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SPECTRUM RESOURCE ASSESSMENT OF THE 1605-2000 kHz BAND

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ABSTRACT

This report is a spectrum resource assessment of the 1605-2000 kHz band. It includes information on rules, regulations, allocations, technical standards, frequency assignments, system characteristics, and applicable compatibility analyses pertinent to the 1605-2000 kHz band. Major issues are discussed concerning changes in the allocation tables due to WARC-79 decisions. Parts of the 1605-2000 kHz band are in transition from radiolocation service use to broadcasting service use. Major problems in this band are the sharing among travelers' information stations, radiolocation, and broadcasting and the proliferation of the cordless telephone. This report analyzes the possibility of sharing between broadcasting and travelers' information stations and radiolocation, along with addressing the problems associated with cordless telephones.

KEY WORDS

1605-2000 kHz
Broadcasting Service
Cordless Telephone
Electromagnetic Compatibility
Radiolocation Service
Radionavigation Service

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 ensure that their conduct of telecommunications activities is consistent with these policies" (United States Department of Commerce, 1978). In support of these requirements, NTIA has undertaken a number of spectrum resource assessments. The objectives of these studies are to assess spectrum utilization, identify existing and/or potential compatibility problems between systems of various departments and agencies, provide recommendations for resolving any compatibility conflicts, and recommend changes to promote efficient use of the radio spectrum and to improve spectrum management procedures. This spectrum resource assessment considers the 1605-2000 kHz frequency band.

In the United States, until the 1979 World Administrative Radio Conference (WARC-79) changes are implemented, the 1605-2000 kHz band is used as follows. The Government uses 1605-1800 kHz for aeronautical radionavigation, fixed, mobile, and radiolocation. Government radionavigation use is Primary from 1800-2000 kHz, with fixed and mobile (except aeronautical mobile) Secondary. This band is shared with the non-Government assignments as follows. From 1605-1715 kHz, aeronautical radionavigation, fixed, land mobile, maritime mobile, and radiolocation are Primary non-Government users on a coequal basis. From 1715-1750 kHz, fixed, land mobile, maritime mobile, and radiolocation are Primary non-Government users on a coequal basis. From 1750-1800 kHz, fixed, mobile, and radiolocation are Primary non-Government users on a coequal basis. From 1800-2000 kHz, radionavigation is the Primary non-Government user and amateur is the Secondary user.

The 1605-2000 kHz band is in a state of transition from present use to the implementation of new allocations as a result of WARC-79 changes. The new U.S. allocations are to the mobile service exclusively from 1605-1615 kHz for both Government and non-Government Travelers' Information Stations (TIS). The non-Government broadcasting service is now exclusive from 1615-1625 kHz and Primary from 1625-1705 kHz with radiolocation Secondary. Fixed, mobile, and radiolocation services are Primary coequal, both Government and non-Government, from 1705-1800 kHz. The amateur service is exclusive from 1800-1900 kHz, and both the Government and non-Government radiolocation services are exclusive from 1900-2000 kHz. The final decision on use of the 1605-1705 kHz band is subject to the outcome of a regional conference of the International Telecommunication Union (ITU) scheduled for 1986 and 1988.

Non-Government use of the aeronautical radionavigation service in the 1605-1715 MHz band is limited to two frequencies, 1638 and 1708 MHz. Government use of aeronautical radionavigation is by the U.S. Army for tactical radio beacons that are used mainly for training purposes with helicopters and small aircraft. Fixed service assignments have been used by the private sector and local governments for various purposes including police work. The mobile service is used mainly by both Government and non-Government TIS. Land mobile assignments are mainly used by local governments for their various communication needs. The maritime mobile service is used for communications between shore and small boats and between boats. The radiolocation service is one of the most-used services within the 1605-2000 kHz band. This service is used for the determination of direction, distance, speed, or position for purposes other than navigation and is used mainly by channel dredging, offshore oil drilling operations, etc. to pinpoint particular locations offshore or on inland waterways.

Low power devices that provide auditory assistance to handicapped persons have been approved for 1610 kHz per the FCC General Docket No. 81-786 (FCC, 1981). Another low power device, whose use is escalating in the 1605-2000 kHz band, is the cordless telephone. Because of the rapid growth in the use of these devices (projected 10 million units in the market by 1987 according to an industry survey), the IRAC established Ad Hoc 184 at its meeting April 13, 1982, with the following terms of reference as summarized below.

> "Perform necessary studies and provide recommendations to the IRAC dealing with spectrum and regulatory alternatives for accommodating cordless telephones. The consideration of the ad hoc group should include:
>
> 1. Identification and evaluation of alternatives for providing interim standards for cordless telephones ...
> 2. Evaluation of spectrum availability, both Government and non-Government, to meet the long-term requirements for cordless telephones ...

3. Evaluation of the proposal to upgrade cordless telephones to devices that operate with an appropriate spectrum support status."

The FCC, in early 1983, originated rules that prohibit the manufacture of cordless telephones that use the 1605-2000 kHz band after October 1, 1984.

Pursuant to the allocation changes adopted at WARC-79, broadcasting is allocated on a Primary basis in the 1605-1705 kHz band in Region 2. Services now utilizing this portion of the band will be either phased into the upper adjacent bands or prove compatibility with the new broadcasting service. Several studies were accomplished prior to WARC-79 by the Corporation for Public Broadcasting and the radiolocation industry that examined the compatibility with, and impact on, broadcasting and the radiolocation service. This spectrum resource assessment identifies compatibility problems that would result from this impending allocation change and recommends spectrum management procedures to accommodate these changes.

OBJECTIVES.

The objectives of this task were to assess the impact of the WARC-79 allocation table changes, to analyze the possibility of sharing between the broadcasting service and TIS and the radiolocation service, and to study the problems associated with cordless telephones in the 1605-2000 kHz band.

APPROACH.

In order to accomplish the above objectives, the following approach was taken.

1. WARC-79 allocation table changes and national recommendations that impact the 1605-2000 kHz band were identified.
2. Systems operating in the 1605-2000 kHz band were identified, along with their technical characteristics and areas of deployment. This was done by:
   a. using the Government Master File (GMF), non-Government Master File, Systems Review File (SRF), published NTIA reports, and other Government reports to identify Government and non-Government frequency assignments and usage,
   b. contacting Government frequency managers for data,
   c. obtaining surveys from major equipment manufacturers and users, and
   d. employing measured data.

3. Data from IRAC/SPS system reviews and the Department of Defense's (DOD) Electromagnetic Compatibility Analysis Center (ECAC) was used to identify systems planned for operation in the 1605-2000 kHz band.
4. Electromagnetic compatibility (EMC) analyses done by Government agencies and those done in support of the IRAC system review process were reviewed.
5. Laboratory measurements of several types of commercial radio receivers were taken. From these measurements, a composite receiver protection ratio graph was drawn and used to assess carrier-to-interference computer models that characterize these receivers.
6. The field strength of radiolocation stations along the Gulf of Mexico was measured in Boulder, Colorado, to assist in determining the extent of skywave coverage.
7. Key spectrum management issues affecting the 1605-2000 kHz band were identified and recommendations are made for their resolution.

SECTION 2.

CONCLUSIONS AND RECOMMENDATIONS

The 1605-2000 kHz band is a shared band between Government and non-Government services. It is also divided into four subbands with assignments to six Primary services. The trend for the Government assignments shows considerable growth from approximately 225 assignments in 1974 to 746 assignments in 1984. It should be noted that non-Government assignments do not reflect use by cordless phones or the amateurs.

Allocation changes adopted by WARC-79 resulted in changes to the national allocation tables that effect the total band. Of particular concern is the change in the 1615-1705 kHz portion of the band which has now been allocated on a Primary basis to the broadcasting service. The changes in allocation within the band introduced problem areas in compatibility between new and existing services and the phasing out of services. These problems were analyzed, and the conclusions and recommendations are presented below.

GENERAL CONCLUSIONS.

1. The Government usage in the 1605-2000 kHz band is mainly by the radiolocation service, aeronautical radionavigation, and TIS, in that order.
2. The non-Government usage in the 1605-2000 kHz band is mainly to the radiolocation services, experimental services, and aeronautical radionavigation, in that order.
3. There are approximately 846 operating units in the Government service.
4. There are approximately 4000 units corresponding to the 1969 assignments in the 1605-2000 kHz band operated by the non-Government users as given in Table 9. Cordless phone or amateur units are not included.
5. The main issues that result from recent allocation changes are the reduced spectrum available for 230 radionavigation assignments, the compatibility of radiolocation services with the broadcast service, and the potential impact of the broadcast service on TIS.
6. There are 746 assignments to the Government of which 89% are between 1605 and 1750 kHz. Of these, 26% are between 1605 and

1615 kHz and are mainly TIS which may not be affected by recent allocation changes, and the remaining 63% are mainly radionavigation and radiolocation assignments that will be affected by recent allocation changes.

7. The radiolocation systems whose operations depend on phase comparison are best suited to the 1605 to 2000 kHz band because of consistent velocity of propagation and low groundwave attenuation.
8. There are no detailed rules or regulations governing the Government TIS in the NTIA Manual of Regulations and Procedures.
9. There are no detailed rules or regulations in the NTIA Manual which address radiolocation systems used in this band.

SPECIFIC CONCLUSIONS.

10. There are only 19 Government assignments between 1615-1625 kHz (mainly radionavigation assignments) that will be affected by the new allocations.
11. There are 335 Government assignments presently between 1625 and 1705 kHz that will be affected by the new broadcasting service being Primary in the band.
12. There are 189 Government TIS assignments at 1610 kHz that could be affected by broadcasting stations if cochannel operation were allowed.
13. The procedures given in Section 6 describe restrictions that are required for sharing of the 1625-1705 kHz band between the radiolocation and broadcasting services.
14. Presently the TIS assigned frequency in the band is at the top of the AM broadcast band at 1610 kHz. Since the groundwave attenuation factor is lower at 1610 kHz, as compared to 1700 kHz, 1610 kHz is more favorable for the broadcasting service. Moving the TIS to 1700 kHz should be considered along with possible use of the 88-108 MHz band.
15. The use of cordless telephones in the band may pose a future compatibility problem with the new broadcasting service depending on how many are in service when the broadcasting stations are brought into service.
16. Radiolocation receivers will not be adversely affected by cordless telephones if a separation distance of 5.3 mi (8.5 km) is maintained.

17. The impact of changes concerning radiolocation in the 1605-2000 kHz band in the Gulf of Mexico or along the Canadian border has not been fully explored.
18. Analysis in Section 6 is based on interference criteria given by radiolocation receiver manufacturers and needs validation. Measurements on radiolocation receiver susceptibility from AM broadcast signals may need to be made to establish interference criteria.
19. Time multiplex radiolocation systems can cause interference in AM receivers with S/I ratios from 10 to 20 dB depending on characteristics of the receiver.
20. Disaster communication services in the 1700-1800 kHz band as given in Chapter 7 of the NTIA Manual (7.3.2) are no longer valid.
21. The CW phase comparison radiolocation channeling plan as given in Chapter 4 of the NTIA Manual (4.3.1) may no longer be valid after the ITU Regional Conference on the 1605-1705 kHz band.

RECOMMENDATIONS.

The following are NTIA staff recommendations based on the technical findings contained in this report. Any action to implement these recommendations will be accomplished under separate correspondence by modification of established rules, regulations, or procedures.

It is recommended that:

1. The procedures described in Section 6 concerning sharing between the broadcasting and radiolocation services should be followed if such sharing becomes necessary.
2. Additional study should be undertaken to further examine alternatives to the use of TIS on the frequency 1610 kHz. This investigation should include, but not be limited to:
   a. TIS remaining on 1610 kHz,
   b. TIS limited to only 530 MHz,
   c. TIS shared with broadcasting in the 535-1705 kHz band,
   d. TIS assigned to 1710 kHz,
   e. TIS shared with broadcasting in the 88-108 MHz band,
   f. TIS transmitted on a subcarrier on broadcasting stations in the 88-108 MHz band,

g. various combinations of the above, and

h. TIS use of "leaky" coaxial cable systems.

3. The NTIA Manual of Regulations and Procedures be revised to include rules and regulations for the Government TIS. A working party among NTIA and interested parties should write and implement this (compatible with the FCC Rules and Regulations).

4. The NTIA Manual of Regulations and Procedures be revised by deleting in Chapter 7, Section 7.3.2, dealing with disaster communications from 1750.5-1796.5 kHz, which is no longer valid.

SECTION 3.

RULES AND REGULATIONS

ALLOCATIONS.

In the United States, the 1605-2000 kHz band, previous to WARC-79, was divided into four subbands (see TABLE 1) with Government and non-Government allocations to aeronuatical radionavigation, fixed, mobile, land mobile, maritime mobile, amateur, and radiolocation services. The lower adjacent band, 535-1605 kHz, was allocated exclusively to the non-Government broadcasting service. The upper adjacent band, 2000-2065 kHz, was allocated to the Government for fixed and mobile services on a shared Primary basis, and the non-Government segment was allocated to the maritime mobile service on a Primary basis.

During the mid 1970's, the U.S. was looking for a way to expand the AM broadcast band to accommodate needed new stations. Consequently, during the preparations for WARC-79, the FCC sent out a number of Notices of Inquiry (NOI) that included the expansion of the AM band. The proposed expansion was for 100 kHz between 1760 and 1860 kHz to be allocated to the AM broadcasting service. This proposal met its main opposition from both Government and non-Government users of radiolocation for precision location of off-shore oil exploration activities, surveying, fishing activities in harbors where precision location was desired, and dredging operations etc. The proposal was supported by the National Association of Broadcasters, the Public Broadcast System, and others concerned with AM broadcasting activities. The U.S. proposal to WARC-79 was to expand the AM band. The proposal received in-depth discussion at WARC-79, and the final disposition was to expand the band to 1705 kHz. International Footnote 480 was added which states that the new use of the 1605-1705 kHz portion of the band shall be subject to a plan to be established by the Regional Administrative Radio Conference (RARC) that is scheduled for 1986 and 1988.

Pursuant to the Final Acts of WARC-79, the Interdepartment Radio Advisory Committee (IRAC) recommended the allocation plan for the 1605-2000 kHz band given in TABLE 2. Broadcasting is allocated from 1615-1625 kHz exclusively and Primary from 1625-1705 kHz with radiolocation Secondary.

The current International and National Table of Frequency Allocations, as summarized in TABLE 2, shows the 1605-2000 kHz band as divided into six subbands: 1605-1615 kHz, 1615-1625 kHz, 1625-1705 kHz, 1705-1800 kHz, 1800-1900 kHz, and 1900-2000 kHz. The 1605-1615 kHz portion is allocated exclusively to both the Government and non-Government mobile service. The 1615-1625 kHz portion is

TABLE 1

PRE-WARC-79 INTERNATIONAL AND UNITED STATES NATIONAL TABLE OF FREQUENCY ALLOCATIONS FOR THE 1605-2000 KHZ BANDS (MAY 1980)

INTERNATIONAL			UNITED STATES				
Region 1 (kHz)	Region 2 (kHz))	Region 3 (kHz)	Band (kHz) 1	National Provisions 2	Government Allocations 3	Non-Government Allocations 4	Remarks 5
1605-2000 FIXED MOBILE except aeronautical mobile 192 193 194 195 195A	1605-1800 FIXED MOBILE AERONAUTICAL RADIONAVIGATION Radiolocation —	1605-1800 FIXED MOBILE 197	1605-1715	US97 US221	AERONAUTICAL RADIONAVIGATION FIXED MOBILE RADIOLOCATION	AERONAUTICAL RADIONAVIGATION FIXED LAND MOBILE MARITIME MOBILE RADIOLOCATION	The following frequencies are designated for use by Government agencies during disasters: 1750.5 kHz (Telegraphy) 1751.5 kHz (Telegraphy) 1752.5 kHz (Telegraphy) 1753.5 kHz (Telegraphy) 1754.5 kHz (Telegraphy) 1755.5 kHz (Telegraphy) 1756.5 kHz (Telegraphy) 1757.5 kHz (Telegraphy) 1761.5 kHz (Telephony at scene of disaster) 1768.5 kHz (Telephony) 1775.5 kHz (Telephony) 1782.5 kHz (Telephony) 1789.5 kHz (Telephony) 1796.5 kHz (Telephony)
			1715-1750		AERONAUTICAL RADIONAVIGATION FIXED MOBILE RADIOLOCATION G33	FIXED LAND MOBILE MARITIME MOBILE RADIOLOCATION	
			1750-1800			FIXED MOBILE RADIOLOCATION NG14	The frequency 1790 kHz is used in a weather network in Alaska and will be integrated into any disaster network in that area, as required.
1800-2000 AMATEUR FIXED MOBILE except aeronautical mobile RADIONAVIGATION 198			1800-2000	198 US18	RADIONAVIGATION Fixed Mobile except aeronautical mobile	RADIONAVIGATION Amateur NG15	

TABLE 1 (continued)

United States Footnotes

US18 - Navigation aids in the U.S. and possessions between 90 and 110 kHz, 190 and 525 kHz, and 1800 and 2000 kHz, are normally operated by the U.S. Government. However, authorizations may be made by the Commission for non-Government operation in these bands subject to the conclusion of appropriate arrangements between the Commission and the Government agencies concerned and upon special showing of need for service which the Government is not yet prepared to render.

US97 - The use of the band 1605-1715 kHz by non-Government stations in the Aeronautical Radionavigation service is limited to the frequencies 1638 and 1708 kHz. Stations in the Radiolocation Service shall not cause harmful interference to stations in Aeronautical Radionavigation service operating on 1638 or 1708 kHz.

US221 - Government and non-Government Travelers Information Stations may be authorized on 530 kHz and 1610 kHz on a secondary basis to all authorized stations operating on a primary basis in the band 510-535 kHz and 1610-1615 kHz, respectively.

NG14 - Stations in the radiolocation service shall not cause harmful interference to stations in the disaster communications service between sunset and sunrise or at any time during an actual or imminent disaster. Conversely, stations in the disaster communications service shall not cause harmful interference to stations in the radiolocation service between sunrise and sunset except during an actual or imminent disaster.

NG15 - The Amateur Service may use the sections of the band 1800-2000 kHz which are not required for LORAN-A in accordance with the following conditions:

(1) The use of these frequencies by the Amateur Service shall not be a bar to the expansion of the radionavigation (LORAN-A) service;

(2) The Amateur Service shall not cause harmful interference to the radio navigation (LORAN-A) service;

(3) Only types A1 and amplitude modulated double and single sideband telephony emission shall be employed;

(4) Amateur operation shall be limited to:

TABLE 1 (continued)

States of:	Maximum DC plate input power in watts			
	1900-1925 kHz	1925-1950 kHz	1950-1975 kHz	1975-2000 kHz
	Day/Night	Day/Night	Day/Night	Day/Night
Maine, Massachusetts, New Hampshire, Rhode Island............	100/25	0	0	100/25
Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania, Vermont...........	200/50	0	0	200/50
Kentucky, North Carolina, Ohio, South Carolina, Tennessee, Virginia, West Virginia.........	500/100	0	0	500/100
Florida, Georgia, Illinois, Indiana, Michigan, Wisconsin....	500/100	100/25	100/25	500/100
Alabama, Arkansas, Iowa, Minnesota, Mississippi, Missouri........................	1000/200	200/50	200/50	1000/200
The remainder of the states and territories.....................	1000/200	1000/200	1000/200	1000/200

(b) This footnote shall be considered as temporary in the sense that it shall remain subject to cancellation or to revisions, in whole or in part, by order of the Commission without hearing whenever the Commission shall deem such cancellation of revision to be necessary or desirable in the light of the priority within this band of the LORAN-A system of radionavigation.

198 - In region 2 the Loran system has priority. Other services to which the band is allocated may use any frequency in this band provided that they do not cause harmful interference to the Loran system. In Region 3 then the Loran system in any particular area operates either on 1 850 or 1 950 kHz, the bands occupied being 1 825-1 875 kHz and 1925-1 975 kHz respectively. Other services to which the band 1 800-2 000 kHz is allocated may use any frequency therein on condition that no harmful interference is caused to the Loran system operating on 1 350 or 1 950 kHz.

G33 - In the band 1715-1800 kHz, stations in the radiolocation service shall not cause harmful interference to stations of the aeronautical radionavigation service.

TABLE 2

CURRENT INTERNATIONAL AND UNITED STATES NATIONAL TABLE OF FREQUENCY ALLOCATIONS FOR THE 1605-2000 KHZ BANDS (JANUARY 1984)

INTERNATIONAL			UNITED STATES				
Region 1 kHz	Region 2 kHz	Region 3 kHz	Band kHz 1	National Provisions 2	Government Allocation 3	Non-Government Allocation 4	Remarks 5
478	1605-1625 BROADCASTING 480 481		1605-1615	US221 480	MOBILE	MOBILE	Traveler's Information Systems
1606.5-1625 MARITIME MOBILE /FIXED/ /LAND MOBILE/ 483 484		1605.5-1800 FIXED MOBILE RADIOLOCATION RADIONAVIGATION 482	1615-1625	US237 480		BROADCASTING	Broadcasting implementation is subject to decisions of a future Region 2 Administrative Radio Conference
1625-1635 RADIOLOCATION 487 485 486	1625-1705 BROADCASTING 480 /FIXED/ /MOBILE/ Radiolocation 481		1625-1705	US238 480	Radiolocation	BROADCASTING Radiolocation	
1635-1800 MARITIME MOBILE /FIXED/ /LAND MOBILE/ 483 484 488	1705-1800 FIXED MOBILE RADIOLOCATION AERONAUTICAL RADIONAVIGATION		1705-1800	US240	FIXED MOBILE RADIOLOCATION	FIXED MOBILE RADIOLOCATION	
1800-1810 RADIOLOCATION 437 485 486	1800-1850 AMATEUR 489	1800-2000 AMATEUR FIXED MOBILE except aeronautical mobile RADIONAVIGATION Radiolocation 489	1800-1900			AMATEUR	
1810-1850 AMATEUR 490 491 492 493							
1850-2000 FIXED MOBILE except aeronautical mobile 484 488 495	1850-2000 AMATEUR FIXED MOBILE except aeronautical mobile RADIOLOCATION RADIONAVIGATION 489 494		1900-2000	US290	RADIOLOCATION	RADIOLOCATION	

US221	Use of the mobile service in the bands 525-535 kHz and 1605-1615 kHz is limited to distribution of public service information from Travelers Information Stations operating on 530 kHz or 1610 kHz.
US237	Until implementation procedures and schedules are determined by a future Regional Conference of the International Telecommunication Union, the band 1615-1625 kHz is also allocated on a primary basis to the radiolocation service.
US238	Until implementation procedures and schedules are determined by a future Regional Conference of the International Telecommunication Union, the band 1625-1705 kHz is allocated to the radiolocation service on a primary basis as a different category of service.
US240	The bands 1715-1725 kHz and 1740-1750 kHz are allocated on a primary basis and the bands 1705-1715 kHz and 1725-1740 kHz on a secondary basis to the aeronautical radionavigation services (radiobeacons).
US290	In the band 1900-2000 kHz amateur stations may continue to operate on a secondary basis to the radiolocation service, pending a decision as to their disposition through a future rule making procedure in conjunction with implementation of the standard broadcasting service in the 1625-1705 kHz band.
480	In Region 2, the use of the band 1605-1705 kHz by stations of the broadcast service shall be subject to a plan to be established by a Regional Administrative Radio Conference (see Recommendation 504).
489	In Region 2, Loran stations operating in the band 1800-2000 kHz shall cease operation on 31 December 1982. In Region 3 the Loran system operates either on 1850 kHz or 1950 kHz, the bands occupied being 1825-1875 kHz and 1925-1975 kHz, respectively. Other services to which the band 1800-2000 kHz is allocated may use any frequency therein on condition that no harmful interference is caused to the Loran system operating on 1850 or 1950 kHz.

allocated for the exclusive use of the non-Government broadcast service. The 1625-1705 kHz portion is allocated to broadcasting as a primary service in the non-Government allocation and to Government and non-Government radiolocation as a Secondary service. The 1705-1800 kHz portion is shared by fixed, mobile, and radiolocation services on a Primary basis for both Government and non-Government allocations. The 1800-1900 kHz portion is exclusively allocated to the non-Government amateur service, and subband 1900-2000 kHz is allocated exclusively to both Government and non-Government radiolocation services.

