waveguide filters.

2. Identify the state-of-the-art in radar emission spectrum control so that recommended changes to the present RSEC emission spectrum bounds would be achievable with current off-the-shelf hardware.

The emission spectrum characteristics of several radars presently operating in the 2700-2900 MHz band were measured using the NTIA RSMS van, and the state-of-the-art in radar transmitter emission spectrum control was identified through discussions with various manufacturers of transmitter output tube devices and waveguide filters.

The emission spectrum of a pulse radar is determined by the modulating pulse shape and width, transmitter RF tube, and RF output tube load. The transmission waveguide, rotary couplers, and antennas also affect the emission spectra but to a lesser degree. At the present time, there are only three types of transmitter output tube devices used in radars in the 2700-2900 MHz band. They are conventional magnetrons, coaxial magnetrons, and klystrons. The following is a discussion on the emission spectrum characteristics of these output tubes.

Conventional Magnetron

Most of the radars presently operating in the 2700-2900 MHz band employ conventional magnetron output tubes listed in TABLE 25. The tuning range and nominal operating characteristics of the tubes are listed in the table. Typical emission spectrum characteristics of conventional magnetrons are documented in a report by Hinkle, Pratt and Matheson (1976).

Figures 27 and 28 show measured emission spectrum of an ASR-5 and ASR-6 radar respectively which use conventional magnetrons. Figure 27 is an extended (300 MHz) measured emission spectrum. Also shown in Figure 27 and 28 are the emission spectrum bound curves for the RSEC and fall-off rates of 40, 60 and 80 dB per decade from the RSEC 40 dB bandwidth, and the radar system parameters used to determine the RSEC emission spectrum bound curves. Both Figures 27 and 28 show that the conventional magnetron does not meet the present RSEC 40 dB bandwidth because of the inherent frequency pulling of the conventional magnetron during the risetime of the modulating pulse. However, the noise

TABLE 25

MAGNETRON TUBE TYPES

TUBE* TYPE	FREQ. RANGE IN MHz	TUNABLE	PEAK POWER (KW/dBm)	PEAK CURRENT (A)	PEAK VOLTAGE (KV)	PULSE WIDTH (μsec)	DUTY CYCLE
5586	2700-2900	YES	800/ 89.0	70	29.5	1.0	.0005
8789 (QK1463)	2700-2900	YES	450/ 86.5	70	30	1.0	.001
4J31	2860-2900	NO	800/ 89.0	70	28	1.0	.0005
(DX276)	2700-2900	YES	450/ 86.5	50	32	1.5	.001
(QK729)	2860-2900	NO	480/ 86.8	50	26	4.0	.0007

*Tube types listed in brackets are manufacturer designators. Those tube types not listed in brackets are Joint Electron Device Engineering Council (JEDEC) designators.

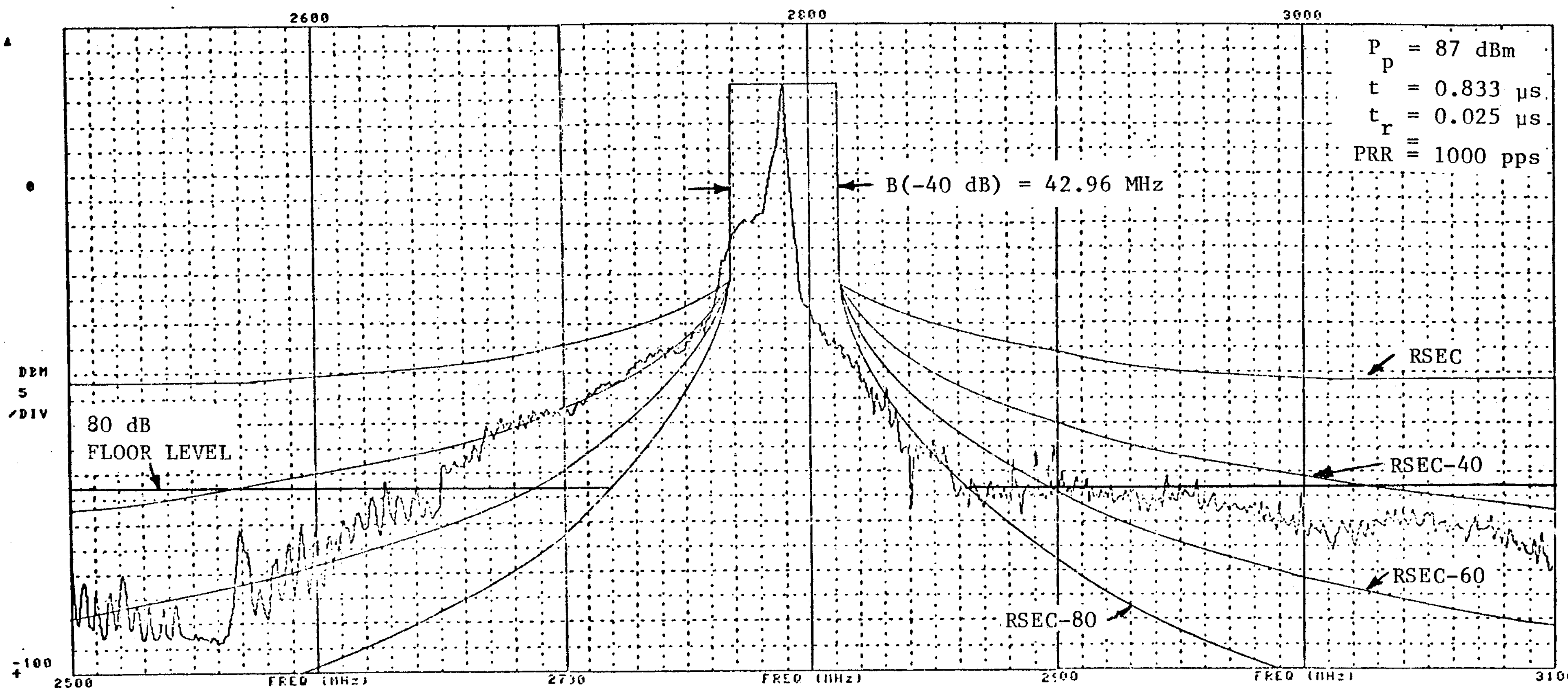


Figure 27. Measured ASR-5 Emission Spectrum (Conventional Magnetron).

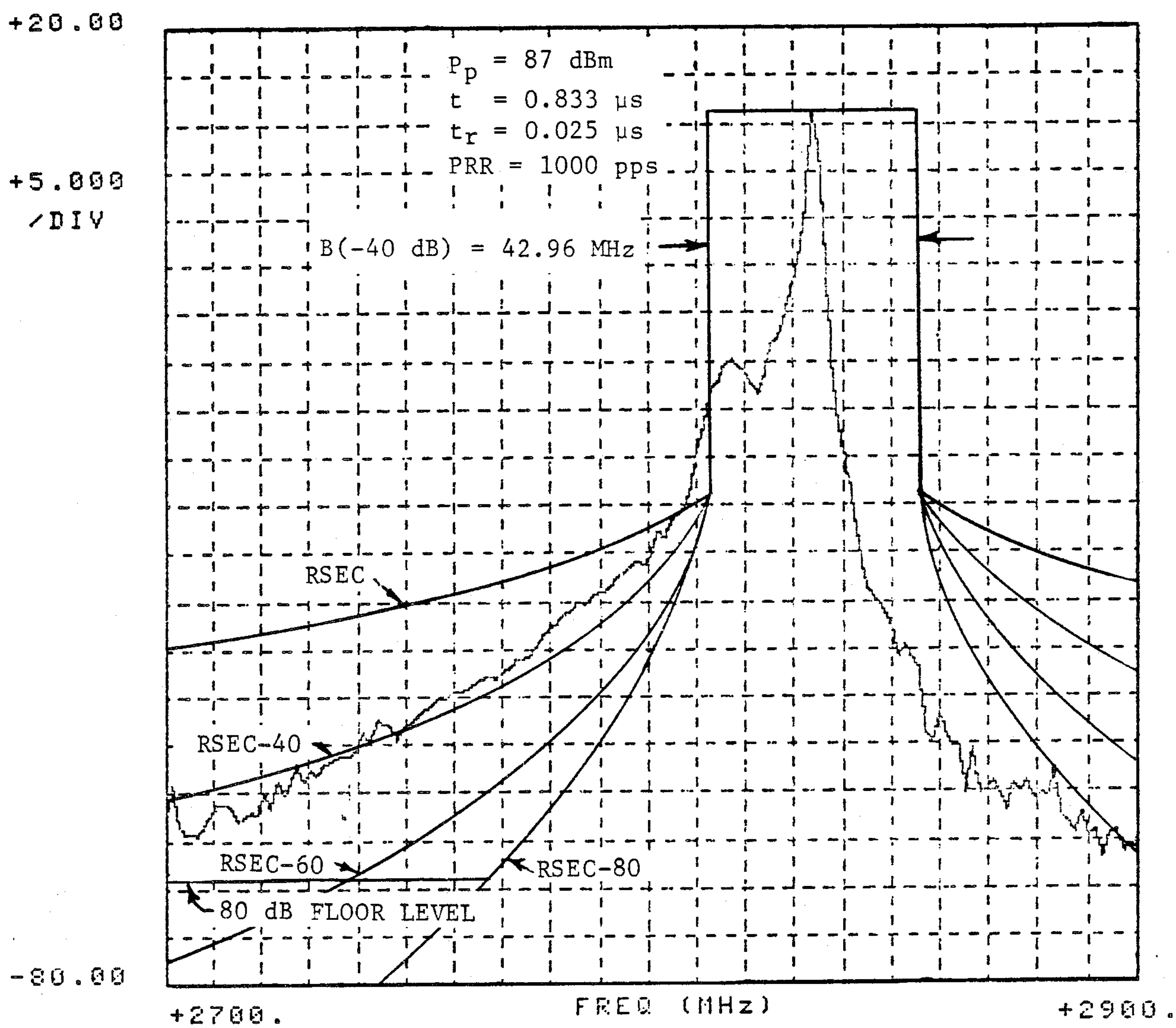


Figure 28. Measured ASR-6 Emission Spectrum (Conventional Magnetron)

level of the conventional magnetron is approximately 70-75 dB down from the fundamental. It is generally characteristic of conventional magnetrons to have relatively high harmonic and non-harmonic spurious emission levels. Major factors which contribute to variations in conventional magnetron noise floor levels are:

1. Magnetron age
2. Modulating pulse shape
3. Magnetron tube type
4. Magnetron anode voltage and current (Peak Power) setting
5. Magnetron load

The above factors are listed in their suspected order of significance. Even though the conventional magnetron has a relatively high noise floor level, it is shown in Figure 28 that the conventional magnetron noise floor is lower than the present RSEC floor level by 10-15 dB. Therefore, the present RSEC floor level appears to be somewhat conservative.

Conventional magnetron emission spectrum characteristics can be made significantly cleaner by using a waveguide filter. The AN/GPN-20 radar uses a conventional magnetron tube (8789, See TABLE 24) and a 5 section bandpass waveguide filter. Figure 29 shows a measured emission spectrum of an AN/GPN-20 with emission spectrum bound curves for the RSEC and fall-off rates of 40, 60, and 80 dB per decade from the RSEC 40 dB bandwidth. As seen in Figure 29, the use of a waveguide filter significantly lowers the sideband emission of a conventional magnetron. Figure 29 shows that by using a waveguide filter the sideband spurious emissions of a conventional magnetron can be suppressed to meet a 60 dB per decade fall-off from the RSEC 40 dB bandwidth. The measured emission spectrum shown in Figure 29 does not quite meet the 80 dB per decade emission spectrum bounds curve, however, proper design of the waveguide bandpass filter would even permit the conventional magnetron tube to meet the 80 dB per decade emission spectrum bound curve.

Coaxial Magnetron

Three radar nomenclatures in the 2700-2900 MHz band use coaxial magnetron output tubes. The NWS WSR-74S weather radar uses a VSM-1197 output tube. The height-finder radars (AN/FPS-6 and AN/FPS-90) which are being updated to AN/FPS-116 use a VSM-1143A or VSM-1143B output tube. Emission Spectrum measurements have been made on the WSR-74S at Volens, Virginia, and also on several height-finder radars.

The WSR-74S radar has the capability to transmit on two different pulse widths, 1.0 and 4.0 μs. Measured emission spectrums for the short pulse (1.0 μs) and long pulse (4.0 μs) are shown in Figures 30 and 31 respectively. Also shown in the figures are the emission spectrum bounds for the RSEC and fall-off rates of 40, 60, and 80 dB per decade from the RSEC 40 dB bandwidth. The coaxial magnetron has a very sharp fall-off around the fundamental frequency which is a big improvement over the conventional magnetron. The emission spectrum floor level of coaxial magnetrons is approximately 70-75 dB down from the fundamental which is similar to the conventional magnetron. In addition to the cleaner emission spectrum around the fundamental, the coaxial magnetron also has a significantly greater life span than the conventional magnetron. It is shown in Figures 30 and 31 that the coaxial magnetron does meet the present RSEC. Like the conventional magnetron, however, the coaxial magnetron can not

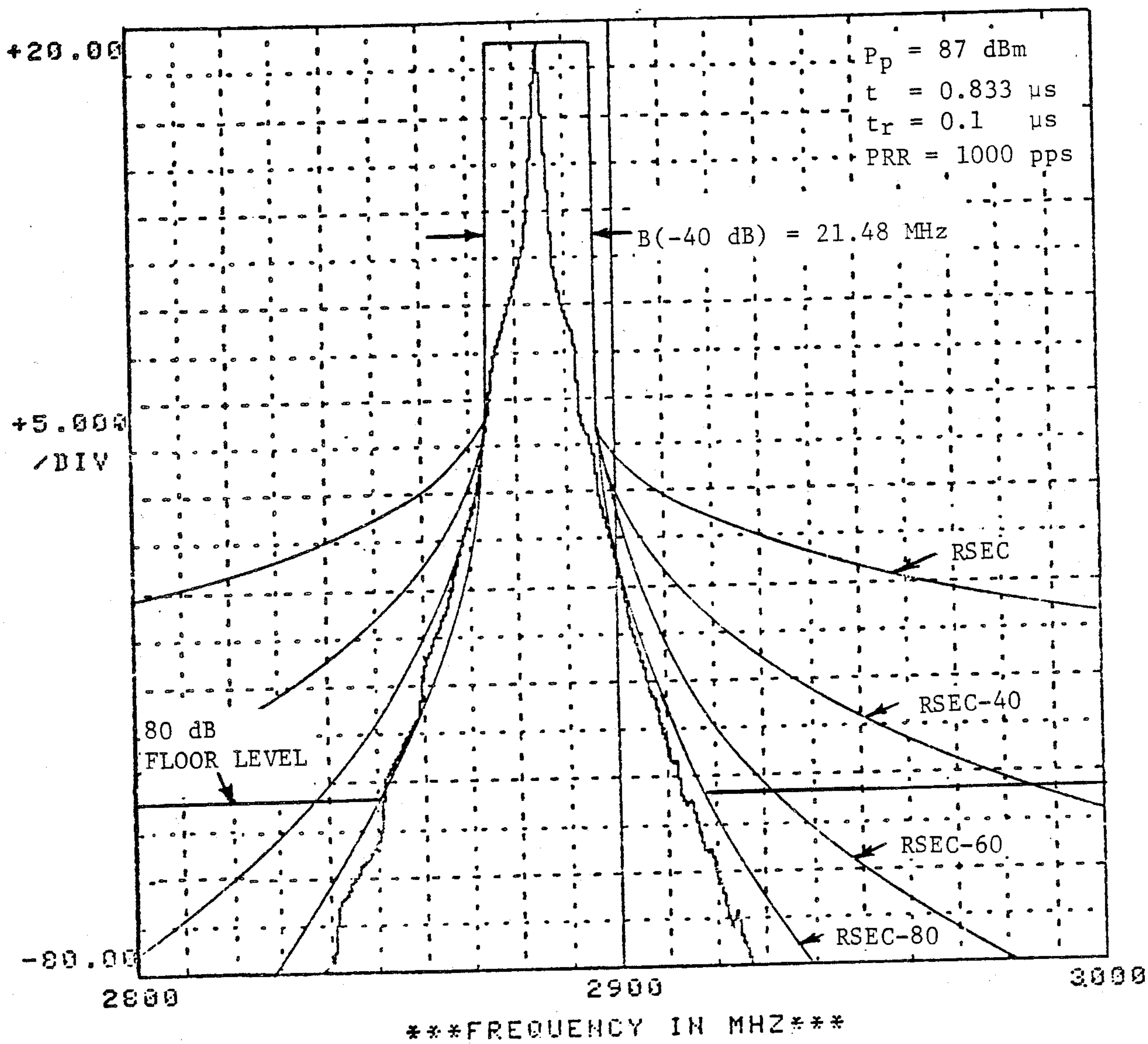


Figure 29. Measured AN/GPN-20 Emission Spectrum (Conventional Magnetron with Waveguide Filter)

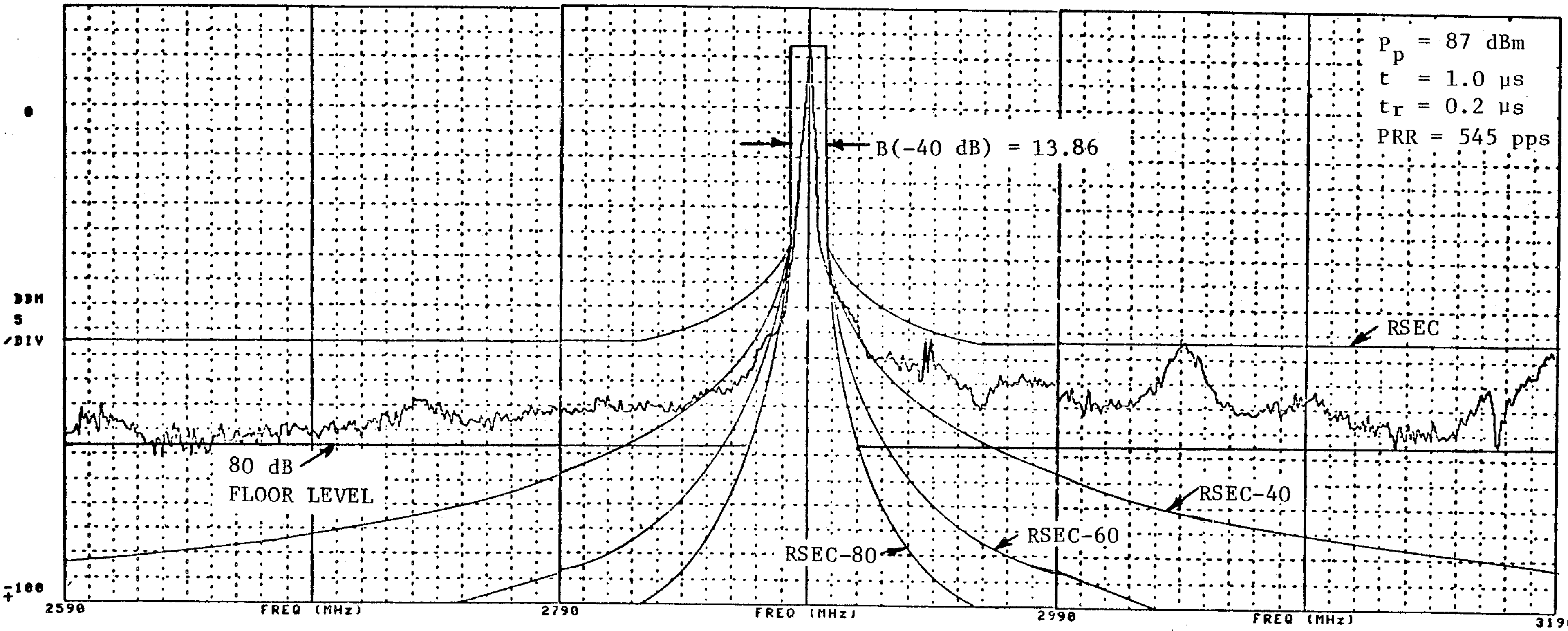


Figure 30. Measured WSR-74S Emission Spectrum, 1.0 μs Pulse (Coaxial Magnetron)

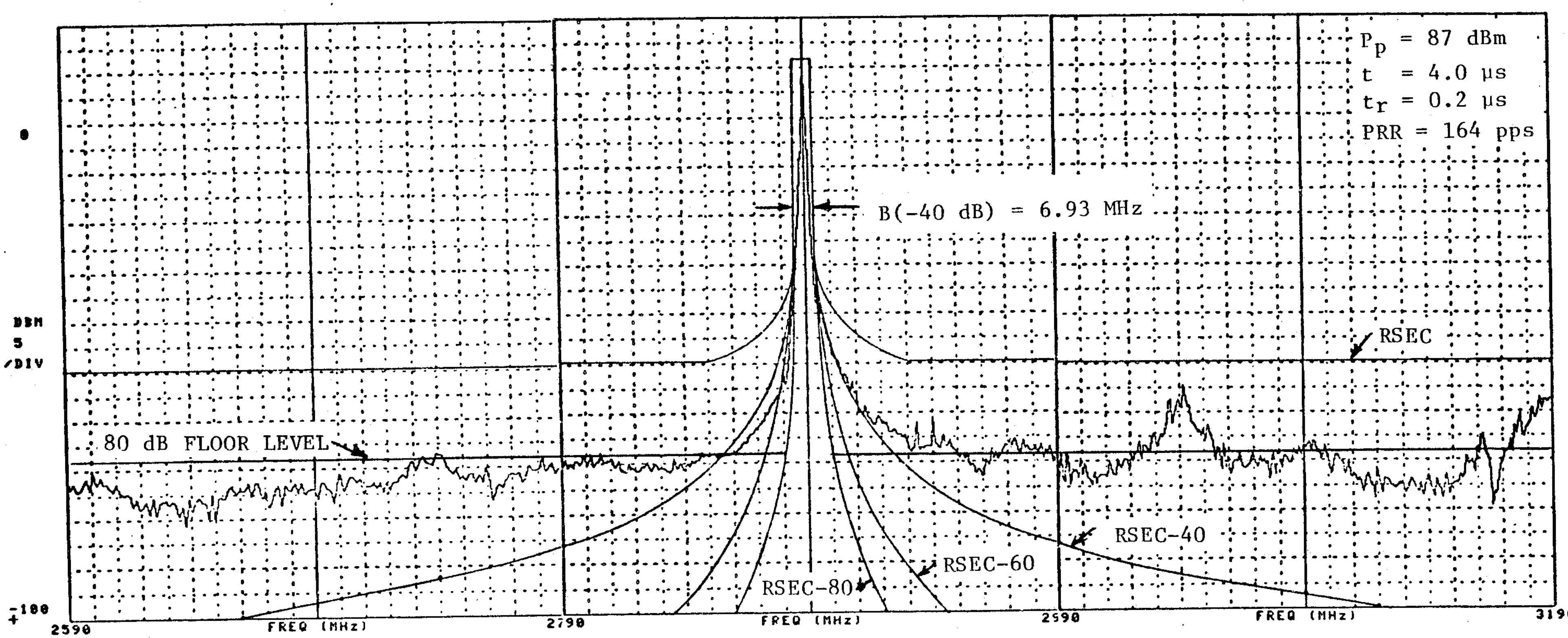


Figure 31. Measured WSR-74S Emission Spectrum, 4.0 µs Pulse (Coaxial Magnetron)

meet the more stringent 40, 60, or 80 dB per decade fall-offs emission spectrum bound unless a waveguide filter is used. At present, there are no radars in the 2700-2900 MHz band which use both a coaxial magnetron and waveguide bandpass filter. However, with the proper designed waveguide filter, the coaxial magnetron should be capable of meeting the 80 dB per decade fall off rate from the RSEC 40 dB bandwidth.

Figure 32 shows the measured emission spectrum of an AN/FPS-90 at San Pedro Hill, California. The figure shows the sharp emission spectrum fall-off around the fundamental typical of coaxial magnetrons and the emission spectrum is below the present RSEC emission spectrum bound level. Emission spectrum measurements have been made on several height-finder radars. Some of these radars had a spurious mode (TE_{121}) approximately 70-80 MHz above the fundamental frequency which is approximately 55 dB down. Figure 33 shows measured emission spectrum of the height-finder at North Truro with the TE_{121} mode emission. There is also a spurious emission sometimes on the lower side of the fundamental.

KLYSTRON

At present, the FAA ASR-8 radar system is the only radar system in the 2700-2900 MHz band which uses a klystron output tube. It uses a Varian VA-87E transmitter output tube, and also has a waveguide bandpass filter for frequency diversity operations. Closed system measurements were made on an ASR-8 radar before and after the waveguide filter.

Figures 34 and 35 show measured emission spectrum before the waveguide filter of the Long Beach ASR-8 A and B channels respectively. In general, klystron emission spectrums are characterized by a very sharp fall-off around the fundamental frequency generally following the theoretical emission spectrum fall-off of the modulating pulse. At approximately 70 to 80 dB down there is a "porch". The fall-off from the "porch" is determined by the selectivity of the cavities in the klystron. The noise floor of the klystron is approximately 110 to 115 dB down from the fundamental. Some factors which contribute to the level (spectral impurities) of the "porch" are:

1. Klystron being operated near or at the saturation level.
2. Incidental phase modulation on the RF drive pulse, and
3. Ripple on the beam voltage.

Careful consideration of the above factors in design of the associated klystron circuitry can significantly reduce the spectral impurities of the "porch".

Figures 34 and 35 show that the klystron can meet the present RSEC. Also channel A (Figure 34) meets the 40 dB per decade fall-off emission spectrum bounds. However, channel B (Figure 35) does not meet the 40 dB per decade emission spectrum bounds. It is believed that with consideration of the previously mentioned factors in the design of the associated klystron circuitry, the klystron can meet the 40 dB per decade fall-off from the RSEC 40 dB bandwidth.

Figures 36 and 37 show the measured emission spectrum after the waveguide filter of the Long Beach ASR-8 A and B channels respectively. The Figures show that with a waveguide filter the radar emission spectrum level is below the 80 dB per decade fall-off line.

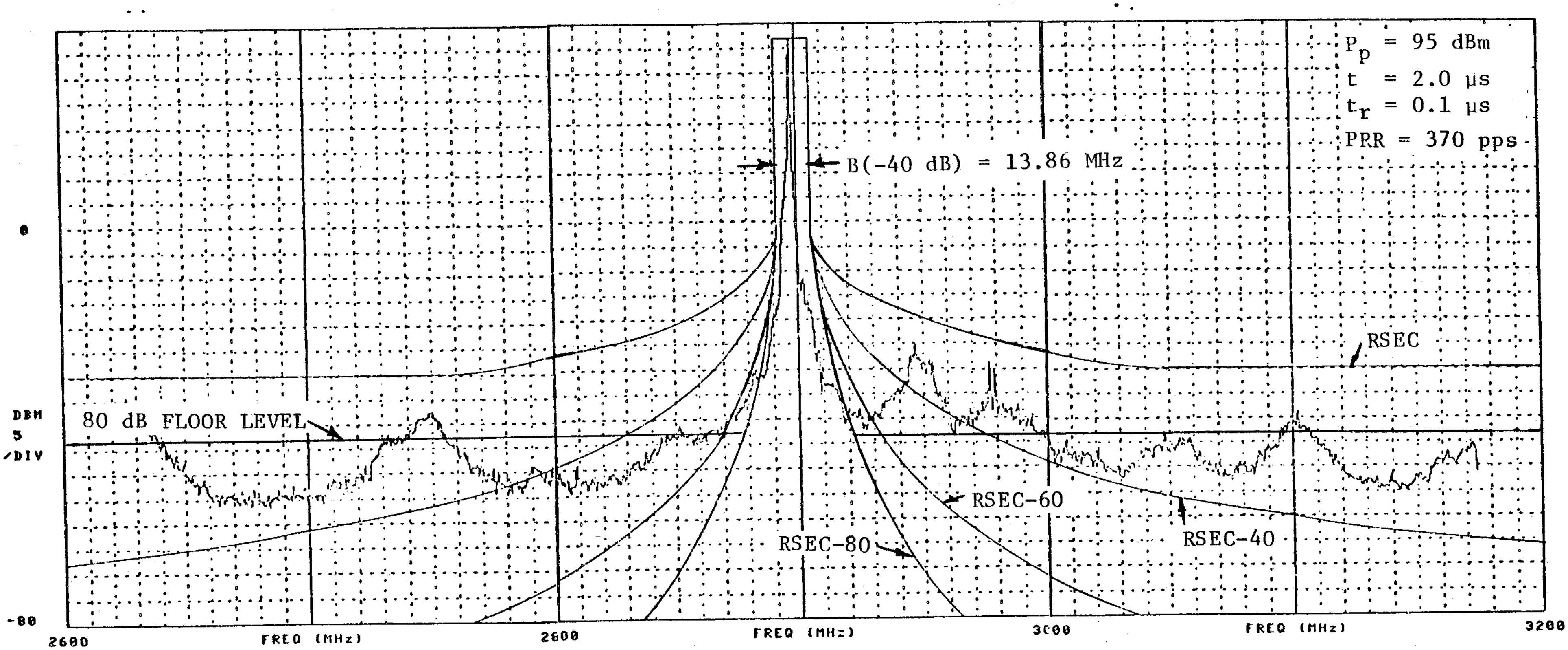


Figure 32. Measured AN/FPS-90 Emission Spectrum (Coaxial Magnetron)

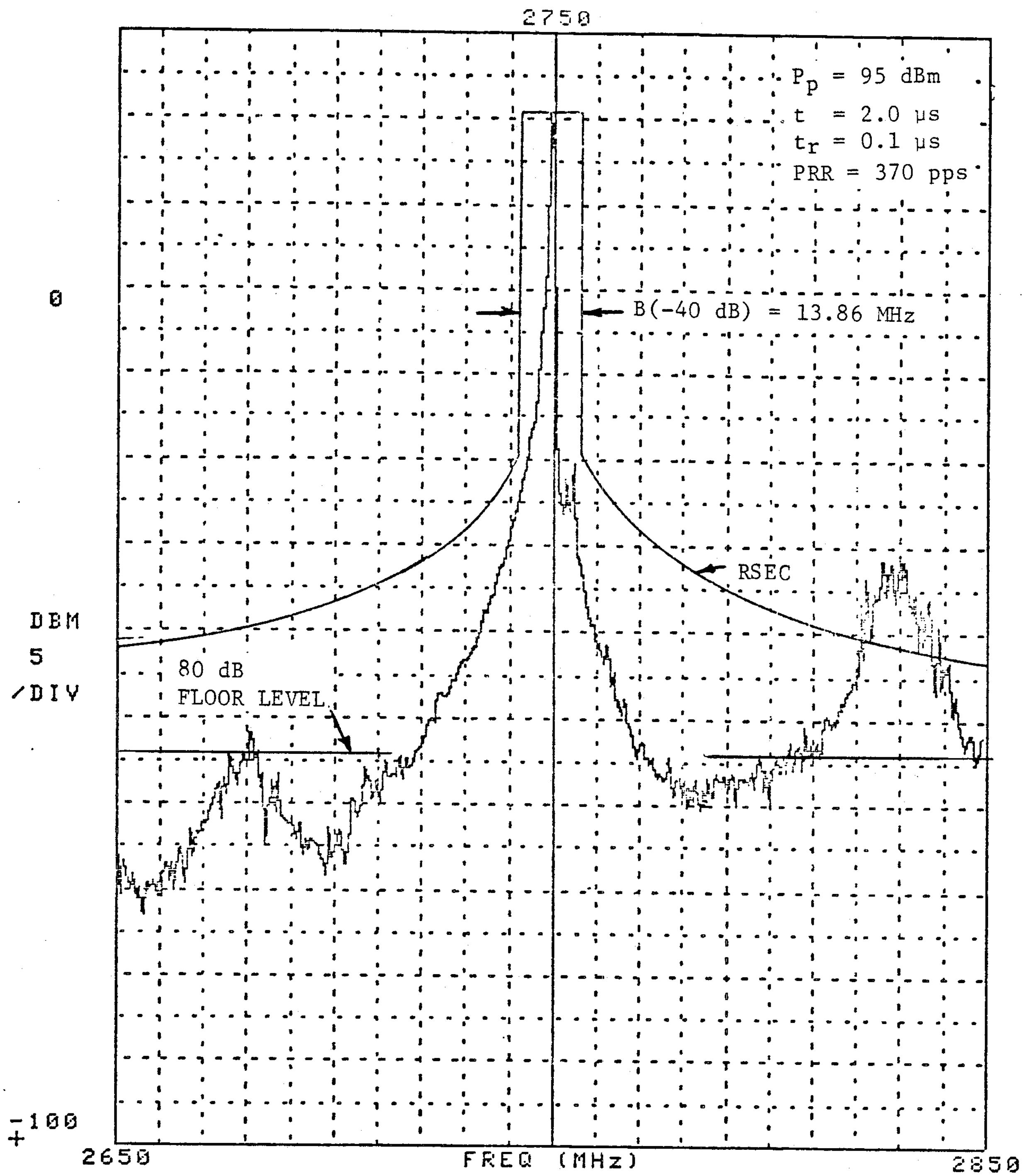


Figure 33. Measured AN/FPS-6 Emission Spectrum (Coaxial Magnetron).

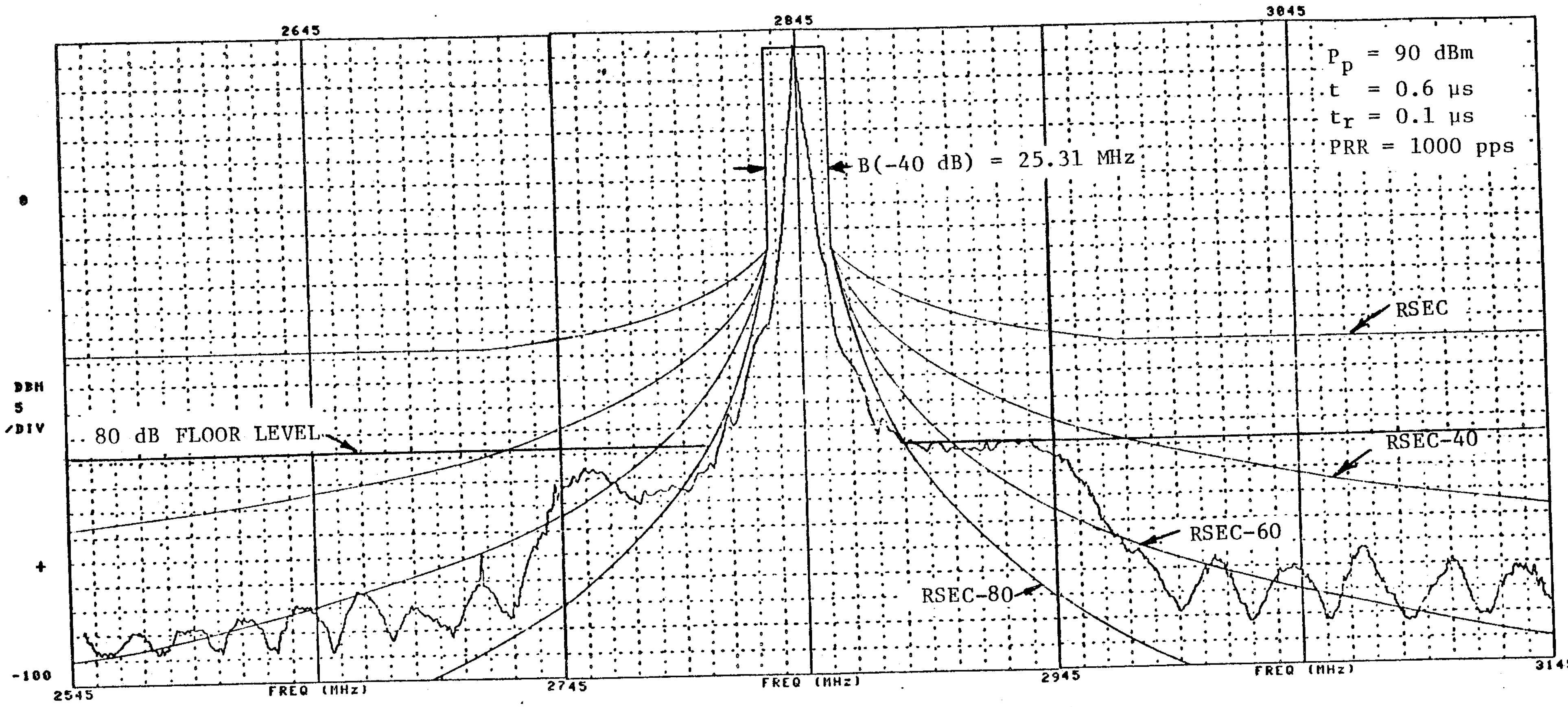


Figure 34. Measured ASR-8 Emission Spectrum, Channel A (Klystron Before Waveguide Filter)

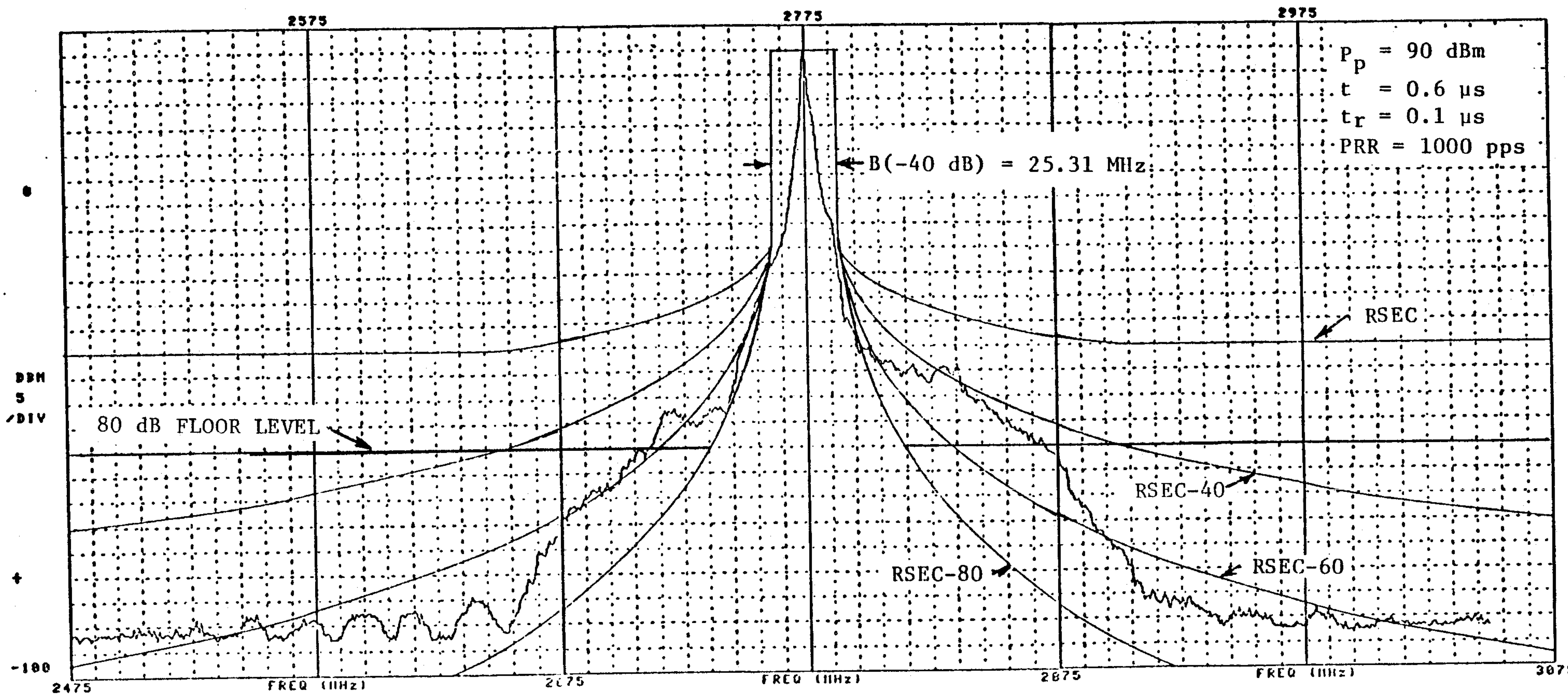


Figure 35. Measured ASR-8 Emission Spectrum, Channel B (Klystron Before Waveguide Filter)

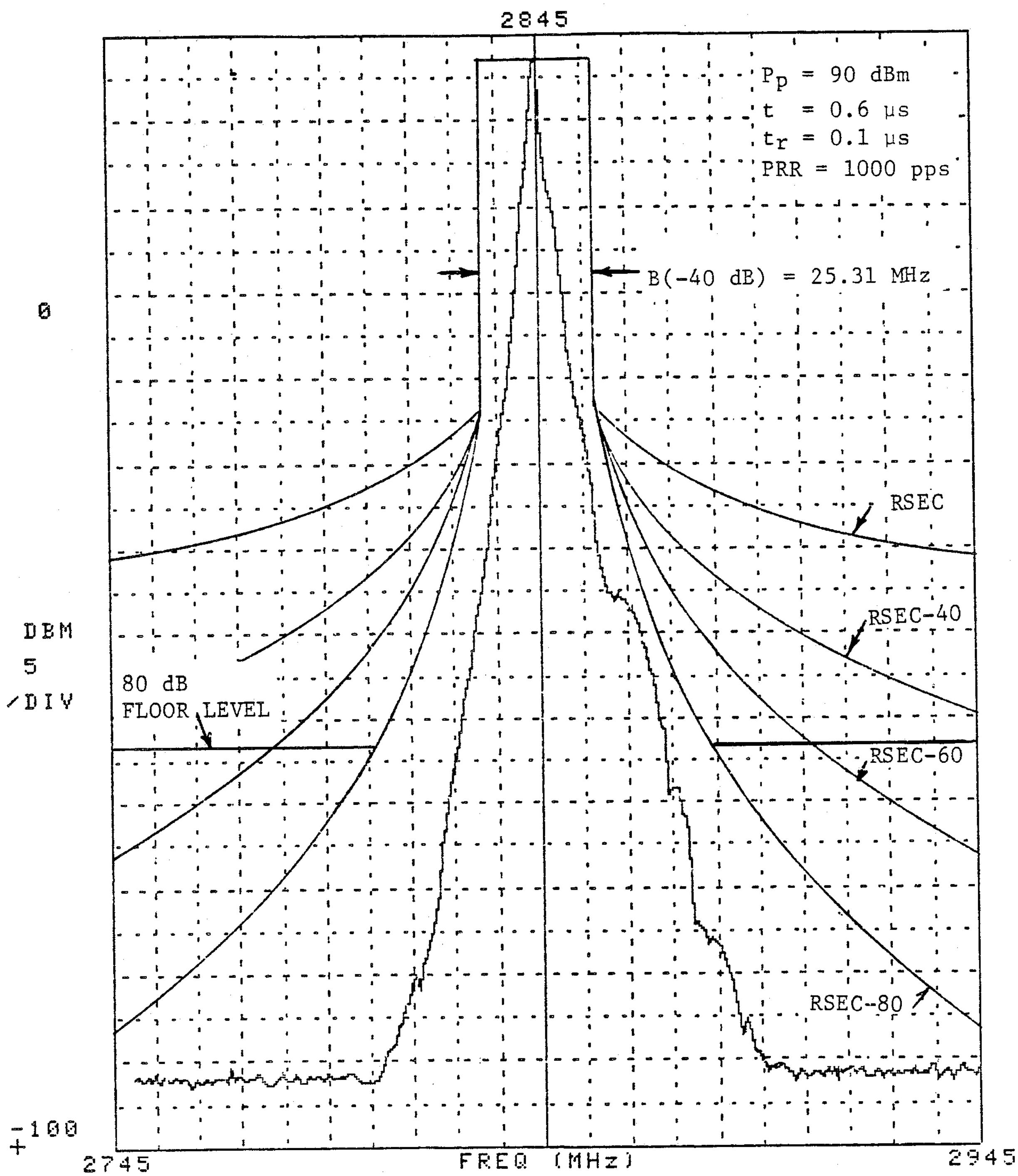


Figure 36. Measured ASR-8 Emission Spectrum Channel A (Klystron After Waveguide Filter)

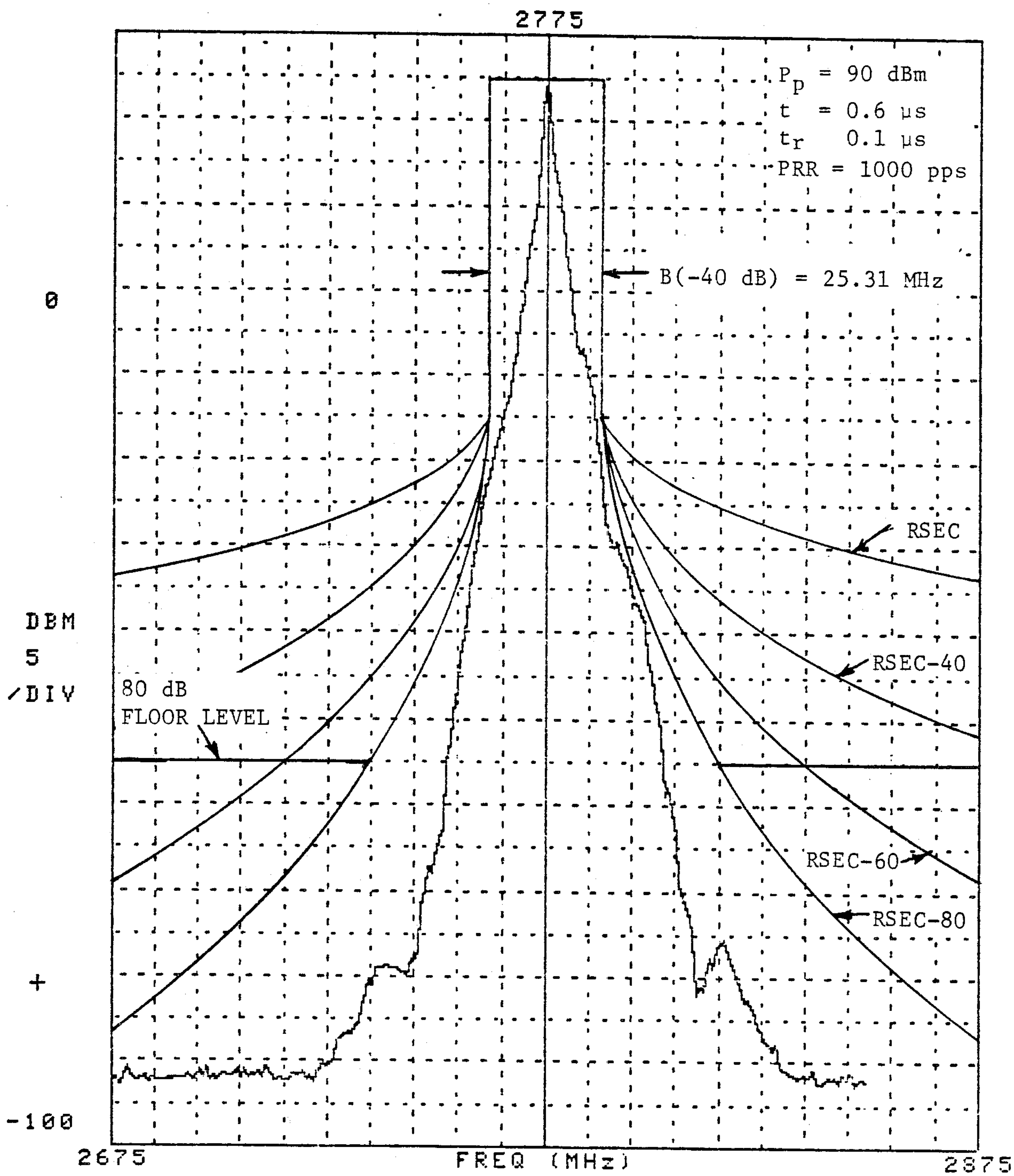


Figure 37. Measured ASR-8 Emission Spectrum, Channel B (Klystron After Waveguide Filter)

Summary of Transmitter Emission Spectrum Characteristics

As a result of the emission spectrum measurements and analysis made on radars in the 2700-2900 MHz band, it was determined that:

1. The conventional magnetron tube without using a waveguide filter does not meet the present RSEC Column B criteria due to the inherent frequency pulling characteristics of the tube during the risetime of the modulation pulse.