Footnote US237 allocates the 1615-1625 kHz band to the radiolocation service on a Primary basis until the decisions of the regional conferences are implemented. Footnote US238 allocates the 1625-1705 kHz band to the radiolocation service on a Primary basis, considering it a different category of service until new procedures are determined by the regional conferences.

Footnote US240 allocates the 1715-1725 kHz and 1740-1750 kHz frequencies to the aeronautical radionavigation service for radio beacons on a Primary basis and the 1705-1715 kHz and 1725-1740 kHz frequencies for radio beacons on a Secondary basis. Footnote US290 allows the band from 1900-2000 kHz to be used by amateur stations on a Secondary basis, subject to future rule making procedures that may be defined by the regional conferences.

In General Docket 84-874 released September 11, 1984, the Federal Communications Commission (FCC) in a Notice of Proposed Rule Making amended Part 90 of the FCC's Rules to implement the 1900-2000 kHz frequency band for the radiolocation service.

Part 90 of the FCC's Rules and Regulations was amended as follows:

"1. Section 90.103(b) - Radiolocation Service Frequency Table is amended to read:

90.103 Radiolocation Service

*   *   *   *   *

(b) ***

Radiolocation Service Frequency Table

Frequency or Band	Limitations
Kilohertz	
*	*
1605-1715	4, 5, 6, 27
1715-1750	5, 6, 27
1750-1800	5, 6, 7, 27
1900-1950	6, 25, 26, 27
1950-2000	6, 25, 27
3230-3400	6, 8
*	*

2. A new subsection 90.103(c)(25) is added to read:

(25) Station assignments on frequencies in this band will be made subject to the conditions that the maximum output power shall not exceed 375 watts and the maximum authorized bandwidth shall not exceed 1.0 kHz.

3. A new subsection 90.103(c)(26) is added to read:

(26) Each frequency assignment in this band is on an exclusive basis within the primary service area to which assigned. The primary service area is the area where the signal intensities are adequate for radiolocation purposes from all stations in the radiolocation system of which the station in question is a part; that is, the primary service area of the station coincides with the primary service area of the system. The normal minimum geographical separation between stations of different licensees shall be at least 1200 mi (1931 km) when stations are operated on the same frequency or on different frequencies separated by less than 1.2 kHz. Where geographical separation of less than 1200 mi (1931 km) is desired under these circumstances, it must be shown that the desired separation will result in a protection ratio of at least 20 decibels throughout the primary service area of other stations.

4. A new subsection 90.103(c)(27) is added to read:

(27) Notwithstanding the bandwidth limitations otherwise set forth in this section of the rules, systems operating

in this band may use such bandwidth as is necessary to proper operation of the system provided that the field strength does not exceed 120 microvolts per meter at 1 mi (1.6 km). Such operations shall be on a secondary basis to stations operating within otherwise applicable technical standards."

The most significant change is subsection 90.103(c)(26) that divides the 1900-2000 kHz band into two bands; 1900-1950 kHz, where each assignment is on an exclusive basis within the Primary service area to which assigned. The normal minimum geographical separation between stations of different licensees is at least 1200 miles (1931 km) when the stations are operating on the same frequency or on different frequencies separated by less than 1.2 kHz; 1950-2000 kHz to be used on non-exclusive or shared assignments in the radiolocation service, but without particular bandwidth limitations. However, if systems operate outside of normal bandwidths, the field strength of such systems can not exceed 120 μV/m at 1 mi (1.6 km) and will be secondary to systems adhering to the normal standards of bandwidth (2 kHz).

TABLE 3 is a side-by-side comparison of pre-WARC allocations and current allocations.

The WARC-79 Final Acts Recommendation 504 recommends that: (1) an RARC be convened to establish a plan for the broadcast service in the 1605-1705 kHz band in Region 2, (2) such a conference be convened in 1985 at the latest, and (3) the exact dates for the plan to be in force be decided at the RARC. Nevertheless, use by the broadcasting service should not commence before July 1, 1987, for the frequencies between 1625 and 1665 kHz and July 1, 1990, for the frequencies between 1665 and 1705 kHz.

The planning conference is now scheduled for two sessions, one in 1986 and another in 1988.

TECHNICAL STANDARDS.

The technical standards, requirements, and objectives applicable to transmitters, receivers, and antennas used by Government radio stations are contained in Chapter 5, Section 5.2.3, of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management (NTIA, 1984). It lists allowable spurious emissions and frequency tolerance standards for Government transmitters within the 1605 to 4000 kHz band.

TABLE 3

COMPARISON OF PRE-WARC AND CURRENT ALLOCATIONS

Pre-WARC

Band kHz 1	National Provisions 2	Government Allocations 3	Non-Government Allocations 4
1605-1715	US97 US221	AERONAUTICAL RADIONAVIGATION FIXED MOBILE RADIOLOCATION	AERONAUTICAL RADIONAVIGATION FIXED LAND MOBILE MARITIME MOBILE RADIOLOCATION
1715-1750		AERONAUTICAL RADIONAVIGATION FIXED MOBILE RADIOLOCATION G33	FIXED LAND MOBILE MARITIME MOBILE RADIOLOCATION
1750-1800			FIXED MOBILE RADIOLOCATION NG14
1800-2000	198 US18	RADIONAVIGATION Fixed Mobile except aeronautical mobile	RADIONAVIGATION Amateur NG15

Current

Band kHz 1	National Provisions 2	Government Allocation 3	Non-Government Allocation 4
1605-1615	US221 480	MOBILE	MOBILE
1615-1625	US237 480		BROADCASTING
1625-1705	US238 480	Radiolocation	BROADCASTING Radiolocation
1705-1800	US240	FIXED MOBILE RADIOLOCATION	FIXED MOBILE RADIOLOCATION
1800-1900			AMATEUR
1900-2000	**US290**	**RADIOLOCATION**	**RADIOLOCATION**

Equipments used by the private sector, including that used by state and local governments, are regulated by the FCC. These telecommunication services are subject to the provisions of the Parts of the FCC Rules and Regulations as given below.

Land Mobile Service.

Major non-Government assignments within the 1605-2000 kHz band fall under FCC Part 90 entitled Private Land Mobile Radio Services. Services that operate under Part 90, which use frequencies in the band, are the public safety radio services (Subpart B), the industrial radio services (Subpart D), and the radiolocation service (Subpart F). Policies governing the assignment of frequencies are found in Subpart H and general technical standards are found in Subpart I. Chapter 4 of the NTIA Manual of Regulations (under 4.3.1, CW Phase Comparison Radiolocation Plan) contains the Government channeling plan for the radiolocation service.

TIS (Travelers' Information Stations).

The rules and technical standards governing the TIS are found in FCC Part 90, Subpart J 90.242. Each TIS transmits only noncommercial voice information pertaining to traffic and road conditions, traffic hazards and travel advisories, directions, availability of lodging, rest stops, and service stations, and descriptions of local points of interest. For stations using a cable antenna, the antenna must be no longer than 1.9 mi (3 km), and the transmitter RF output power is not to exceed 50 watts. The field strength of the emission must not exceed 2 mV/m when measured with a standard field strength meter at a distance of 197 ft (60 meters) from any part of the station. When the station uses a conventional antenna (i.e. vertical monopole, directional array), the antenna height above ground cannot exceed 15.0 meters. Only vertical polarization can be used and the transmitter RF output power cannot exceed 10 watts. The field strength of the emission shall not exceed 2 mV/m when measured with a standard field strength meter at a distance of 0.93 mi (1.5 km) from the transmitting antenna system. The TIS operating frequency in this band is 1610 kHz.

Radionavigation Service.

Aviation radionavigation land stations, in the past, have been authorized between 1800-2000 kHz. The rules and technical standards governing the use of this service are found in FCC Part 87, Subparts A and N.

Maritime and Alaska-Public Services.

Stations on land in the maritime services and Alaska-public fixed service have some frequencies assigned in the 1605-2000 kHz band. These assignments are covered in FCC Part 81, Subparts I and Q specifically, and the standard technical requirements for land stations in the band are covered in Subpart E. Also, on-board ship stations in the maritime services are covered in FCC Part 83, with the standard technical requirements found in Subpart E. It should be noted, however, that the FCC under General Docket #81-786 in its second NOI is making provisions to move these assignments out of this band.

Broadcasting Service (FCC).

Rules and regulations must be developed for this service in the 1605-1705 kHz band. The AM technical standards are given in Part 73, Subsections 73.181 through 73.190. The basic transmission standards for the various station classes are given in TABLE 4.

Amateur Service.

The amateur radio service is Primary in the 1800-1900 kHz portion of the band, and rules and regulations for amateurs are given in FCC Part 97, with technical standards given in Subpart C.

Disaster Service.

According to the current NTIA Manual and FCC Rules and Regulations, both Government and non-Government disaster communication services are assigned frequencies between 1700 and 1800 kHz. The Government regulations covering this service are found in Chapter 7 of the NTIA Manual, specifically 7.3.2. The non-Government rules and regulations are found in FCC Part 99, with operating requirements given in Subpart D.

The U.S. Government may use frequencies in this band for disaster communication purposes. The NTIA Manual, Chapter 7, Section 7.3.2, states that "these frequencies are to provide for essential communications incident to or in connection with disasters or other incidents that involve loss of communication facilities normally available or that require the temporary establishment of communication facilities beyond those normally available."

There are 14 frequencies listed for use between 1750.5 and 1796.5 kHz. The power used is to be the minimum necessary to effect the required communications, taking into account the necessity of avoiding harmful interference to other disaster communication stations.

TABLE 4

BASIC STANDARDS FOR AM STATIONS

Class of Station	Class of Channel Used	Permissible Power (kW)	Signal Intensity Contour of Area Protected from Objectionable Interference[1] (μV/m)		Permissible Interference Signal on Same Channel[2] (μV/m)	
			Day[3]	Night	Day[3]	Night[4]
I-A	Clear	50	SC 100 AC 500	SC 500 (50% skywave)[7] AC 500	5	25[7]
I-B	Clear	10 to 50	SC 100 AC 500	SC 500 (50% skywave) AC 500[3]	5	25
II-A	Clear	0.25 to 50 (daytime) 10 to 50 (nighttime)	500	500[3]	25	25
II-B and II-D	Clear	0.25 to 50	500	2500[3,5]	25	125
II-B and II-D[8]	Clear	0.25 to 1[8]	500	10000[8]	25	500[8]
III-A	Regional	1 to 5	500	2500	25	125
III-B	Regional	0.5 to 1 (nighttime) and 5 (daytime)	500	4000	25	200
IV	Local	0.5 (nighttime) and 0.25 to 1 (daytime)	500	Not prescribed[6]	25	Not prescribed[6]

1 When a station is already limited by interference from other stations to a contour of higher value than that normally protected for its class, this contour shall be the established standard for such a station with respect to interference from all other stations.

2 For adjacent channel, see FCC Rules 73.182(W).

3 Groundwave.

4 Skywave field intensity for 10 percent or more of the time.

5 These values are with respect to interference from all stations except Class I-B; these stations may cause interference to a field intensity contour of high value. However, it is recommended that Class II stations be so located that the interference received from Class I-B stations will not exceed these values. If the Class II stations are limited by Class I-B stations to high values, then such values shall be the established standard with respect to protection from all other stations.

6 See FCC Rules 73.182(a)(4).

7 Class I-A stations on channels reserved for the exclusive use of one station during nighttime hours are protected from cochannel interference on that basis.

8 Applies only to Class II-B stations coming within Section 73.21(a)(2)(ii)(C) and to the operation of limited-time Class II-D stations during nighttime hours other than those that were authorized to operate as of June 1, 1980.

SC = Same Channel; AC = Adjacent Channel

However, recent FCC Rulemaking on "Operation Secure" deleted the disaster service. Both the NTIA Manual and FCC Rules and Regulations will need to be revised to show these changes.

Cordless Telephones.

Cordless telephones operate under Part 15 of the FCC Rules. Each device consists of at least two units, a base that transmits in the vicinity of 1600-2000 kHz and a remote "handset" that transmits on one of five frequencies within the 49.82-49.90 MHz band.

A Report and Order was released (January 10, 1984) by the FCC in General Docket No. 83-325 amending Part 15 of the FCC's Rules to add new interim provisions for cordless telephones as follows:

CORDLESS TELEPHONES

§15.220 Interim provisions for a Cordless telephone

A cordless telephone which complies with the provisions of §§15.221-15.225, inclusive, may be manufactured or imported until February 15, 1989, and marketed until February 15, 1990.

§15.221 Interim frequencies for cordless telephones

A cordless telephone may be operated on one or more of the following frequencies, provided it complies with the provisions in §§15.220-15.225, inclusive.

46.610 MHz	49.830 MHz
46.630 MHz	49.845 MHz
46.670 MHz	49.860 MHz
46.710 MHz	49.875 MHz
46.730 MHz	49.890 MHz
46.830 MHz	49.670 MHz
46.830 MHz	49.770 MHz
46.870 MHz	49.930 MHz
46.930 MHz	49.970 MHz
46.970 MHz	49.990 MHz

§15.222 Technical specifications for cordless telephones

A cordless telephone must comply with all the technical specifications in this section.

(a) Frequency tolerance of carrier: ±0.01%. The tolerance shall be maintained for a temperature variation of 20°C to +50°C a normal supply voltage, and for variation in the primary voltage from 85% to 115% of the rated supply voltage at a temperature of 20°C.

(b) Emission shall be confined within a 20 kHz band centered on the carrier frequency.

(c) The field strength of the carrier frequency shall not exceed 10,000 μV/m at 9.8 ft (3 meters).

(d) The out-of-band emissions, including harmonics, on any frequency more than 10 kHz removed from the carrier shall not exceed the field strength limitations in the following table:

Frequency (MHz)	Field Strength (μV/m at 3 m)
25 to 85	100
88 to 216	150
216 to 1000	200

The spectrum shall be scanned from 25 to 1000 MHz and all signals exceeding 20 μV/m at 9.8 ft (3 meters) shall be reported.

(e) The cordless telephone shall be completely self-contained with the antenna permanently attached to the enclosure containing the phone.

(f) A cordless telephone which receives electrical power from the public utility power lines shall limit the radio frequency energy coupled back into the power lines to less than 100 μV.

(g) A cordless telephone system shall provide some minimum means of preventing the base station from unintentionally going off-hook and seizing local telephone network loops.

§15.223 Certification requirement.

Both the base station and portable handset of a cordless telephone shall be certificated by the Commission pursuant to the procedures in Subpart B of this Part. The transmitter portion of a cordless telephone shall be certificated to show compliance with the requirements in §§15.220-15.225, inclusive. The receive portion shall be certificated to show compliance with the requirements in Subpar C of this Part. A single application for certification (FCC Form 731) may be filed for a cordless telephone provided it clearly identifies all parts of the device and provides adequate data to show compliance with the appropriate ru parts.

NOTE: A cordless telephone, which is intended to be connected to a public telephone network, shall also comply with regulations in Part 68 of this Chapter.

§15.224 Labelling and identification requirements for a cordless telephone.

Both the base station and portable handset of a cordless telephone system shall be identified and labelled pursuant to §§2.925, 2.926, and 2.1045 of Part 2 of this Chapter. In addition, the label attached to the handset portion shall contain the following statement:

"This cordless phone is a low power communications device operating pursuant to the provisions of Part 15 of FCC Rules, privacy of communications may not be ensured when using this phone. Operation is subject to two conditions: (1) it may not cause harmful interference; and, (2) it must accept any interference received, including that which may cause undesirable operation."

§15.225 Non-Interference requirement.

Notwithstanding compliance with the technical specifications herein, a cordless telephone is subject to general conditions of §15.3 of this part. The operator of a cordless telephone may be required to stop operating his device upon finding that the device is causing harmful interference and it is in the public interest to stop operation until the interference problem has been corrected.

* * * * *

The base unit signal is coupled onto the commercial power lines and distribution network, and sometimes the telephone lines, and is generally radiated with sufficient strength to be received by the handset unit about 600 ft (182 m) away. This is referred to as "carrier current" operation and is governed by Section 15.7 of the FCC Rules entitled "General Requirement for Restricted Radiation Devices." Section 15.7 establishes a limit on the radiated field from any unlicensed RF generator as 15 μV/m, measured at any point at a distance of the wavelength (λ) divided by 2π from the generator. (Note: There do exist cordless phones that operate simplex at 49 MHz and do not utilize the 1600-2000 kHz band). FCC equipment authorization is not required for devices that operate under §15.7.

The 49 MHz portable handset transmitter is classified as a low power commu- cation device under Part 15. The permitted frequencies of operation in the 4 band are set forth in Section 15.117. The technical specifications given ir Section 15.118, among other things, limit the RF energy on the carrier frequen to a maximum of 10,000 μV/m at a distance of 9.8 ft (3 meters). Low power communication devices require FCC equipment authorization in accordance with the procedures set forth in Part 2, Subpart J.

Radiolocation Service.

Chapter 4 of the NTIA Manual, Subsection 4.3.1 entitled CW Phase Comparison Plan, contains the channeling plan for the Government radiolocation service. This plan is restricted to systems employing harmonically related emissions, with frequency assignments within the 1650.0-1655.0 kHz and 3300.4-3310.4 kHz bands. The mean antenna power is limited to 100 watts for both emissions, and any harmful interference between authorized systems is resolved by user coordination.

The non-Government radiolocation service is regulated by FCC Part 90, Subpart F, that limits output transmitter power to 375 watts maximum throughout the 1605-1800 kHz band, with a maximum transmitted bandwidth of 2 kHz.

Since the CW radiolocation users may not be allowed to operate in this band following the Regional Broadcasting Conference which will be determining the use of the 1605-1705 kHz band, the NTIA Manual will need to be revised to show new allocations, changed channeling plans, and technical standards for the radiolocation service in the 1605-2000 kHz band.

SECTION 4.

SPECTRUM USAGE AND MAJOR SYSTEMS

GENERAL.

The major portion of the 1605-2000 kHz band is shared between Government and non-Government users. There have been a number of services operating in the band, including aeronautical radionavigation, fixed, mobile, land mobile, maritime mobile, radiolocation, and radionavigation, with amateur as Secondary in the 1800-2000 kHz portion. Twelve Government departments and agencies use services within the band. The greatest number of assignments (262) for a given service is for radiolocation. This is followed by the aeronautical radiobeacon stations with 230 assignments, 227 of which are used by the U.S. Army. The TIS has 189 assignments, and these three areas make up 91% of the Government assignments in the band.

The table of allocations released January 1984 reflects WARC-79 changes in this band and allocates the 1605-1705 kHz portion of the band to the non-Government broadcasting service. This will change the present characteristics of the band considerably, since most existing services in this portion of the band will have to be phased out to be accommodated in the 1705-2000 kHz portion or other frequency bands (i.e. cordless telephones to the 46/49 MHz bands).

This section will provide an assessment of current spectrum use of the 1605-2000 kHz band and discuss major systems now using the band.

SPECTRUM USAGE.

Government Frequency Assignments.

Government frequency assignments are given, by agency and station class, in TABLE 5. The U.S. Army has the greatest number of assignments, with 255 (89%) for aeronautical radiobeacon stations. The Department of Interior (DoI) has 144 assignments, 97% of which are for TIS. The Navy has 212 assignments, and 81% of these are for the radiolocation services. The above assignments make up 82% of the Government use of the 1605-2000 kHz band.

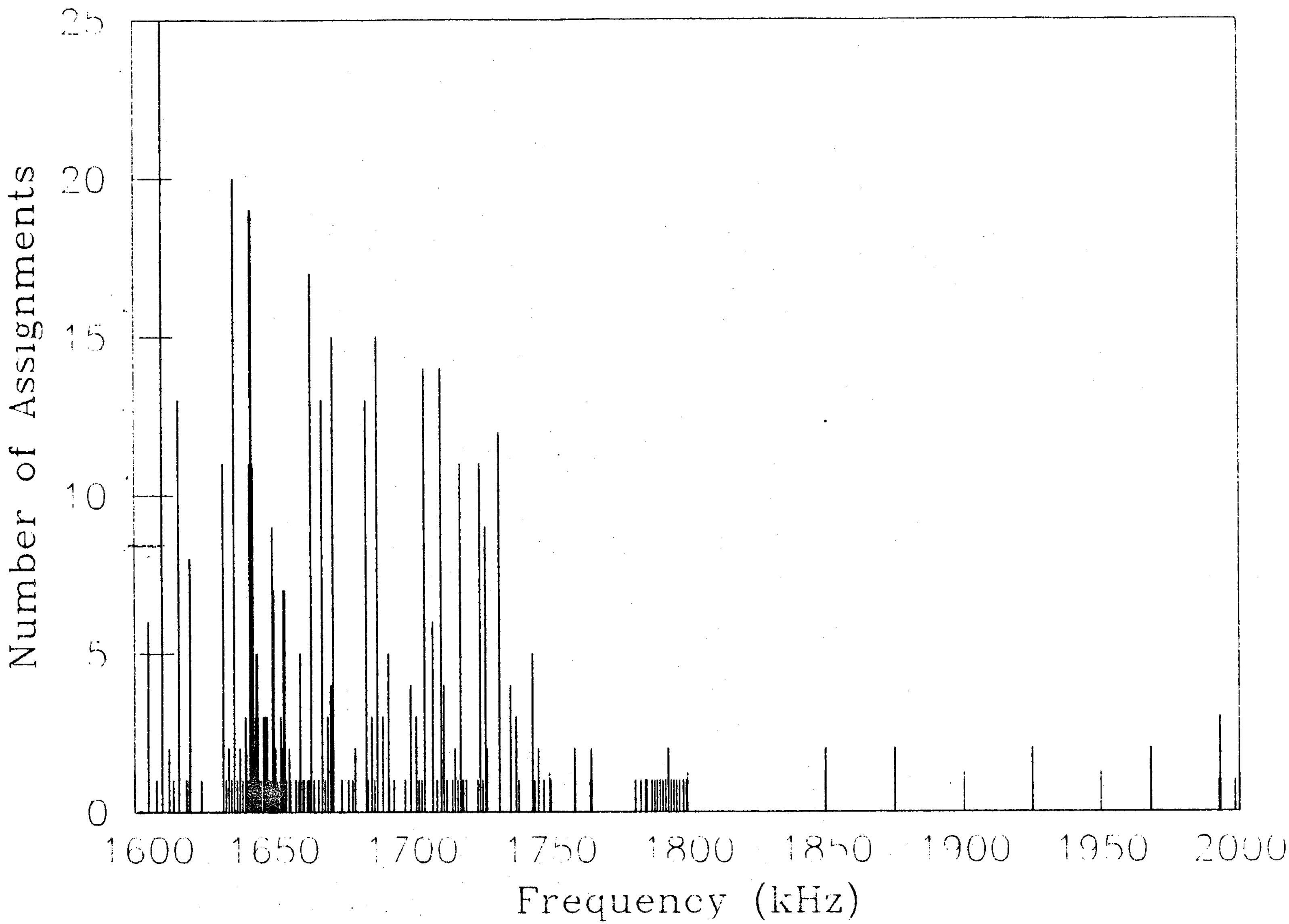
Figure 1 shows the distribution of Government assignments for 476 discrete frequencies within the band. As can be seen, there is very little Government use of the band above 1800 kHz. Since the TIS is assigned one frequency at 1610 kHz, that frequency is the most used frequency in the Government service with 189 assignments. There are 594 of the 746 Government assignments between 1605-1705 kHz.