2. The coaxial magnetron and klystron do meet the present RSEC column B criteria.

3. The noise floor level specified in the RSEC is approximately 60 dB down for typical parameters of radars in the 2700-2900 MHz band. The measured noise floor level of conventional and coaxial magnetrons is approximately 70-75 dB down from the fundamental level, and the noise floor level of klystrons is approximately 110-115 dB down from the fundamental level. Therefore, for radars in the 2700-2900 MHz band the present RSEC noise floor level of 60 dB is somewhat conservative.

4. Emission spectrum levels much more stringent than the present RSEC can be achieved by the use of bandpass waveguide filters.

TABLE 26 summarizes the capability of conventional magnetron, coaxial magnetron and klystron tubes to meet the present RSEC and the proposed changes to the RSEC. It is recommended that all new fixed radars in the 2700-2900 MHz band have an emission spectrum level which from the present RSEC 40 dB bandwidth falls-off at 40 dB per decade to a fixed floor level of 80 dB. Also the new radars planned for the band should be designed and constructured to permit without modification to the basic equipment, field incorporation of, the capability to meet an 80 dB per decade fall-off from the RSEC 40 dB bandwidth down to a floor level of 80 dB. The later more stringent emission spectrum bounds would be used in designated heavily used areas (See Figure 8 and TABLE 22) and for collocated radar sites when required. Only the klystron tube can meet the recommended RSEC emission spectrum bound for non-heavily used areas without the use of a waveguide filter. The conventional and coaxial magnetrons both will require the use of a waveguide filter to meet the 40 dB per decade fall-off and 80 dB noise floor level for non-heavily used areas. For the recommended emission spectrum bounds for heavily used areas and collocated operation, the conventional magnetron, coaxial magnetron and klystron will require the use of a waveguide filter.

The cost of waveguide filters was obtained from several manufacturers. It was found that fixed-tuned five section filter costs approximately five to seven thousand dollars each, and tunable waveguide filters cost approximately twenty to thirty thousand dollars each.

Figures 34 and 35 indicates that the ASR-9 and NEXRAD radar systems can be collocated (less than two mile separation distance) if klystrons are used with at least 130 MHz of frequency separation. However, the ASR-9 and NEXRAD systems can be collocated with only approximately 60 MHz of frequency separation if a klystron and waveguide filter or used (See Figure 36 and 37).

TABLE 26

TRANSMITTER OUTPUT TUBE COMPLIANCE
WITH PRESENT AND PROPOSED RSEC

TRANSMITTER OUTPUT	PRESENT RSEC COLUMN B	PROPOSED RSEC	
		NON-HEAVILY USED AREAS	HEAVILY USED AREAS
CONVENTIONAL MAGNETRON	NO	NO	NO
CONVENTIONAL MAGNETRON WITH WAVEGUIDE FILTER	YES	YES	YES
COAXIAL MAGNETRON	YES	NO	NO
COAXIAL MAGNETRON WITH WAVEGUIDE FILTER	YES	YES	YES
KLYSTRON	YES	YES	NO
KLYSTRON WITH WAVEGUIDE FILTER	YES	YES	YES

YES - Implies Tube Will Meet Criteria
NO - Implies Tube Will Not Meet Criteria

Also the ASR-9 and NEXRAD systems can be collocated with only approximately 60 MHz of frequency separation if a magnetron and waveguide filter is used (See Figure 29).

TRANSMITTER OUTPUT POWER LEVEL

Many of the Ground Control Approach (GCA) radars deployed by the Military have control areas of less than 60 nautical miles. The air traffic control areas of the GCA radars are typically between 10 and 30 nautical miles, and therefore do not require the same transmitter output power as do the 60 nautical mile radars for a specified probability of detection. For cost benefit reasons, recent Military radar procurements in the 2700-2900 MHz band have been from FAA developed radars which are designed for operation out to 60 nautical miles. More efficient utilization of the band could be achieved if radars were designed to have the capability to vary the transmitter output power level. However, Trade-off in track continuity must be considered.

The transmitter output power level of klystron tubes can be readily varied up to 12 dB (change in radar detection range by factor of two) by changing the RF drive pulse level or beam voltage. In general, it is more desirable to change the beam voltage since the prime system power can be reduced and should result in the life of the tube being increased. The beam voltage can be readily changed by putting taps on the power transformer. However, there may be a slight drop in tube efficiency as the beam voltage is changed.

The output power of crossed-field tubes (conventional magnetrons and coaxial magnetrons) can not be as readily changed as klytron tubes. The output power level of crossed-field tubes can be changed from 3-6 dB. However, to change the transmitter output power by 12 dB would require the development of a family of tubes designed for the radar. It was believed that two crossed-field tubes would be adequate to cover a 12 dB range in transmitter output power level. It was the consensus of the TSC Working Group that the feature of variable transmitter output power level was desirable from a spectrum conservative viewpoint. However, the requirement of variable transmitter output power level did not appear to be viable requirement because of the difficulty in implementing in radar systems which use cross-field device output tubes.

RECEIVER INTERFERENCE SUPPRESSION CIRCUITRY

In addition to clearer transmitter emission spectrum characteristics, more efficient use of the 2700-2900 MHz band can also be achieved by use of receiver signal processing techniques. Many of the new radar systems planned for deployment in the band will have to operate in heavily used areas where many of the old radar system will have relatively high tranmitter spurious emission levels. Therefore, many of the new radar systems may be subjected to asynchronous pulsed interference in performing their missions.

In order to assure that the performance of new radar systems in the 2700-2900 MHz band are not degraded in heavily used areas, it is imperative that emphasis be placed on interference vulnerability when defining design specifications of new equipment procurements to ensure that system performance requirements can be satisfied in the type of asynchronous pulsed interference environment anticipated. Radar procurement design specifications of systems planned for deployment in the 2700-2900 MHz band in heavily used areas should include Radio Frequency (RF) preselector filter characteristics and

Intermediate Frequency (IF) filter characteristics which minimize the inband energy of undesired signals. Also the system should be designed and constructed to permit, without modification to the basic equipment, the ability to incorporate signal processing circuitry or software to suppress asynchronous pulsed interference. Many of the radars presently in the band have interference suppression circuitry or software. Appendix A contains a compendium of interference suppression techniques used by aeronautical radionavigational radars.

In order to design and develop signal processing circuitry or software to suppress asynchronous pulsed interference, it is necessary to be cognizant of the characteristics of the interfering signals encountered in the operational environment. One of the tasks the IRAC assigned to the TSC was to describe the theoretical environmental signal characteristics (pulse width, pulse repetition frequency, and expected signal levels) which new radars in the 2700-2900 MHz band may be subjected to in performing their operational requirement.

ENVIRONMENTAL SIGNAL CHARACTERISTICS

The following environmental signal characteristics description was developed as an aid in the design and development of receiver signal processing circuitry or software to suppress asynchronous pulsed interference. The environmental signal characteristics were developed by taking into consideration the nominal radar system characteristics of existing and planned radars for the band, field observations of Plan Position Indicator (PPI) scopes (Hinkle, Pratt, Matheson, 1976) and measurements of radar pulsed densities in the Los Angeles and San Francisco areas (Matheson, Smilley, and Lawrence, 1981). Nominal system characteristics of radars in the 2700-2900 MHz band were discussed in Section 4 and summarized in TABLES 13 and 14. Expected pulse densities in heavily used areas were discussed in Section 5.

In heavily used areas, new radar deployments may receive interference from one or two radars. The probability of receiving interference from two radars in the same time interval (i.e., victim radar mainbeam pointing at bearing or one interfering radar while second interfering radar mainbeam is pointing at bearing of victim radar) is low, but finite. The pulse width of the demodulated interfering signal will be a function of the interfering radar pulse width and receiver bandwidth characteristics. The detected pulse characteristics will also be affected by frequency separation. The total number of interfering pulses detected and peak Interference-to-Noise Ratio (INR) at the victim receiver IF output is a function of the frequency and distance separation as well as siting and terrain topography around and between the radar sites, and will vary as a function of time. The time variation of the peak INR is also influenced by the antenna pattern sidelobe and mainbeam characteristics and antenna scan characteristics of the interfering and victim radars. TABLE 27 summarizes the range of environmental signal characteristics that a radar operating in a heavily used area may be subjected to in performing its operational requirements.

TABLE 27

ENVIRONMENTAL SIGNAL CHARACTERISTICS THAT HAVE A BEARING ON RECEIVER PERFORMANCE

Pulse Width: 0.5 to 4.0 us
Pulse Repetition Frequency (PRF): 100 to 2000 pps
Interference-to-Noise Ratio (INR) at IF Output: $\leq$50 dB

PROPOSED RSEC CHANGES

After examining frequency-distance curves for characteristics of future planned systems, present radar deployment patterns, and projected growth in the 2700-2900 MHz band, it was the opinion of the TSC Working Group 1 that some changes should be made to the present Radar Spectrum Engineering Criteria (RSEC) for new fixed radars which operate in the 2700-2900 MHz band. The following is a summary of the proposed changes recommended by TSC Working Group 1 for the RSEC contained in Part 5.3 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management (NTIA, 1979). Presently radars in the 2700-2900 MHz band are subject to RSEC Criteria C. Appendix C of this report contains a complete copy of the proposed RSEC for new fixed radars in the 2700-2900 MHz band.

The following is a summary of the major changes to the present RSEC Criteria C proposed for new fixed radars in the 2700-2900 MHz band:

1. For non-FM pulse radars, a pulse risetime of less than 0.1t should be justified. This changes the formula for the B(-40 dB) bandwidth (Paragraph 3.1).

2. The emission levels beyond the frequencies B(-40 dB)/2 from F_o were changed to 40 dB per decade roll-off and an 80 dB floor level, X (dB)=80 dB (Paragraph 4).

3. To improve the accommodation of radar systems in the 2700-2900 MHz band which operate in close proximity to other equipment in the band or operate in designated heavily used areas, the radar shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of system EMC provisions. These provisions include the requirement to meet specifications in accordance with paragraphs a and b below and the recommendation to meet guidelines in accordance with paragraph c below.

a. Emission Levels

The radar emission levels at the antenna input shall be no greater than the values obtainable from the curves in Figure 2. At the frequency B(-40 dB)/2 displaced from F_o, the level shall be at least 40 dB below the maximum value. Beyond the frequencies B(-40 dB)/2 from F_o, the equipment shall have the capability to achieve up to 80 dB per decade (S=80) roll-off lines of Figure 2 to a maximum spectral power density of X(dB) = 80 dB.

b. Radar System PRF

The radar system shall be designed to operate with an adjustable pulse repetition frequency (s), PRF (s), with a nominal difference of ± 1% (minimum). This will permit the selection of PRF's to allow certain types of receiver interference suppression circuitry to be effective.

c. Receiver Interference Suppression Circuitry

Radar systems in this band should have provisions incorporated into the system to suppress pulsed interference. The following information is intended for use as an aid in the design and development of receiver signal processing circuitry or software to suppress asynchronous pulsed interference. A description of the parametric range of the expected environmental signal characteristics at the receiver IF output is:

Peak Interference-to-Noise Ratio: $\leq$ 50 dB
Pulse width: 0.5 to 4.0 us
PRF: 100 to 2000 pps

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APPENDIX A

INTERFERENCE SUPPRESSION TECHNIQUES

INTRODUCTION

Many of the new radar systems planned for deployment in the 2700-2900 MHz band will operate in designated heavily used areas or in a collocated environment where many of the old radar systems will have relatively high transmitter spurious emission levels. Therefore, the new radar systems may be subjected to pulsed interference in performing their missions. The incorporation of interference suppression circuitry or software in the design of new radar systems will ensure that system performance requirements can be satisfied in the type of pulsed interference environment anticipated. Environmental signal characteristics for the 2700-2900 MHz band are discussed in Section 6.

Interference suppression techniques, often called Electronic Counter - Countermeasures (ECCM), are generally classified into three categories: antenna, transmitter and receiver. The receiver interference suppression techniques are further categorized into predetection, detection and post-detection. It suffices to say that, ECCM is vast electronic field in itself. In recent years there have been several comprehensive treatise on this area (Johnston, 1979) and (Maksimov, 1979).

The following is a cursory discussion on several receiver post-detection interference suppression techniques currently used in radionavigation and meteorological radars.

INTEGRATOR

Description

The process of summing the echo pulses from a target is called integration. Integrators are generally used in radars for two reasons:

1. To enhance weak desired tagets for PPI display.

2. To suppress asynchronous pulsed interference.

The principle of the radar video integrator is that radar signal returns from a point target consist of a series of pulses generated as the radar antenna beam scans past the target, all of which fall in the same range bin in successive periods (synchronous with the system). It is this series of synchronous pulses from a target which permits integration of target returns to enhance the weak signals. The integrator also suppresses asynchronous pulsed interference since the interfering pulses will not be separated in time by the radar period, and thus will not occur in the same range bin in successive periods (asynchronous with the system). Therefore, the asynchronous interference will not add-up, and can be suppressed.

Basically two types of integrators have been used in radionavigation radars. The most common type of integrator is the feedback integrator shown in Figure A-1. A binary integrator shown in Figure A-2 is used in the ASR-7 and AN/GPN-12 radars.

Feedback Integrator

The feedback integrator shown in Figure A-1 consists of an input limiter, an adder, and a feedback loop with an output limiter and a delay equal to the time between transmitter pulses (1/PRF). The overall gain, K, of the feedback loop is less than unity to prevent instability. The input limiter serves as a video clipping circuit to provide constant level input pulses to the feedback integrator, and is a necessary integrator circuitry element to suppress asynchronous pulsed interference. The input limiter limit level is usually adjustable, and controls the transfer properties of the feedback integrator.

The signal transfer properties of the feedback integrator to noise, desired signal, and asynchronous pulsed interference are discussed in detail in a report by Hinkle, Pratt and Levy (1979).

Figure A-3 shows a simulated normal channel radar unintegrated output for three interference sources (ASR-5, INR = 10 dB; ASR-8, INR = 15 dB; and AN/FPS=90, INR = 20 dB), and a desired target signal-to-noise ratio of 15 dB. Figure A-4 shows for the same interference condition the radar output after feedback integration for an input limit level setting of 0.34 volts. The asynchronous interference has been suppressed by the feedback integrator.

Binary Integrator

The binary integrator shown in Figure A-2 consists of a threshold detector or comparator, binary counter (adder/subtractor circuit), a five bit shift register memory, and a digital-to-analog (D/A) converter. Each PRF period is divided into range bins. If a pulse of target return pulse train exceeds the comparator threshold level, the enhancer stores a one level digital signal in the shift register memory for that range bin. If the successive pulses of the target return pulse train continue above the comparator threshold in the given range bin, the binary counter will add one level to the stored digital signal in the shift register memory in each PRF period until a maximum integrator level of 31 is reached. If in any PRF period the signal fails to exceed the comparator threshold, the binary counter subtracts one from the stored integrator state in a given range bin until a digital signal level of zero is reached. The subtraction provides the target return pulse train signal decay required after the antenna beam has passed the target, and also enables the suppression of asynchronous interfering signals. The voltage amplitude at the enhancer D/A converter output is determined by the binary counter level (0 to 31) for the particular range bin times .125 volts. Therefore, for a binary counter level of 31, the maximum enhancer output voltage would be 3.875 volts (31 x .125).

The FAA modified the ASR-7 binary integrator to improve the desired signal probability of detection, target azimuth shift, and angular resolution loss caused by the conventional integrator used in the ASR-7 radar. A detailed discussion of the transfer properties of the binary integrator are given by Hinkle, Pratt and Levy (1979).

Figure A-4 shows a simulated normal channel radar unintegrated output for three interference sources (ASR-5, INR = 10 dB; ASR-8, INR = 15 dB; and AN/FPS-90, INR = 20 dB), and a desired target signal-to-noise ratio of 15 dB. Figure A-5 shows for the same interference condition the radar output after binary integration. The asynchronous interference has been suppressed.

Trade-offs:

Target azimuth shift: $.9^{\circ}$ for feedback integrator
$.2^{\circ}$ for binary integrator

Angular Resolution: 1.2° for feedback integrator
0° for binary integrator

Desired Signal Sensitivity:

Approximately 1 dB decrease when integrator is adjusted to suppress pulsed interference with the "Normal" video mode and with "MTI" in the 2 and 3 pulse canceller mode without feedback. However, in the "MTI" mode with feedback, the sensitivity loss can exceed 2 dB; adjusting the integrator to suppress interference may not be a practical solution in this case.

References

1. (Hinkle, Pratt and Levy, 1979)

2. (Skolik, 1962)

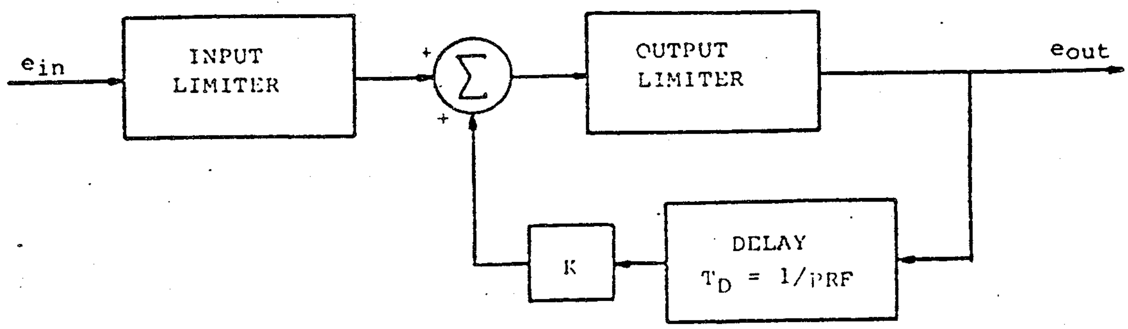

Figure A-1. Feedback Integrator Block Diagram

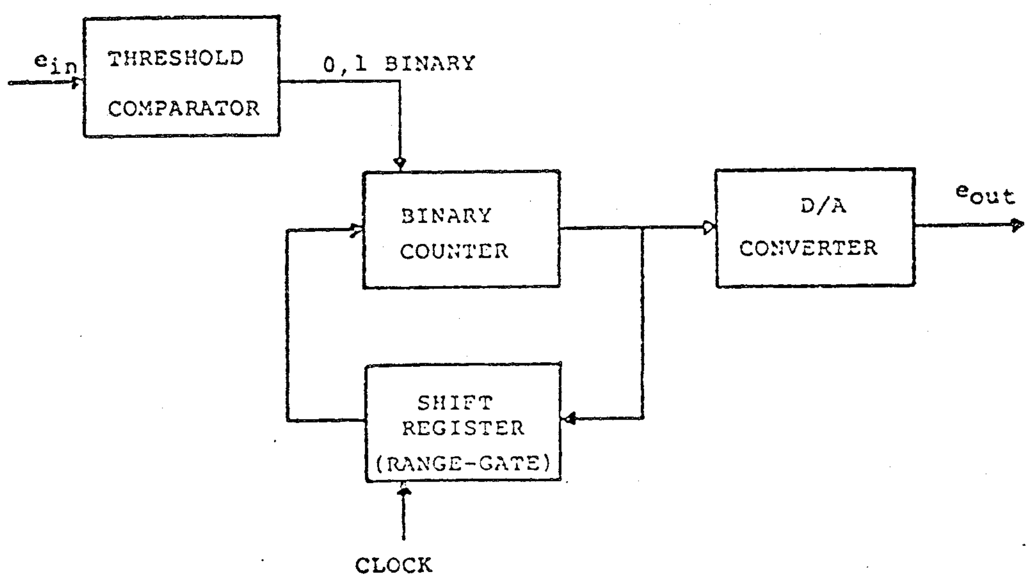

Figure A-2. ASR-7 (AN/GPN-12) Binary Integrator Block Diagram

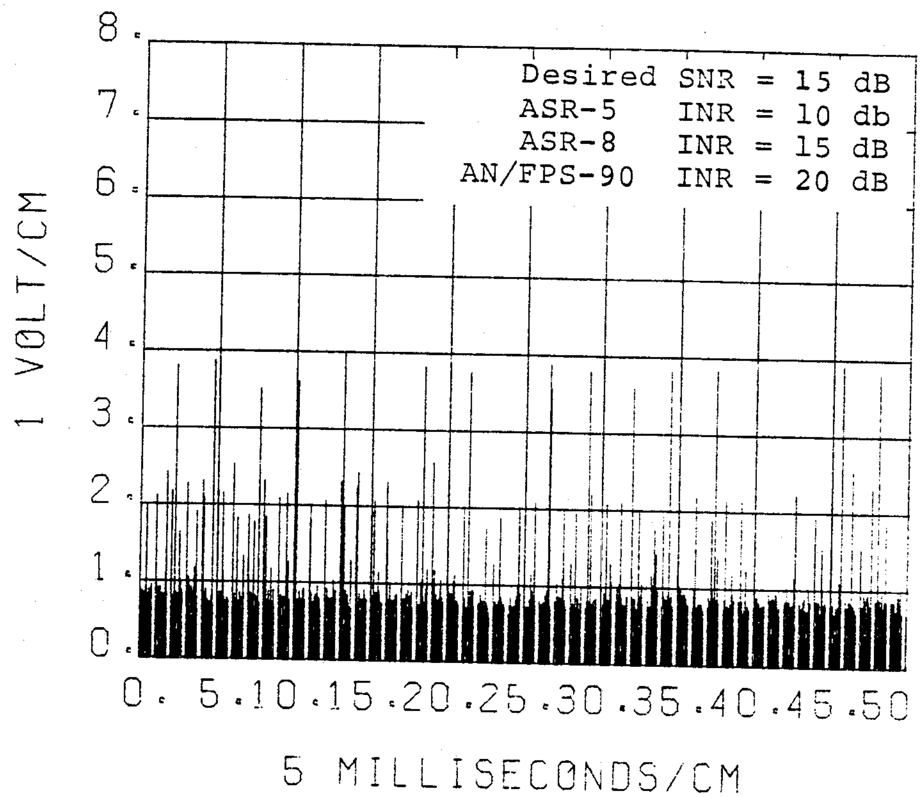

Figure A-3. Simulated Normal Channel Unintegrated Radar Output with Interference

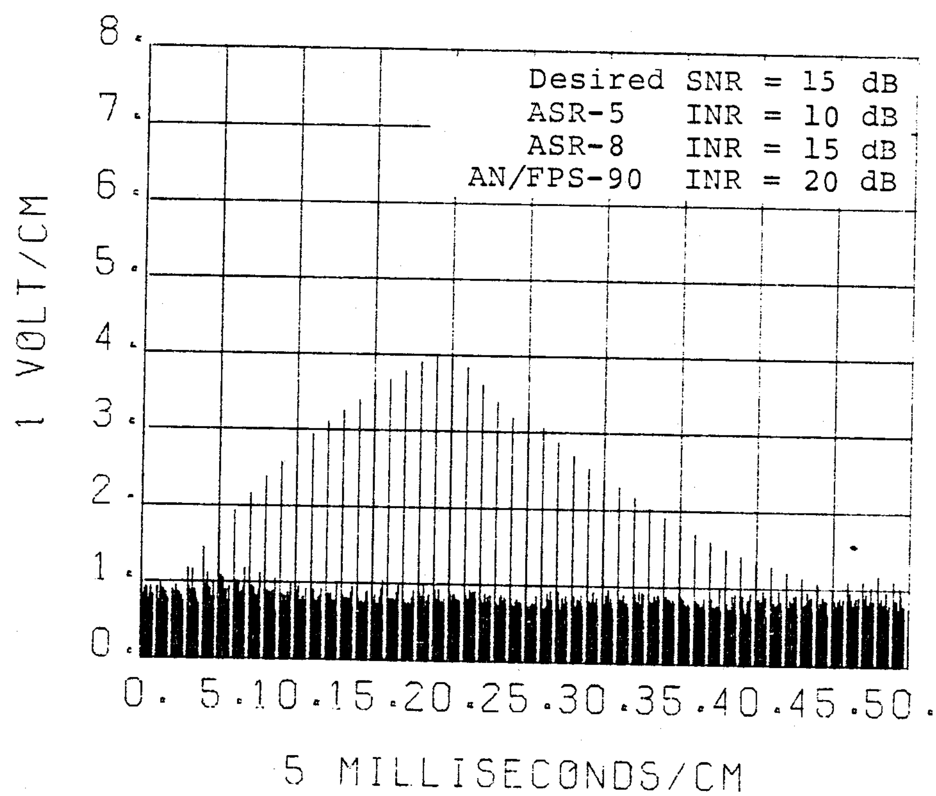

Figure A-4. Simulated Normal Channel Integrated Radar Output with Interference

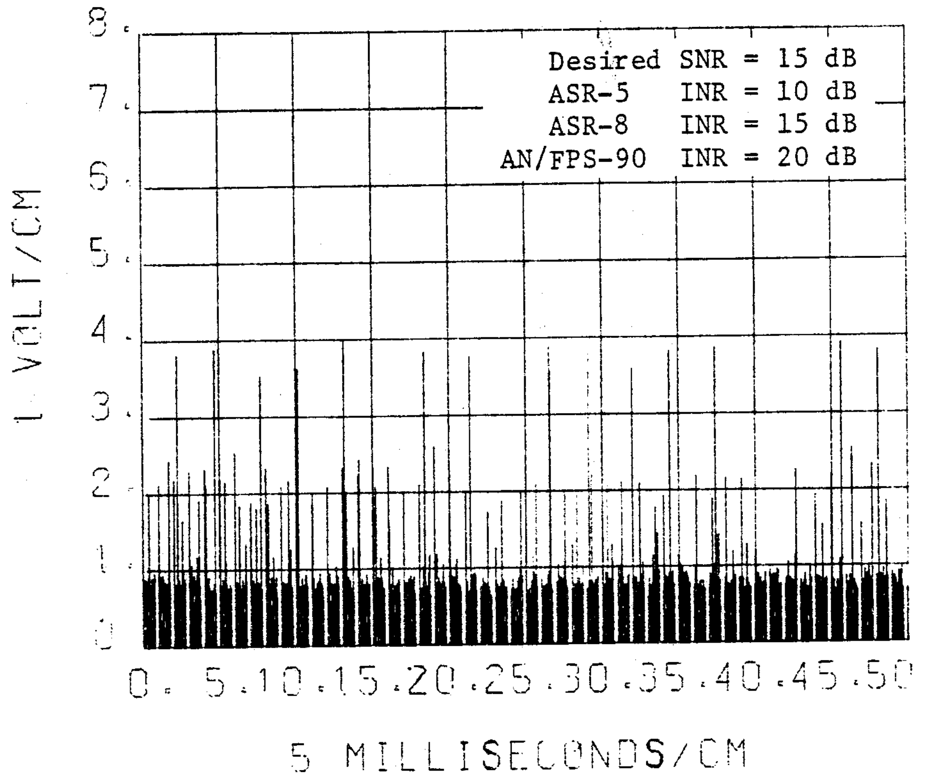

Figure A-5. Simulated Normal Channel Unintegrated Radar Output with Interference

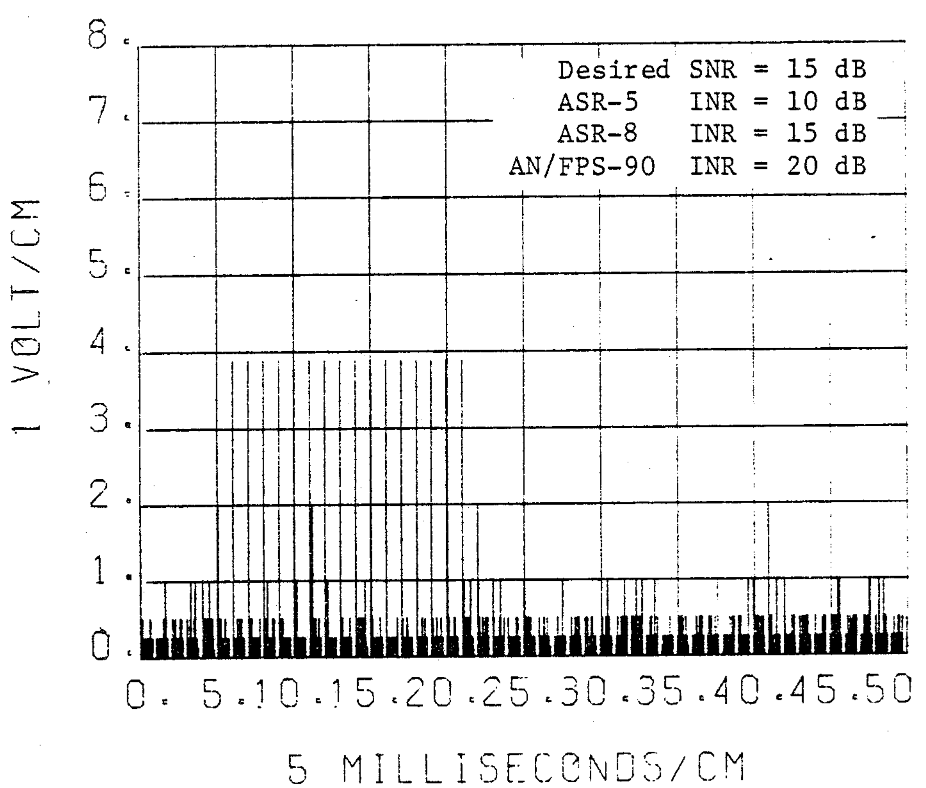

Figure A-6. Simulated Normal Channel Integrated Radar Output with Interference

DOUBLE-THRESHOLD DETECTION

Description

The double-threshold detector is a post detection signal processing technique used in radionavigation and search radars. The FAA double-threshold detection post-processing equipment is called a Common Digitizer (CD). A similar type of post-processing equipment (AN/FYQ-47) is also used by the DoD on search radars.

The function of the double-threshold detection circuit is to extract or identify targets from radar target pulse returns. However, the double-threshold method of detection also has an inherent capability to suppress false alarms caused by asynchronous pulsed interference. It also should be noted that the double-threshold detector is also refered to as a binary integrator, not to be confused with the binary integrator previously discussed. Figure A-7 shows a simplified block diagram of a double-threshold detector.

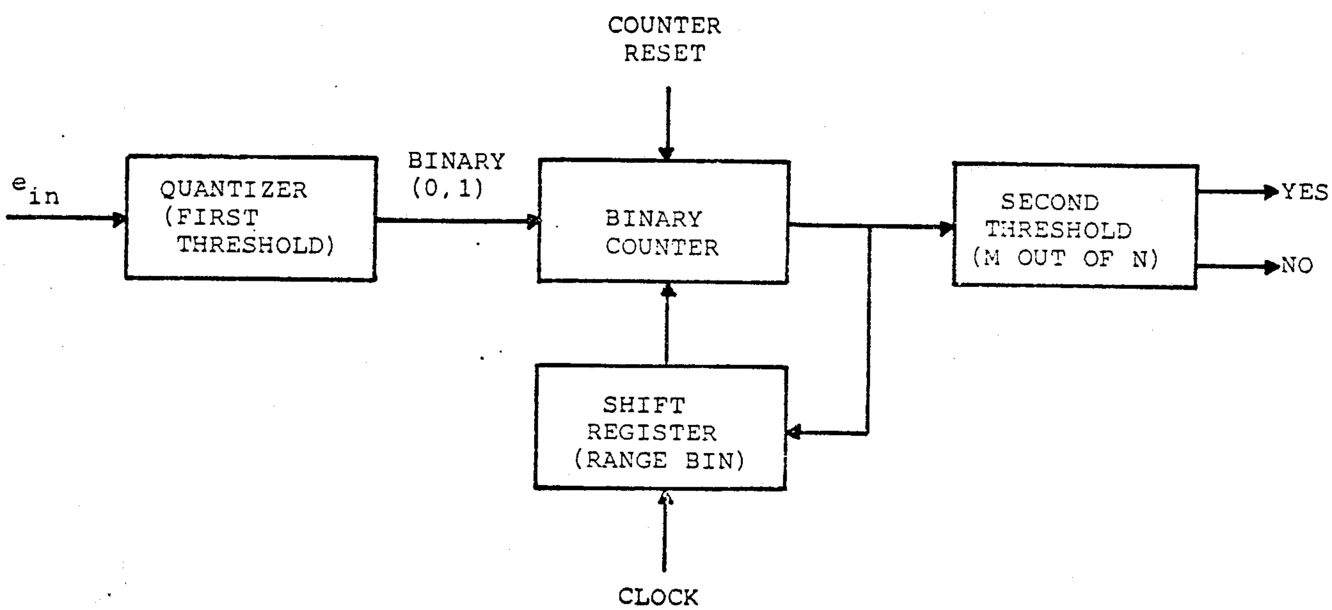

Figure A-7. Double-Threshold Detector Block Diagram

The "double-threshold" detector consists of establishing a bias level, T, the "first threshold", at the output of the radar, and then counting the number of pulses whose amplitude exceeds the bias level, T, in a "sliding window". The sliding window consists of N successive repetition periods in a given range bin. Where N, in accordance with usual practice, is assumed to be equal to the number of pulses omitted as the beam turns through an angle equal to the width between the one-way half-power antenna beam. If in any given range bin the number of pulses exceeding T in the sliding window is greater than or equal to a preassigned number M, the "second threshold", a target is declared to be present in that range bin. The values of the first threshold, T, and second threshold, M, are chosen to meet a particular probability of false alarm, P_{fa}, probability of detection, P_d. From this description, it is apparent why this targt detection technique is called both double-threshold detection and binary integration.

There are also more complex double threshold detection criteria than discussed above. For example, the FAA ARSR-3 has a fixed window size of 32 elements with separate leading and trailing edge target criteria. Also the FAA ARTS IIIA Radar Data Acquisition Subsystem (RDAS) has a variable window size with separate leading and trailing edge target criteria.

Intuitively, the double-threshold technique should be useful in reducing the effects of asynchronous pulsed interference. Target echos received as the beam scans past a target will occur in the same range bin. However, interfering pulses, occurring at random in the repetition period, will be unlikely to occur in any given range bin more than a few times in N repetition periods, unless the interfering pulse density is extremely high. Several studies have been made on the effects of asynchronous pulsed interference on double-threshold detection circuitry (Linder and Swerling, 1956) and (Hinkle, Pratt and Levy, 1979).

Trade-offs

The double threshold detector has a slightly poorer performance than the integrators which sum the target return pulses. The performance (P_d and P_{fa}) of the double threshold detector in suppression asynchronous pulse interference depends on both the first and second thresholds.

References

1. (Swerling, P., 1952)

2. (Linder, I.W. Jr, and Swerling, P., 1956)

3. (Di Franco and Rubin, 1968)

4. (Hinkle, Pratt and Levy, 1979)

PRF DISCRIMINATOR

Figure A-8 shows a simplified block diagram of a Pulse Repetition Frequency (PRF) discriminator. The PRF discriminator utilizes a threshold comparator, delay (shift register) and a coincidence circuit (AND gate) to suppress asynchronous interfering pulses that do not have the same PRF (interpulse period) as the desired signal. The discriminator usually operates at video, target pulses above the threshold are passed by the comparator; one pulse repetition period later, a second target pulse arrives at the input to the coincidence circuit just as the first leaves the shift register. In this scheme, all except the first pulse in the target return pulse train are processed. The threshold level of the comparator is generally set at a 6 to 8 dB threshold-to-noise ratio. More complex PRF discriminators can be designed to suppress multiples of the desired signal PRF.

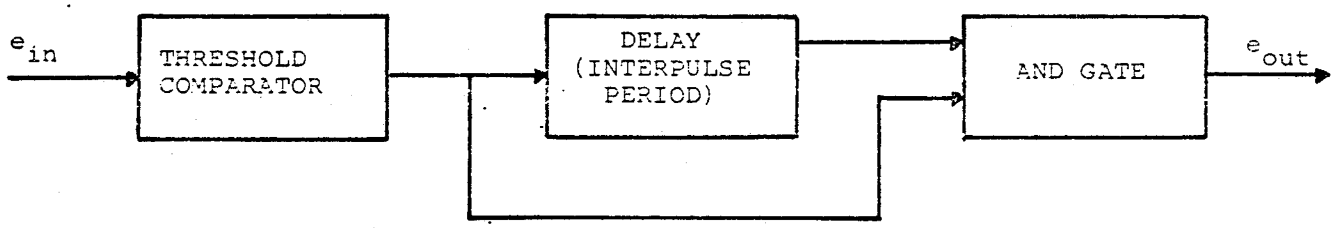

Figure A-8. PRF Discriminator Block Diagram

Trade-offs

The PRF Discriminator does not enhance the desired signal as the feedback and binary integrator circuits. Also there is a loss in desired signal sensitivity which is a function of the comparator threshold setting.

References

1. (Brown, 1973)

2. (Blythe, 1970)

3. (Skolink, 1970)

PULSE WIDTH DISCRIMINATOR

If the pulse width of the interference differs from that of the victim radar, it may be used to provide a means for discrimination. One method of implementing a pulse width discriminator is shown in Figure A-9. The input pulse is differentiated and split into two channels. In one channel the differentiated pulse is delayed a time corresponding to the width of the desired pulse τ , while in the other channel the differentiated pulse is inverted. If the input pulse were of width τ , the differentiated trailing edge inverted pulse would coincide in time with the leading edge pulse delayed in time τ . The coincidence circuit permits signals in the two channels to pass only if they are in exact time coincidence. If the input pulse were not of width τ , the two spikes would not be coincident in time and the pulse would be rejected.

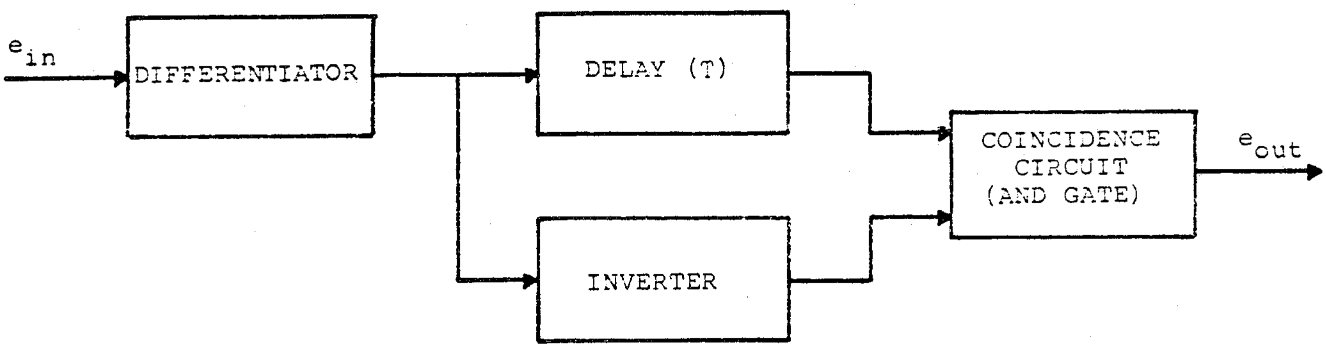

Figure A-9. Pulse Width Discriminator Block Diagram

Pulse width discriminators are generally not effective against off-tuned interference due to the inherent receiver IF output impulse response on the leading and trailing edge of an off-tuned pulsed signal. The leading and trailing edge impulse response of an off-tuned pulsed signal are typically similar to the desired signal because of the matched radar IF filter.

Trade-offs

The utilization of pulse-width discriminators generally results in reduced receiver sensitivity and probability of detection.

References

1. (Skolnik, 1962)

2. (Skolnik, 1970)

PULSE AMPLITUDE DISCRIMINATION

Description

Asynchronous pulsed interference can also be suppressed if the interfering signal levels are several dB above the receiver noise or clutter level. Pulse amplitude discrimination is used in the FAA MTD-II to suppress asynchronous pulsed interference. In the MTD-II, the signal level in the same range bin is added for several consecutive radar pulse periods. The magnitude is then stored and the average computed. Each range bin is then compared with four or five times the average. If any range bin exceeds this number, it is replaced by the average of the range bins. When there is interference in only one of the range bins and noise only in the other range bins, asynchronous pulsed interference with a peak INR greater than 12 to 14 dB (depending on the criteria of 4 or 5 times the average) will be eliminated from further processing in the radar.

Many different software algorithms can be developed to suppress asynchronous pulsed interferences based on pulse amplitude discrimination. The radar mission and type of radar signal processing must be taken into consideration in determining an appropriate pulse-amplitude discrimination algorithm.

Trade-offs

Desired signal trade-offs should be minimal with proper choice of algorithms. Pulse amplitude discriminators do not suppress weak interfering signals, and they do not work well if the presence of strong clutter.

References

1. (Cartledge and O'Donnell, 1976)

2. (McCrae and Ward, 1980)

APPENDIX B

DISTANCE SEPARATIONS

INTRODUCTION

This appendix contains a list of number of radars within specified distance separations from a particular radar operating in the 2700-2900 MHz band. This information was used to identify radar deployment patterns in the U.S., and to evaluate the present RSEC emission spectrum requirements. A more detailed discussion on the information contained in this appendix, and how this information was used is given in Sections 5 and 6 of this report.

TABLE B-1 lists radar locations in the 2700-2900 MHz band in order by state. TABLE B-2 lists radar locations in order by Government agency for convenience. TABLE B-3 identifies the abbreviations used for the agencies and station classes in TABLES B-1 and B-2.