TABLE 5

GOVERNMENT ASSIGNMENTS IN THE 1605-2000 KHZ BAND

Department Agency	Station Class or Service*														Number of Assignments	Percent of Assignments
	LR/MR	LR	MR	RLB	RL	XD	XM	XR	XT	MOB	MOEB	SP	FB	FX/MO		
Air Force								1	1		1	1	1	3	8	1.1
Army		15	11	227									1	1	255	34.2
Coast Guard													1		1	0.1
NASA										2					2	0.3
Navy	149	17	1		5				39					1	212	28.4
DOA													41		41	5.5
DOC	53	14						2		3					72	9.6
DOE							2	1							3	0.4
DOI				3		1							140		144	19.3
DOT									1				1		2	0.3
Treasury													4		4	0.5
TVA	2														2	0.3
Number of Assignments	204	46	12	230	5	1	2	4	41	5	1	1	189	5	746	
Percentage of Assignments	27.3	6.1	1.6	31.0	0.7	0.1	0.3	0.5	5.5	0.7	0.1	0.1	25.3	0.7		

*Station class abbreviations are taken from the NTIA Manual.



August 1984

Figure 1. Distribution of Government frequency assignments in the 1600-2000 kHz band.

Figure 2 gives the geographic distribution of the Government frequency assignments in the 1605-2000 kHz band. Radiolocation stations are in abundance along all coastal areas. The bulk of these assignments is to the U.S. Navy and the National Ocean Survey in the Department of Commerce.

The Government TIS stations are found around the various National parks and other federally controlled recreation areas and monuments. The geographic distribution of the TIS assignments is given in Figure 3. The distribution of TIS assignments, by State, is given in TABLE 6, There are only 30 non-Government TIS assignments, and they are included in the table and marked non-Government. As seen in Figure 3 and TABLE 6, the largest number of TIS assignments are located in California (26), Florida (14), Montana (19), and Wyoming (29).

The other major service in the band is the radionavigation service. The geographic distribution of these assignments is given in Figure 4. These are assignments at various Army airfields for training personnel in the use of the tactical radiobeacon system, used mainly for temporary helicopter bases in simulated combat situations.

Figure 5 shows the growth trend for Government assignments in the band. As shown, there has been considerable growth between 1974 and 1984. Most of this growth (83%) has occurred in the 1605-1715 kHz portion of the band. The major growth in assignments can be attributed to Army radionavigation, DoI TIS, and Navy radiolocation stations, respectively.

Government and Non-Government Frequency Assignments.

Government assignments in the 1605-2000 kHz band represent only 27% of the total assignments. The remaining 73% is assigned to the private sector as given in TABLE 7. The radiolocation service dominates the private sector use of the band. Most of the 256 assignments under experimental development (XD) are to companies engaged in radiolocation systems development and services. Between 70 and 75% of the non-Government assignments are to the radiolocation service used mainly for positioning of service craft on coastal and inland waterways and the location and positioning of off-shore oil rigs. Figure 6 shows the geographic distribution of non-Government assignments, with radiolocation assignments along the east coast and Gulf of Mexico being the dominant feature.

There are 103 assignments to low power radionavigation land stations in the 1900-2000 kHz band. These are licensed to the airlines and were used to calibrate aircraft Loran A receivers. Since Loran A was discontinued in the U.S. in January 1981, these licenses will probably not be renewed.

Figure 2. Geographic distribution of Government frequency assignments in the 1605-2000 kHz band.

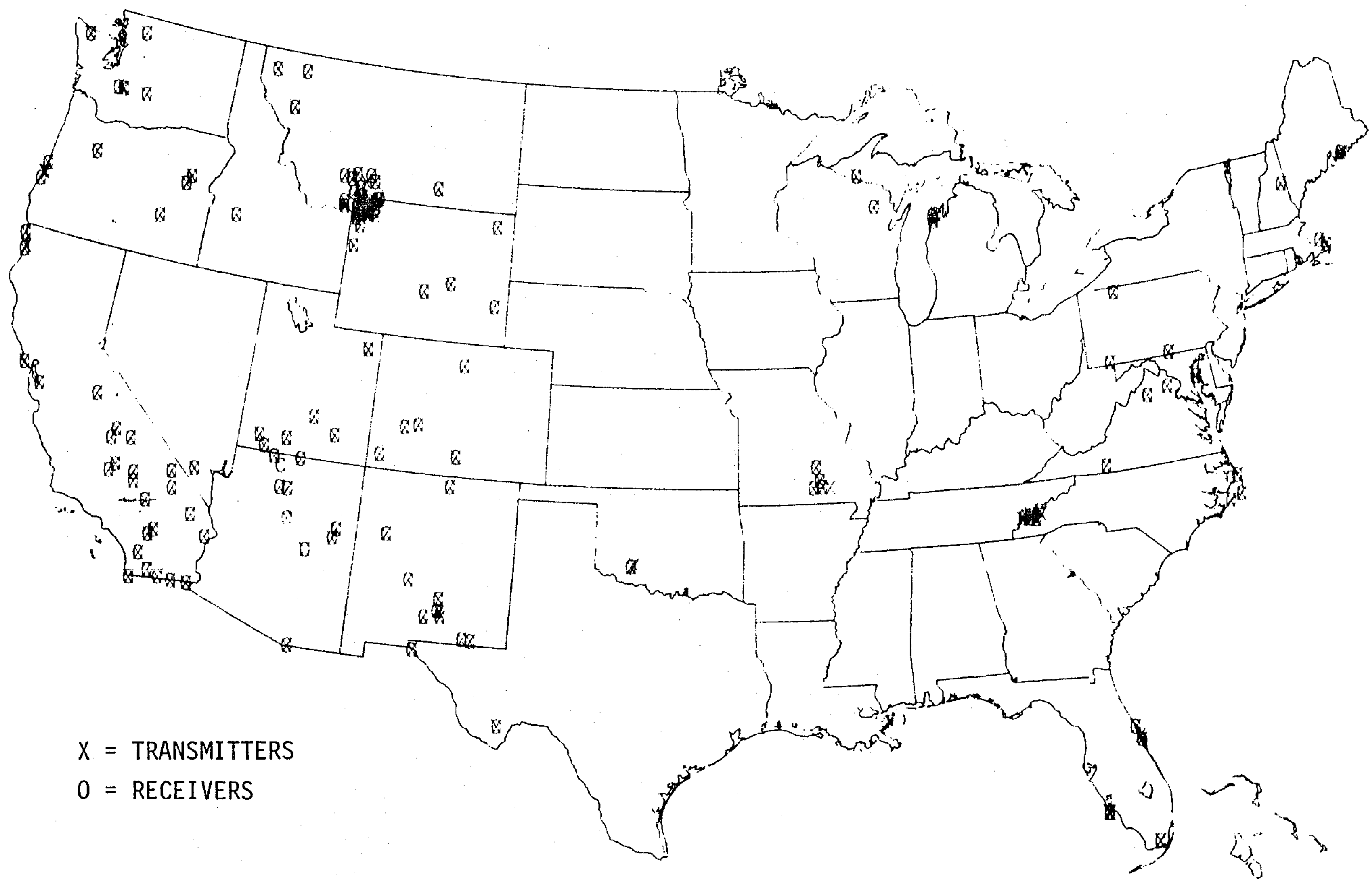


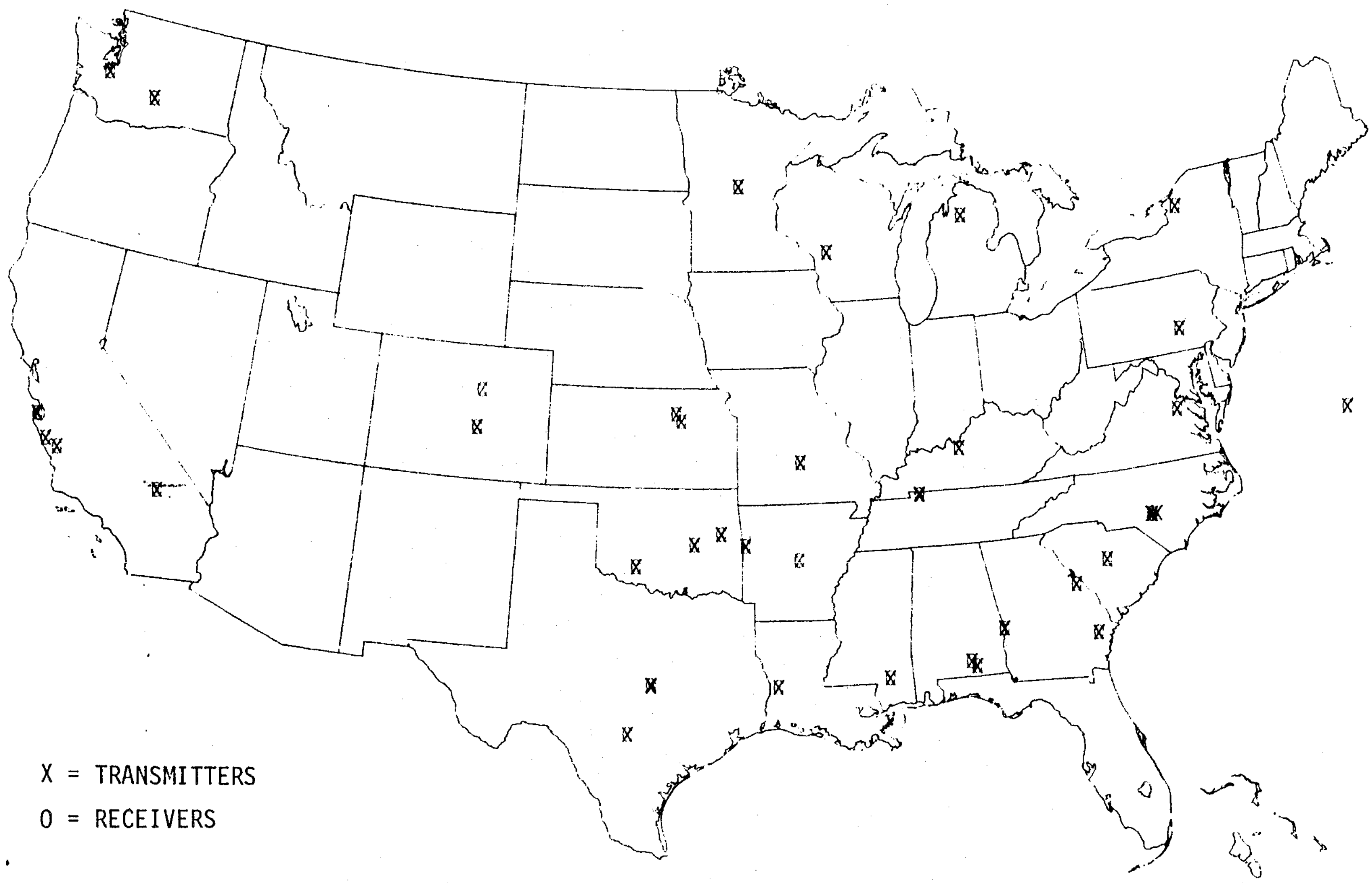
Figure 3. Geographic distribution of Government TIS assignments for the 1605-1615 kHz band.

TABLE 6

DISTRIBUTION OF TRAVELERS' INFORMATION STATIONS BY GEOGRAPHICAL LOCATION, 1610 KHZ (AUGUST 1984)

Number of Assignments		
Government	Non-Government	Geographical Location
10		Alaska
10	1	Arizona
26	5	California
5		Colorado
14	1	Florida
1		Hawaii
1	2	Idaho
	2	Illinois
	2	Iowa
	1	Kentucky
2		Massachusetts
1		Maryland
2		Maine
4		Michigan
	1	Minnesota
5	3	Missouri
19		Montana
7		North Carolina
1		Nevada
1		New Hampshire
10	1	New Mexico
	1	Ohio
2	1	Oklahoma
8	1	Oregon
3		Pennsylvania
	1	South Dakota
9	1	Tennessee
2	2	Texas
7		Utah
3	1	Virginia
6	3	Washington
1		Wisconsin
29		Wyoming
Total Assignments 189	30	

Note: 33 states listed; 17 states with no assignments.



August 1984

Figure 4. Geographic distribution of radionavigation assignments in the 1605-2000 kHz band.

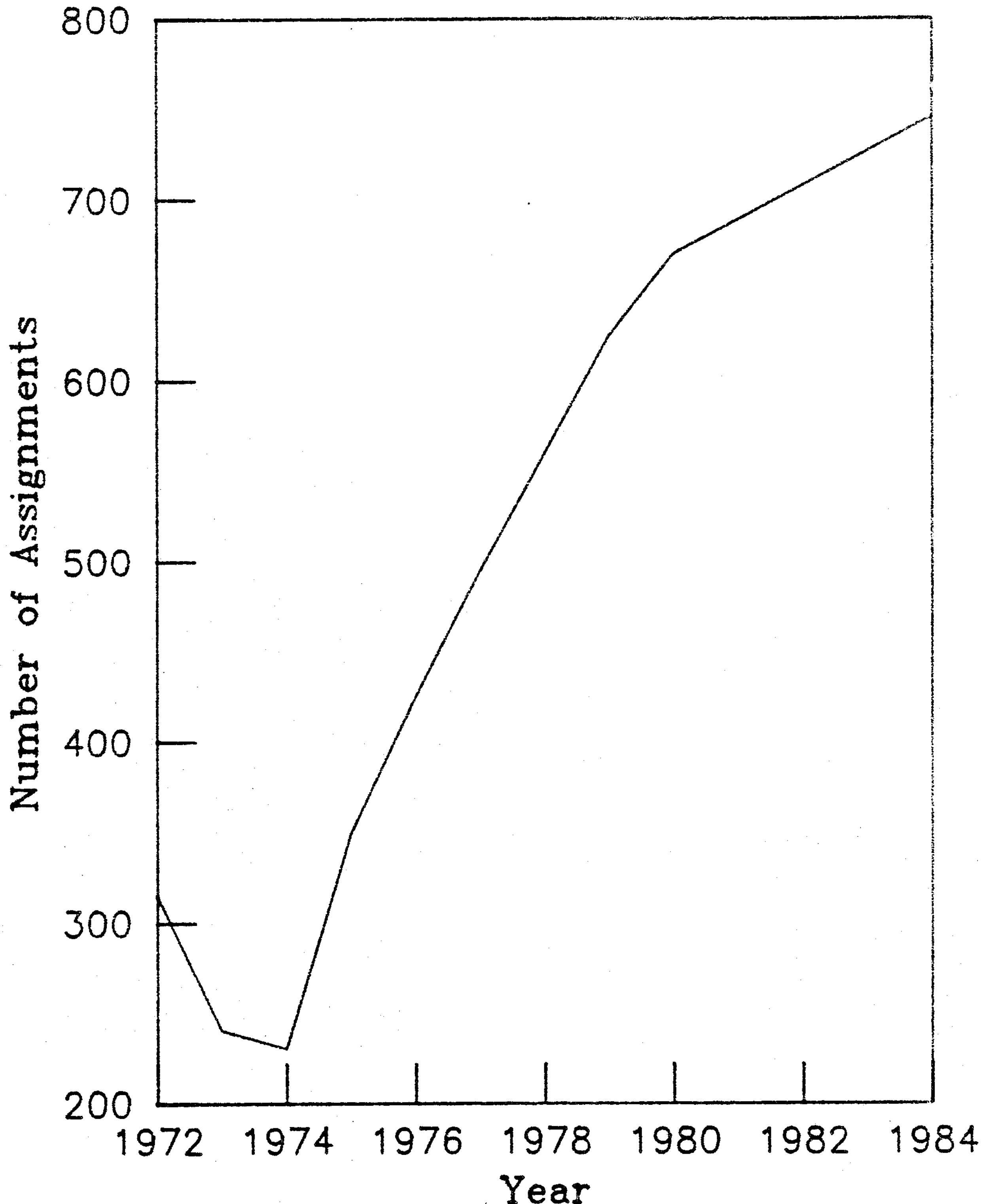


Figure 5. Government band occupancy growth for 1605-2000 kHz band.

TABLE 7

NON-GOVERNMENT ASSIGNMENTS IN THE 1605-2000 KHZ BAND

Service	Number of Assignments
Aviation Services	
Radionavigation Land Stations (AR)	103
Broadcast Services	
Auxiliary Broadcast (BA)	57
Common Carrier Services	
International Fixed Public (CI)	2
Industrial Services, Fixed, Mobile	
Business (IB)	7
Petroleum (IP)	144
Public Safety Services	
Local Government (PL)	24
Police (PP)	1
Radiolocation Services	
Radiolocation Service (RS)	1370
Experimental Services	
Experimental Contract (XC)	1
Experimental Development (XD)	256
Experimental Research (XR)	4
Total:	1969

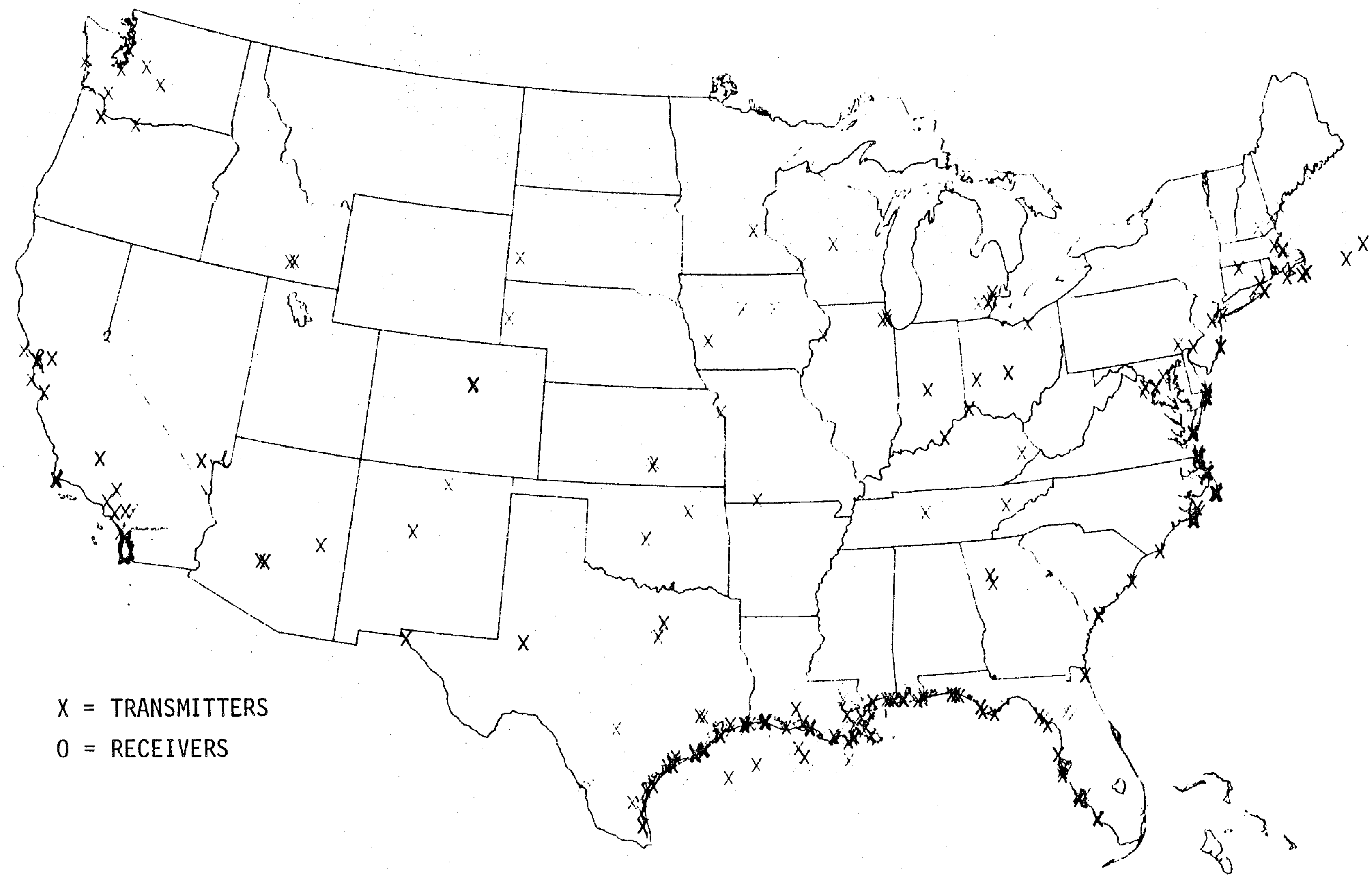


Figure 6. Geographic distribution of non-Government frequency assignments in the 1605-2000 kHz band.

Auxiliary broadcast assignments are authorized to radio stations for use in live-on-the-scene remote pickup of various local events or news coverage purposes. The remaining assignments are distributed between a number of services for communication purposes.

TABLE 8 gives the number of systems (equipment units) per station class in the band. Again the major equipment assignments are to the radiolocation services, in particular to support the petroleum industry.

MAJOR SYSTEMS IN THE 1605-2000 KHZ BAND.

Radiolocation.

The greatest number of Government frequency assignments is allocated to the radiolocation service. This service provides accurate positioning and guidance information to vessels or other vehicles involved in navigation, hydrography, dredging, and surveying. The radiolocation systems in the 1605-2000 kHz band, both Government and non-Government, typically use groundwave phase comparison techniques that are based on frequency or time multiplexing schemes. By measuring phase differences of groundwave signals from known fixed locations, the location of a mobile unit, relative to fixed transmitters, can be determined.

These systems depend on an absolute measurement of groundwave phase, including a running count of the number of 180° increments of phase difference between a remote location and fixed transmitters. Generally, the fixed transmitters are based very near the sea coast, and the phase tabulation is recorded by a receiver on board a vessel as it moves away from the coast.

Depending on the system type, one or two 180° increments are defined as a lane, and all phase comparison systems must be calibrated at some known point to initialize the lane count sequence. If a continuous track is broken through signal loss, the lane count must be re-established by returning to a point with a known lane count. Usually, the signal loss is caused by low signal strength, noise, or skywave interference from the system's own transmitters. Within limits, depending on system configuration and operator skill, the problem of a lost lane count can be partially solved. One method requires a graphical display, whereby missing counts can be identified and accounted for. A second method requires shifting the system operating frequency about 10% to periodically generate new position curves. When the new curves are compared to the old curves, an accurate position can be found. But neither of these methods is effective after a large number of counts is lost.

TABLE 8

DISTRIBUTION OF THE NUMBER OF ITINERANT TRANSMITTER UNITS IN USE BY STATION CLASS ACCORDING TO THE NGMF 1605-2000 KHZ BAND

Station Class		Number of Transmitters
FB:	Base Station (TIS 26)	283
FC:	Public Coast Station	13
FL:	Land Station	14
FX:	Fixed Station	286
FBR:	Base (Remote Pickup) Station	19
FXP:	International Fixed Station (Telephony)	2
MLR:	Remote Pickup Mobile Station	56
MO:	Mobile Station (IP 732) Petroleum	794
PL:	Radiolocation Land Station	1918
PO:	Radiolocation Mobile Station	82
RLT:	Radionavigation Land Test Station	296
Total Number of Transmitters:		3763

*NGMF = Non-Government Master File.

Frequency Multiplex Systems. These systems measure phase differences of medium frequency (MF) signals, transmitted simultaneously from several fixed locations, by comparing the phase of heterodyne audio frequencies, thereby eliminating the difficulty of RF phase measurements, yet retaining the equivalent sensitivity of RF type measurements.

An instrument measurement accuracy of ±0.02 lanes is possible, and positional accuracy is related to the angle of intersection of the hyperbolic lines of position.

Daytime ranges of over 300 nautical miles (nmi), (557 km), can be obtained, while nighttime ranges are limited by skywave interference to about 90 nmi (167 km). Since the mobile unit uses receive only equipment, any number of users may operate within one net. One company (Offshore Navigation, Inc.), operates more than 40 of these nets on a permanent basis around the Gulf of Mexico from Brownsville, Texas, to Tampa, Florida. These nets provide continuous service to this area.

Some other kinds of frequency multiplexed systems require frequency assignments with a harmonic relationship. Government frequency assignments for these systems are within the 1650-1655 and 3300.4-3310.4 kHz bands, with applications for other frequencies considered on a case-by-case basis.

A typical system is the type N Raydist that requires four fixed transmitters (a center transmitter, two end transmitters, and a relay transmitter that is in close proximity to the center transmitter). The end transmitter transmits at different frequencies that are offset slightly from the center transmitter frequency. The relay transceiver receives signals from the center and end transmitters and transmits a signal modulated by two beat frequencies from the center transmitter and each end transmitter. These heterodyne frequencies provide the reference, against which the phase measurements are made. At the mobile unit, these beat frequencies are filtered, and each is phase-compared with a similar frequency signal that is derived from filtered signals received directly from the center and end transmitters.

One set of equal, phase-difference lines is hyperbolic, with the center and one end station as foci, and a second set is hyperbolic, with the center and the other end station as foci. When the sets of lines are overlapped, the intersection provides the position of the vessel.

Time Multiplexed Systems. These systems use a single RF for position determination by multiplexing accurately timed RF pulse transmissions from fixed and mobile units. The timing of all units must be synchronized to allow accurate phase measurements. System timing is based on a timing pulse transmitted by any one unit that has been designated as the master unit. Usually this unit has the oto transmit a strong signal that is received throughout the system. All other units receive its timing pulse and synchronize to it.

A mobile unit initiates the ranging process by transmitting a pulse that is called an interrogation burst. The fixed units receive this signal and, in sequence, they broadcast a reply pulse that is phase locked to the RF excursions within the pulse as received from the mobile unit. Since the units are physically separated, the RF excursion phase angle of each transmitted pulse is a function of the distance from the mobile unit to the fixed unit. By comparing the phase of the received RF excursions against the phase that was originally broadcast, a lane progression, relative to the fixed unit, can be measured.

A typical time multiplexed system is the ARGO DM-54 system. It has an advertised operational day range of 400 nmi (742 km) and a night range of 125 to 300 nmi (232 km to 557 km). The range accuracy is given as 0.02 lanes, instrumental, and 0.05 lanes, achievable field accuracy. The frequency requirement is a single frequency between 1600 and 2000 kHz for range measurements and a second frequency from 9 to 10.5 percent higher than the primary range frequency for the option of lane identification. Lane identification can identify lane count errors if the error does not exceed plus, or minus, five lanes by phase difference measurements between the primary range frequency and the secondary frequency.

The advertised output power per unit is 100 watts, with a transmitted bandwidth requirement of 80 Hz. The antenna options range from 100-ft (30.5 m) towers and 27-ft (8.2 m) whip antennas at the fixed units to a 36-ft (11 m) center-load whip and a 35-ft (10.7 m) whip for mobile installations.

Radionavigation.

The second largest number of Government frequency assignments is to the radionavigation service, including navigational systems used for Army aircraft navigation during tactical and training missions. Generally, these are type AN/TRN-30 systems.

These systems transmit a homing, or beacon, signal to aircraft equipped with AN/ARN-59, 83, or the more recent AN/ARN-89 direction finding receivers. The transmission is an amplitude modulated RF signal on any one of 964 channels in the frequency ranges from 200 to 535.5 and 1605 to 1750.5 kHz in tunable increments of 500 Hz. The RF signal is modulated by a 1020 Hz tone that is automatically keyed to form Morse code characters in up to four-letter groups. The transmission range of the beacon is from 15 (27.8 km) to 100 nmi (186 km), depending on the system configuration or mode of operation used.

The beacon is used in two configurations: pathfinder (AN/TRN-30(V)1) and tactical and semifixed (AN/TRN-30(V)2). In the pathfinder configuration, the beacon is a low-to-medium power, short- to-medium range, portable, direction finding beacon. For low power, short-range operation, a 15-ft (4.6 m) center loaded antenna is used. For medium power, medium range operation, a 30-ft (9.1 m) top loaded antenna is used.

In the tactical and semifixed configuration, the radiobeacon is set up in a semipermanent installation and used as a medium-to-high power and medium-to-long range direction finding beacon. A top loaded 60-ft (18.3 m) antenna is used with this configuration.

The pathfinder configuration provides a transmission range of 17.5 mi (28 km) with the 15-ft (4.6 m) antenna and 28.75 mi (46 km) with the 30-ft (9.1 m) antenna. The tactical and semifixed configuration provides a range of 58 mi (93 km) and 116 mi (185 km), respectively, as the beacon output power is raised from 60 watts (tactical mode) to 180 watts (semifixed mode).

The Army purchased an additional 566 AN/TRN-30 beacons during the 1981-82 period, at a cost of about $2 million, with a projected use through the 1990s.

Cordless Telephone.

In small numbers, cordless telephones have been using the 1605-2000 kHz band for some 20 years. However, with the advent of a standardized miniature telephone plug and wide application of integrated circuitry, the cost of these telephones has declined, and vast numbers are expected to be in use in the near future.

Each cordless telephone system consists of two FM units, a "base" unit that is physically connected to the telephone wires and a portable "handset" unit connected to the base unit through RF radiation in the 1605-2000 kHz band. To permit normal telephone conversations, most cordless telephones operate in a duplex mode. In other words, both base and handset units can transmit and receive simultaneously. Each base and portable handset unit transmits and receives on separate frequencies so a unit's transmitter does not feed energy back into that unit's receiver. Cordless telephones on the market use one of five specific frequencies within the 49,800-49,900 kHz band, either 49,830, 49,845, 49,860, 49,875, or 49,890 kHz, and nearly all manufacturers randomly pair one of these frequencies with a frequency within the 1605-2000 kHz band. However, some models of cordless telephones are sold that have both units cochanneled in the 49,800-49,900 kHz band. These do not require a second frequency, since a simplex operation mode is utilized, giving priority to the handset unit.

A survey of nine vendors of cordless telephones, covering 36 models priced from $89.95 to $399.95, showed advertised possible distances of separation from the base unit to the handset unit of 50 ft (15.2 m) to 1000 ft (305 m). Three manufacturers claim that certain proprietary techniques enable some of their portable units to operate up to 1000 ft (305 m) from the base without an increase in unit output power.

Travelers Information Station (TIS).

The third largest number of Government assignments in the 1605-2000 kHz band is to TIS, licensed in the mobile service, with 172 station assignments. There are two frequencies assigned to TIS, 530 and 1610 kHz; and, although TIS comes within the international definition of broadcasting, it is administered domestically as a mobile service.

A TIS is a low power AM broadcasting system that consists of a small radio transmitter or a cluster of transmitters, usually programmed by an endless audio tape, that transmit information to motorists, pertaining to traffic and road conditions. The majority of Government TIS installations are at national parks and provide information regarding lodging, rest stops and service stations, and descriptions of local points of interest within the park. The non-Government installations are restricted to the immediate vicinity of air, train, and bus terminals, public parks and historical sites, bridges, tunnels, and Federal interstate highway interchanges.

Because 530 and 1610 kHz are just outside the lower and upper ends of the MF broadcasting band, not all car radios are able to tune in the TIS frequencies. According to the Travelers' Information Station Planning Handbook, March 1979, about 80% of car radios are able to receive the TIS stations.

Two types of antennas have been approved by the FCC for use by TIS installations, a conventional vertical monopole and a "leaky" cable antenna. With the monopole, the antenna height is restricted to 49 ft (15 m), the transmitter output power to the monopole cannot exceed 10 watts, and the system cannot radiate a field strength in excess of 2 mV/m at a distance of 0.93 mi (1.5 km) from the monopole.

The TIS transmitter output power cannot exceed 50 watts when coupled to a "leaky" cable antenna, and the length of the cable antenna cannot exceed 1.86 mi (3 km). Additionally, the transmitter output power must be adjustable downward so that the field strength emission does not exceed 2 mV/m at a distance of 197 ft (60 m) from any part of the station.

Amateur.

The amateur service is presently assigned to the 1800-2000 kHz band on a Secondary basis. With the implementation of the WARC-79 decisions, amateurs are assigned to the 1800-1900 kHz band on an exclusive basis, and they may use 1900-2000 kHz until new services proposed for this band become operational per Footnote US290. These frequency bands were inclusive in the original 160-meter amateur band of 1750-2000 kHz that was heavily used before World War II.

This band, of all the amateur service assigned bands below 30 MHz, is least affected by the 11 year solar cycle and, therefore, not subject to the violent ionospheric fluctuations that are sometimes found in the HF amateur band assignments. As a general rule, amateur communications are confined to groundwave and one-hop skywave propagation.

The maximum allowable transmitter input power for this band varies from area to area in the U.S. and its possessions, depending upon necessary protection requirements of other services. But generally, the maximum input power is limited to 1 kilowatt, average power. However, input powers used seldom exceed a few hundred watts.

Most transmitters are amplitude modulated, transmitting a single sideband, or they are keyed to transmit Morse Code. The 1800-2000 kHz assignment is the only MF amateur band. Consequently, with the usual MF requirement for very large antenna structures, this band supports the amateur's continual research and development effort aimed toward development of physically small and efficient antennas.

The FCC in General Docket 84-875, dated January 24, 1985, proposes to make 1900-2000 kHz Primary to the radiolocation service and restricts use by the amateur service.

SECTION 5.

PROBLEM DEFINITION

This section addresses potential interference problems in the 1605-2000 kHz band via a matrix that identifies the relative degree of compatibility between services using the band. The matrix was developed from information presented in preceding sections that define frequency usage, the various classes of systems, and major systems operating in the band. Issues raised in this section are examined in more detail in the following sections.

PROBLEM ASSESSMENT MATRIX.

Three categories of compatibility problems are used for the matrix in Figure 7. They are defined as follows.

Potential problems are defined as a category that requires additional study to fully define and resolve compatibility issues. The resolution of these problems may require the operational restriction of systems involved, system design changes, technical standards revision, and/or new operations procedures.

Manageable problems are defined as interactions where interference is possible under worst case conditions, but which can be avoided by using standard frequency management techniques.

No problem implies that the systems involved are separated sufficiently in frequency or distance, such that no interference would be expected even under worst case conditions.

POTENTIAL PROBLEM.

TIS/Broadcasting.

Currently, the 1605-1615 kHz frequency band is allocated exclusively for TIS. With the planned expansion of broadcasting into the 1605-1705 kHz frequency band and possible cochannel use with TIS, depending on the outcome of the regional conference, a detailed review of the impact on TIS is needed. Exclusive allocation may still be required to provide the current service. Additional constraints on adjacent channel operations (class of service) may be required to minimize interference to TIS. Nighttime operations of TIS may require very large separation distances for adjacent channel operation. Section 6 is an analysis of the potential problems.

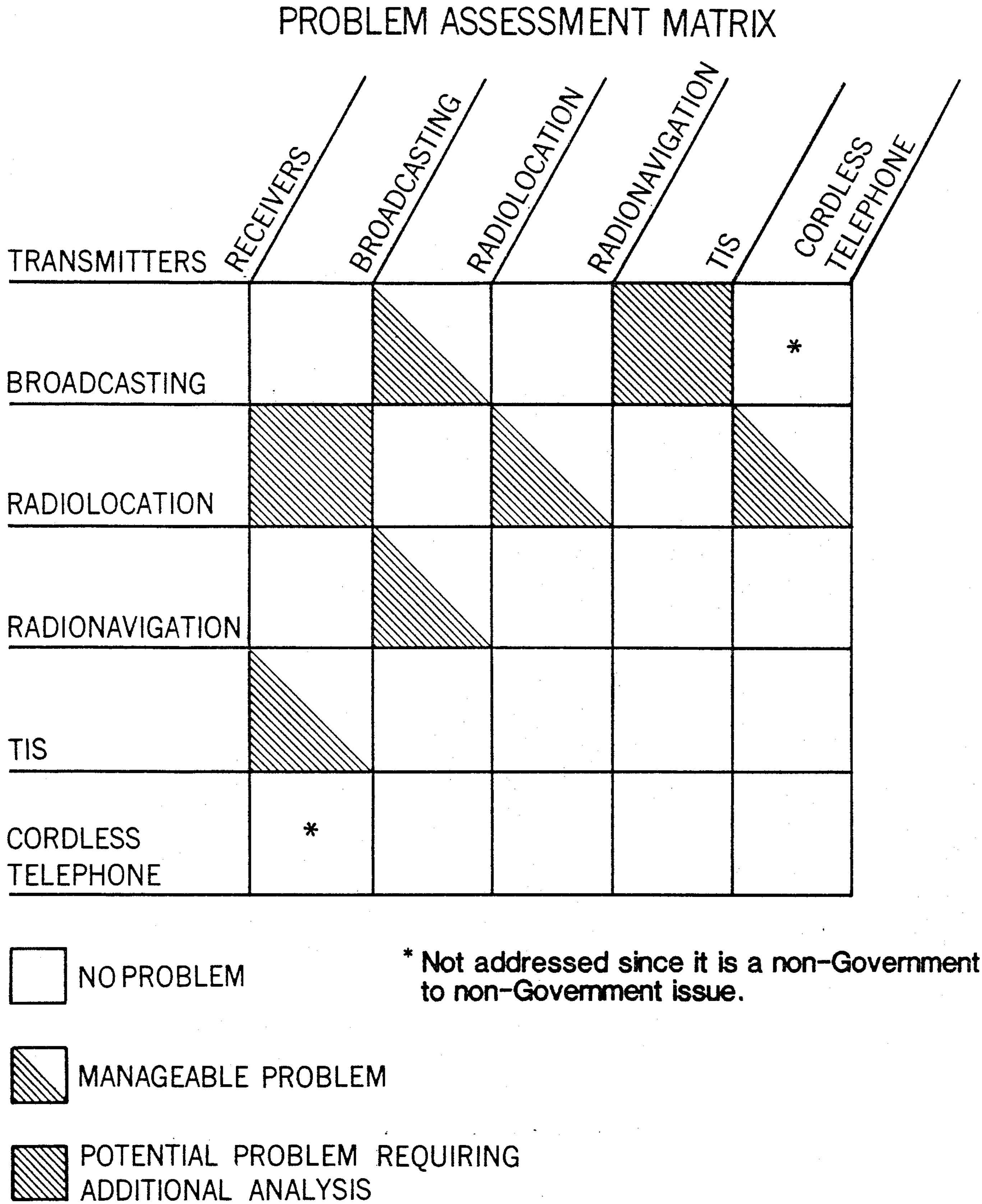


Figure 7. Problem assessment matrix.

Radiolocation/Broadcasting.

A potential problem addressed in Section 6 is the interference between a radiolocation transmitter and an AM receiver, particularly automobile receivers. If an automobile were traveling down a coast highway (most radiolocation stations tend to be in coastal areas) and came in close proximity to a cochannel radiolocation station, the interference introduced into the automobile receiver could potentially mask the desired signal.

MANAGEABLE PROBLEMS.

Broadcasting/Radiolocation.

A potential problem that requires additional analysis is the impact of the introduction of the broadcasting service into the 1625-1705 kHz portion of the 1605-2000 kHz band.

Broadcasting is the Primary service in this band segment, with radiolocation the Secondary service. In Section 6 of this report, the radiolocation service is shown to comply with the present FCC protection requirements for the broadcasting service during the day when cochannel transmitters are separated by 100 mi (161 km) or less, depending upon the effective radiated power of the broadcast station. Nighttime operation is much more restrictive, and cochannel transmitters may require separations greater than 1000 mi (1613 km), depending again on the effective radiated power of the broadcast station.

There are no industry standards describing the minimal signal-to-interference (S/I) ratio requirements for radiolocation systems, and little is known about specific system requirements. Consequently, additional study is needed to define the adverse effect of broadcasting on cochannel radiolocation systems. However, since the radiolocation systems are Secondary, they will have to accept any interference from broadcasting stations.

Until the assignment of broadcast station classes to the frequencies between 1625-1705 kHz, the seriousness of these problems is not well defined. However, it appears that potential problems will need to be resolved on a case-by-case basis for both day and night cases.

Radiolocation/Radionavigation.

Footnote US240 to the new Frequency Allocation Table states that the bands 1715-1725 kHz and 1740-1750 kHz are allocated on a Primary basis and the bands 17051715 kHz and 1725-1740 kHz on a Secondary basis to the aeronautical radionavigation service. These are the bands that will be shared by the radiolocation and radionavigation services. When the radionavigation systems are deployed inland more than a few miles, it is unlikely that they will experience any daytime interference. Nighttime operations will suffer from skywave interference, and usable frequencies for the systems will likely have to be determined on a case-by-case requirement.

Radiolocation/Cordless Telephone.

Daytime interference from the radiolocation service to cordless telephones operating in the 1625-1800 and 1900-2000 kHz bands is likely in areas within a few miles of land-based radiolocation stations. Skywave interference at night may cause interference over large areas when the telephone handset receiver frequency is cochannel with a radiolocation transmitter.

Interference from cordless telephones to radiolocation systems is likely only when the telephone base stations are near the receivers at the land-based stations, since the mobile stations are generally a long way from residential areas. The occurrence of interference from cordless telephones may vary with the weather, as the MF transmitter in the base unit is not very frequency stable. The frequency is determined by an LC (Inductance-Capacitance) oscillator whose frequency of oscillation may vary with ambient temperature conditions.

Cordless Telephone/Radionavigation.

Most of the cordless telephones manufactured to date operate in the duplex mode using channels around 49 MHz for the handset transmitter and frequencies around 1700 kHz for the base station transmitter. Radionavigation receivers on overflying helicopters may be particularly susceptible to interference from cordless telephone base stations. These transmitters feed a carrier current at some frequency between 1605 and 2000 kHz into the home power wiring so radiation from the power line can be received at a handset which may be remote 500 ft (152 m) or 600 ft (183 m) from the base unit. The strength of this electromagnetic radiation is a function of the transmitter power and the height and length of nearby above-ground power lines. The interference potential is analogous to that now being experienced by aircraft flying over cable TV systems with leaky coaxial cables supported on power poles.

The FCC in its Report and Order under General Docket 83-325 made frequencies available at 46 and 49 MHz for the use of cordless telephones. Also, the use of frequencies in the 1605-1705 kHz band by cordless telephone manufacturers could not be continued after October 1, 1984. Consequently, the potential interference problem between radionavigation and cordless telephones will become academic as both systems are eventually phased out of the 1605-2000 kHz band.

SECTION 6.
SHARING PROBLEM ANALYSIS

GENERAL.

This section discusses the key spectrum management issues concerning the 1605-2000 kHz band. A potentially serious problem may be the impact of broadcasting stations on TIS. Although the new U.S. allocation table shows TIS to be exclusive at 1610 kHz, the actual use of the 1605-1705 kHz band in Region 2 will not be known until the ITU regional conferences have been held and final agreements implemented. The impact on 1610 kHz from adjacent countries will not be known until this ITU conference decides on allowed transmitter power etc. The FCC released a First Notice of Inquiry in General Docket No. 84-467, May 16, 1984, inviting comments to assist them in developing recommendations for the United States proposals for the Administrative Radio Conference for planning of broadcasting in the 1605-1705 kHz band. Some of the comments received suggest possible changes in the allocation of frequencies to TIS and the use of high power stations in the 1605-1705 kHz band in the United States.

A major issue in this band is the future accommodation of the existing radiolocation service since the broadcasting service in the 1625-1705 kHz band segment will become a Primary service.

A potentially serious problem in the 1605-2000 kHz bands is the interference from cordless telephone transmitters to other services and the interference from the Government radio services to the cordless telephone receivers. Numerous consumer complaints of interference to the telephone system could have an adverse impact on Government operation in this band, even though cordless telephones are there on a noninterference basis and have no priority.

SHARING BETWEEN TIS AND BROADCASTING.

Traveler's Information Stations Sharing Considerations.

With the anticipated expansion of the broadcast band into the 1605-1705 kHz band, it is necessary to determine the extent of interference on TIS that is allocated at 1610 kHz.

Possible interference sources include cochannel broadcast stations, other TIS transmitters, and adjacent broadcast channel operations. Additionally, consideration must be given to the TIS interference impact on broadcast stations.

At present, there are two allocated frequencies for TIS, 530 and 1610 MHz. Some of the TIS stations operate with buried "leaky" coaxial cable systems. The resulting signal strength required is relatively small and is only usable for several hundred feet. TIS is also permitted to use a monopole antenna that has a field strength limited to a maximum of 2 mV/m at 0.93 mi (1.5 km). This antenna provides usable signals to a distance of approximately 5 mi (8.1 km) (actual distance depends on ground conductivity). This monopole antenna and associated maximum field strength will be used in the evaluation of sharing cochannel and adjacent channel operations.

Regulations concerning TIS operation do not specify protection boundary contour levels for cochannel or adjacent channel stations. The Department of Interior (DoI) has conducted a measurement program with the Denver Service Center, and the results have been included in a memorandum to the IRAC Ad Hoc 193 Chairman stating DoI recommendations on band structuring. As seen in the memorandum, required field intensities have been specified. These include the following:

1. 250 μV/m field strength is needed for the area coverage
2. the nearest cochannel station must not exceed 90 μV/m
3. interference from the nearest adjacent channel station must be less than 160 μV/m.

It should be noted that item two above provides a minimal signal-to-interference (S/I) ratio of 250/90, or approximately 2.8 to 1. This is greatly reduced from what is required bu cochannel broadcasting stations, which is 20 to 1. The 20 to 1 ratio is considered to be the minimum protection level; however, DoI memorandum values will be considered in the following discussion.

Daytime Sharing Considerations.

The groundwave field intensity graph (FCC 73.184, Graph 19A), encompassing the 1560-1640 kHz frequency band, will be used to determine TIS daytime coverage radius and interfering signal separation distances. Figure 8 shows the signal strengths that would be obtained from a transmitter and antenna that provides 100 mV/m field intensity at a distance of 1 mile. To use this graph with other power levels and antenna systems, it is necessary to make appropriate adaptations. Field intensity variations can be reflected as a direct ratio. Power variations are related to field strength as the square root of the power ratio under consideration.