TABLE B-1

RADAR DISTANCE SEPARATIONS IN ORDER
BY STATE

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AF	RLS	MAXWELL	ALA	1	0	1	0	0
AF	RL	DNNLYFLD	ALA	0	0	2	0	0
AF	RLS	HAMILTON	ALA	0	0	0	0	0
C	WXD	CENTRVLL	ALA	0	0	0	0	1
FAA	RLS	MONTGMRY	ALA	1	0	0	0	1
FAA	RL	BIRMNGHM	ALA	0	0	0	0	0
FAA	RLS	MOBILE	ALA	0	0	0	0	0
FAA	RLS	HUNTSVLL	ALA	0	0	0	0	0
AF	RLS	VAIDEN	ALA	0	0	0	0	1
AF	LR	PHOENIX	ARIZ	1	0	0	0	1
AF	RLS	LUKE	ARIZ	0	0	0	1	1
AF	RL	HOLBROOK	ARIZ	0	0	0	0	0
AF	RLS	WILLIAMS	ARIZ	0	0	0	0	1
FAA	RLS	TUCSON	ARIZ	0	0	0	0	0
FAA	RLS	HMBDTMTN	ARIZ	1	0	0	0	1
FAA	RLS	PHOENIX	ARIZ	0	0	0	0	3
N	RL	YUMA	ARIZ	0	0	0	0	0
AF	RLS	LUKE	ARIZ	0	0	0	1	3
AR	LR	FTHUACHC	ARIZ	3	0	0	0	0
AR	LR	OATMNMTN	ARIZ	0	0	0	0	1
AR	LR	FTHUACHC	ARIZ	3	0	0	0	0
AR	LR	FTHUACHC	ARIZ	3	0	0	0	0
AR	LR	FTHUACHC	ARIZ	3	0	0	0	0
AF	RLS	BLYTHVLL	ARK	0	0	0	0	0
AF	RLS	LITTLRCK	ARK	0	0	1	1	0
C	WXD	LITTLRCK	ARK	0	0	2	0	0
FAA	RLS	LITTLRCK	ARK	0	0	1	1	0
FAA	RLS	FT SMITH	ARK	0	0	0	0	0
AF	LR	ALMADEN	CAL	0	0	0	0	1
AF	LR	CAMBRIA	CAL	0	0	0	0	0
AF	LR	PT ARENA	CAL	0	0	0	0	0
AF	LR	MTLAGUNA	CAL	0	0	0	0	0
AF	LR	KLAMATH	CAL	0	0	0	0	0
AF	RLS	CASTLE	CAL	0	0	0	0	0
AF	RLS	VANDNBRG	CAL	0	0	0	0	0
AF	RLS	BEALE	CAL	1	0	0	0	0
AF	LR	MILLVLLY	CAL	0	0	0	0	4
AF	RLS	TRAVIS	CAL	0	0	0	0	1
AF	RLS	HAYWARD	CAL	0	0	1	3	1
AF	RLS	CP PARKS	CAL	0	0	0	1	4
AF	RLS	GEORGE	CAL	0	0	0	0	1
AF	LR	PASORBLS	CAL	0	0	0	0	0
AF	LR	SNPDRHLL	CAL	1	0	0	3	1
AF	RLS	MARCH	CAL	0	0	0	1	2
AR	RLS	LOSALMTS	CAL	0	0	1	0	5
C	WXD	SACRAMNT	CAL	0	0	1	1	0
FAA	RLS	SACRAMNT	CAL	0	0	2	0	0
FAA	RL	MARYSVLL	CAL	1	0	0	0	0
FAA	RLS	MIRAMAR	CAL	0	0	0	2	1
FAA	RLS	LONGBECH	CAL	0	0	1	2	3
FAA	RLS	PALM SPR	CAL	0	0	0	0	0
FAA	RLS	OAKLAND	CAL	0	0	3	0	4
FAA	RLS	MTN VIEW	CAL	0	0	0	0	4
FAA	LR	LOSANGLS	CAL	1	0	0	3	1
FAA	RLS	MONTEREY	CAL	0	0	0	0	0
FAA	RLS	LOSANGLS	CAL	1	0	0	2	2
FAA	RLS	EL TORO	CAL	0	0	0	0	3
FAA	RLS	ONTARIO	CAL	0	0	0	0	4
FAA	RLS	BURBANK	CAL	0	0	0	1	3
FAA	RLS	FRESNO	CAL	0	0	0	0	0
FAA	RLS	EDWARDS	CAL	0	2	0	0	3

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
FAA	RLS	SANTBRBR	CAL	0	0	0	0	0
FAA	RLS	PNMTVLLY	CAL	0	0	0	0	1
FAA	RLS	OWNSVLLY	CAL	0	0	0	0	0
FAA	RLS	SRLSVLLY	CAL	0	0	0	0	4
FAA	RLS	INDWLSVL	CAL	0	0	2	0	1
FAA	RLS	VELVETPK	CAL	0	0	0	0	1
FAA	RLS	LOSANGLS	CAL	1	0	2	2	5
FAA	RLS	FRMTVLLY	CAL	0	0	0	0	1
FAA	RLS	BAKRSFLD	CAL	0	0	0	0	0
FAA	RLS	STOCKTON	CAL	0	0	0	0	0
N	RL	ALAMEDA	CAL	0	0	1	1	3
N	MR	CHINA L	CAL	0	0	2	0	1
N	RL	LEMOORE	CAL	0	0	0	0	0
N	RLS	NO I	CAL	0	0	0	2	0
N	RLS	PT MUGU	CAL	0	1	0	0	0
N	RL	IMPRLBCH	CAL	0	0	0	1	1
AF	RLS	MATHER	CAL	0	0	1	1	0
AF	RL	NORTON	CAL	0	0	0	2	1
N	RLS	SNCLMNTI	CAL	0	0	0	0	0
N	RLTM	MARE I	CAL	0	0	0	0	5
NASA	LR	GOLDSTON	CAL	0	0	0	0	1
N	LR	SANTCRZI	CAL	0	0	0	0	0
N	LR	LAGUNAPK	CAL	0	1	0	0	0
N	LR	SANNCLSI	CAL	0	0	0	0	0
AF	RL	LA JUNTA	COLO	0	0	0	0	0
AF	RLS	BUCKLEY	COLO	1	0	2	0	0
AF	RLS	BUCKLEY	COLO	1	0	2	0	0
C	WXD	LIMON	COLO	0	0	0	0	0
FAA	RLS	COLO SPR	COLO	0	0	0	0	0
FAA	RLS	DENVER	COLO	1	0	2	0	1
NSF	WXD	BOULDER	COLO	0	0	0	0	2
NSF	WXD	GROVER	COLO	0	0	0	0	0
AF	LR	GREELEY	COLO	0	0	0	0	0
FAA	RLS	WNDSRLKS	CONN	0	0	0	0	0
FAA	RLS	WASH	DC	0	0	1	0	3
AF	RLS	DOVER	DEL	1	0	0	0	0
AF	RLS	DOVER	DEL	1	0	0	0	0
AF	LR	TYNDALL	FLA	1	3	0	0	1
AF	RLS	HOMESTED	FLA	0	0	1	0	2
AF	LR	JCKSNVLL	FLA	1	0	0	3	1
AF	LR	FTWLTNBC	FLA	0	0	3	1	0
AF	LR	CSANBLAS	FLA	0	0	0	0	3
AF	LR	EGLIN	FLA	2	0	1	1	0
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	RLS	EGLIN	FLA	2	0	1	1	0
AF	RLS	HURLBURT	FLA	0	0	1	3	0
AF	RLS	MACDILL	FLA	0	1	0	1	1
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	LR	MACDILL	FLA	0	1	1	0	1
AF	RLS	TYNDALL	FLA	2	2	0	0	0
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	MR	CCANAVRL	FLA	1	0	0	0	4
AF	LR	AVON PK	FLA	1	0	0	0	0
AF	RLS	TYNDALL	FLA	1	3	0	0	0
AF	LR	DUETTE	FLA	0	0	0	0	3
AF	LR	CROSS CY	FLA	0	0	0	0	0
C	WXD	DAYTNBCH	FLA	1	0	0	0	0
C	WXD	KEY W	FLA	1	0	1	0	0
C	WXD	PENSACOL	FLA	0	0	0	2	0
C	WXD	APALCHCL	FLA	0	0	0	0	1
C	WXD	TAMPA	FLA	0	0	0	2	2
C	WXD	MIAMI	FLA	0	0	1	1	2
C	WXD	WPALMBCH	FLA	1	0	0	0	0
FAA	RLS	MIAMI	FLA	0	0	1	1	2
FAA	RLS	PENSACOL	FLA	1	0	0	1	2

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
FAA	RLS	JCKSNVLL	FLA	0	0	1	0	4
FAA	RLS	ORLANDO	FLA	0	0	0	0	0
FAA	RLS	PALMBECH	FLA	1	0	0	0	0
FAA	RLS	FTLADRDL	FLA	0	0	0	0	2
FAA	RLS	TALLAHSS	FLA	0	0	0	0	0
FAA	RLS	DAYTNBCH	FLA	1	0	0	0	0
FAA	RLS	SARASOTA	FLA	0	0	0	0	1
FAA	RLS	PENSACOL	FLA	1	0	0	1	2
FAA	LR	TYNDALL	FLA	1	3	0	0	0
FAA	LR	MIAMI	FLA	0	0	1	2	0
FAA	LR	PATRICK	FLA	3	0	0	0	2
FAA	LR	KEY W	FLA	1	0	1	0	0
N	RL	KEY W	FLA	0	0	2	0	0
N	RL	JCKSNVLL	FLA	1	0	0	2	2
N	RLS	PENSACOL	FLA	0	0	0	0	0
AF	LR	AVON PK	FLA	1	0	0	0	0
N	RL	WHTNGFLD	FLA	0	0	0	0	2
N	RLS	MAYPORT	FLA	0	0	1	2	2
AF	MOB	EGLIN	FLA	2	0	1	1	0
N	RL	JCKSNVLL	FLA	1	0	0	3	1
AF	LR	CCANAVRL	FLA	1	0	0	0	4
AF	MR	TYNDALL	FLA	1	3	0	0	1
AF	RL	MACON	GA	0	4	3	0	0
AF	LR	STATESBR	GA	0	0	0	0	0
AF	RLS	DOBBINS	GA	1	0	0	0	1
AF	RLS	SMARTFLD	GA	2	0	1	4	0
AF	RLS	ROBINS	GA	3	1	0	3	0
C	WXD	WAYCROSS	GA	0	0	0	0	0
C	WXD	ATHENS	GA	0	0	0	0	0
FAA	RL	ATLANTA	GA	0	0	0	0	2
FAA	RLS	MACON	GA	3	1	0	3	0
FAA	RLS	SAVANNAH	GA	0	0	1	0	0
FAA	RLS	COLUMBUS	GA	0	0	0	0	0
FAA	RLS	AUGUSTA	GA	0	0	0	0	0
FAA	RLS	SAVANNAH	GA	0	0	1	0	0
AF	RLS	SMARTFLD	GA	2	0	1	4	0
AF	RLS	ROBINS	GA	3	1	0	3	0
AF	RLS	DOBBINS	GA	1	0	0	1	1
AF	RLS	SMARTFLD	GA	2	0	1	4	0
AF	RLS	ROBINS	GA	3	1	0	3	0
AF	RL	WILDER	IDA	1	0	0	0	0
AF	RLS	MTN HOME	IDA	1	0	0	0	0
AF	LR	WILDER	IDA	1	0	0	0	0
AF	RLS	MTN HOME	IDA	1	0	0	0	0
FAA	RLS	BOISE	IDA	0	0	0	0	0
AF	RL	COERDALN	IDA	0	0	0	2	2
AF	RLS	SCOTT	ILL	2	0	0	0	0
AF	RLS	SCOTT	ILL	2	0	0	0	0
AF	RLS	SCOTT	ILL	2	0	0	0	0
C	WXD	MARSELLS	ILL	0	0	0	0	0
FAA	RLS	CHICAGO	ILL	0	0	0	0	1
FAA	RLS	CHICAGO	ILL	0	0	1	0	1
FAA	RLS	SPRNGFLD	ILL	0	0	0	0	0
FAA	RLS	PEORIA	ILL	0	0	0	0	0
FAA	RLS	MOLINE	ILL	0	0	0	0	0
FAA	RLS	CHAMPAGN	ILL	0	0	0	0	0
FAA	RLS	ROCKFORD	ILL	0	0	0	0	0
N	RLS	GLENVIEW	ILL	0	0	1	0	0
AF	RLS	GRISSOM	INDA	1	0	0	0	0
AF	RLS	FT WAYNE	INDA	0	0	1	0	0
AF	LR	GRISSOM	INDA	1	0	0	0	0
C	WXD	EVANSVLL	INDA	1	0	0	0	0
FAA	RLS	FT WAYNE	INDA	0	0	1	0	0
FAA	RLS	SO BEND	INDA	0	0	0	0	0

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
FAA	RLS	EVANSVLL	INDA	1	0	0	0	0
FAA	RLS	INDINPLS	INDA	0	0	0	0	0
FAA	RLS	TERREHAT	INDA	0	0	0	0	0
C	WXD	DESMOINS	IOWA	1	0	0	0	0
FAA	RLS	DESMOINS	IOWA	1	0	0	0	0
FAA	RLS	CEDRRPDS	IOWA	0	0	0	0	0
FAA	RLS	SIOUX CY	IOWA	0	0	0	0	0
FAA	RLS	WATERLOO	IOWA	0	0	0	0	0
AF	RLS	MCCONNLL	KANS	0	0	2	0	0
C	WXD	WICHITA	KANS	1	0	1	0	0
C	WXD	GARDENCY	KANS	0	0	0	0	0
FAA	RLS	WICHITA	KANS	1	0	1	0	0
AF	RL	RICHMOND	KY	0	0	0	0	0
AR	RLS	FTCMPBLL	KY	0	0	0	0	0
C	WXD	JACKSON	KY	0	0	0	0	0
FAA	RLS	COVINGTN	KY	2	0	0	0	0
FAA	RLS	LOUISVLL	KY	0	0	0	0	0
AF	LR	SLIDELL	LA	0	0	1	0	0
AF	LR	LCHARLES	LA	0	1	0	0	0
AF	LR	BARKSDAL	LA	1	0	0	0	0
AF	RLS	ENGLAND	LA	1	0	0	0	0
AF	RLS	ENGLAND	LA	1	0	0	0	0
C	WXD	LCHARLES	LA	0	2	0	0	0
C	WXD	SLIDELL	LA	0	0	1	0	0
FAA	RLS	SHREVPRT	LA	1	0	0	0	0
FAA	RLS	BATONROG	LA	0	0	0	0	0
FAA	RLS	NORLEANS	LA	0	0	0	0	1
FAA	RLS	LCHARLES	LA	0	1	1	0	0
FAA	RLS	MONROE	LA	0	0	0	0	0
FAA	RLS	LAFAYETT	LA	0	0	0	0	0
N	RLS	NORLEANS	LA	0	0	0	0	1
AF	RLS	HAMMOND	LA	0	0	0	0	0
AF	LR	NO TRURO	MASS	0	0	0	0	1
C	WXD	BOSTON	MASS	0	1	0	0	1
C	WXD	WORCESTR	MASS	0	0	0	0	0
C	WXD	CHATHAM	MASS	0	0	0	0	2
FAA	RLS	FALMOUTH	MASS	0	0	0	0	1
FAA	RLS	BOSTON	MASS	0	1	0	1	1
N	RL	SOWEYMTH	MASS	0	0	0	1	1
C	WXD	LXNGTNPK	MD	1	0	0	0	0
FAA	RLS	BALTIMOR	MD	0	0	1	0	2
FAA	RLS	CP SPR	MD	0	0	1	0	2
N	RLS	PATXNTRV	MD	1	0	0	0	0
AF	RLS	FT MEADE	MD	0	0	1	0	2
AF	LR	BCKSHRBR	ME	0	0	0	0	0
AF	LR	CASWELL	ME	0	1	0	0	0
AF	RLS	LORING	ME	0	1	0	0	0
AF	LR	ASHLAND	ME	0	0	0	0	0
C	WXD	BRUNSWCK	ME	0	1	0	0	1
FAA	RLS	PORTLAND	ME	0	0	0	0	2
FAA	RLS	BANGOR	ME	0	0	0	0	0
N	RL	BRUNSWCK	ME	0	1	0	0	1
AF	RLS	WURTSMTH	MICH	0	0	0	0	0
AF	RL	BAYSHORE	MICH	0	0	0	0	0
AF	RLS	KISAWYER	MICH	0	0	0	0	0
AF	RLS	SELFRIDG	MICH	0	0	0	0	1
AF	LR	EMPIRE	MICH	0	0	0	0	1
C	WXD	DETROIT	MICH	0	0	0	0	2
FAA	RLS	GRRAPIDS	MICH	0	0	0	0	0
FAA	RLS	FLINT	MICH	0	0	0	0	0
FAA	RLS	LANSING	MICH	0	0	0	0	0
FAA	RLS	SAGINAW	MICH	0	0	0	0	0
FAA	RLS	DETROIT	MICH	0	0	0	0	1
FAA	RLS	MUSKEGON	MICH	0	0	0	0	0
FAA	RLS	KALAMAZO	MICH	0	0	0	0	0
AF	RLS	ALPENA	MICH	0	0	0	0	0

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AF	RLS	DULUTH	MINN	1	0	0	0	0
C	WXD	MINNEPLS	MINN	1	0	0	0	1
FAA	RLS	ROCHESTR	MINN	0	0	0	0	0
FAA	RLS	DULUTH	MINN	1	0	0	0	0
FAA	RLS	MINNEPLS	MINN	1	0	0	0	1
AF	RLS	ANOKA	MINN	0	0	0	0	2
AF	RL	KEESLER	MISS	2	0	1	0	2
AF	RL	KEESLER	MISS	2	0	1	0	2
AF	RL	KEESLER	MISS	1	0	0	0	4
AF	RL	KEESLER	MISS	1	0	0	0	4
AF	RL	COLUMBUS	MISS	0	1	0	0	0
AF	RLS	KEESLER	MISS	2	0	1	0	4
AF	RLS	COLUMBUS	MISS	1	0	0	0	0
C	WXD	JACKSON	MISS	1	0	0	0	0
FAA	RLS	JACKSON	MISS	1	0	0	0	0
FAA	RLS	MERIDIAN	MISS	0	0	0	0	1
FAA	RLS	GULFPORT	MISS	0	1	0	3	0
AF	RLS	KEYFIELD	MISS	0	0	0	0	1
AF	RL	SMRTTFLD	MO	0	0	0	1	1
C	WXD	MONETT	MO	0	0	0	0	0
C	WXD	STCHARLS	MO	0	0	0	2	0
FAA	RLS	KANS CY	MO	0	0	0	0	0
FAA	RLS	ST LOUIS	MO	0	0	0	1	1
FAA	RLS	SPRNGFLD	MO	0	0	0	0	0
AF	LR	KALISPLL	MONT	0	0	0	0	0
AF	LR	MALMSTRM	MONT	1	0	0	0	0
C	WXD	MISSOULA	MONT	0	0	0	0	0
FAA	RLS	BILLINGS	MONT	0	0	0	0	0
FAA	RLS	GT FALLS	MONT	1	0	0	0	0
AF	RL	DAGMAR	MONT	0	0	0	0	0
AF	LR	FTFISHER	NC	0	0	0	0	2
AF	RLS	POPE	NC	1	0	0	0	1
AF	RLS	POPE	NC	1	0	0	0	1
C	WXD	CHATTERS	NC	0	0	0	0	1
C	WXD	RALEIGH	NC	1	0	0	0	0
C	WXD	WILMNGTN	NC	0	0	1	0	1
FAA	RLS	CHARLOTT	NC	0	0	0	0	0
FAA	RLS	GREENSBR	NC	0	0	0	0	0
FAA	RLS	RALEIGH	NC	1	0	0	0	0
FAA	RLS	FAYTTVLL	NC	0	0	0	0	2
FAA	RLS	ASHEVILL	NC	0	0	0	0	0
FAA	RLS	WILMNGTN	NC	0	0	1	0	1
N	RLS	CHERRYPT	NC	0	0	0	0	0
N	RLS	N RV	NC	1	0	0	0	0
AF	RLS	SYMJHNSN	NC	0	0	0	0	0
N	RL	N RV	NC	1	0	0	0	0
AF	LR	FINLEY	NDAK	0	0	0	0	0
AF	RLS	MINOT	NDAK	0	0	0	0	0
AF	RLS	GR FORKS	NDAK	0	0	0	0	0
AF	RL	BISMARCK	NDAK	0	0	0	0	0
AF	LR	WATFRDCY	NDAK	0	0	0	0	0
C	WXD	FARGO	NDAK	1	0	0	0	0
FAA	RLS	FARGO	NDAK	1	0	0	0	0
AF	RL	HASTINGS	NEBR	0	0	0	0	0
C	WXD	GR I	NEBR	0	0	0	0	1
C	WXD	ALLIANCE	NEBR	0	0	0	0	0
FAA	RLS	OMAHA	NEBR	0	0	0	0	0
FAA	RLS	LINCOLN	NEBR	0	0	0	0	0
AF	LR	HAWTHORN	NEV	0	0	0	0	0
AF	RL	TONPHRNG	NEV	0	0	0	0	0
AF	RL	NELLIS	NEV	2	0	0	1	0
AF	RL	CALIENTE	NEV	0	0	0	0	1
AF	RLS	NELLIS	NEV	2	0	0	1	0
AF	RLS	CALIENTE	NEV	0	0	0	0	1
AF	RLS	TONPHRNG	NEV	0	0	0	0	0
FAA	RLS	LASVEGAS	NEV	0	0	0	3	0
FAA	RLS	RENO	NEV	0	0	0	0	0

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
N	RL	FALLON	NEV	0	0	0	0	0
AF	RLS	NELLIS	NEV	2	0	0	1	0
AF	RLS	PEASE	NH	1	0	0	0	0
AF	RL	PEASE	NH	1	0	0	0	0
FAA	RLS	MANCHSTR	NH	0	0	0	0	0
AF	RLS	MCGUIRE	NJ	1	0	0	1	1
AF	RLS	MCGUIRE	NJ	1	0	0	1	1
FAA	RLS	ATLNTCCY	NJ	3	0	0	0	0
FAA	RLS	ATLNTCCY	NJ	3	0	0	0	0
FAA	RLS	NEWARK	NJ	0	0	0	1	1
FAA	RL	ATLNTCCY	NJ	3	0	0	0	0
FAA	RL	ATLNTCCY	NJ	3	0	0	0	0
FAA	RLS	CLMNTN	NJ	0	0	0	0	4
N	RL	LAKEHRST	NJ	0	0	0	2	0
AF	RLS	HOLLOMAN	NMEX	1	0	0	0	2
AF	LR	SILVERCY	NMEX	0	0	0	0	0
AF	RLS	CANNON	NMEX	1	0	0	0	0
AF	RLS	KIRTLAND	NMEX	1	0	0	0	0
AF	RLS	HOLLOMAN	NMEX	1	0	0	0	2
AF	RLS	CANNON	NMEX	1	0	0	0	0
AR	LR	WSMR	NMEX	0	0	0	0	1
AR	LR	WSMR	NMEX	0	0	0	0	0
AR	LR	WSMR	NMEX	0	0	0	0	3
AR	MR	WSMR	NMEX	0	0	0	0	3
AR	LR	MCGREGOR	NMEX	0	0	0	0	3
FAA	RLS	ALBUQURQ	NMEX	1	0	0	0	0
AF	LR	MONTAUK	NY	0	0	0	0	0
AF	RL	PLTTSBRG	NY	1	0	0	0	1
AF	RL	WATERTWN	NY	0	0	0	0	0
AF	RLS	PLTTSBRG	NY	1	0	0	0	1
AF	LR	VERONA	NY	0	0	0	1	2
AF	LR	UTICA	NY	0	0	0	1	1
C	WXD	BUFFALO	NY	1	0	0	0	0
C	WXD	NY CY	NY	0	0	0	2	1
C	WXD	BINGHMTN	NY	1	0	0	0	0
FAA	RLS	SYRACUSE	NY	0	0	0	0	1
FAA	RLS	WHITPLNS	NY	0	0	0	0	2
FAA	RLS	BUFFALO	NY	1	0	0	0	0
FAA	RLS	ROME	NY	0	0	0	2	0
FAA	RLS	ALBANY	NY	0	0	0	0	0
FAA	RLS	BINGHMTN	NY	1	0	0	0	0
FAA	RLS	ROCHESTR	NY	0	0	0	0	0
FAA	RLS	JAMAICA	NY	0	0	0	0	3
FAA	RLS	ELMIRA	NY	0	0	0	0	0
FAA	RLS	ISLIP	NY	0	0	0	0	0
C	WXD	CINCINNT	OHIO	1	0	0	0	0
C	WXD	CLEVELND	OHIO	0	0	0	1	0
C	WXD	COLUMBUS	OHIO	1	0	0	1	0
FAA	RLS	AKRON	OHIO	0	0	0	0	0
FAA	RLS	TOLEDO	OHIO	0	0	0	0	0
FAA	RLS	CLEVELND	OHIO	0	0	0	1	0
FAA	RLS	COLUMBUS	OHIO	1	0	0	1	0
FAA	RLS	YONGSTWN	OHIO	0	0	0	0	0
FAA	RLS	DAYTON	OHIO	0	0	0	0	0
AF	RL	RCKNBCKR	OHIO	0	0	0	2	0
AF	RL	MXWSHMRF	OKLA	3	0	0	1	5
AF	RL	ADA	OKLA	1	0	0	0	0
AF	RL	TINKER	OKLA	0	0	0	8	1
AF	RL	KEGELMAN	OKLA	1	0	0	0	2
AF	RL	ALTUS	OKLA	1	0	0	0	1
AF	RLS	KEGELMAN	OKLA	1	0	0	0	0
AF	RLS	ADA	OKLA	0	1	0	0	0
AF	RLS	NORMAN	OKLA	3	0	0	5	1
AF	RLS	VANCE	OKLA	1	0	0	0	0
AF	RLS	VANCE	OKLA	1	0	0	0	0
AF	RLS	ALTUS	OKLA	1	0	0	0	1

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AR	RLS	FT SILL	OKLA	0	0	0	0	1
C	WXD	OKLA CY	OKLA	3	0	0	6	0
C	WXD	OKLA CY	OKLA	0	0	4	5	0
C	WXD	NORMAN	OKLA	3	0	0	0	4
C	WXD	NORMAN	OKLA	3	0	0	1	5
C	WXD	ANADARKO	OKLA	0	0	0	0	1
FAA	RLS	TULSA	OKLA	0	0	0	0	0
FAA	RLS	OKLA CY	OKLA	3	0	0	6	0
FAA	RLS	OKLA CY	OKLA	3	0	0	6	0
AF	RLS	FREDERCK	OKLA	0	0	0	0	2
AF	RLS	WLRGRSFD	OKLA	3	0	0	6	0
AF	LR	MT HEBO	OREG	0	0	0	0	1
AF	LR	DALLAS	OREG	0	0	0	0	1
C	WXD	MEDFORD	OREG	0	0	0	0	0
FAA	RLS	PORTLAND	OREG	0	0	0	0	0
C	WXD	CORAOPLS	PA	0	1	0	0	0
FAA	RLS	WILKSBRR	PA	0	0	0	0	0
FAA	RLS	HARRSBRG	PA	0	0	0	0	0
FAA	RLS	PHILDLPH	PA	0	0	0	0	2
FAA	RLS	ERIE	PA	0	0	0	0	0
FAA	RLS	ALLENTWN	PA	0	0	0	0	0
FAA	RLS	PTTSBRGH	PA	0	1	0	0	0
FAA	RLS	READING	PA	0	0	0	0	0
N	RL	WILLWGRV	PA	0	0	0	0	1
FAA	RLS	QUONSTPT	RI	0	0	0	0	0
AF	LR	NOCHRLSN	SC	2	0	0	0	1
AF	RLS	SHAW	SC	1	0	0	0	1
AF	RLS	SHAW	SC	1	0	0	0	1
AF	LR	JEDBURG	SC	0	0	0	0	3
C	WXD	CHARLSTN	SC	2	0	0	0	1
FAA	RLS	GREENVLL	SC	0	0	0	0	0
FAA	RLS	CHARLSTN	SC	2	0	0	0	1
FAA	RLS	COLUMBIA	SC	0	0	0	0	1
N	RLS	BEAUFORT	SC	0	0	0	0	0
AF	RLS	MCENTIRE	SC	0	0	0	0	3
AF	RLS	MYRTLBCH	SC	0	0	0	0	0
AF	RLS	ELLSWRTH	SDAK	2	0	0	0	0
AF	RLS	ELLSWRTH	SDAK	2	0	0	0	0
AF	RLS	ELLSWRTH	SDAK	2	0	0	0	0
C	WXD	HURON	SDAK	0	0	0	0	0
FAA	RLS	SIOXFLLS	SDAK	0	0	0	0	0
C	WXD	MILLNGTN	TENN	2	0	0	0	2
C	WXD	OLDHCKRY	TENN	0	0	0	1	0
C	WXD	MTHOLSTN	TENN	0	0	0	0	1
FAA	RLS	MEMPHIS	TENN	0	0	1	0	3
FAA	RLS	KNOXVILL	TENN	0	0	0	0	0
FAA	RLS	CHATTANG	TENN	0	0	0	0	0
FAA	RLS	BRISTOL	TENN	0	0	0	0	1
FAA	RLS	NASHVILL	TENN	0	0	0	1	0
N	RL	MEMPHIS	TENN	0	0	1	0	3
N	RLS	MILLNGTN	TENN	2	0	0	0	2
N	RLS	MILLNGTN	TENN	2	0	0	0	2
AF	LR	ELLINGTN	TEX	1	0	1	1	1
AF	LR	DILTON	TEX	0	0	0	0	0
AF	LR	ODESSA	TEX	0	0	0	0	0
AF	LR	EL PASO	TEX	0	0	0	1	1
AF	RLA	LAUGHLIN	TEX	0	0	0	0	0
AF	RLS	RANDOLPH	TEX	0	0	0	1	1
AF	RLS	CARSWELL	TEX	1	0	0	0	1
AF	RLS	SHEPPARD	TEX	1	0	0	0	0
AF	RLS	CARSWELL	TEX	1	0	0	0	1
AF	RLS	REESE	TEX	0	0	0	1	0
AF	RLS	SHEPPARD	TEX	1	0	0	0	0
AF	RL	ELLINGTN	TEX	1	0	1	1	1
AR	RLS	FT HOOD	TEX	1	0	0	0	0
C	WXD	AMARILLO	TEX	1	0	0	0	0

TABLE B-1 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
C	WXD	BRWNSVLL	TEX	0	0	0	0	0
C	WXD	GALVESTN	TEX	0	0	0	0	2
C	WXD	MIDLAND	TEX	1	0	0	0	0
C	WXD	HONDO	TEX	0	0	0	0	0
C	WXD	VICTORIA	TEX	0	0	0	0	0
C	WXD	STPHNVLL	TEX	0	0	0	0	0
C	WXD	LONGVIEW	TEX	0	1	0	0	0
FAA	RLS	CRPSCHRS	TEX	0	0	0	0	1
FAA	RLS	EL PASO	TEX	0	0	0	1	1
FAA	RLS	EL PASO	TEX	0	0	0	1	1
FAA	RL	AMARILLO	TEX	1	0	0	0	0
FAA	RL	LUBBOCK	TEX	0	0	0	1	0
FAA	RLS	AUSTIN	TEX	0	0	0	0	0
FAA	RLS	ABILENE	TEX	0	0	0	0	0
FAA	RLS	COLLYVLL	TEX	0	0	0	0	4
FAA	RLS	MIDLAND	TEX	1	0	0	0	0
FAA	RLS	BEAUMONT	TEX	0	0	0	0	0
FAA	RLS	DALLAS	TEX	0	0	0	1	1
FAA	RLS	SANANTON	TEX	0	0	0	2	0
FAA	RLS	HOUSTON	TEX	0	0	0	3	0
FAA	RLS	LONGVIEW	TEX	0	1	0	0	0
FAA	RLS	HOUSTON	TEX	0	2	2	1	0
FAA	RLS	WACO	TEX	0	0	0	0	0
N	RL	DALLAS	TEX	0	0	0	1	1
N	RL	CHASEFLD	TEX	0	0	0	0	0
N	RL	KINGSVLL	TEX	0	0	0	0	1
N	RLS	DALLAS	TEX	0	0	0	0	0
NSF	RLS	PALESTIN	TEX	0	0	0	0	0
AF	RL	KELLY	TEX	0	0	0	1	1
AR	RLS	FT HOOD	TEX	1	0	0	0	0
NG	LR	CLLGSTTN	TEX	0	0	0	0	0
AF	RLS	WENDOVER	UTAH	0	0	0	0	0
AR	MR	GREEN RV	UTAH	0	0	0	0	0
FAA	RLS	SALTL CY	UTAH	0	0	0	0	1
FAA	RLS	OGDEN	UTAH	0	0	0	0	1
AF	RLS	LANGLEY	VA	0	0	0	1	3
C	WXD	VOLENS	VA	0	0	0	0	0
FAA	RLS	CHANTLLY	VA	0	0	0	0	1
FAA	RLS	NORFOLK	VA	0	0	3	0	1
FAA	RLS	RICHMOND	VA	0	0	0	0	0
FAA	RLS	ROANOKE	VA	0	0	0	0	1
N	RL	OCEANA	VA	1	0	1	0	2
N	RL	NORFOLK	VA	0	0	1	1	2
N	RL	OCEANA	VA	1	0	1	0	2
NASA	LR	WALLOPSI	VA	0	0	0	0	0
NASA	WXD	BLCKSBRG	VA	0	0	0	0	1
AF	LR	MICAPEAK	WASH	0	0	0	1	4
AF	LR	MAKAH	WASH	0	0	0	0	0
AF	RLS	FAIRCHLD	WASH	1	1	1	0	1
AF	RLS	PAINEFLD	WASH	0	0	0	0	0
AF	RL	SPOKANE	WASH	1	0	2	0	2
FAA	RLS	MCCHORD	WASH	0	0	0	0	1
FAA	RLS	FAIRCHLD	WASH	1	1	1	0	1
FAA	RLS	SEATTLE	WASH	0	0	0	0	1
FAA	RLS	SPOKANE	WASH	1	2	0	0	2
FAA	RLS	KIONA	WASH	0	0	0	0	0
N	RL	WHIDBEYI	WASH	0	1	0	0	0
N	RL	WHIDBEYI	WASH	0	1	0	0	0
C	WXD	NEENAH	WIS	0	0	0	0	1
FAA	RLS	MADISON	WIS	0	0	0	0	0
FAA	RLS	GREENBAY	WIS	0	0	0	0	1
FAA	RLS	MILWAUKE	WIS	0	0	0	0	0
AF	RLS	VOLKFILD	WIS	0	0	0	0	0
FAA	RLS	CHARLSTN	WVA	0	0	0	0	0
FAA	RLS	HUNTNGTN	WVA	0	0	0	0	0
FAA	RLS	CASPER	WYO	0	0	0	0	0
AF	LR	LTTLAMRC	WYO	0	0	0	0	0

TABLE B-2

RADAR DISTANCE SEPARATIONS IN ORDER
BY GOVERNMENT AGENCY

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AF	RLS	MAXWELL	ALA	1	0	1	0	0
AF	RL	DNNLYFLD	ALA	0	0	2	0	0
AF	RLS	HAMILTON	ALA	0	0	0	0	0
AF	RLS	VAIDEN	ALA	0	0	0	0	1
AF	LR	PHOENIX	ARIZ	1	0	0	0	1
AF	RLS	LUKE	ARIZ	0	0	0	1	1
AF	RL	HOLBROOK	ARIZ	0	0	0	0	0
AF	RLS	WILLIAMS	ARIZ	0	0	0	0	1
AF	RLS	LUKE	ARIZ	0	0	0	1	3
AF	RLS	BLYTHVLL	ARK	0	0	0	0	0
AF	RLS	LITTLRCK	ARK	0	0	1	1	0
AF	LR	ALMADEN	CAL	0	0	0	0	1
AF	LR	CAMBRIA	CAL	0	0	0	0	0
AF	LR	PT ARENA	CAL	0	0	0	0	0
AF	LR	MTLAGUNA	CAL	0	0	0	0	0
AF	LR	KLAMATH	CAL	0	0	0	0	0
AF	RLS	CASTLE	CAL	0	0	0	0	0
AF	RLS	VANDNBRG	CAL	0	0	0	0	0
AF	RLS	BEALE	CAL	1	0	0	0	0
AF	LR	MILLVLLY	CAL	0	0	0	0	4
AF	RLS	TRAVIS	CAL	0	0	0	0	1
AF	RLS	HAYWARD	CAL	0	0	1	3	1
AF	RLS	CP PARKS	CAL	0	0	0	1	4
AF	RLS	GEORGE	CAL	0	0	0	0	1
AF	LR	PASORBLS	CAL	0	0	0	0	0
AF	LR	SNPDRHLL	CAL	1	0	0	3	1
AF	RLS	MARCH	CAL	0	0	0	1	2
AF	RLS	MATHER	CAL	0	0	1	1	0
AF	RL	NORTON	CAL	0	0	0	2	1
AF	RL	LA JUNTA	COLO	0	0	0	0	0
AF	RLS	BUCKLEY	COLO	1	0	2	0	0
AF	RLS	BUCKLEY	COLO	1	0	2	0	0
AF	LR	GREELEY	COLO	0	0	0	0	0
AF	RLS	DOVER	DEL	1	0	0	0	0
AF	RLS	DOVER	DEL	1	0	0	0	0
AF	LR	TYNDALL	FLA	1	3	0	0	1
AF	RLS	HOMESTED	FLA	0	0	1	0	2
AF	LR	JCKSNVLL	FLA	1	0	0	3	1
AF	LR	FTWLTNBC	FLA	0	0	3	1	0
AF	LR	CSANBLAS	FLA	0	0	0	0	3
AF	LR	EGLIN	FLA	2	0	1	1	0
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	RLS	EGLIN	FLA	2	0	1	1	0
AF	RLS	HURLBURT	FLA	0	0	1	3	0
AF	RLS	MACDILL	FLA	0	1	0	1	1
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	LR	MACDILL	FLA	0	1	1	0	1
AF	RLS	TYNDALL	FLA	2	2	0	0	0
AF	RLS	PATRICK	FLA	3	0	0	0	2
AF	MR	CCANAVRL	FLA	1	0	0	0	4
AF	LR	AVON PK	FLA	1	0	0	0	0
AF	RLS	TYNDALL	FLA	1	3	0	0	0
AF	LR	DUETTE	FLA	0	0	0	0	3
AF	LR	CROSS CY	FLA	0	0	0	0	0
AF	LR	AVON PK	FLA	1	0	0	0	0
AF	MOB	EGLIN	FLA	2	0	1	1	0
AF	LR	CCANAVRL	FLA	1	0	0	0	4
AF	MR	TYNDALL	FLA	1	3	0	0	1
AF	RL	MACON	GA	0	4	3	0	0
AF	LR	STATESBR	GA	0	0	0	0	0
AF	RLS	DOBBINS	GA	1	0	0	0	1

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AF	RLS	SMARTFLD	GA	2	0	1	4	0
AF	RLS	ROBINS	GA	3	1	0	3	0
AF	RLS	SMARTFLD	GA	2	0	1	4	0
AF	RLS	ROBINS	GA	3	1	0	3	0
AF	RLS	DOBBINS	GA	1	0	0	1	1
AF	RLS	SMARTFLD	GA	2	0	1	4	0
AF	RLS	ROBINS	GA	3	1	0	3	0
AF	RL	WILDER	IDA	1	0	0	0	0
AF	RLS	MTN HOME	IDA	1	0	0	0	0
AF	LR	WILDER	IDA	1	0	0	0	0
AF	RLS	MTN HOME	IDA	1	0	0	0	0
AF	RL	COERDALN	IDA	0	0	0	2	2
AF	RLS	SCOTT	ILL	2	0	0	0	0
AF	RLS	SCOTT	ILL	2	0	0	0	0
AF	RLS	SCOTT	ILL	2	0	0	0	0
AF	RLS	GRISSOM	INDA	1	0	0	0	0
AF	RLS	FT WAYNE	INDA	0	0	1	0	0
AF	LR	GRISSOM	INDA	1	0	0	0	0
AF	RLS	MCCONNLL	KANS	0	0	2	0	0
AF	RL	RICHMOND	KY	0	0	0	0	0
AF	LR	SLIDELL	LA	0	0	1	0	0
AF	LR	LCHARLES	LA	0	1	0	0	0
AF	LR	BARKSDAL	LA	1	0	0	0	0
AF	RLS	ENGLAND	LA	1	0	0	0	0
AF	RLS	ENGLAND	LA	1	0	0	0	0
AF	RLS	HAMMOND	LA	0	0	0	0	0
AF	LR	NO TRURO	MASS	0	0	0	0	1
AF	RLS	FT MEADE	MD	0	0	1	0	2
AF	LR	BCKSHRBR	ME	0	0	0	0	0
AF	LR	CASWELL	ME	0	1	0	0	0
AF	RLS	LORING	ME	0	1	0	0	0
AF	LR	ASHLAND	ME	0	0	0	0	0
AF	RLS	WURTSMTH	MICH	0	0	0	0	0
AF	RL	BAYSHORE	MICH	0	0	0	0	0
AF	RLS	KISAWYER	MICH	0	0	0	0	0
AF	RLS	SELFRIDG	MICH	0	0	0	0	1
AF	LR	EMPIRE	MICH	0	0	0	0	1
AF	RLS	ALPENA	MICH	0	0	0	0	0
AF	RLS	DULUTH	MINN	1	0	0	0	0
AF	RLS	ANOKA	MINN	0	0	0	0	2
AF	RL	KEESLER	MISS	2	0	1	0	2
AF	RL	KEESLER	MISS	2	0	1	0	2
AF	RL	KEESLER	MISS	1	0	0	0	4
AF	RL	KEESLER	MISS	1	0	0	0	4
AF	RL	COLUMBUS	MISS	0	1	0	0	0
AF	RLS	KEESLER	MISS	2	0	1	0	4
AF	RLS	COLUMBUS	MISS	1	0	0	0	0
AF	RLS	KEYFIELD	MISS	0	0	0	0	1
AF	RL	SMRTTFLD	MO	0	0	0	1	1
AF	LR	KALISPLL	MONT	0	0	0	0	0
AF	LR	MALMSTRM	MONT	1	0	0	0	0
AF	RL	DAGMAR	MONT	0	0	0	0	0
AF	LR	FTFISHER	NC	0	0	0	0	2
AF	RLS	POPE	NC	1	0	0	0	1
AF	RLS	POPE	NC	1	0	0	0	1
AF	RLS	SYMJHNSN	NC	0	0	0	0	0
AF	LR	FINLEY	NDAK	0	0	0	0	0
AF	RLS	MINOT	NDAK	0	0	0	0	0
AF	RLS	GR FORKS	NDAK	0	0	0	0	0
AF	RL	BISMARCK	NDAK	0	0	0	0	0
AF	LR	WATFRDCY	NDAK	0	0	0	0	0
AF	RL	HASTINGS	NEBR	0	0	0	0	0
AF	LR	HAWTHORN	NEV	0	0	0	0	0
AF	RL	TONPHRNG	NEV	0	0	0	0	0
AF	RL	NELLIS	NEV	2	0	0	1	0
AF	RL	CALIENTE	NEV	0	0	0	0	1

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
AF	RLS	NELLIS	NEV	2	0	0	1	0
AF	RLS	CALIENTE	NEV	0	0	0	0	1
AF	RLS	TONPHRNG	NEV	0	0	0	0	0
AF	RLS	NELLIS	NEV	2	0	0	1	0
AF	RLS	PEASE	NH	1	0	0	0	0
AF	RL	PEASE	NH	1	0	0	0	0
AF	RLS	MCGUIRE	NJ	1	0	0	1	1
AF	RLS	MCGUIRE	NJ	1	0	0	1	1
AF	RLS	HOLLOMAN	NMEX	1	0	0	0	2
AF	LR	SILVERCY	NMEX	0	0	0	0	0
AF	RLS	CANNON	NMEX	1	0	0	0	0
AF	RLS	KIRTLAND	NMEX	1	0	0	0	0
AF	RLS	HOLLOMAN	NMEX	1	0	0	0	2
AF	RLS	CANNON	NMEX	1	0	0	0	0
AF	LR	MONTAUK	NY	0	0	0	0	0
AF	RL	PLTTSBRG	NY	1	0	0	0	1
AF	RL	WATERTWN	NY	0	0	0	0	0
AF	RLS	PLTTSBRG	NY	1	0	0	0	1
AF	LR	VERONA	NY	0	0	0	1	2
AF	LR	UTICA	NY	0	0	0	1	1
AI	RL	RCKNBCKR	OHIO	0	0	0	2	0
AF	RL	MXWSHMRF	OKLA	3	0	0	1	5
AF	RL	ADA	OKLA	1	0	0	0	0
AF	RL	TINKER	OKLA	0	0	0	8	1
AF	RL	KEGELMAN	OKLA	1	0	0	0	2
AF	RL	ALTUS	OKLA	1	0	0	0	1
AF	RLS	KEGELMAN	OKLA	1	0	0	0	0
AF	RLS	ADA	OKLA	0	1	0	0	0
AF	RLS	NORMAN	OKLA	3	0	0	5	1
AF	RLS	VANCE	OKLA	1	0	0	0	0
AF	RLS	VANCE	OKLA	1	0	0	0	0
AF	RLS	ALTUS	OKLA	1	0	0	0	1
AF	RLS	FREDERCK	OKLA	0	0	0	0	2
AF	RLS	WLRGRSFD	OKLA	3	0	0	6	0
AF	LR	MT HEBO	OREG	0	0	0	0	1
AF	LR	DALLAS	OREG	0	0	0	0	1
AF	LR	NOCHRLSN	SC	2	0	0	0	1
AF	RLS	SHAW	SC	1	0	0	0	1
AF	RLS	SHAW	SC	1	0	0	0	1
AF	LR	JEDBURG	SC	0	0	0	0	3
AF	RLS	MCENTIRE	SC	0	0	0	0	3
AF	RLS	MYRTLBCH	SC	0	0	0	0	0
AF	RLS	ELLSWRTH	SDAK	2	0	0	0	0
AF	RLS	ELLSWRTH	SDAK	2	0	0	0	0
AF	RLS	ELLSWRTH	SDAK	2	0	0	0	0
AF	LR	ELLINGTN	TEX	1	0	1	1	1
AF	LR	OILTON	TEX	0	0	0	0	0
AF	LR	ODESSA	TEX	0	0	0	0	0
AF	LR	EL PASO	TEX	0	0	0	1	1
AF	RLA	LAUGHLIN	TEX	0	0	0	0	0
AF	RLS	RANDOLPH	TEX	0	0	0	1	1
AF	RLS	CARSWELL	TEX	1	0	0	0	1
AF	RLS	SHEPPARD	TEX	1	0	0	0	0
AF	RLS	CARSWELL	TEX	1	0	0	0	1
AF	RLS	REESE	TEX	0	0	0	1	0
AF	RLS	SHEPPARD	TEX	1	0	0	0	0
AF	RL	ELLINGTN	TEX	1	0	1	1	1
AF	RL	KELLY	TEX	0	0	0	1	1
AF	RLS	WENDOVER	UTAH	0	0	0	0	0
AF	RLS	LANGLEY	VA	0	0	0	1	3
AF	LR	MICAPEAK	WASH	0	0	0	1	4
AF	LR	MAKAH	WASH	0	0	0	0	0
AF	RLS	FAIRCHLD	WASH	1	1	1	0	1
AF	RLS	PAINEFLD	WASH	0	0	0	0	0
AF	RL	SPOKANE	WASH	1	0	2	0	2
AF	RLS	VOLKFILD	WIS	0	0	0	0	0
AF	LR	LTTLAMRC	WYO	0	0	0	0	0