Taking into account the difference between antenna power levels illustrated by the FCC graph and the distance for a given field strength (0.93 mi for 2 mV/m field intensity for the TIS station) results in the following conversion factor for TIS operation:

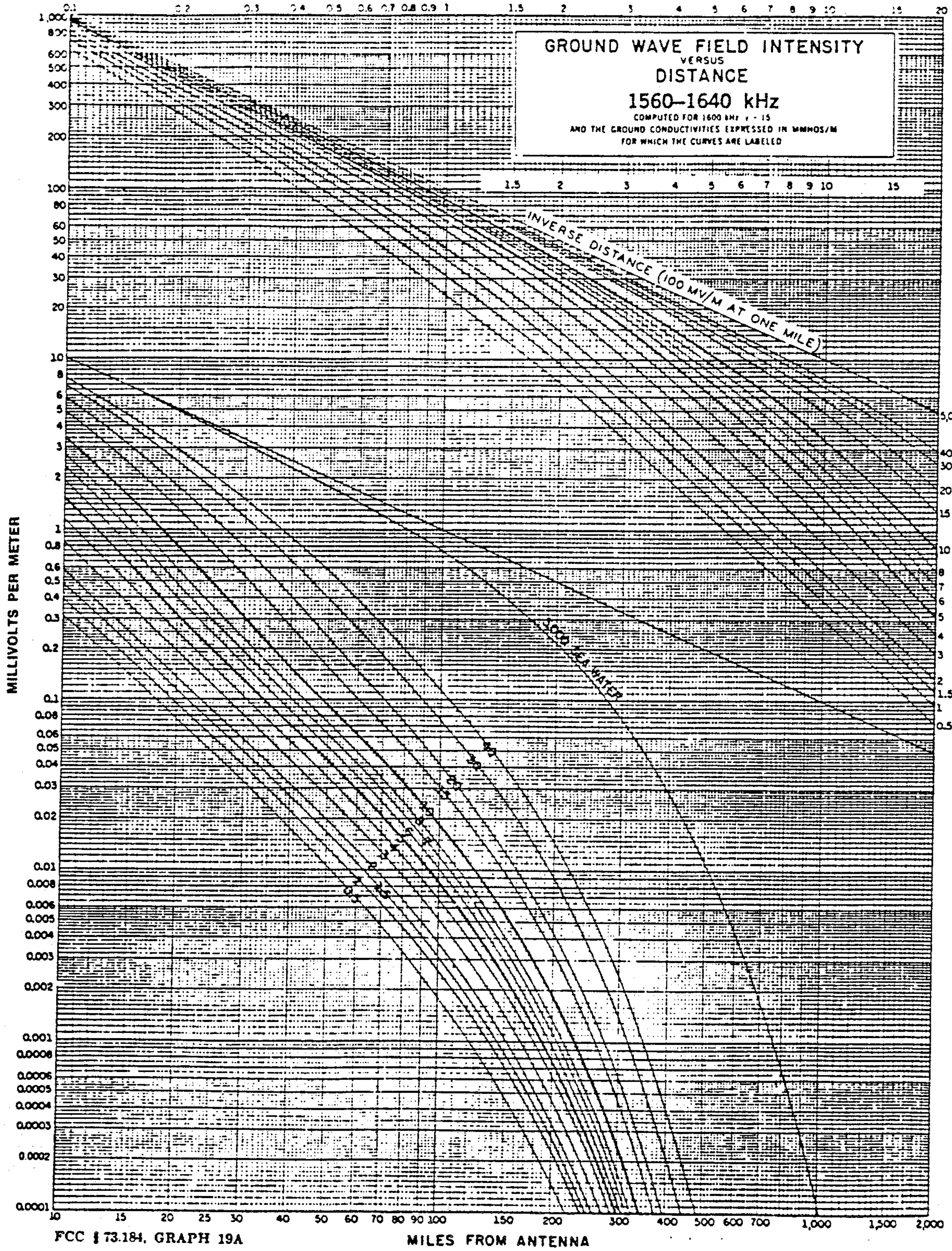


Figure 8. Groundwave field intensity.

$$\frac{100 \text{ mV/m}}{2 \text{ mV/m}} \times \frac{1}{0.93} = 53.8$$

From the DoI memorandum, a 250 μV/m field is needed for adequate signal reception. This 250 μV/m would be multiplied by the conversion factor 53.8, giving a corresponding field intensity on the FCC graph of 13,450 μV/m. By selecting a representative value for ground conductivity, the radius of coverage can be found. TABLE 9 shows the radius of coverage for specified field intensities and ground conductivity of 2 mmhos/m and 15 mmhos/m. These values of conductivity were selected as being representative of a range of inland transmitter sites for some TIS locations.

TABLE 9
TIS RADII OF COVERAGE (DAYTIME)

Field Strength Contours (μV/m)	Ground Conductivity (mmhos/m)	
	2	15
	Distance (Miles)	
5.0	14.4	40.0
12.5	9.2	27.0
25.0	6.7	19.5
90.0	3.6	10.0
100.0	3.4	9.3
160.0	2.6	6.9
250.0	2.1	5.0
500.0	1.4	2.9

It is necessary to generate comparable values for the current class of broadcast stations so the separation distances can be determined. Class 1 broadcast stations have more efficient antennas and transmit at higher power levels than shown on the FCC graph. To develop a conversion for a Class 1 broadcast station, with an antenna that has 225 mV/m at 1 mile with 1 kW input power, it is necessary to take into consideration increased power levels (i.e., a 10 kW transmitter). The conversion factor for this example is obtained by the following:

$$\frac{100 \text{ mV/m}}{225 \text{ mV/m}} \times \sqrt{\frac{1 \text{ kW}}{10 \text{ kW}}} = 0.14$$

TABLES 10, 11, and 12 show the radius of coverage for the specified power levels and antenna requirements for the Class I, II, III, and IV stations (Classes II and III have been combined).

Using the data from TABLES 9, 10, 11, and 12, the separation distances can be determined for the various classes of broadcast stations. TABLE 13 shows the separation distances needed between TIS and broadcast stations to provide a 20:1 protection ratio for selected values of TIS field strength for daytime propagation conditions. These separation distances would be needed for cochannel operation with the broadcast band for current classes of broadcast stations. TABLE 14 shows the adjacent channel separation distances needed for TIS and broadcast stations using a unity protection ratio at selected TIS protection levels.

Nighttime Sharing for TIS Example.

The TIS nighttime protection levels have not been specified for the purposes of this example, and so the daytime levels mentioned in the DoI memorandum will be used. The protection level selected for this example is the 90 μV/m for the field intensity level. The separation distance for nighttime is a function of skywave interference. Again, for this example, the 10% interference level is selected. Because of the relatively large separation distance required for the 90 μV/m level, the signal takeoff angles are very close to horizontal; therefore, horizontal gain values of the antenna will be used.

The next consideration is to determine the relative signal strengths so that separation distances can be determined for various power levels associated with the specific classes of broadcast stations. Figure 9 is used for Class I stations and Figure 10 for Class II, III, and IV stations. Both curves are based on 100 mV/m at the angle pertinent to the angle of transmission for one reflection. Field strengths can be determined by direct ratio and the resultant field strengths

TABLE 10

CLASS I BROADCAST STATION RADII OF COVERAGE (DAYTIME)

Field Strength Contours (μV/m)	Station Power			
	10 kW		50 kW	
	Ground Conductivity (mmhos/m)			
	2	15	2	15
	Distance (Miles)			
5.0	165	275	205	320
12.5	130	220	160	280
25.0	104	195	135	235
90.0	61	137	85	173
100.0	58	130	80	165
160.0	47	112	67	145
250.0	38	94	55	126
500.0	27	70	40	98

TABLE 11

CLASSES II AND III BROADCAST STATION RADII OF COVERAGE (DAYTIME)

Field Strength Contours (μV/m)	Station Power							
	1 kW		5 kW		10 kW		50 kW	
	Ground Conductivity (mmhos/m)							
	2	15	2	15	2	15	2	15
	Distance (Miles)							
5.0	109	205	142	256	156	263	192	307
12.5	78	162	105	200	120	220	150	260
25.0	58	131	81	168	94	185	128	225
90.0	32	81	47	111	54	127	77	166
100.0	31	76	44	105	51	120	74	156
160.0	24	63	36	88	41	101	60	136
250.0	20	51	29	73	34	85	49	116
500.0	15	39	20	53	24	63	36	88

TABLE 12

CLASS IV BROADCAST STATION RADII OF COVERAGE (DAYTIME)

Field Strength Contours (μV/m)	Station Power 1 kW, Ground Conductivity (mmhos/m) 2	15
	Distance (Miles)	
5.0	105	200
12.5	72	155
25.0	54	125
90.0	29	75
100.0	28	72
160.0	22	59
250.0	18	47
500.0	14	37

TABLE 13

TIS COCHANNEL BROADCAST TRANSMITTER SEPARATION DISTANCE AT THREE CONTOUR LEVELS
(20:1 PROTECTION RATIO) (DAYTIME)

Field Strength Contours of TIS (μV/m)	Daytime Station Power															
	Class I				Classes II and III								Class IV	
	10 kW		50 kW		1 kW		5 kW		10 kW		50 kW		1 kW	
	Ground Conductivity (mmhos/m)													
	2	15	2	15	2	15	2	15	2	15	2	15	2	15
	Distance (Miles)													
100	168	284	208	329	112	214	145	265	159	272	195	316	108	209
250	132	229	162	289	80	167	107	205	122	225	152	265	75	164
500	105	198	136	238	59	134	82	171	95	188	129	228	55	128

TABLE 14

TIS ADJACENT BROADCAST TRANSMITTER SEPARATION DISTANCE AT THREE CONTOUR LEVELS
(1:1 PROTECTION RATIO) (DAYTIME)

Field Strength Contours of TIS (μV/m)	Daytime Station Power													
	Class I				Classes II and III								Class IV	
	10 kW		50 kW		1 kW		5 kW		10 kW		50 kW		1 kW	
	Ground Conductivity (mmhos/m)													
	2	15	2	15	2	15	2	15	2	15	2	15	2	15
	Distance (Miles)													
100	61	139	83	174	34	85	47	114	54	129	77	165	31	81
250	40	99	57	131	22	56	31	78	36	90	51	121	20	52
500	28	73	41	101	16	42	21	56	25	66	37	91	15	40

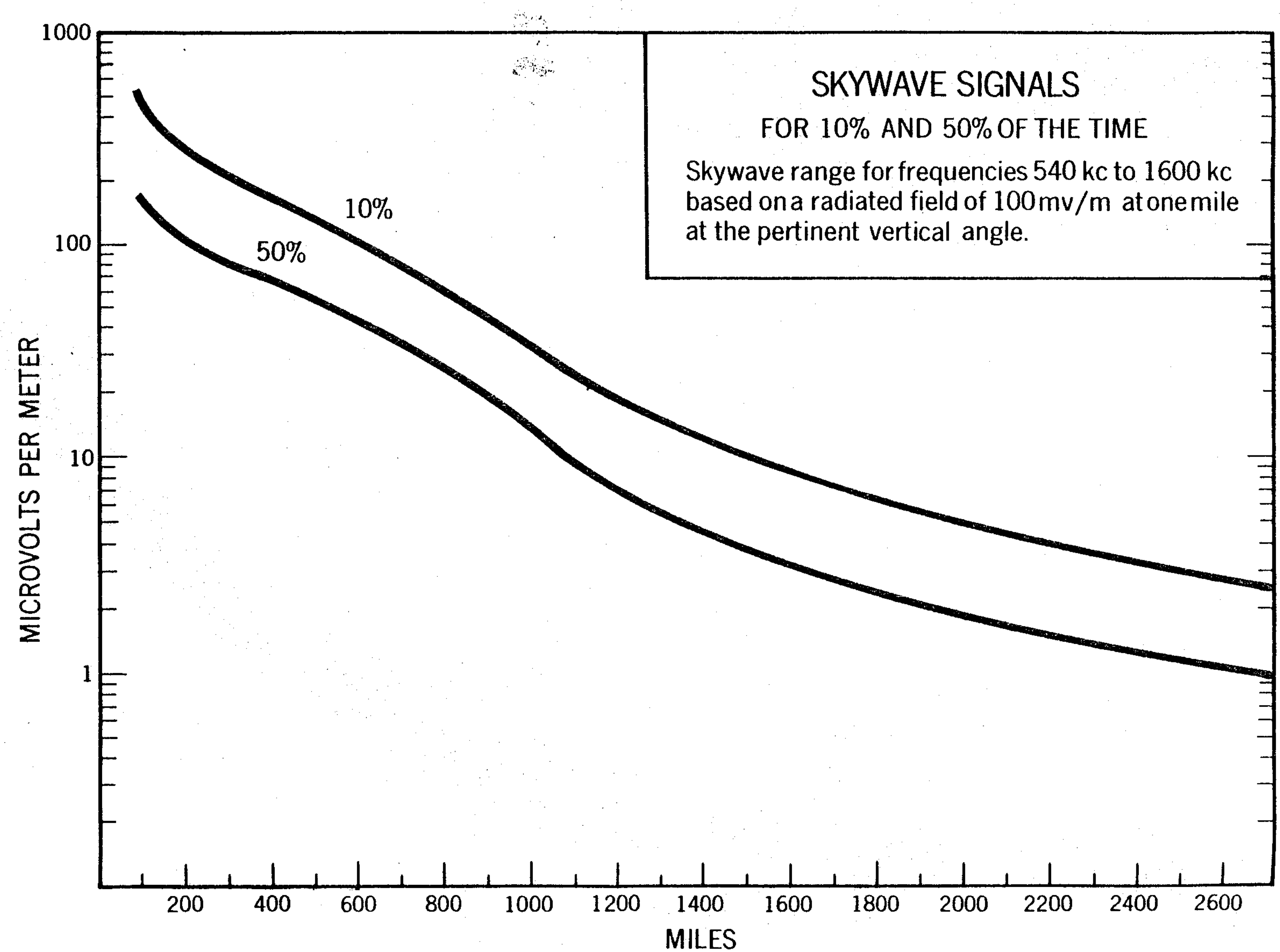


Figure 9. Field strength vs. distance for skywave signals from Class I broadcasting stations.

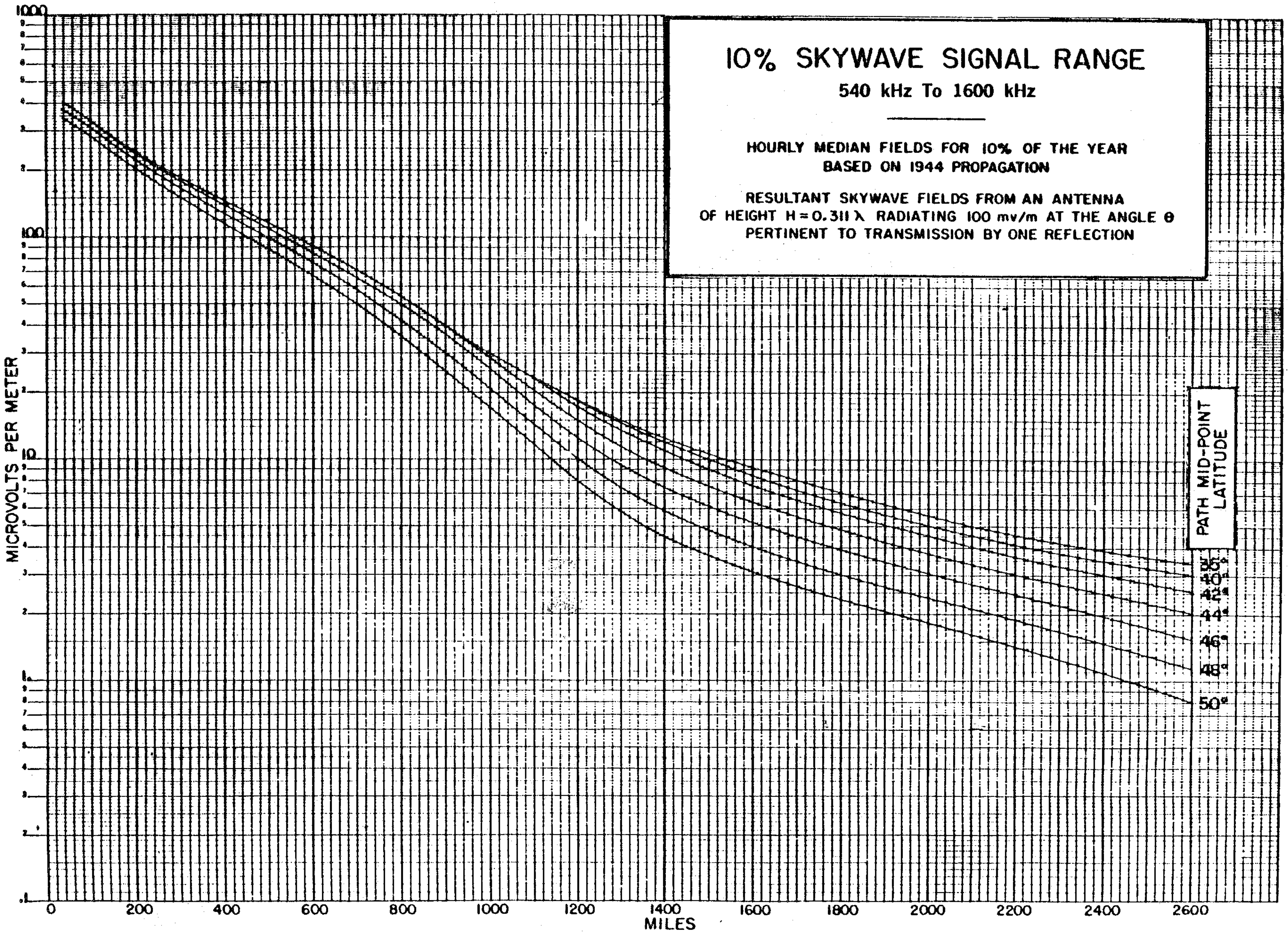


Figure 10. Field strength vs. distance for 10% skywave signals from Class II, III, and IV stations.

associated with power variations by the square root of the power ratio. A latitude of 40° (Central United States) is taken as a representative latitude for the example. Also, minimum required antenna efficiencies for the broadcast antennas are utilized (Class I, 225 mV/m; Class II and III, 175 mV/m; and Class IV, 150 mV/m). Assuming these antenna characteristics and representative power levels are for various broadcast stations, the separation distances can be approximated. TABLE 15 shows these resulting separation distances.

Adjacent channel interference levels have not been established for TIS. TABLE 16 shows minimum distance for adjacent channel separation for various protection levels.

SHARING BETWEEN BROADCASTING AND RADIOLOCATION.

The following analysis provides a method to determine distance and/or frequency separations that will be required between transmitter sites to adequately protect the broadcasting service from interference and still allow operation of the radiolocation service within 1625-1705 kHz.

In the 1605-2000 kHz band, the radio propagation of concern in this analysis is via a groundwave and skywave mode. Propagation conditions in this band differ substantially from day to night. The groundwave mode is present at all times, but the skywave mode is propagated only during nighttime from about local sunset to local sunrise.

The groundwave provides a stable and reliable service near the transmitter with the received field strength being highly dependent upon the distance of separation and the electrical conductivity of the earth between the transmitter and receiver. The groundwave is least attenuated over salt water.

The skywave signal is reflected or refracted in the ionosphere and may propagate over great distances if some radiation from the transmitting antenna is at low vertical angles. Skywave signals are subject to field strength variations and generally fade up and down at a slow rate, with the excursions sometimes going in and out of the indigenous noise.

Sharing Criteria.

Within the U.S. standard broadcast band of 535-1605 kHz, three classes of channels for broadcasting have been established. Namely, clear channels for the use of high-power stations, regional channels for the use of medium power stations, and local channels for the use of low power stations. With the advent of the broadcasting service in the 1605-1705 kHz band, any or all of these channel classes may be assigned within the band.

TABLE 15

TIS AND COCHANNEL BROADCAST STATION SKYWAVE SEPARATION DISTANCES FOR FOUR CONTOUR FIELD STRENGTH LEVELS (NIGHTTIME)

Field Strength Contours (μV/m)	AM Broadcasting Station Power							
	Class I		Classes II and III					Class IV
	10 kW	50 kW	0.5 kW	1 kW	5 kW	10 kW	50 kW	0.25 kW
	Distance (Miles)							
5.0	>2800	>2800	2220	>2800	>2800	>2800	>2800	1780
12.5	>2800	>2800	1480	1720	2580	>2800	>2800	1250
25.0	2320	>2800	1140	1320	1810	2120	>2800	960
90.0	1390	1920	690	815	1130	1220	1720	480

TABLE 16

TIS AND ADJACENT BROADCAST STATION SKYWAVE SEPARATION DISTANCES FOR SELECTED CONTOUR FIELD STRENGTH LEVELS

Field Strength Contours (μV/m)	AM Broadcasting Station Power							
	Class I		Classes II and III					Class IV
	10 kW	50 kW	0.5 kW	1 kW	5 kW	10 kW	50 kW	0.25 kW
	Distance (Miles)							
100	1330	1800	660	790	1060	1200	1620	460
160	1130	1500	450	600	900	1000	1400	250
250	970	1240	260	420	740	860	1150	100
500	740	1020	<40	140	460	600	900	<40

The established procedure for the sharing of broadcasting frequencies within the U.S. is developed in Part 73 of the FCC Rules and Regulations. The most significant part of the sharing procedure is the definition of a protection contour around each broadcasting transmitter and the required ratio of desired to undesired signals at this protection contour. This contour is a line of constant field strength around the transmitter, with designated values of field strength that vary according to the different classes of broadcasting stations and between daytime and nighttime. As an example, Class I stations are cochannel daytime protected to their 100 μV/m contour and nighttime protected out to their 500 μV/m contour, and Class IV stations are cochannel daytime protected out to their 500 μV/m contour. When cochannel interference to broadcast stations is considered, the required ratio of desired-to-undesired station groundwave at the protected contour is 20:1. When the frequencies are separated by 10 kHz, the permitted ratio is 1:1 (FCC Rules and Regulations, Part 73.182(v)).

Laboratory measurements of the six selected car radios provided information for carrier separations from 0 to 0.5 kHz. These measurements were taken using two RF frequency synthesizers feeding into ports of a combiner, with the output matched onto the antenna input jack of a car radio. One synthesizer was programmed to the fixed frequency of the car radio (1600 kHz) and adjusted for an output level that provided a nominal value of receiver AGC voltage, with no evidence of receiver overload. The second synthesizer RF output level was set at 26 dB below the fixed frequency source and frequency swept ±10 kHz either side of zero frequency with the fixed source. At the -26 dB level, the introduction of the second signal source did not preceptibly change the receiver AGC voltage established by the first signal source. As the second generator was frequency swept, a power meter connnected across the receiver audio output was logged by a computer that plotted the selectivity curves. Figure 11 is a block diagram of the instrumentation and Figure 12 is a composite of the resultant frequency response curves of the receivers. Because some of the receivers had very similar characteristics, not all six curves are discernible.

At zero frequency separation between the carriers, as shown in Figure 12, the receiver outputs were down 25 to 30 dB below the outputs when compared to a carrier separation of 2 or 3 kHz. The rolloff down to zero frequency separation is a function of the receiver's audio bandpass.

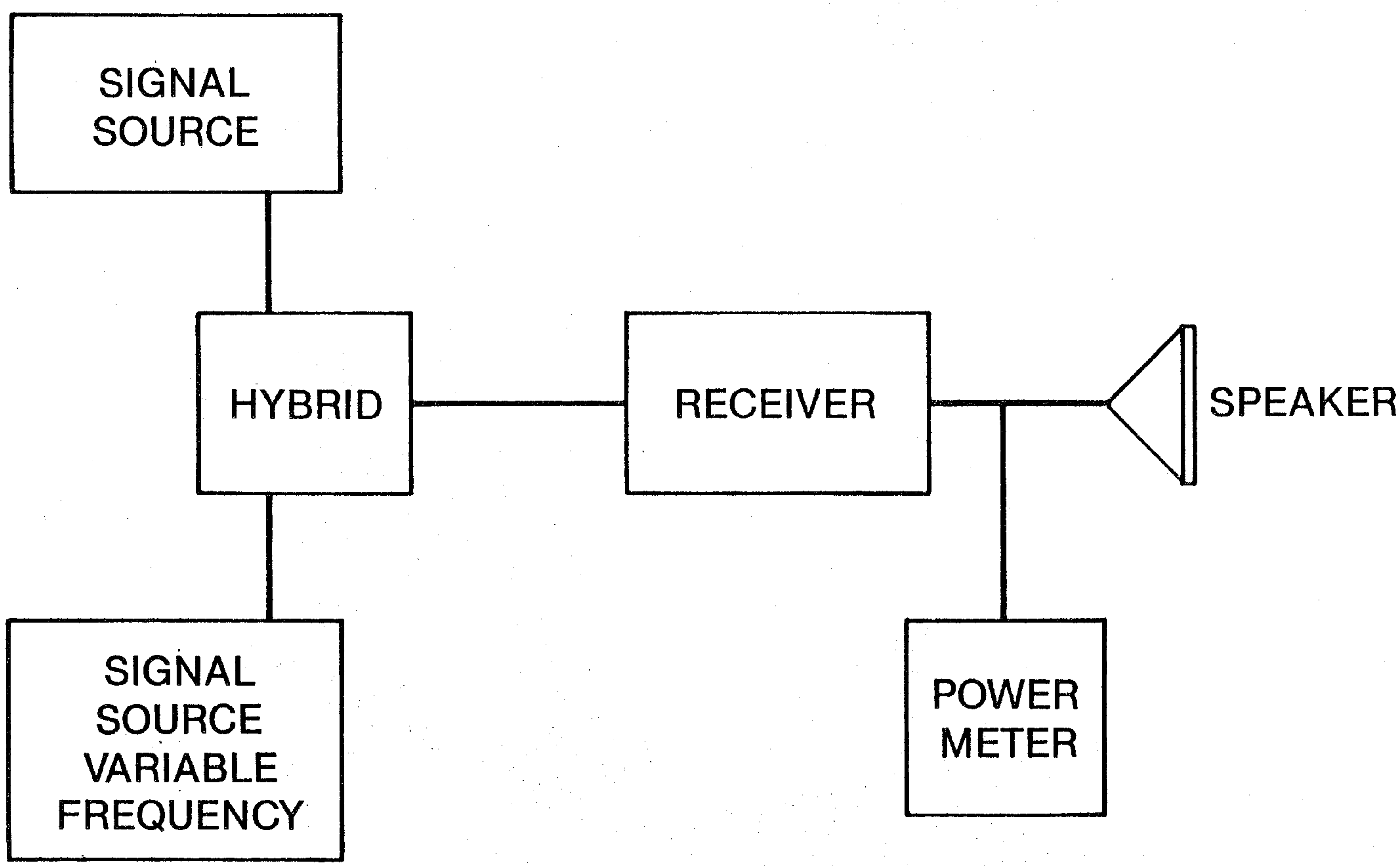


Figure 11. Block diagram of test setup for receiver measurement.

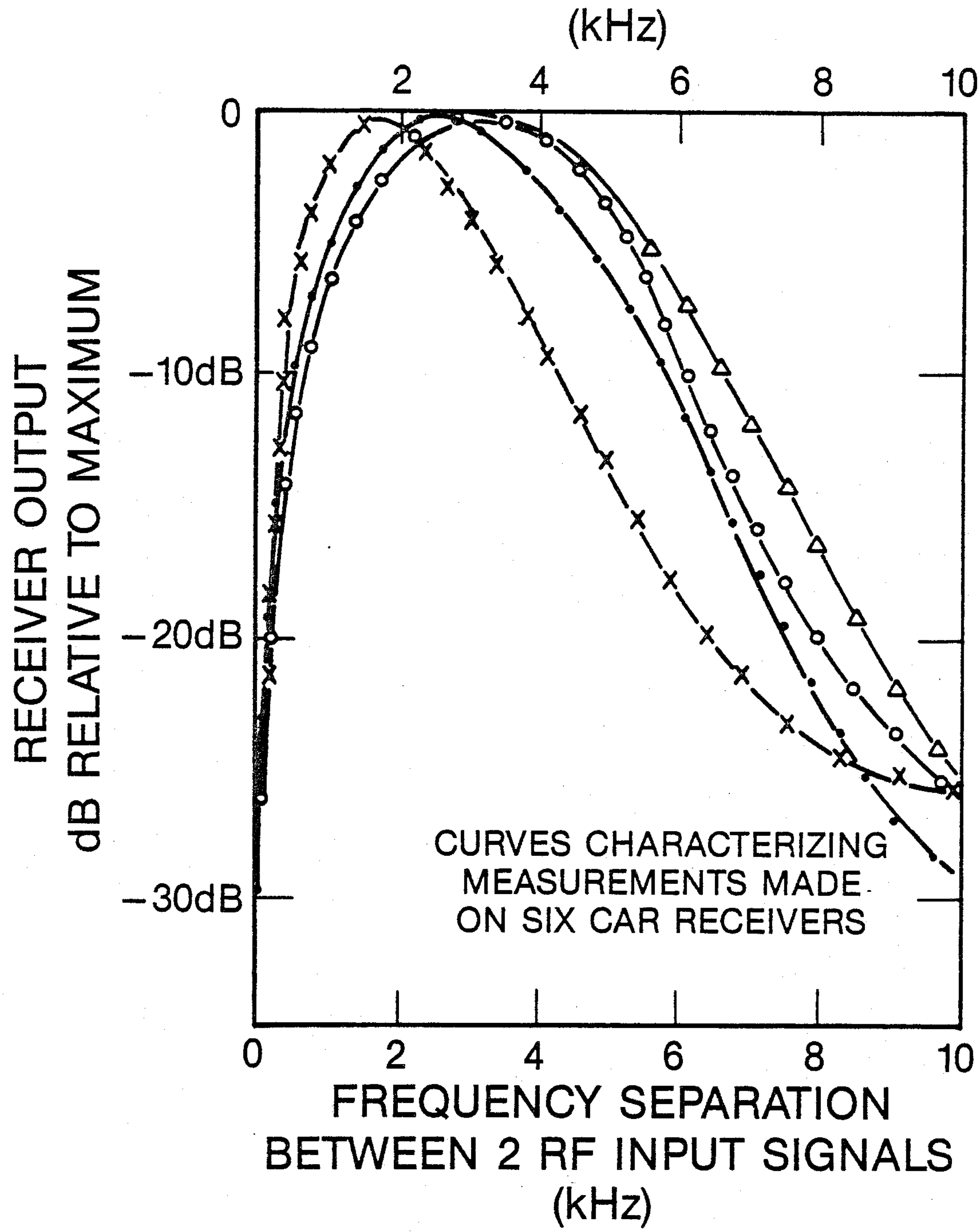


Figure 12. Results of laboratory receiver measurements.

At zero frequency separation, with both carriers unmodulated, the receiver output is the noise level from the demodulator and the audio amplifiers. When the dominant carrier is modulated and a much weaker carrier is unmodulated, the receiver output will be minimally distorted with the introduction of the unmodulated signal when it is down 26 dB below the modulated signal.

Since the transmitters of a time-multiplexed radiolocation system share a common frequency, the system may be considered as a CW source. The power of the received signal from such a network may vary with the location and output power of the individual transmitters, but overall, the interference from the network to the broadcast service may be considered as a case of desired AM versus undesired CW.

In the case of a broadcast transmitter and a single frequency CW radiolocation station (time-multiplexed) with cochannel frequency assignments, it is unlikely that the carriers will be on the same frequency for any appreciable time. Instead, they are more likely to drift back and forth through the assigned frequency.

If the radiolocation system is frequency multiplexed, there are many transmitters on simultaneously and slightly separated in frequency within an allocated 2 kHz bandwidth. A broadcast receiver tuned on the radiolocation transmitter frequency will receive these transmitter emissions within its bandpass. However, the radiolocation transmitters generally are not power or phase coherent one to another, so the radiated spectrum is difficult to characterize. For the purposes of this report, the frequency-multiplexed system is considered as a case of desired AM versus undesired AM.

DAYTIME SHARING.

It is anticipated that some of the broadcasting stations planned for in the 1605-1705 kHz band will be Class IV type stations. This class of station is protected in the daytime out to its 500 μV/m contour. This field strength value is one of the criteria used in the sharing analysis.

During the day, in the absence of skywave propagation, transmitter spatial separations required for specified received S/Is are generally less than the separations required at night. Considering groundwave propagation and assuming a given ratio of desired signal to undesired signal input at the receiver, the necessary frequency and/or distance separations between the transmitters may be determined.

Transmitters in the radiolocation service have a maximum allowable power output of 375 W, although lower powers are typically used. Each radiolocation frequency assignment has a maximum allowable bandwidth of 2 kHz, which usually encompasses several transmissions radiated from fixed and mobile transmitters in frequency or time multiplex. The fixed transmitters have the greatest interference potential since they are most likely to have efficient antennas. At these frequencies, efficient groundwave radiators are usually small towers about 100 ft (30 m) high, with some ground radials at the tower base. As a contrast, mobile antennas are usually short whips that, under ideal conditions, will radiate only a small percentage of the transmitter output power due to the low value of antenna radiation resistance inherent in electrically short antennas.

In the following analysis, the typical Government radiolocation transmitter at a fixed location was assumed to have a power output of 375 W to a quarterwave vertical antenna over an adequate ground screen and located over earth of low conductivity, such as sand that is just inland from the sea. The typical mobile station is assumed to be a maritime installation with a transmitter output power of 100 W to a 25 ft (7.6 m) long whip antenna. Additionally, the radiolocation operating frequency is assumed to be cochannel or near the frequency of a proposed Class IV broadcast station frequency.

Transmitter units in a frequency-multiplexed radiolocation system have very small individual bandwidth emissions. A total system has a bandwidth assignment of 2 kHz, and many transmitters may be operated simultaneously within this assignment. Consequently, all transmitters in the system are considered as potential interferers.

Transmitters in a time-multiplexed system are on a common net frequency, but are pulsed on and off in sequence at a slow rate. A typical bandwidth requirement for one of these emitters is less than 100 Hz, unless a land identifier option is in use, in which case a second frequency that is about 10% higher than the common net frequency is periodically required. Even when the transmitter net frequency is near the low end of the 1625-1705 kHz band, a lane identifier pulse will be transmitted at a frequency above 1705 kHz. In view of these operating parameters and for the purpose of this analysis, the output of a transmitter of this system was assumed to be a single frequency, continuous wave emission.

Daytime Sharing Example.

In this example, the radiolocation station is found to have the potential to produce objectionable interference at the protection contour of a proposed broadcast station. The radiolocation station, because of its secondary allocation status, must then make appropriate adjustments in location, power output or frequency, or combinations of these to protect the broadcasting stations.

The magnitude of interference at the broadcast receiver or at the broadcasting station's protected service contour, produced by the radiolocation transmitter, can be determined by the use of parameters associated with the transmitting antenna and propagation path loss variables. The FCC has published electromagnetic field strength curves that take into account propagation variables that can be used to determine the interference from a radiolocation transmitter.

Use of the field strength versus distance curves (see Figure 8) requires knowledge of the effective field (mV/m at 1 mi (1.6 km)) radiated from the transmitting antenna. The values illustrated in Figure 8 were based on a frequency of 1600 kHz. For 1700 kHz, the results will be similar, but the values of predicted field strength will be about 2 dB lower. The strength of the field 1 mi (1.6 km) from the antenna is a measure of the efficiency of an antenna system, and in the case of a vertical antenna, is a function of the antenna height, the number and length of the ground radials, and the values of surrounding ground conductivity. For an existing radiolocation system, the field at 1 mi (1.6 km) can be measured. For a proposed broadcast station installation, Part 73.182(v) of the FCC Rules and Regulations states that the effective field at 1 mi (1.6 km), for 1 kW for various classes of broadcast stations, shall not be less than: Class I, 225 mV/m; Class II and III, 175 mV/m; and Class IV, 150 mV/m.

To determine the possible interference, first the value for ground conductivity between the radiolocation station and the proposed broadcast station can be determined from Figure 13. Second, a field strength versus distance curve that best describes the existing ground conductivity between the broadcast transmitter and the radiolocation station is selected (see Figure 8). Knowing the effective field at 1 mi (1.6 km), the boundary of the protected service area of the proposed broadcast station is determined. Class I stations are daytime cochannel protected out to their 100 μV/M contour, and all other classes are protected out to their 500 μV/m contour (Part 73.182 (v), FCC Rules and Regulations). The field strength of the radiolocation station where a straight line drawn between the broadcast transmitter to the radiolocation transmitter intersects the proper protection contour is then measured. If a time-multiplexed system is being measured, use the highest reading of field strength noted as the system transmitters are cycled on and off. Measurements of a frequency-multiplexed system may not resolve field strength contributions from the individual transmitters due to bandwidth limitations of the field strength meter, but the interference field strength from the system can be measured.

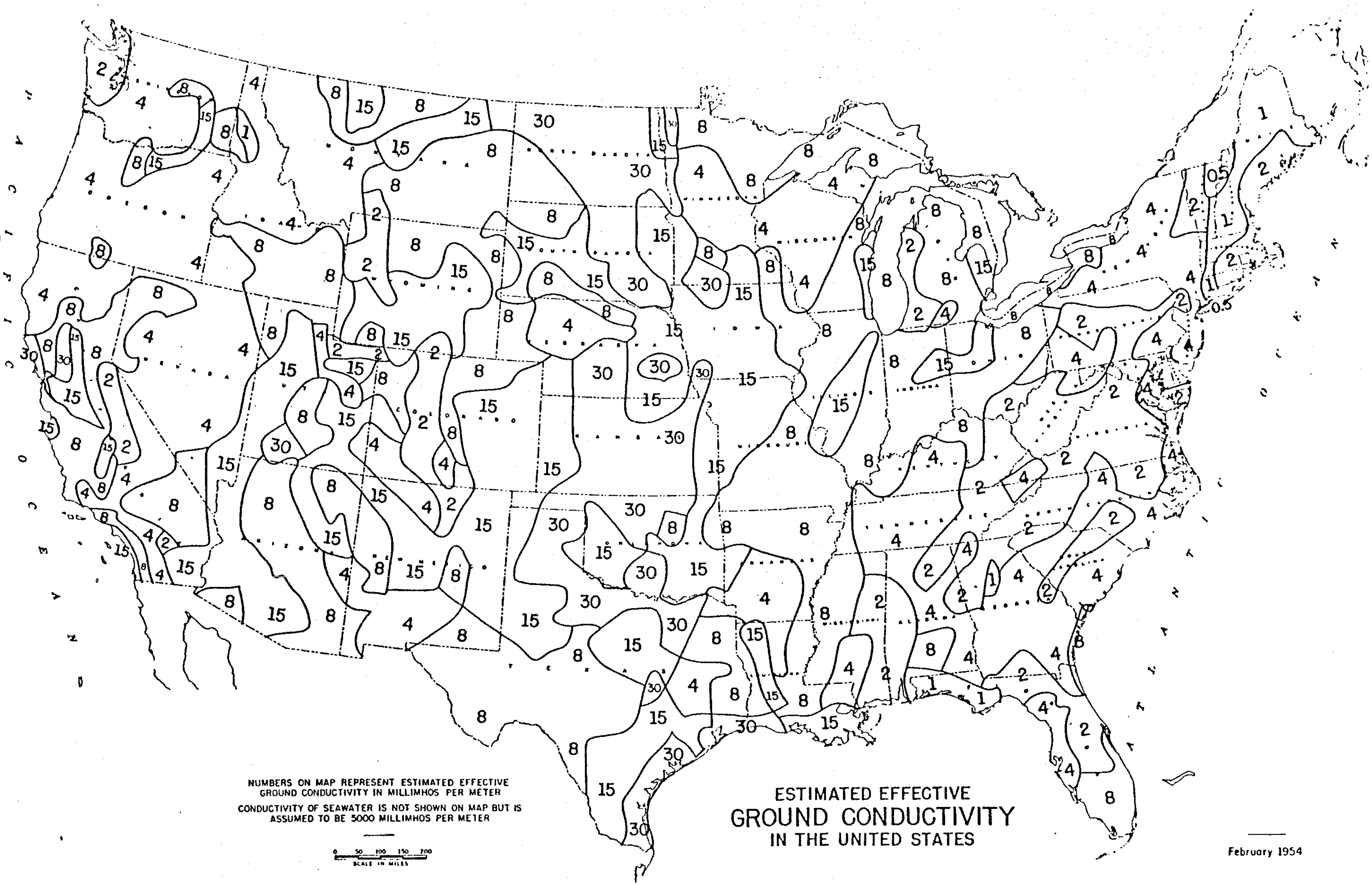


Figure 13. Ground conductivity (mmho/m) map.

After the S/I (broadcast/radiolocation) at the protection contour is determined, and if the radiolocation transmitters are cochannel with the proposed broadcast station, interference-free service exists when the minimum ratio of field intensity of a desired groundwave to an undesired groundwave signal is 20:1 (Part 73.182(w), FCC Rules and Regulations).

The following are some examples of potential interference determined by this method. A Government time-multiplexed system that operates at 1620 kHz must protect a proposed 1 kW daytime cochannel Class IV station that will be 25 mi (40 km) away from the nearest fixed radiolocation transmitter within the system (see Figure 14). The broadcast station antenna is expected to have an effective radiated field of 150 mV/m at 1 mi (1.6 km). The ground conductivity at each transmitter and of the intervening terrain is 2 mmhos/m. Since a Class IV station is protected during the day out to its 500 μV/m contour, it is first necessary to find the radial distance from the broadcast transmitter out to its 500 μV/m contour using the curve labeled 2 mmhos/m in Figure 8. All curves in Figure 8 are plotted for an effective radiated field of 100 mV/m at 1 mi (1.6 km). Consequently, the distance to the 333 μV/m contour for an effective radiated field of 100 mV/m is equivalent to the 500 μV/m contour for an effective radiated field of 150 mV/m; therefore,

$$[\frac{100}{150} \times 500 = 333]$$

From the appropriate curve, the radial distance out to the 333 μV/m contour is about 13 mi (21 km). This is the radius of the daytime-protected area around the proposed broadcast station and is the location at which the field strengths from the radiolocation stations are measured. Since the transmitters are to be cochannel, the field strength measured from the radiolocation system cannot exceed 25 μV/m, or 500/20.

To determine the values of field strength radiated from antennas with effective fields that differ from 100 mV/m at 1 mi (1.6 km), multiply the ratio of the differing field to 100 mV/m times the field strength value read from Figure 8.

As an example, if the radiolocation transmitter has an effective radiated field of 50 mV/m at 1 mi (1.6 km) for a kilowatt, the field strength incident at the proposed broadcast station's 500 μV/m contour can be determined. (This contour is 12 mi (19.2 km) from the radiolocation station.) From the 2 mmhos/m curve in Figure 8, the field strength at 12 mi (19.2 km) is about 400 μV/m for an antenna with an effective radiated field of 100 mV/m at 1 mi (1.6 km). For an antenna with an effective radiated field of 50 mV/m, the expected field strength of

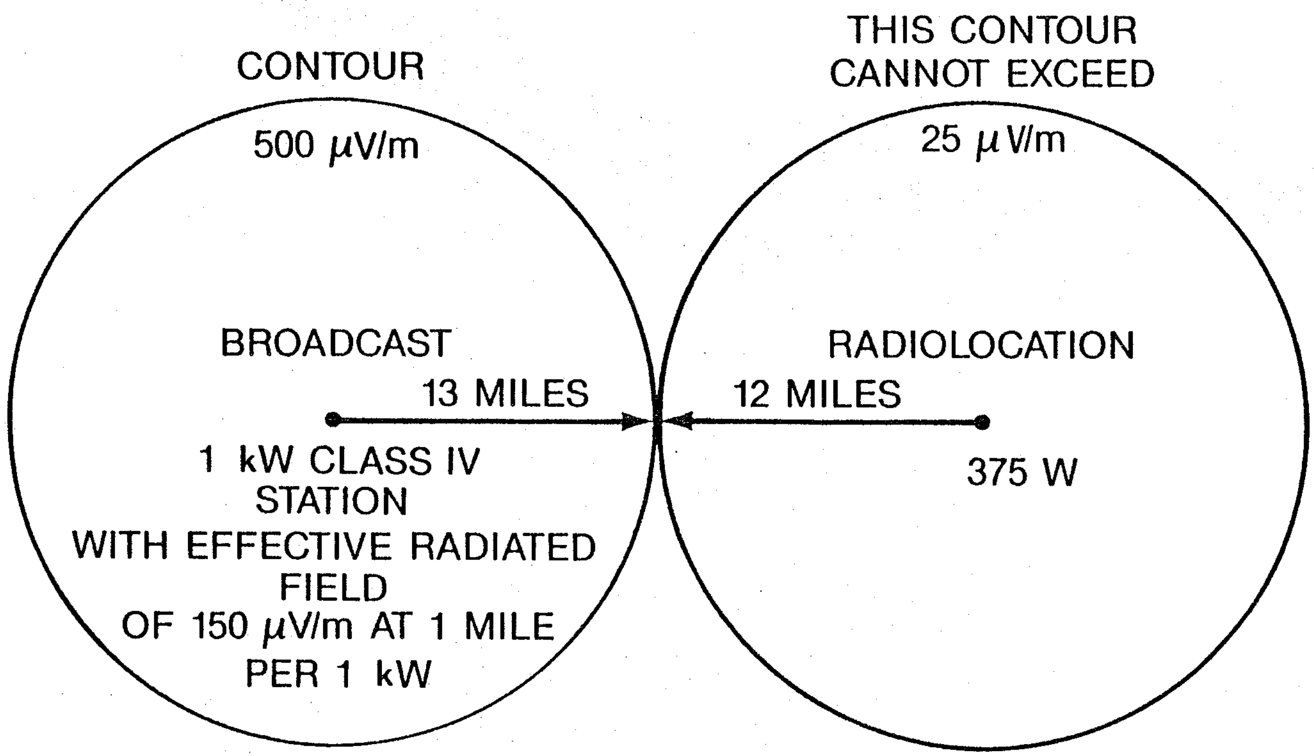


Figure 14. Groundwave protection example.

400 μV/m is reduced to 200 μV/m or:

$$[\ \frac{50}{100} \times 400 = 200\ ]$$

Since the curves in Figure 8 are based on a transmitter output power of 1 kW and the radiolocation transmitter has an output power of 375 W, a further reduction of the expected field strength must be considered. Field strength varies with the square root of the power ratio so that 200 μV/m is reduced to 122 μV/m, or:

$$[200 \times \sqrt{\frac{375}{1000}} = 122]$$

For the cochannel case, the S/I cannot exceed 20:1, so either the output power of the radiolocation station must be reduced or the frequency of the radiolocation system must be changed, or both options must be considered to prevent harmful interference to the broadcast station.

To lower the predicted field strength from 122 μV/m to 25 μV/m by transmitter output, power reduction will require the radiolocation transmitter to go from 375 W to 16 W, $16 = 375 \times (25/122)^2$, or a reduction of 14 dB, $-14 = 10 \log_{10} 16/375$. Part of the required 14 dB gain in the S/I may also be accomplished by moving the radiolocation system frequency out of the audio bandpass.

Also, the radiolocation transmitter may be physically relocated to provide the necessary protection to the proposed broadcast station. The following computation will provide the required separation between the radiolocation transmitter and the proposed broadcast station's 500 μV/m protection contour. Since at this contour the field strength ratio cannot be less than 20:1, the radiolocation station's field must not exceed 25 μV/m. To enter data into Figure 8, the effective field at 1 mi (1.6 km) must be normalized to 100 mV/m per mile. Consequently, the 25 μV/m is doubled since the radiolocation station's effective field at 1 mi (1.6 km) is 50 mV/m. The resultant 50 μV/m must be divided by the square root of the power ratio:

$$[25 \frac{(100)}{50} \quad \frac{1000}{375} = 81.65]$$

The normalized value of 81.65 μV/m may be entered in Figure 8, and the resultant distance on the 2 mmho curve is about 26 mi (42 km). Hence, the radiolocation station must be at least 26 mi (42 km) away from the 500 μV/m contour or 39 mi

(63 km) from the proposed broadcast transmitter if the radiolocation transmitter output power is not reduced or the operating frequency changed.

Nighttime Sharing Example.

The three classes of broadcasting stations have differing values of nighttime protection from cochannel and adjacent channel interference (TABLE 5).

Class IV stations operate on local channels, normally providing Primary service to a city or town and the suburban or rural areas contiguous thereto, with powers not less than 250 watts, nor more than 250 watts nighttime and 1 kW daytime. On local channels, the separation required for the daytime protection also determines the nighttime separation (Part 73.182(4), FCC Rules and Regulations). Consequently, when a radiolocation station must protect a Class IV station, the daytime and nighttime protection requirements are the same, and skywave interference to Class IV stations is not considered separately.