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
C	WXD	CENTRVLL	ALA	0	0	0	0	1
C	WXD	LITTLRCK	ARK	0	0	2	0	0
C	WXD	SACRAMNT	CAL	0	0	1	1	0
C	WXD	LIMON	COLO	0	0	0	0	0
C	WXD	DAYTNBCH	FLA	1	0	0	0	0
C	WXD	KEY W	FLA	1	0	1	0	0
C	WXD	PENSACOL	FLA	0	0	0	2	0
C	WXD	APALCHCL	FLA	0	0	0	0	1
C	WXD	TAMPA	FLA	0	0	0	2	2
C	WXD	MIAMI	FLA	0	0	1	1	2
C	WXD	WPALMBCH	FLA	1	0	0	0	0
C	WXD	WAYCROSS	GA	0	0	0	0	0
C	WXD	ATHENS	GA	0	0	0	0	0
C	WXD	MARSELLS	ILL	0	0	0	0	0
C	WXD	EVANSVLL	INDA	1	0	0	0	0
C	WXD	DESMOINS	IOWA	1	0	0	0	0
C	WXD	WICHITA	KANS	1	0	1	0	0
C	WXD	GARDENCY	KANS	0	0	0	0	0
C	WXD	JACKSON	KY	0	0	0	0	0
C	WXD	LCHARLES	LA	0	2	0	0	0
C	WXD	SLIDELL	LA	0	0	1	0	0
C	WXD	BOSTON	MASS	0	1	0	0	1
C	WXD	WORCESTR	MASS	0	0	0	0	0
C	WXD	CHATHAM	MASS	0	0	0	0	2
C	WXD	LXNGTNPK	MD	1	0	0	0	0
C	WXD	BRUNSWCK	ME	0	1	0	0	1
C	WXD	DETROIT	MICH	0	0	0	0	2
C	WXD	MINNEPLS	MINN	1	0	0	0	1
C	WXD	JACKSON	MISS	1	0	0	0	0
C	WXD	MONETT	MO	0	0	0	0	0
C	WXD	STCHARLS	MO	0	0	0	2	0
C	WXD	MISSOULA	MONT	0	0	0	0	0
C	WXD	CHATTERS	NC	0	0	0	0	1
C	WXD	RALEIGH	NC	1	0	0	0	0
C	WXD	WILMNGTN	NC	0	0	1	0	1
C	WXD	FARGO	NDAK	1	0	0	0	0
C	WXD	GR I	NEBR	0	0	0	0	1
C	WXD	ALLIANCE	NEBR	0	0	0	0	0
C	WXD	BUFFALO	NY	1	0	0	0	0
C	WXD	NY CY	NY	0	0	0	2	1
C	WXD	BINGHMTN	NY	1	0	0	0	0
C	WXD	CINCINNT	OHIO	1	0	0	0	0
C	WXD	CLEVELND	OHIO	0	0	0	1	0
C	WXD	COLUMBUS	OHIO	1	0	0	1	0
C	WXD	OKLA CY	OKLA	3	0	0	6	0
C	WXD	OKLA CY	OKLA	0	0	4	5	0
C	WXD	NORMAN	OKLA	3	0	0	0	4
C	WXD	NORMAN	OKLA	3	0	0	1	5
C	WXD	ANADARKO	OKLA	0	0	0	0	1
C	WXD	MEDFORD	OREG	0	0	0	0	0
C	WXD	CORAOPLS	PA	0	1	0	0	0
C	WXD	CHARLSTN	SC	2	0	0	0	1
C	WXD	HURON	SDAK	0	0	0	0	0
C	WXD	MILLNGTN	TENN	2	0	0	0	2
C	WXD	OLDHCKRY	TENN	0	0	0	1	0
C	WXD	MTHOLSTN	TENN	0	0	0	0	1
C	WXD	AMARILLO	TEX	1	0	0	0	0
C	WXD	BRWNSVLL	TEX	0	0	0	0	0
C	WXD	GALVESTN	TEX	0	0	0	0	2
C	WXD	MIDLAND	TEX	1	0	0	0	0
C	WXD	HONDO	TEX	0	0	0	0	0
C	WXD	VICTORIA	TEX	0	0	0	0	0
C	WXD	STPHNVLL	TEX	0	0	0	0	0
C	WXD	LONGVIEW	TEX	0	1	0	0	0
C	WXD	VOLENS	VA	0	0	0	0	0
C	WXD	NEENAH	WIS	0	0	0	0	1

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
FAA	RLS	MONTGMRY	ALA	1	0	0	0	1
FAA	RL	BIRMNGHM	ALA	0	0	0	0	0
FAA	RLS	MOBILE	ALA	0	0	0	0	0
FAA	RLS	HUNTSVLL	ALA	0	0	0	0	0
FAA	RLS	TUCSON	ARIZ	0	0	0	0	0
FAA	RLS	HMBDTMTN	ARIZ	1	0	0	0	1
FAA	RLS	PHOENIX	ARIZ	0	0	0	0	3
FAA	RLS	LITTLRCK	ARK	0	0	1	1	0
FAA	RLS	FT SMITH	ARK	0	0	0	0	0
FAA	RLS	SACRAMNT	CAL	0	0	2	0	0
FAA	RL	MARYSVLL	CAL	1	0	0	0	0
FAA	RLS	MIRAMAR	CAL	0	0	0	2	1
FAA	RLS	LONGBECH	CAL	0	0	1	2	3
FAA	RLS	PALM SPR	CAL	0	0	0	0	0
FAA	RLS	OAKLAND	CAL	0	0	3	0	4
FAA	RLS	MTN VIEW	CAL	0	0	0	0	4
FAA	LR	LOSANGLS	CAL	1	0	0	3	1
FAA	RLS	MONTEREY	CAL	0	0	0	0	0
FAA	RLS	LOSANGLS	CAL	1	0	0	2	2
FAA	RLS	EL TORO	CAL	0	0	0	0	3
FAA	RLS	ONTARIO	CAL	0	0	0	0	4
FAA	RLS	BURBANK	CAL	0	0	0	1	3
FAA	RLS	FRESNO	CAL	0	0	0	0	0
FAA	RLS	EDWARDS	CAL	0	2	0	0	3
FAA	RLS	SANTBRBR	CAL	0	0	0	0	0
FAA	RLS	PNMTVLLY	CAL	0	0	0	0	1
FAA	RLS	OWNSVLLY	CAL	0	0	0	0	0
FAA	RLS	SRLSVLLY	CAL	0	0	0	0	4
FAA	RLS	INDWLSVL	CAL	0	0	2	0	1
FAA	RLS	VELVETPK	CAL	0	0	0	0	1
FAA	RLS	LOSANGLS	CAL	1	0	2	2	5
FAA	RLS	FRMTVLLY	CAL	0	0	0	0	1
FAA	RLS	BAKRSFLD	CAL	0	0	0	0	0
FAA	RLS	STOCKTON	CAL	0	0	0	0	0
FAA	RLS	COLO SPR	COLO	0	0	0	0	0
FAA	RLS	DENVER	COLO	1	0	2	0	1
FAA	RLS	WNDSRLKS	CONN	0	0	0	0	0
FAA	RLS	WASH	DC	0	0	1	0	3
FAA	RLS	MIAMI	FLA	0	0	1	1	2
FAA	RLS	PENSACOL	FLA	1	0	0	1	2
FAA	RLS	JCKSNVLL	FLA	0	0	1	0	4
FAA	RLS	ORLANDO	FLA	0	0	0	0	0
FAA	RLS	PALMBECH	FLA	1	0	0	0	0
FAA	RLS	FTLADRDL	FLA	0	0	0	0	2
FAA	RLS	TALLAHSS	FLA	0	0	0	0	0
FAA	RLS	DAYTNBCH	FLA	1	0	0	0	0
FAA	RLS	SARASOTA	FLA	0	0	0	0	1
FAA	RLS	PENSACOL	FLA	1	0	0	1	2
FAA	LR	TYNDALL	FLA	1	3	0	0	0
FAA	LR	MIAMI	FLA	0	0	1	2	0
FAA	LR	PATRICK	FLA	3	0	0	0	2
FAA	LR	KEY W	FLA	1	0	1	0	0
FAA	RL	ATLANTA	GA	0	0	0	0	2
FAA	RLS	MACON	GA	3	1	0	3	0
FAA	RLS	SAVANNAH	GA	0	0	1	0	0
FAA	RLS	COLUMBUS	GA	0	0	0	0	0
FAA	RLS	AUGUSTA	GA	0	0	0	0	0
FAA	RLS	SAVANNAH	GA	0	0	1	0	0
FAA	RLS	BOISE	IDA	0	0	0	0	0
FAA	RLS	CHICAGO	ILL	0	0	0	0	1
FAA	RLS	CHICAGO	ILL	0	0	1	0	1
FAA	RLS	SPRNGFLD	ILL	0	0	0	0	0
FAA	RLS	PEORIA	ILL	0	0	0	0	0
FAA	RLS	MOLINE	ILL	0	0	0	0	0
FAA	RLS	CHAMPAGN	ILL	0	0	0	0	0
FAA	RLS	ROCKFORD	ILL	0	0	0	0	0
FAA	RLS	FT WAYNE	INDA	0	0	1	0	0

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
FAA	RLS	SO BEND	INDA	0	0	0	0	0
FAA	RLS	EVANSVLL	INDA	1	0	0	0	0
FAA	RLS	INDINPLS	INDA	0	0	0	0	0
FAA	RLS	TERREHAT	INDA	0	0	0	0	0
FAA	RLS	DESMOINS	IOWA	1	0	0	0	0
FAA	RLS	CEDRRPDS	IOWA	0	0	0	0	0
FAA	RLS	SIOUX CY	IOWA	0	0	0	0	0
FAA	RLS	WATERLOO	IOWA	0	0	0	0	0
FAA	RLS	COVINGTN	KY	2	0	0	0	0
FAA	RLS	LOUISVLL	KY	0	0	0	0	0
FAA	RLS	SHREVPRT	LA	1	0	0	0	0
FAA	RLS	BATUNROG	LA	0	0	0	0	0
FAA	RLS	NORLEANS	LA	0	0	0	0	1
FAA	RLS	LCHARLES	LA	0	1	1	0	0
FAA	RLS	MONROE	LA	0	0	0	0	0
FAA	RLS	LAFAYETT	LA	0	0	0	0	0
FAA	RLS	FALMOUTH	MASS	0	0	0	0	1
FAA	RLS	BOSTON	MASS	0	1	0	1	1
FAA	RLS	BALTIMOR	MD	0	0	1	0	2
FAA	RLS	CP SPR	MD	0	0	1	0	2
FAA	RLS	PORTLAND	ME	0	0	0	0	2
FAA	RLS	BANGOR	ME	0	0	0	0	0
FAA	RLS	GRRAPIDS	MICH	0	0	0	0	0
FAA	RLS	FLINT	MICH	0	0	0	0	0
FAA	RLS	LANSING	MICH	0	0	0	0	0
FAA	RLS	SAGINAW	MICH	0	0	0	0	0
FAA	RLS	DETROIT	MICH	0	0	0	0	1
FAA	RLS	MUSKEGON	MICH	0	0	0	0	0
FAA	RLS	KALAMAZO	MICH	0	0	0	0	0
FAA	RLS	ROCHESTR	MINN	0	0	0	0	0
FAA	RLS	DULUTH	MINN	1	0	0	0	0
FAA	RLS	MINNEPLS	MINN	1	0	0	0	1
FAA	RLS	JACKSON	MISS	1	0	0	0	0
FAA	RLS	MERIDIAN	MISS	0	0	0	0	1
FAA	RLS	GULFPORT	MISS	0	1	0	3	0
FAA	RLS	KANS CY	MO	0	0	0	0	0
FAA	RLS	ST LOUIS	MO	0	0	0	1	1
FAA	RLS	SPRNGFLD	MO	0	0	0	0	0
FAA	RLS	BILLINGS	MONT	0	0	0	0	0
FAA	RLS	GT FALLS	MONT	1	0	0	0	0
FAA	RLS	CHARLOTT	NC	0	0	0	0	0
FAA	RLS	GREENSBR	NC	0	0	0	0	0
FAA	RLS	RALEIGH	NC	1	0	0	0	0
FAA	RLS	FAYTTVLL	NC	0	0	0	0	2
FAA	RLS	ASHEVILL	NC	0	0	0	0	0
FAA	RLS	WILMNGTN	NC	0	0	1	0	1
FAA	RLS	FARGO	NDAK	1	0	0	0	0
FAA	RLS	OMAHA	NEBR	0	0	0	0	0
FAA	RLS	LINCOLN	NEBR	0	0	0	0	0
FAA	RLS	LASVEGAS	NEV	0	0	0	3	0
FAA	RLS	RENO	NEV	0	0	0	0	0
FAA	RLS	MANCHSTR	NH	0	0	0	0	0
FAA	RLS	ATLNTCCY	NJ	3	0	0	0	0
FAA	RLS	ATLNTCCY	NJ	3	0	0	0	0
FAA	RLS	NEWARK	NJ	0	0	0	1	1
FAA	RL	ATLNTCCY	NJ	3	0	0	0	0
FAA	RL	ATLNTCCY	NJ	3	0	0	0	0
FAA	RLS	CLMNTN	NJ	0	0	0	0	4
FAA	RLS	ALBUQURQ	NMEX	1	0	0	0	0
FAA	RLS	SYRACUSE	NY	0	0	0	0	1
FAA	RLS	WHITPLNS	NY	0	0	0	0	2
FAA	RLS	BUFFALO	NY	1	0	0	0	0
FAA	RLS	ROME	NY	0	0	0	2	0
FAA	RLS	ALBANY	NY	0	0	0	0	0
FAA	RLS	BINGHMTN	NY	1	0	0	0	0
FAA	RLS	ROCHESTR	NY	0	0	0	0	0
FAA	RLS	JAMAICA	NY	0	0	0	0	3

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
FAA	RLS	ELMIRA	NY	0	0	0	0	0
FAA	RLS	ISLIP	NY	0	0	0	0	0
FAA	RLS	AKRON	OHIO	0	0	0	0	0
FAA	RLS	TOLEDO	OHIO	0	0	0	0	0
FAA	RLS	CLEVELND	OHIO	0	0	0	0	0
FAA	RLS	COLUMBUS	OHIO	0	0	0	1	0
FAA	RLS	YONGSTWN	OHIO	1	0	0	1	0
FAA	RLS	DAYTON	OHIO	0	0	0	0	0
FAA	RLS	TULSA	OKLA	0	0	0	0	0
FAA	RLS	OKLA CY	OKLA	0	0	0	0	0
FAA	RLS	OKLA CY	OKLA	3	0	0	6	0
FAA	RLS	PORTLAND	OREG	3	0	0	6	0
FAA	RLS	WILKSBRR	PA	0	0	0	0	0
FAA	RLS	HARRSBRG	PA	0	0	0	0	0
FAA	RLS	PHILDLPH	PA	0	0	0	0	0
FAA	RLS	ERIE	PA	0	0	0	0	2
FAA	RLS	ALLENTWN	PA	0	0	0	0	0
FAA	RLS	PTTSBRGH	PA	0	0	0	0	0
FAA	RLS	READING	PA	0	1	0	0	0
FAA	RLS	QUONSTPT	RI	0	0	0	0	0
FAA	RLS	GREENVLL	SC	0	0	0	0	0
FAA	RLS	CHARLSTN	SC	0	0	0	0	0
FAA	RLS	COLUMBIA	SC	2	0	0	0	1
FAA	RLS	SIOXFLLS	SDAK	0	0	0	0	1
FAA	RLS	MEMPHIS	TENN	0	0	0	0	0
FAA	RLS	KNOXVILL	TENN	0	0	1	0	3
FAA	RLS	CHATTANG	TENN	0	0	0	0	0
FAA	RLS	BRISTOL	TENN	0	0	0	0	0
FAA	RLS	NASHVILL	TENN	0	0	0	0	1
FAA	RLS	CRPSCHRS	TEX	0	0	0	1	0
FAA	RLS	EL PASO	TEX	0	0	0	0	1
FAA	RLS	EL PASO	TEX	0	0	0	1	1
FAA	RL	AMARILLO	TEX	0	0	0	1	1
FAA	RL	LUBBOCK	TEX	1	0	0	0	0
FAA	RLS	AUSTIN	TEX	0	0	0	1	0
FAA	RLS	ABILENE	TEX	0	0	0	0	0
FAA	RLS	COLLYVLL	TEX	0	0	0	0	0
FAA	RLS	MIDLAND	TEX	0	0	0	0	4
FAA	RLS	BEAUMONT	TEX	1	0	0	0	0
FAA	RLS	DALLAS	TEX	0	0	0	0	0
FAA	RLS	SANANTON	TEX	0	0	0	1	1
FAA	RLS	HOUSTON	TEX	0	0	0	2	0
FAA	RLS	LONGVIEW	TEX	0	0	0	3	0
FAA	RLS	HOUSTON	TEX	0	1	0	0	0
FAA	RLS	WACO	TEX	0	2	2	1	0
FAA	RLS	SALTL CY	UTAH	0	0	0	0	0
FAA	RLS	OGDEN	UTAH	0	0	0	0	1
FAA	RLS	CHANTLLY	VA	0	0	0	0	1
FAA	RLS	NORFOLK	VA	0	0	0	0	1
FAA	RLS	RICHMOND	VA	0	0	3	0	1
FAA	RLS	ROANOKE	VA	0	0	0	0	0
FAA	RLS	MCCHORD	WASH	0	0	0	0	1
FAA	RLS	FAIRCHLD	WASH	0	0	0	0	1
FAA	RLS	SEATTLE	WASH	1	1	1	0	1
FAA	RLS	SPOKANE	WASH	0	0	0	0	1
FAA	RLS	KIONA	WASH	1	2	0	0	2
FAA	RLS	MADISON	WIS	0	0	0	0	0
FAA	RLS	GREENBAY	WIS	0	0	0	0	0
FAA	RLS	MILWAUKE	WIS	0	0	0	0	1
FAA	RLS	CHARLSTN	WVA	0	0	0	0	0
FAA	RLS	HUNTNGTN	WVA	0	0	0	0	0
FAA	RLS	CASPER	WYO	0	0	0	0	0

TABLE B-2 (Continued)

AGENCY	STATION CLASS	CITY	STATE	SEPARATION DISTANCE 0-2	2-5	5-10	10-15	15-30
N	RL	YUMA	ARIZ	0	0	0	0	0
N	RL	ALAMEDA	CAL	0	0	1	1	3
N	MR	CHINA L	CAL	0	0	2	0	1
N	RL	LEMOORE	CAL	0	0	0	0	0
N	RLS	NO I	CAL	0	0	0	2	0
N	RLS	PT MUGU	CAL	0	1	0	0	0
N	RL	IMPRLBCH	CAL	0	0	0	1	1
N	RLS	SNCLMNTI	CAL	0	0	0	0	0
N	RLTM	MARE I	CAL	0	0	0	0	5
N	LR	SANTCRZI	CAL	0	0	0	0	0
N	LR	LAGUNAPK	CAL	0	1	0	0	0
N	LR	SANNCLSI	CAL	0	0	0	0	0
N	RL	KEY W	FLA	0	0	2	0	0
N	RL	JCKSNVLL	FLA	1	0	0	2	2
N	RLS	PENSACOL	FLA	0	0	0	0	0
N	RL	WHTNGFLD	FLA	0	0	0	0	2
N	RLS	MAYPORT	FLA	0	0	1	2	2
N	RL	JCKSNVLL	FLA	1	0	0	3	1
N	RLS	GLENVIEW	ILL	0	0	1	0	0
N	RLS	NORLEANS	LA	0	0	0	0	1
N	RL	SOWEYMTH	MASS	0	0	0	1	1
N	RLS	PATXNTRV	MD	1	0	0	0	0
N	RL	BRUNSWCK	ME	0	1	0	0	1
N	RLS	CHERRYPT	NC	0	0	0	0	0
N	RLS	N RV	NC	1	0	0	0	0
N	RL	N RV	NC	1	0	0	0	0
N	RL	FALLON	NEV	0	0	0	0	0
N	RL	LAKEHRST	NJ	0	0	0	2	0
N	RL	WILLWGRV	PA	0	0	0	0	1
N	RLS	BEAUFORT	SC	0	0	0	0	0
N	RL	MEMPHIS	TENN	0	0	1	0	3
N	RLS	MILLNGTN	TENN	2	0	0	0	2
N	RLS	MILLNGTN	TENN	2	0	0	0	2
N	RL	DALLAS	TEX	0	0	0	1	1
N	RL	CHASEFLD	TEX	0	0	0	0	0
N	RL	KINGSVLL	TEX	0	0	0	0	1
N	RLS	DALLAS	TEX	0	0	0	0	0
N	RL	OCEANA	VA	1	0	1	0	2
N	RL	NORFOLK	VA	0	0	1	1	2
N	RL	OCEANA	VA	1	0	1	0	2
N	RL	WHIDBEYI	WASH	0	1	0	0	0
N	RL	WHIDBEYI	WASH	0	1	0	0	0

TABLE B-3

ABBREVIATIONS

AGENCY	ABBREVIATION
Air Force	AF
Army	AR
Department of Commerce	C
Federal Aviation Administration	FAA
Navy (Includes Marine Corps)	N
National Aeronautics and Space Administration	NASA
National Science Foundation	NSF

STATION CLASS	ABBREVIATION
Radiolocation Land Station	LR
Radio Beacon Mobile Station	MOB
Radiolocation Mobile Station	MR
Radionavigation Land Station	RL
Surveillance Radar Station	RLS
Meteorological Radar Station	WXD

APPENDIX C

PROPOSED RSEC

INTRODUCTION

This appendix contains the proposed Radar Spectrum Engineering Criteria (RSEC) developed by the TSC Working Group 1 for fixed radars in the 2700-2900 MHz band. The proposed RSEC will enhance the accomodation of new systems in designated heavily used areas and for collocated operations.

PROPOSED RSEC FOR FIXED RADARS
IN 2700-2900 MHz BAND

1. Effective Dates

Technical criteria for new fixed radars in the 2700-2900 MHz band shall become effective on 1 October 1982. (New radars are those for which the initial system procurement contract is let after 1 October 1982.)

2. Applicability

These criteria are applicable to fixed radars in the 2700-2900 MHz band. All radars subject to these criteria shall be designed and constructed to meet the basic minimum electromagnetic compatibility (EMC) requirements stated herein. In addition to the basic minimum EMC requirements, radar systems in the 2700-2900 MHz band which are intended to operate in close proximity to other equipment in the band or operate in areas specified in Annex D shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of EMC enhancement provisions. These additional provisions will improve the electromagnetic compatibility of the radar thus improving the accommodation of the radar system in the band. These provisions are stated in paragraph 9.

3. Radar Emission Bandwidth

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

3.1 For non-FM pulse radars (including spread spectrum or coded pulse radars):

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}}$$

For non-FM pulse radars, a pulse rise time of less than 0.1t shall be justified.

3.2 For FM-pulse radars (intentional FM):

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2B_c$$

For FM pulse radars with pulse rise time of less than 0.1 microseconds, a justification for the short rise time shall be provided.

3.3 For Frequency hopping radars[7]:

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2B_c + B_s$$

For frequency hopping radars with pulse compression, but with pulse rise time of less than 0.1 microseconds, a justification for the short rise time shall be provided.

For frequency hopping radars without pulse compression, but with pulse rise time of less than 0.01 microseconds, an operational justification for the short rise time shall be provided.