Nighttime protection requirements for the other station classes can best be determined on a case-by-case basis. One specific example is as follows. A radiolocation station in New Orleans will be cochannel on 1630 kHz with a proposed Class III station in Chicago. The radiolocation transmitter is radiating a measured field of 63 mV/m at 1 mi (1.6 km) from a 0.25 wavelength vertical antenna in the great-circle direction of Chicago. The distance separating the transmitters is 825 mi (1331 km). In Figure 15, entitled "Angles of Departure vs. Transmission Range" (FCC 73.190 Fig. 6A), the upper and lower angles for this path distance are 6.5° and 3.5°. These are the upper and lower bounds for variation in the vertical takeoff angle due to variations in ionospheric height (H_e) and scattering. The maximum value of field strength occurring between these angles, illustrated in Figure 16, is about 99% of the horizontal field of 63 mV/m or 62 mV/m. The mid-point latitude of the transmission path is about 35°N, and from Figure 10 (FCC 73.90-2), the 10% skywave field at 825 mi (1331 km) is 50 μV/m for 100 mV/m radiated field. Multiplying by 62/100 to adjust this value to the actual radiation gives 31 μV/m as the interfering signal strength. At a 20:1 ratio, the limitation to the proposed Chicago station will be the 620 μV/m contour.

Since Class IIIA stations are nighttime protected from objectional interference at the 2500 μV/m contour, and Class IIIB stations are nighttime protected out to the 4000 μV/m contour, the radiolocation station will not cause objectionable interference to a proposed Class III broadcast station in Chicago.

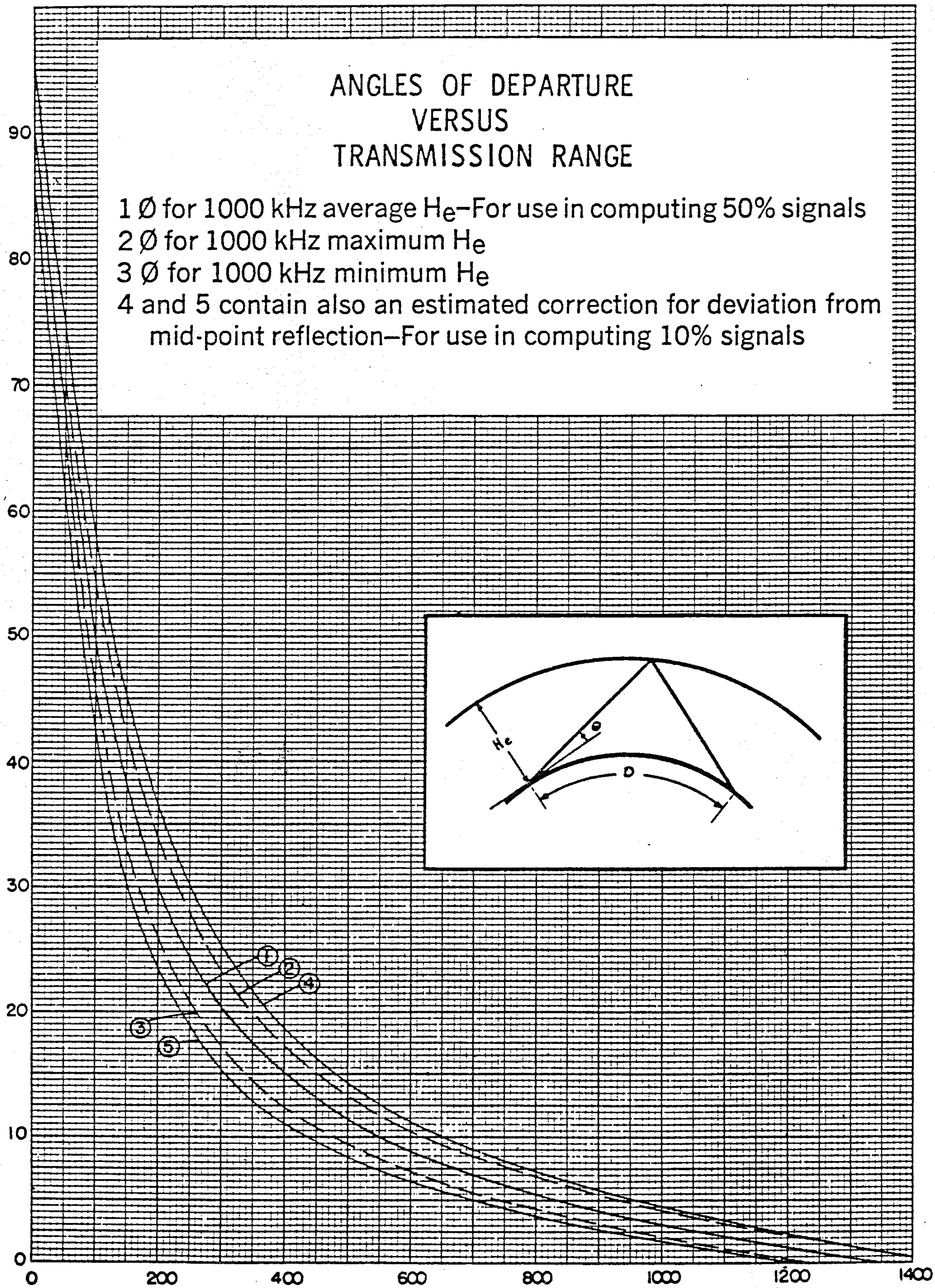


Figure 15. Angles of departure vs. transmission range.

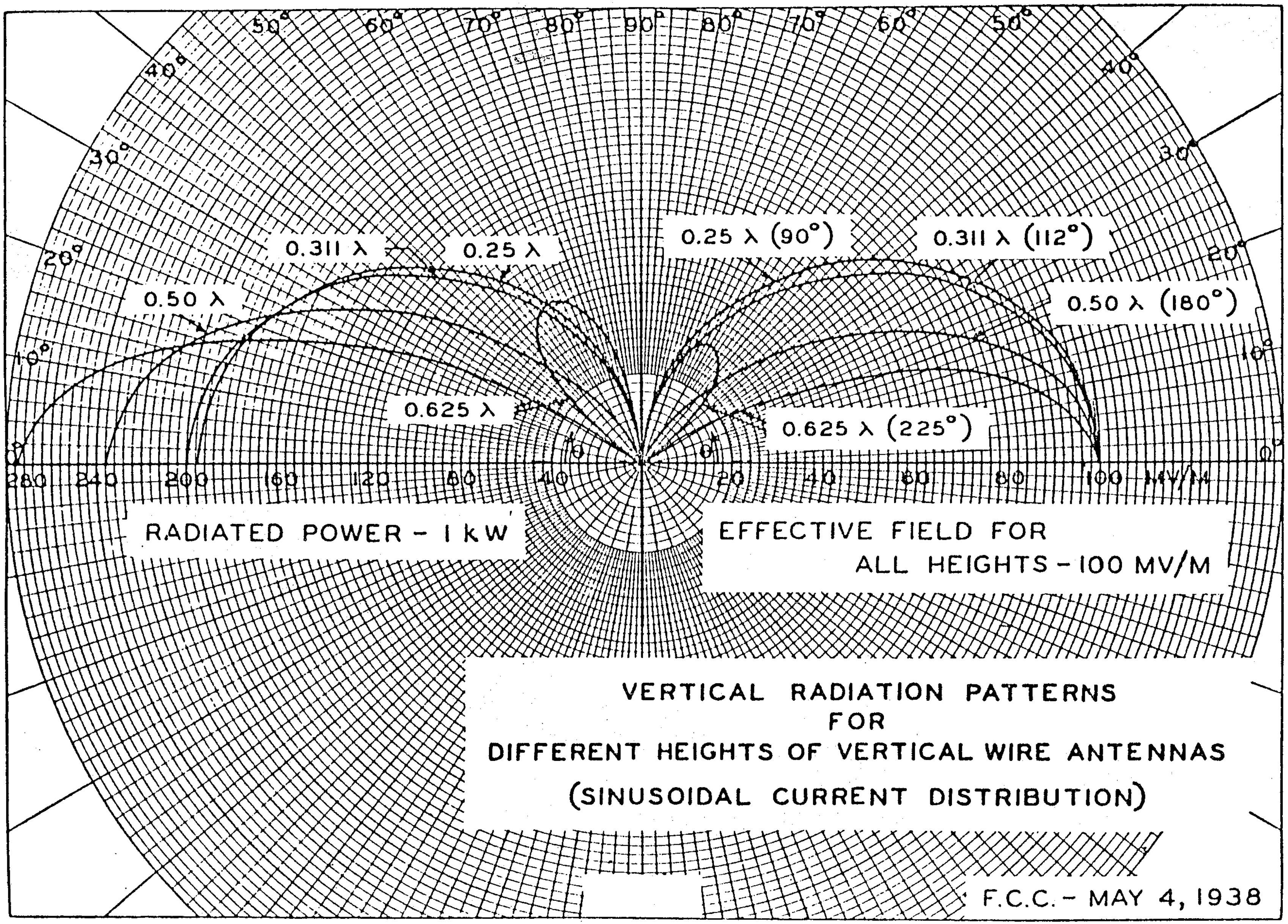


Figure 16. Vertical radiation patterns.

The method of interfering signal computation in FCC 73.185 was used in the preceding example and in the data calculations for the curves in Figures 17 and 18. Figure 17 shows the 62 mV/m radiated field example plotted for the regional channel assignments and that a Class IIIA station could be as near as about 275 mi (443 km) to the radiolocation station before objectionable nighttime interference would occur. Two other values of radiated field from the radiolocation transmitter are plotted to indicate the transmitter separation distance dependence on radiated field strengths from the radiolocation transmitter.

Figure 18 indicates that the distance of separation required for the clear channel assignment example could exceed 1000 mi (1613 km) if the field at 1 mi (1.6 km) from the radiolocation transmitter is greater than 70 mV/m.

BROADCAST TO RADIOLOCATION.

Radiolocation receivers are typically narrow bandwidth devices; some have RF bandwidths of 10 kHz and IF bandwidths of 100 Hz. When these receivers are subjected to interference from a broadcast transmitter, the interference energy will be primarily within these bandwidths.

In the case of interference from the sidebands of the broadcast transmitter, the power density of the interfering signal within a receiver bandwidth will be a function of the interference frequency spectra and the percentage level of the modulation of the broadcast transmitter. The spectra of possible modulation signals are infinitely variable and consequently difficult to characterize, but in general, the power density in the sidebands will tend to decrease as the radiolocation receiver is off-tuned from the broadcast carrier frequency. In this case, the power density in the receiver bandpass is a function of the amount of receiver off-tune from the broadcast carrier.

Broadcast stations utilize audio processor devices to limit the random peaks of the modulating waveform and to boost the low values so that the resulting average audio energy of the waveform is increased. In some cases, large amounts of fast gain reduction are used so that the resulting audio mix is almost a solid sound, with the low-level high frequencies modulating at nearly the same percentage as the high-level low frequencies. For purposes of this analysis, the power density in the sidebands was considered to be uniform across the bandpass of the transmitter and within the bandwidth of a receiver tuned across the sideband spectrum.

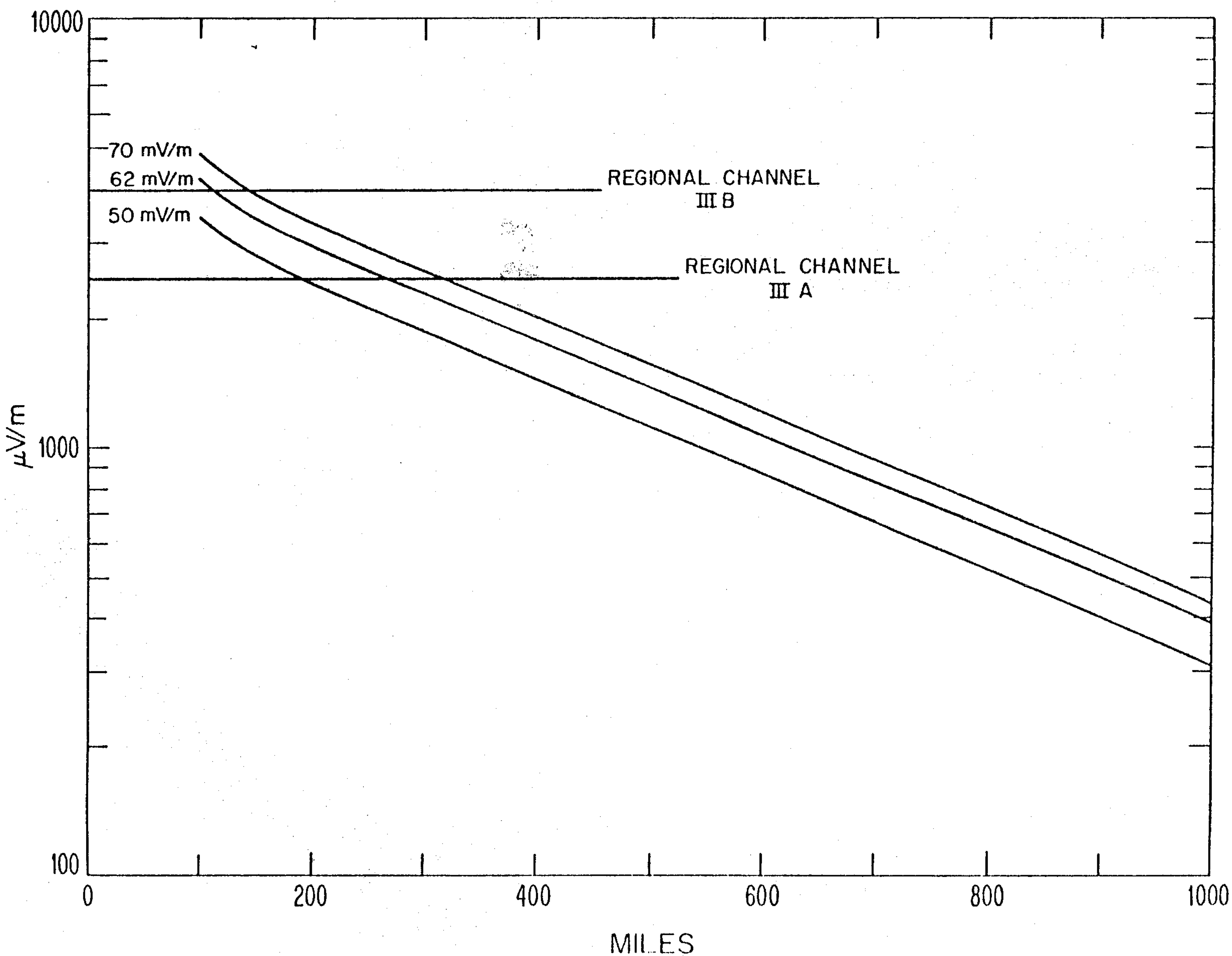


Figure 17. Regional channel station protection.

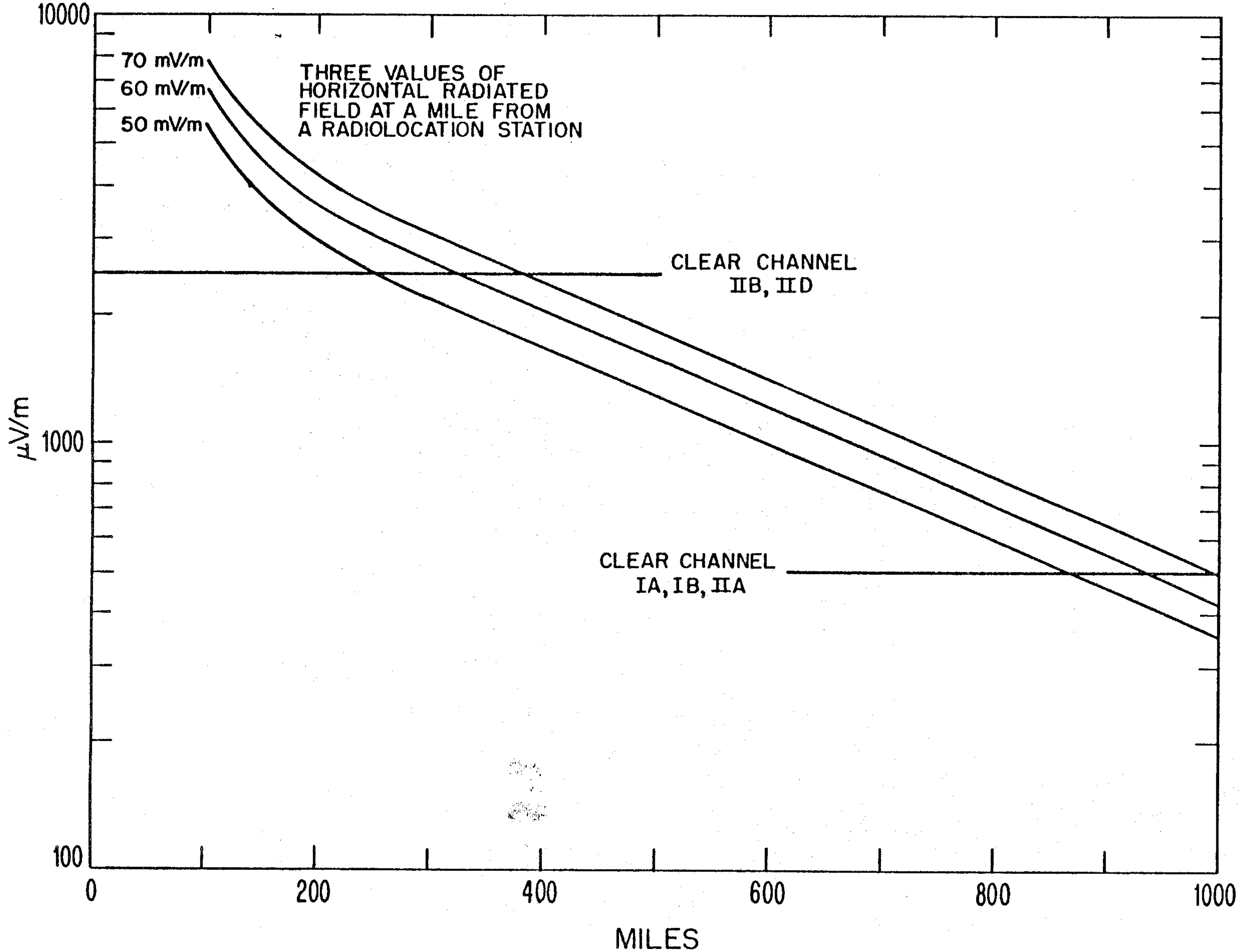


Figure 18. Clear channel station protection.

A fairly short interval of this type of modulation may constitute a serious interference problem to radiolocation receivers, considering that a vessel moving at 10 knots can traverse more than 20 lanes of the radiolocation system during the time a 3-minute record is playing.

A broadcast transmitter programming this type of modulation format will transmit a total power of up to 1/4 of the carrier power (depending upon signal content) in each 5 kHz sideband. A 100 Hz segment of sideband will have 1/200 of the carrier power or be 23 dB below the carrier power.

Radiolocation industry sources (Roussel, 1982, Off Shore Navigation, Inc.) state that the required carrier-to-interference ratio (C/I) for radiolocation receivers is largely dependent on the system type. Time-multiplexed systems are much more tolerant of interference than most frequency-multiplexed systems. When the interfering signal level is as high as 1% of the desired signal (-20 dB), the output reading from a frequency-multiplexed receiver is prone to jitter and instability.

Unfortunately, some of these frequency-multiplexed systems use basic frequencies within the 1650-1655 kHz band and, also, harmonically related frequencies in the 3300-3310 kHz band. They and are virtually frequency bound within this 5 kHz band. Consequently, these systems are likely to receive interference from the broadcast service when broadcasting commences in the 1605-1705 kHz band.

These radiolocation systems can function properly, as long as the interference level does not reduce the C/I below 20 dB. This requirement is equivalent to a received radiolocation field strength voltage that is at least 10 times greater than the field of the interfering signal.

With reference to the daytime sharing example in the preceding discussion entitled "Sharing Between Broadcasting and Radiolocation" for the cochannel case, the groundwave field strength from the radiolocation transmitter will be at least ten times the value of the broadcast station out to a distance of 3.25 mi (5.2 km) from the radiolocation transmitter and along a line between the transmitters. This distance was obtained from Figure 8 by a simple trial and error solution and is substantiated by the following. At a distance of 21.75 mi (35.08 km) from the broadcast antenna, the normalized field strength (fs) from Figure 8 is 0.12 mV/m. Multiplying this value by (150/100) to compensate for the effective field radiated from the broadcast antenna system, the resultant fs is 0.18 mV/m. At a distance of 3.25 mi (5.2 km) from the radiolocation antenna, the normalized fs from Figure 11 is 5.8 mV/m. Multiplying this value by (50/100) to compensate for the effective field radiated from the radiolocation antenna, and by ($\sqrt{375/1000}$)

to account for the variance of the radiated power from 1 kW, the resultant fs is 1.77 mV/m; and the radiated fields are in a ratio of 10 to 1, so the radiolocation receiver experiences no harmful interference when the broadcast tranmitter is directly inland from the radiolocation transmitter and receiver.

When the transmitters are placed differently, the radiolocation system may be very limited in operating range. Consider a placement where the transmitters are on opposite sides of a salt water bay and separated by 25 mi (40.3 km). If the system's parameters are the same as before and the inverse distance curve of Figure 8 is used to provide normalized field strength values vs. distances, TABLE 17 can be formulated.

TABLE 17

FIELD STRENGTH AS A FUNCTION OF DISTANCE FROM AN AM BROADCASTING STATION AND A RADIO LOCATION STATION ACROSS A SALT WATER BAY

Miles	mV/m	mV/m	Miles	mV/m
Distance from Broadcast Transmitter	Broadcast Transmitter Carrier	Broadcast 100 Hz of Sideband	Distance from Radioloc Transmitter	Radioloc Transmitter Carrier
2	75.0	5.31	25	1.22
5	30.0	2.12	20	1.53
10	15.0	1.06	15	2.05
15	10.0	0.71	10	3.06
20	7.5	0.53	5	6.10
25	6.0	0.42	2	15.30

The values of groundwave field strength versus distance in columns 2, 3, and 4 are plotted in Figure 19, along with the level of tolerable interference 20 dB below the radiolocation carrier. From these curves, the radiolocation service is usable only out to about 5.5 mi (8.8 km), directly off-shore from the radiolocation transmitter.

If the transmitters are cochannel in this case, the radiolocation service will be almost unusable. At 2 mi (3.2 km) from the radiolocation transmitter, the C/I for the radiolocation service is about 8 dB, which is not sufficient for some frequency-multiplexed systems.