3.4 For CW radars:

$$B(-40dB) = 0.0003\ F_o$$

3.5 For FM/CW radars:

$$B(-40dB) = 0.0003\ F_o + 2B_d$$

4. Emission Levels

The radar emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequency $\pm$ B(-40 dB)/2 displaced from F_o the level shall be at least 40 dB below the maximum value. Beyond the frequencies $\pm$ B(-40 dB)/2 from F_o, the emission level (s) shall be below the 40 dB per decade (S=40) roll-off lines of Figure 2 down to a -X dB level that is 80 dB below the maximum spectral power density.

5. Antenna Pattern

Since electromagnetic compatibility considerations involved phenomena which many occur at any angle, the allowable antenna patterns for many radars may be usefully described by "median gain" relative to an isotropic antenna[8]. Antennas operated by their rotation through 360 degrees of

NOTE

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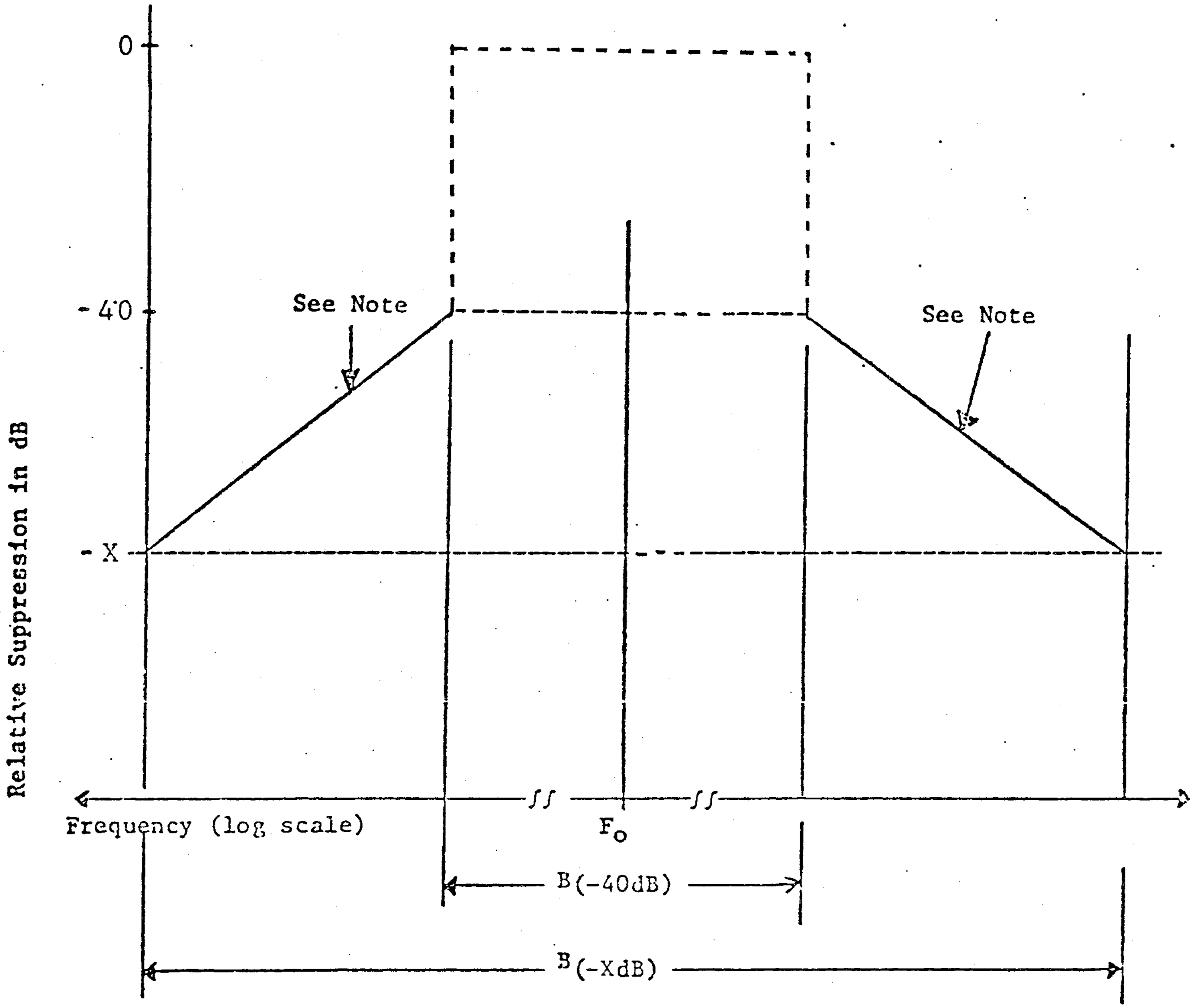
7) These formulas yield the total composite B(-40 dB) bandwidth of a frequency hopping radar as if all channels included within B_s were operating simultaneously. Individual channels will have a B(-40 dB) radar emission bandwidth given by 3.1 or 3.2 above. For frequency hopping radars, the radar spectrum shall not intrude into adjacent spectrum regions on the high or low side of the band, defined by B_s, more than would occur if the radar were fixed tuned at carrier frequencies equivalent to the end values of B_s and was complying with the constraints of 3.1 and 3.2 above.

8) Median gain is defined as that level over an angular region at which the probability is 50% that the observed or measured gain at any position of the antenna will be less than or equal to that level.

Figure 2. Radar Emission Bandwidth and Emission Levels



NOTE: The roll-off slope, S, from the -40 dB to -X dB points is at 20 dB per decade for Criteria B and C, and 40 to 80 dB per decade for Criteria D. The maximum emission spectrum level between the -40 dB and -X dB points for S dB per decade slope is described by the formula:

$$\text{Suppression (dB)} = -S \cdot \log \left| \frac{F - F_o}{\frac{1}{2}B(-40dB)} \right| - 40$$

where: $\frac{1}{2}B(-40dB) \leq \left| F - F_o \right| \leq \frac{1}{2}B(-XdB)$

and: $B(-XdB) = (10^a)\, B(-40dB)$

$$a = \frac{X-40}{S}$$

the horizontal plane shall have a "median gain" of -10 dB or less, as measured on an antenna test range, in the principal horizontal plane. For other antennas, suppression of lobes other than the main antenna beam shall be provided to the following levels, referred to the main beam:

first three sidelobes - 17 dB;

all other lobes - 26 dB.

6. Frequency Tolerance

Radar transmitters shall meet a frequency tolerance no greater than 800 parts/million.

7. Radar Tunability

Radar systems shall be tunable over the entire 2700-2900 MHz band.

8. Radar Receiver

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 2. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver image rejection shall be at least 50 dB; rejection of other spurious responses shall be at least 60 dB. Radar receivers shall not exhibit any local oscillator radiation greater than -40 dBm at the antenna input terminals. Frequency stability of receivers shall be commensurate with, or better than, that of the associated transmitters.

9. Additional EMC Provisions

To improve the accommodation of radar systems in the 2700-2900 MHz band which operate in close proximity to other equipment in the band or operate in areas specified in Annex D, the radar shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of system EMC provisions. These provisions include the requirement to meet specifications in accordance with paragraphs 9.1 and 9.2 below and the recommendation to meet guidelines in accordance with paragraph 9.3 below.

9.1 Emission Levels

The radar emission levels at the antenna input shall be no greater than the values obtainable from the curves in Figure 2. At the frequency $\pm$ B(-40 dB)/2 displaced from F_o, the level shall be at least 40 dB below the maximum value. Beyond the frequencies $\pm$ B(-40 dB)/2 from F_o, the equipment shall have the capability to achieve up to 80 dB per decade (S = 80) roll-off lines of Figure 2. The emission levels shall be below the appropriate dB per decade roll-off lines of Figure 2 down to a -X dB level that is 80 dB below the maximum spectral power density.

9.2 Radar System PRF

The radar system shall be designed to operate with an adjustable pulse repetition frequency (s), PRF (s), with a nominal difference of ± 1% (minimum). This will permit the selection of PRF's to allow certain types of receiver interference suppression circuitry to be effective.

9.3 Receiver Interference Suppression Circuitry

Radar systems in this band should have provisions incorporated into the system to suppress pulsed interference. The following information is intended for use as an aid in the design and development of receiver signal processing circuitry or software to suppress asynchronous pulsed interference. A description of the parametric range of the expected environmental signal characteristics at the receiver IF output is:

Peak Interference-to-Noise Ratio: $\leq$ 50 dB
Pulse width: 0.5 to 4.0 μ sec
PRF : 100 to 2000 pps

10. Measurement capability

In order to coordinate radar operations in the field, an accurate measurement of the operating frequency is necessary. An accuracy of ± 100 parts in 10^6 is adequate. Of comparable importance is the capability to measure pulse rise time and spectrum occupancy. Accordingly, each Government agency shall have access to the instrumentation necessary to make a frequency measurement to at least ± 100 parts in 10^6 and suitable oscilloscopes and spectrum analyzers to measure time and frequency parameters necessary to determine conformance with these criteria. For fast rise time devices, such as magnetrons, oscilloscopes with bandwidths of at least 50 MHz should be used.

APPENDIX D

SYSTEM CHARACTERISTICS

INTRODUCTION

This appendix contains a compendium of system characteristics of radars presently operating and planned for the 2700 - 2900 MHz band.

TABLE D-1

ASR-5 SYSTEM CHARACTERISTICS*

ANTENNA CHARACTERISTICS

A. Type:	Shaped beam, cosecant squared in elevation from half power point to +30 degrees
B. Gain:	34 dBi
C. Beamwidth:	elevation: 5 degrees azimuth: 1.5 degrees
D. Polarization:	Linear, vertical, or circular; remotely selectable
E. Antenna Rotation Rate:	13 or 15 RPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Magnetron (5586, DX276 or QK1643)
B. Frequency:	Tunable 2700-2900 MHz
C. Peak Power:	400 - 500 kW
D. Pulse width:	0.833 microseconds
E. PRF:	Selectable 900 to 1200 PPS (2-pulse stagger on or off)

RECEIVER CHARACTERISTICS

A. System Noise Figure:	4 dB maximum
B. Receiver Bandwidth:	Normal IF: 2.7 MHz MTI IF: 5.0 MHz Normal Video: 2.0 MHz MTI Video: 2.0 MHz
C. Minimum Discernible Signal (MDS):	Normal Receiver: -109 dBm MTI Receiver: -107 dBm
D. Scope Range (NM):	60 nautical miles

*Also applicable to ASR-4, ASR-6 and AN/FPN-47

TABLE D-2

ASR-7 SYSTEM CHARACTERISTICS*

ANTENNA CHARACTERISTICS

A. Type:	Shaped beam, cosecant squared in elevation from upper half power point to +30 degrees
B. Gain:	34 dBi
C. Beamwidth:	elevation: 5 degrees azimuth: 1.5 degrees
D. Polarization:	Linear, vertical, or circular; remotely selectable
E. Antenna Rotation Rate:	15 RPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Magnetron (DX276, 8798)
B. Frequency:	Tunable 2700-2900 MHz
C. Peak Power:	425 kW
D. Pulse width:	0.833 microseconds
E. PRF:	6-pulse stagger with 1002 PPS average, or fixed (selectable from 713 -1200 PPS)

RECEIVER CHARACTERISTICS

A. System Noise Figure:	4.75 dB
B. Receiver Bandwidth:	Normal IF: 2.7 MHz MTI IF: 5.0 MHz
C. Minimum Discernible Signal (MDS):	Normal Receiver: -108 dBm Log Receiver: -106 dBm MTI Receiver: -106 dBm Log MTI Receiver: -104 dBm
D. Scope Range (NM):	60 nautical miles

*Also applicable to AN/GPN-12

TABLE D-3

ASR-8 SYSTEM CHARACTERISTICS*

ANTENNA CHARACTERISTICS

A. Type:	Shaped Beam, cosecant squared in elevation from half power point to +30 degrees
B. Gain:	33.5 dBi Normal Beam 32.5 dBi Passive Beam
C. Beamwidth:	elevation: 4.8 degrees azimuth: 1.35 degrees
D. Polarization:	Linear vertical or circular, remotely selectable
E. Antenna Rotation Rate:	12.5 RPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Klystron (VA-87E)
B. Frequency:	Tunable 2700-2900 MHz
C. Peak Power:	1.4 MW
D. Pulse width:	0.6 microseconds
E. PRF:	4-pulse stagger with 1040 average, or fixed (selectable from 700 - 1200 PPS)

RECEIVER CHARACTERISTICS

A. System Noise Figure:	4.0 dB maximum
B. Receiver Bandwidth:	Normal IF: 1.2 MHz MTI IF: 5.0 MHz Log IF: 1.2 MHz MTI Video: 585 kHz
C. Minimum Discernible Signal (MDS):	Normal Receiver: -110 dBm Log Receiver: -109 dBm MTI Receiver: -108 dBm
D. Scope Range (NM):	60 nautical miles

*Also applicable to AN/GPN-27

TABLE D-4

ASR-9 SYSTEM CHARACTERISTICS*

ANTENNA CHARACTERISTICS

A. Type:	Shaped Beam, cosecant squared in elevation from half power point to +30 degrees
B. Gain:	33.5 dBi Normal Beam 32.5 dBi Passive Beam
C. Beamwidth:	elevation: 4.8 degrees azimuth: 1.35 degrees
D. Polarization:	Linear vertical or circular, remotely selectable
E. Antenna Rotation Rate:	15.0 RPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Klystron (VA-87E)
B. Frequency:	Tunable 2700-2900 MHz
C. Peak Power:	1.4 MW
D. Pulse width:	1.05 microseconds
E. PRF:	1200 PPS maximum. The PRF will alternate between two Coherent Processing Intervals (CPI's). The PRF of the CPI's shall be removed by 20 percent.

RECEIVER CHARACTERISTICS

A. System Noise Figure:	4.0 dB maximum
B. Receiver Bandwidth:	1.1 MHz
C. Minimum Discernible Signal (MDS):	-108 dBm
D. Scope Range (NM):	60 nautical miles

*This system is in the developmental stage. Therefore, the above system characteristics may not be representative of the production, system.

TABLE D-5

WSR-57 SYSTEM CHARACTERISTICS

ANTENNA CHARACTERISTICS

A.	Type:	Parabolic dish (12 ft. diameter)
B.	Gain:	38 dBi
C.	Beamwidth:	2.2 degrees
D.	Polarization:	Linear, horizontal
E.	Antenna Rotation Rate:	0 to 5 RPM -5 to +45 degrees elevation

TRANSMITTER CHARACTERISTICS

A.	Output Tube:	Magnetron (QK729-733)
B.	Frequency:	Tunable 2700 - 2900 MHz
C.	Peak Power:	500 kW
D.	Pulse width:	0.5 microseconds (short pulse) 4.0 microseconds (long pulse)
E.	PRF:	658 PPS (short pulse) 164 PPS (long pulse)

RECEIVER CHARACTERISTICS

A.	System Noise Figure:	4.0 dB
B.	Receiver IF Bandwidth:	4.5 MHz for short pulse and 0.75 MHz for long pulse
C.	Minimum discernible Signal (MDS):	-100 dBm (short pulse) -108 dBm (long pulse)
D.	Scope Range (NM):	250 nautical miles

TABLE D-6

WSR-74S SYSTEM CHARACTERISTICS

ANTENNA CHARACTERISTICS

A.	Type:	Parabolic dish (12 ft. diameter)
B.	Gain:	38 dBi
C.	Beamwidth:	2.2 degrees
D.	Polarization:	Linear, horizontal
E.	Antenna Rotation Rate:	0 to 5 RPM -5 to +45 degrees elevation

TRANSMITTER CHARACTERISTICS

A.	Output Tube:	Coaxial Magnetron
B.	Frequency:	Tunable 2700 - 2900 MHz
C.	Peak Power:	556 kW
D.	Pulse width:	1 microsecond (short pulse) 4 microseconds (long pulse)
E.	PRF:	545 PPS on short pulse 164 PPS on long pulse

RECEIVER CHARACTERISTICS

A.	System Noise Figure:	
B.	Receiver IF Bandwidth:	Not less than 1.5 MHz for short pulse and .375 MHz for long pulse
C.	Minimum Discernible Signal (MDS):	
D.	Scope Range (NM):	50, 125, and 250 nautical miles

TABLE D-7

NEXRAD SYSTEM CHARACTERISTICS*

ANTENNA CHARACTERISTICS

A.	Type:	Parabolic dish (24 ft. diameter)
B.	Gain:	45 dBi
C.	Beamwidth:	1.0 degrees
D.	Polarization:	Linear, horizontal
E.	Antenna rotation Rate	1 to 3 RPM -1 to +20 degrees elevation

TRANSMITTER CHARACTERISTICS

A.	Output Tube:	Klystron
B.	Frequency:	Tunable 2700 - 2900 MHz
C.	Peak Power:	1.0 MW
D.	Pulse width:	1.0 microsecond
E.	PRF	300 to 1300 PPS

RECEIVER CHARACTERISTICS

A.	System Noise Figure:	4.0 dB
B.	Receiver IF Bandwidth:	1.1 MHz
C.	Minimum Discernible Signal (MDS):	-110 dBm for 0 dB SNR
D.	Scope Range:	460 km Reflectivity Information 230 km Doppler Information

*This system is in the developmental stage. Therefore, the above system characteristics may not be representative of the production system.

TABLE D-8

AN/FPS-6 SYSTEM PARAMETERS*

ANTENNA CHARACTERISTICS

A. Type:	Shaped beam, fan beam in azimuth
B. Gain:	39 dBi
C. Beamwidth:	vertical: 0.85 degrees horizontal: 3.2 degrees
D. Polarization:	
E. Antenna Rotation Rate:	7.5 RPM, 20-30 CPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Coaxial Magnetron (VSM-1143)
B. Frequency:	Tunable 2700 - 2900 MHz
C. Peak Power:	3.5 MW
D. Pulse width:	2.0 microseconds
E. PRF:	250 to 400 PPS

RECEIVER CHARACTERISTICS

A. System Noise Figure:	8.0 dB
B. Receiver Bandwidth:	800 kHz
C. Minimum Discernible Signal (MDS):	Normal: -106 dBm
D. Scope Range (NM):	200 nautical miles

*Also applicable to AN/FPS-90 and AN/FPS-116

TABLE D-9

AN/GPN-20 SYSTEM CHARACTERISTICS

ANTENNA CHARACTERISTICS

A. Type:	Shaped beam, cosecant squared in elevation from half power point to +30 degrees
B. Gain:	33.5 dBi Normal Beam 32.5 dBi Passive Beam
C. Beamwidth:	elevation: 4.8 degrees azimuth: 1.35 degrees
D. Polarization:	Vertical or circular (LH)
E. Antenna Rotation Rate:	12 or 15 RPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Magnetron (8798), diplex filtered
B. Frequency:	Tunable 2700 - 2900 MHz
C. Peak Power:	500 kW
D. Pulse width:	0.833 microseconds
E. PRF:	Staggered with 1040 average (selectable from 849 -1204 PPS)

RECEIVER CHARACTERISTICS

A. System Noise Figure:	4 dB
B. Receiver Bandwidth:	Normal IF: 1.2 MHz MTI IF: 5.0 MHz Log IF: 1.2 MHz MTI Video 585 kHz
C. Minimum Discernible Signal (MDS):	Normal Receiver: -110 dBm Log Receiver: -109 dBm MTI Receiver: -108 dBm
D. Scope Range (NM):	60 nautical miles

TABLE D-10

AN/CPN-4 SYSTEM CHARACTERISTICS

ANTENNA CHARACTERISTICS	
A. Type:	Shaped beam, cosecant squared in elevation from halfpower point to +30 degrees
B. Gain:	31 dBi
C. Beamwidth:	elevation: 3.6 degrees azimuth: 2.2 degrees
D. Polarization:	Horizontal or circular, remotely selectable
E. Antenna Rotation Rate:	20 ± 2 RPM
TRANSMITTER CHARACTERISTICS	
A. Output Tube:	Magnetron (5586)
B. Frequency:	Tunable 2780 to 2820 MHz
C. Peak Power:	600 kW
D. Pulse width:	0.5 microseconds
E. PRF:	1500 PPS
RECEIVER CHARACTERISTICS	
A. System Noise Figure:	4.0 dB
B. Receiver Bandwidth:	Normal IF: 2.25 MHz MTI IF: 4.5 MHz
C. Minimum Discernible Signal (MDS):	Normal: -106 dBm MTI: -104 dBm
D. Scope Range (NM):	30 nautical miles

TABLE D-11

AN/MPN-13 SYSTEM CHARACTERISTICS*

ANTENNA CHARACTERISTICS

A. Type:	Shaped beam, cosecant squared in elevation from half power point to +30 degrees
B. Gain:	32 dBi
C. Beamwidth:	elevation: 3.6 degrees aximuth: 2.2 degrees
D. Polarization:	Horizontal or circular, remotely selectable
E. Antenna Rotation Rate:	15 RPM

TRANSMITTER CHARACTERISTICS

A. Output Tube:	Magnetron (8798)
B. Frequency:	Tunable 2780 to 2820 MHz
C. Peak Power:	750 kW
D. Pulse width:	0.7 microseconds
E. PRF:	1100 PPS (3-pulse stagger on or off)

RECEIVER CHARACTERISTICS

A. System Noise Figure:	4.0 dB
B. Receiver Bandwidth:	Normal: 2.25 MHz MTI: 4.5 MHz
C. Minimum Discernible Signal (MDS):	Normal: -106 dBm MTI: -104 dB
D. Scope Range (NM):	60 nautical miles

*Also applicable to AN/MPN-14 and AN/MPN-15

TABLE D-12

AN/TPN-24 SYSTEM CHARACTERISTICS

ANTENNA CHARACTERISTICS		
A.	Type:	Shaped beam, cosecant squared in elevation from half power point to +30 degrees
B.	Gain:	33.6 dBi
C.	Beamwidth:	elevation: 6 degrees azimuth: 1.55 degrees
D.	Polarization:	Vertical or circular
E.	Antenna Rotation Rate:	15 RPM
TRANSMITTER CHARACTERISTICS		
A.	Output Tube:	Magnetron (8798), diplex filtered
B.	Frequency:	Tunable 2700-2900 MHz
C.	Peak Power:	450 kW
D.	Pulse width:	1.0 microsecond
E.	PRF:	12 staggered (1050 Hz average)
RECEIVER CHARACTERISTICS		
A.	System Noise Figure:	2.5 dB
B.	Receiver Bandwidth:	Normal: 1.0 MHz
C.	Minimum Discernible Signal (MDS):	Normal: -112 dBm for 6 dB SNR
D.	Scope Range (NM):	60 nautical miles

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14. SUPPLEMENTARY NOTES

15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report on the 2700-2900 MHz band provides background information and summarizes the findings on tasks assigned to the Interdepartment Radio Advisory Committee (IRAC) Technical Subcommittee by the IRAC (IRAC Doc. 21572). Equipment characteristics, radar deployment patterns, usage of the band based on Radio Spectrum Measurement System (RSMS) van measurements, and projected usage of the band in the 1980's are discussed. Also the accommodation of new systems planned for the band was studied. Based on the projected growth in the band and present and projected radar deployment patterns, recommendations were made to the IRAC which would enhance the accommodation of new systems planned for the band.

16. Key Words *(Alphabetical order, separated by semicolons)*

1) 2700-2900 MHz Band
2) Radar Spectrum Engineering Criteria (RSEC)
3) Interference

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