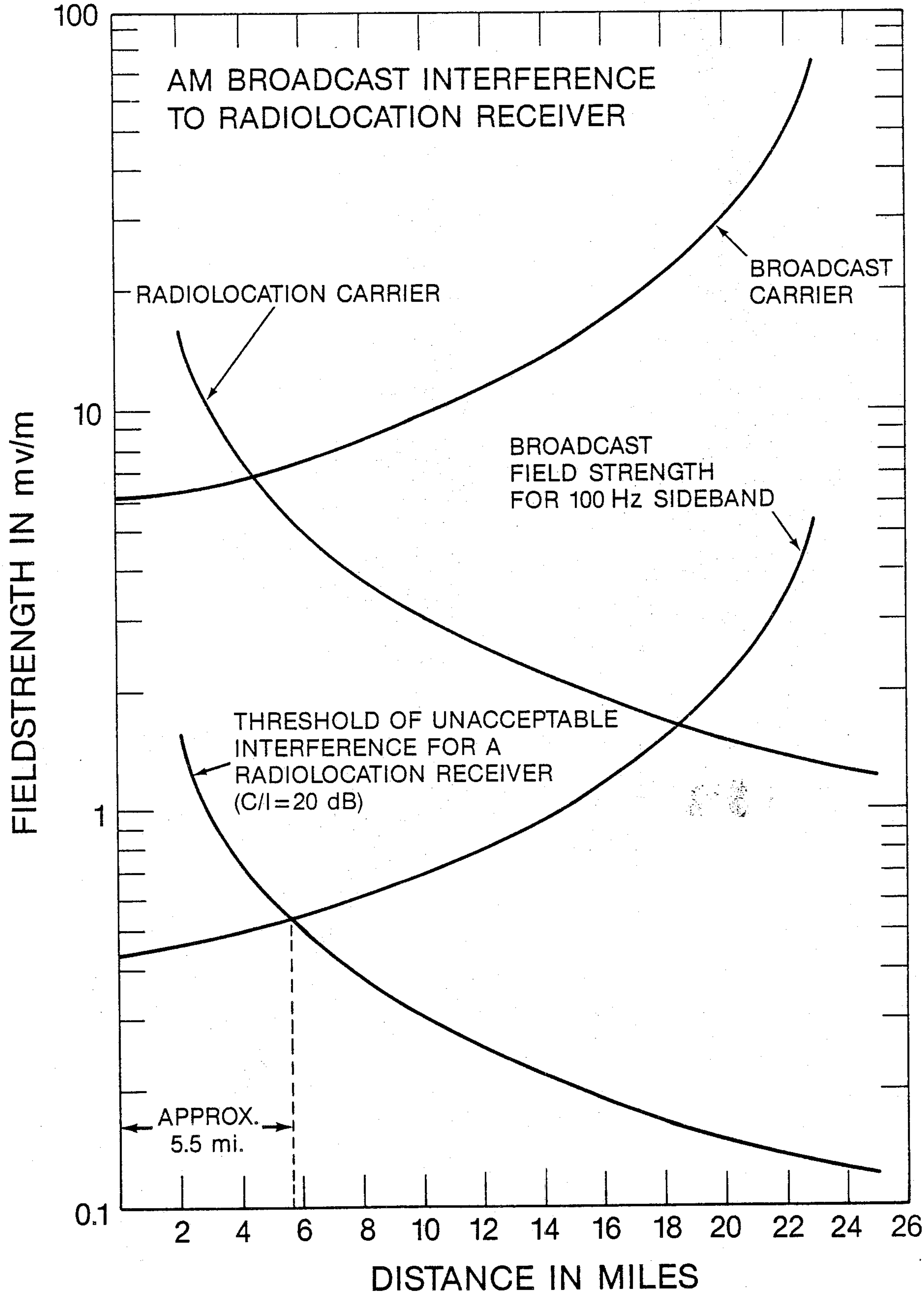


Figure 19. AM broadcasting interference to a frequency-multiplexed radiolocation receiver.

In general, the radiolocation service is less likely to suffer harmful groundwave interference when the broadcast transmitter is located inland from the radiolocation transmitter.

Nighttime interference to radiolocation systems can be determined by the methods described in the preceding "Nighttime Sharing Example." Assume that both of the transmitters will be cochannel on 1650 kHz with a 250 W broadcast transmitter at a distance of 500 mi (806 km) from the radiolocation receiver and the radiolocation transmitter 20 mi (32.2 km) from the receiver. At these distances, the interfering signal is skywave propagated, and the radiolocation signal is likely to be groundwave propagated. Using Figure 8, the groundwave radiolocation signal at 25 mi (40.3 km) will be 1.22 mV/m. The interfering skywave signal is determined as follows. In Figure 15, the lower and upper angles for a 500 mi (806 km) path are approximately 6.5° and 11°. The maximum value of field strength occurring between these angles (see Figure 16) is about 97% of the horizontal field, $150 \sqrt{250/1000} = 75 (0.97) = 72.75$ mV/m, where 150 is the effective radiated field for a 1 kW broadcast station and $\sqrt{250/1000}$ is the field reduction factor when the transmitter power is reduced to 250 W.

In Figure 10, the 10% skywave field at 500 mi (806 km), assuming a path midpoint latitude of 40°, is 110 μV/m for a 100 mV/m radiated field. Multiplying 110 μV/m by 72.75/100 to obtain the actual field from the normalized field value gives 80 μV/m as the interfering field strength at the radiolocation receiver.

These incident field strength values at the radiolocation receiver result in a C/I of 23.7 dB and satisfactory operation of the radiolocation systems. Placing the radiolocation receiver farther than 36 mi (58 km) off-shore will reduce the received radiolocation signal below 800 μV/m and lower the C/I below the required 20 dB value.

Radiolocation Interference to AM Radio Receiver Measurements.

Measurements were taken for two typical AM car radios to determine the effects on performance from a CW interferer when the radio was tuned to a selected frequency with a single-tone AM modulation. The CW signal was varied in amplitude and frequency across the radio passband. The areas of interest included noting any desensitization of the radio from the CW interference (AGC changes), S/I effects (SINAD measurements), and signal distortion.

The test setup in Figure 20 shows the (simulated radiolocation signal) approach taken to determine the effects of a CW interference signal on a typical AM automobile receiver. The first signal source provides the reference AM signal with single

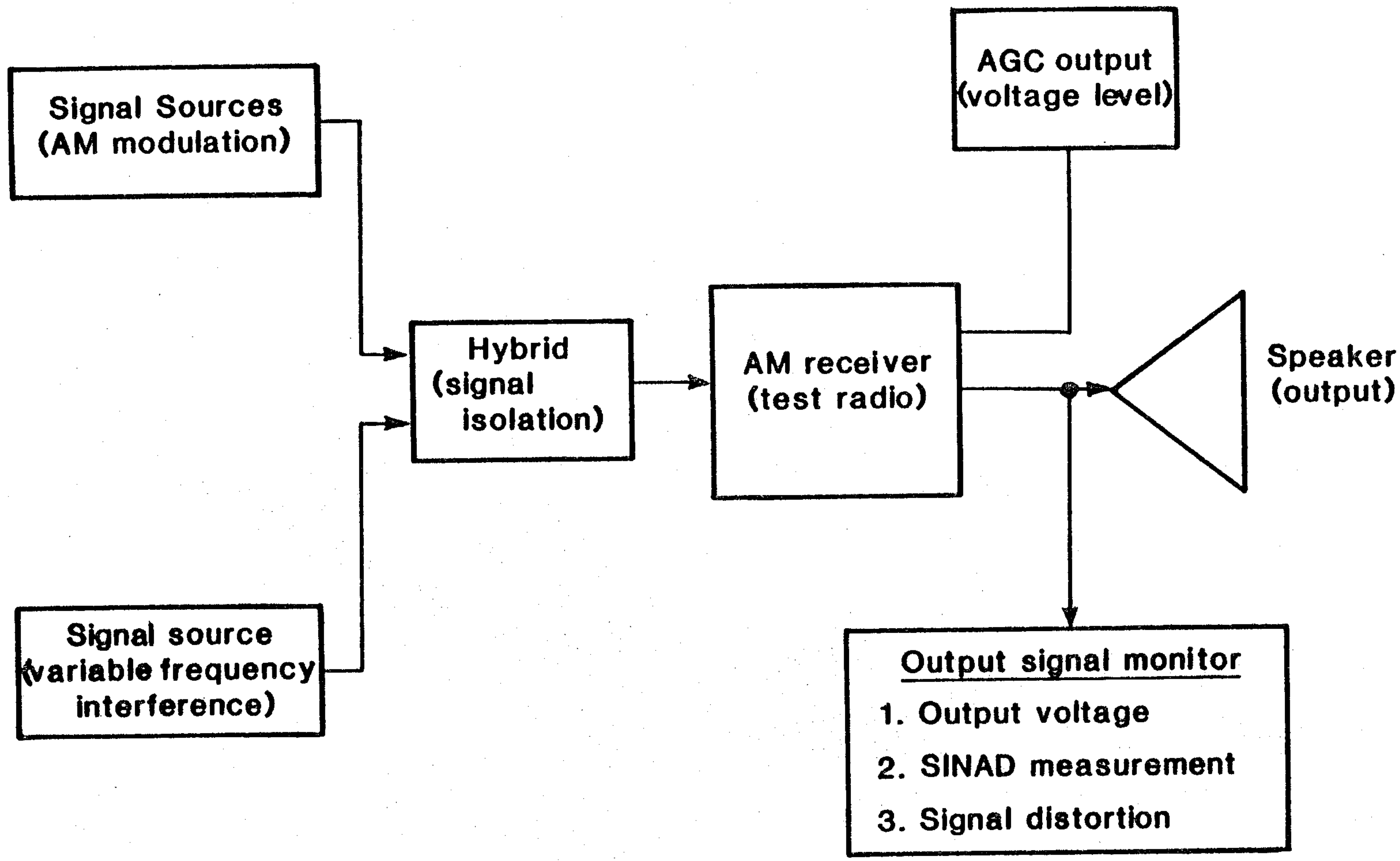


Figure 20. Block diagram of test setup receiver CW interference measurements.

tone amplitude modulation that was set at 50% for the tests. The modulation tones used were 400 and 1000 Hz. The second signal source served as the interfering signal. The signal source's amplitude was adjusted to give the desired S/Is. The frequency of this source was initially adjusted to be the same frequency as the reference signal generation (1610 kHz). This provided the cochannel interference data. After completion of the S/I test of cochannel interference, the interfering signal source frequency was decreased in 1 kHz increments until all the desired combinations of S/I and frequency range were completed within the 5 kHz bandwidth.

The two signal sources were combined in the hybrid combiner to maintain appropriate signal isolation. The output level of the hybrid was adjusted such that the test receiver would operate between 30-40 dB above the threshold of the receiver. This provided an adequate input signal and also provided a margin well below receiver saturation.

The receiver AGC was monitored to check for any receiver desensitization due to the interfering signal during the course of the tests. Other measurements included the following: audio AC level measurements across a resistive load connected across the speaker output; determining the SINAD, which is a measure of the output signal quality for a given audio power; and, also, determining the percent of harmonic distortion of the AM signal output under the various selected interference levels and frequencies.

The results of the tests on the two sample radios are shown in Figures 21 and 22. The S/I was varied over a 30 dB range (this range was determined experimentally). At the 30 dB S/I, the interference signal had no noticeable effect on either of the radios tested. As the interference signal was increased to a value equal to the desired signal (0 dB), both receivers exhibited very erratic operation. This erratic operation was demonstrated by very high harmonic distortion in the output. The SINAD measurement is a ratio of (signal + noise + distortion)/(noise + distortion). A SINAD of 12 dB (Duff, 1976) was selected as the minimum acceptable limit for system performance, and this value is shown by the dashed line across the SINAD curves. Note that the curve, 1 kHz offset from the carrier frequency (1610 kHz), is much more sensitive to interference. As the interference frequency offset is increased, this sensitivity decreases. The important thing to notice is that as interference levels exceed the S/I of 20 dB, very significant losses in radio performance occur.

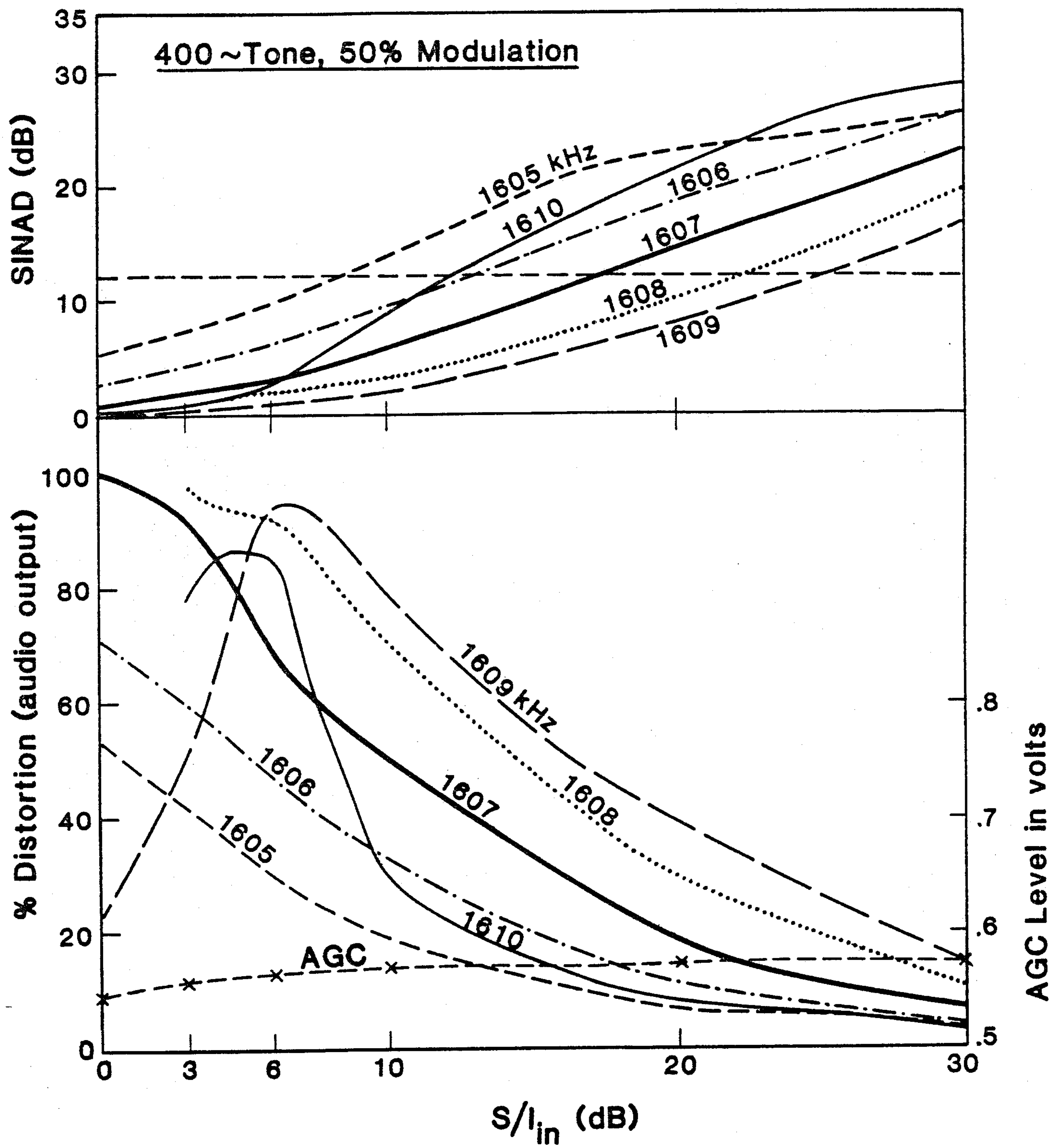


Figure 21. Distortion and SINAD measurements for test radio #1.

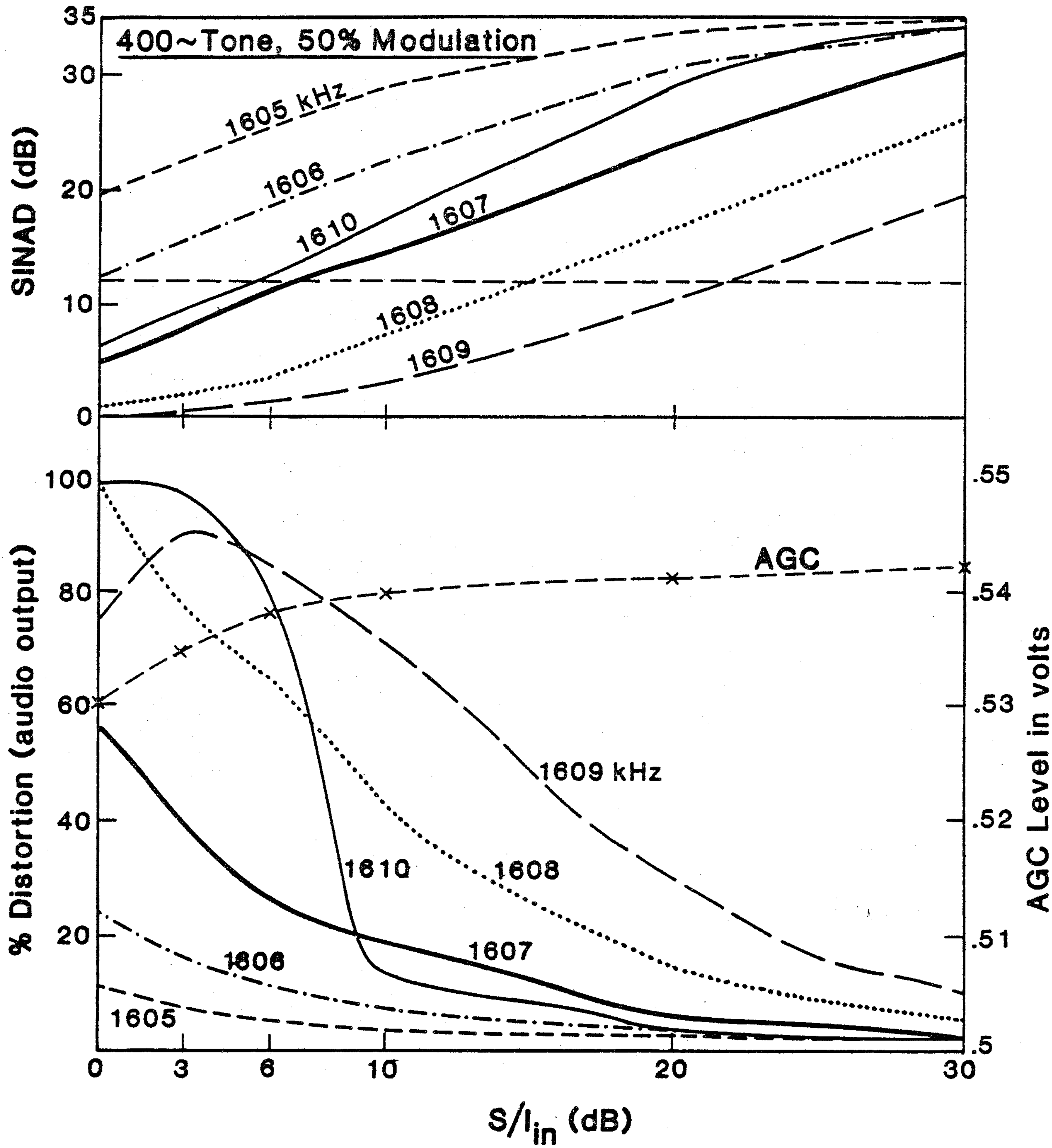


Figure 22. Distortion and SINAD measurements for test radio-#2.

The quality of test radio No. 2, by design and cost, was better than radio No. 1. The test results show better SINAD measurements for radio No. 2 as compared to radio No. 1.

Figure 23 shows the AGC voltage level as a function of the input signal level. The 0 dB reading represents the same AM signal level used in the measurements described above. Note that saturation effects (flattening of the curves) are not evident. The actual voltage level magnitude variations shown are assumed to be a result of different design approaches being implemented.

Figures 24 and 25 are plots of audio output levels as a function of S/I. Again, the highest level (largest generated intermodulation and spurious frequencies) occurred at the 1 kHz separation from the AM carrier frequency. This was the case whether a 400 Hz tone or a 1000 Hz tone was used to modulate the carrier. However, the generation of unwanted frequencies was greater for the 1000 Hz tone modulation as might be expected.

Initially, desensitization of the receiver was also of concern. The anticipated effect of desensitization was that the audio output of the receiver would decrease as the interfering signal was increased. In Figures 24 and 25, this effect can be noticed at specific frequencies. At other frequencies, the audio output actually increases. The significant item to note is that the receiver nonlinearities literally obliterate the signal well before the receiver is desensitized. The test results on the two receivers demonstrate the dominate role that the nonlinearities play when compared to desensitization.

The receivers were then tuned to a local Boulder, CO, AM station at 1490 kHz and the audio gain set about midrange (good, clear, sound level). The CW interference signal was then introduced as in the previous tests. The audible quality of the radio's output from the speaker, as perceived by the test engineers, significantly deteriorated with levels greater than 20 dB below the desired AM signal. With the CW signal 10 dB below the desired signal, the distortion was great enough to mask intelligibility due to the spurious frequencies generated in the radios. Again, the major problem was not desensitization of the radio due to AGC action, but the distortion frequencies generated by the introduction of the CW interferer.

TABLE 18 gives separation distances between broadcasting and radiolocation stations based on maximum power levels for the various classes of broadcasting stations and allowable maximum power transmission from radiolocation transmitters (375 W). This table shows distances for the various criteria used in the analysis. The 26 dB levels represent the 20:1 protection ratio for broadcasting stations as

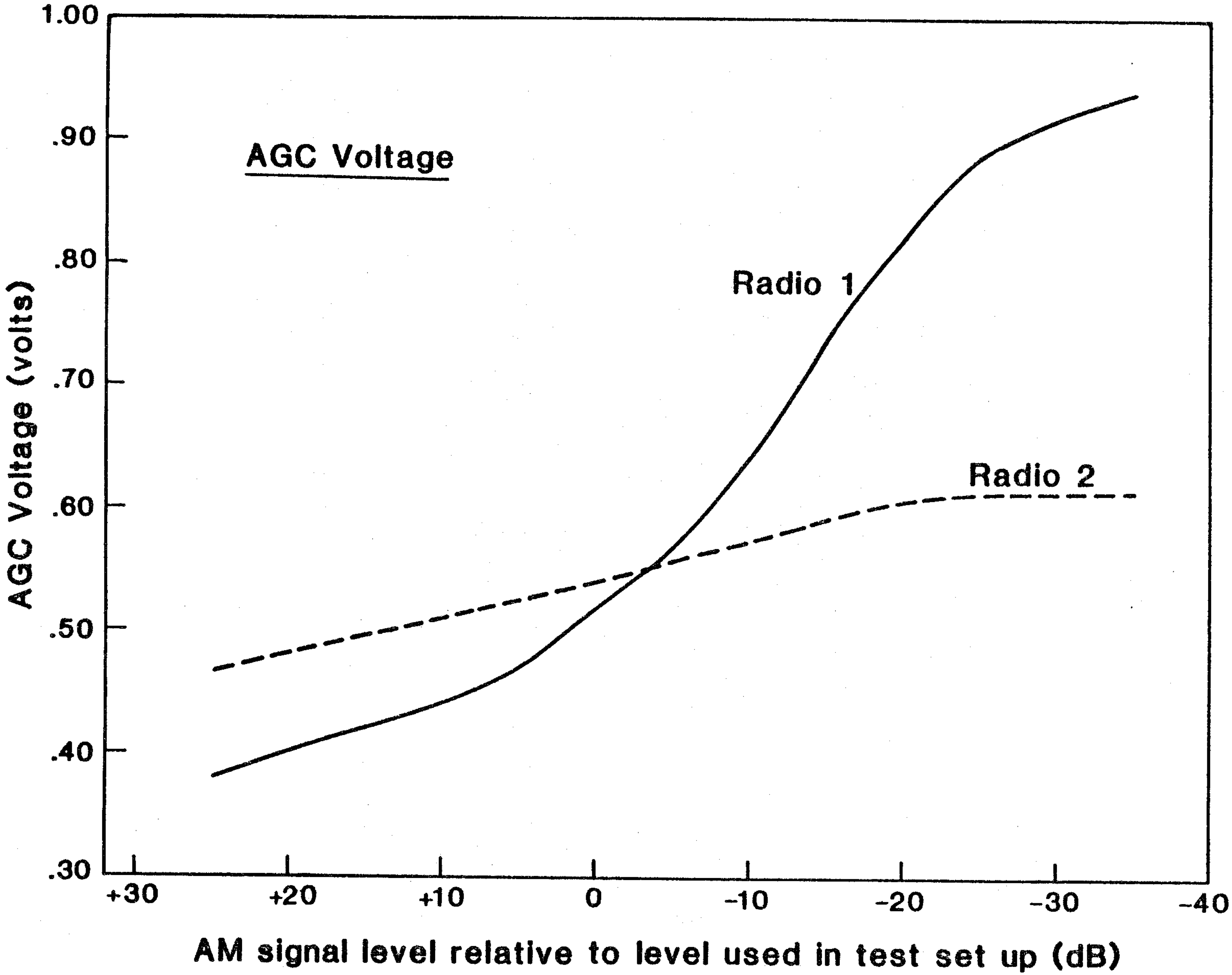


Figure 23. AGC characteristics for test radios.

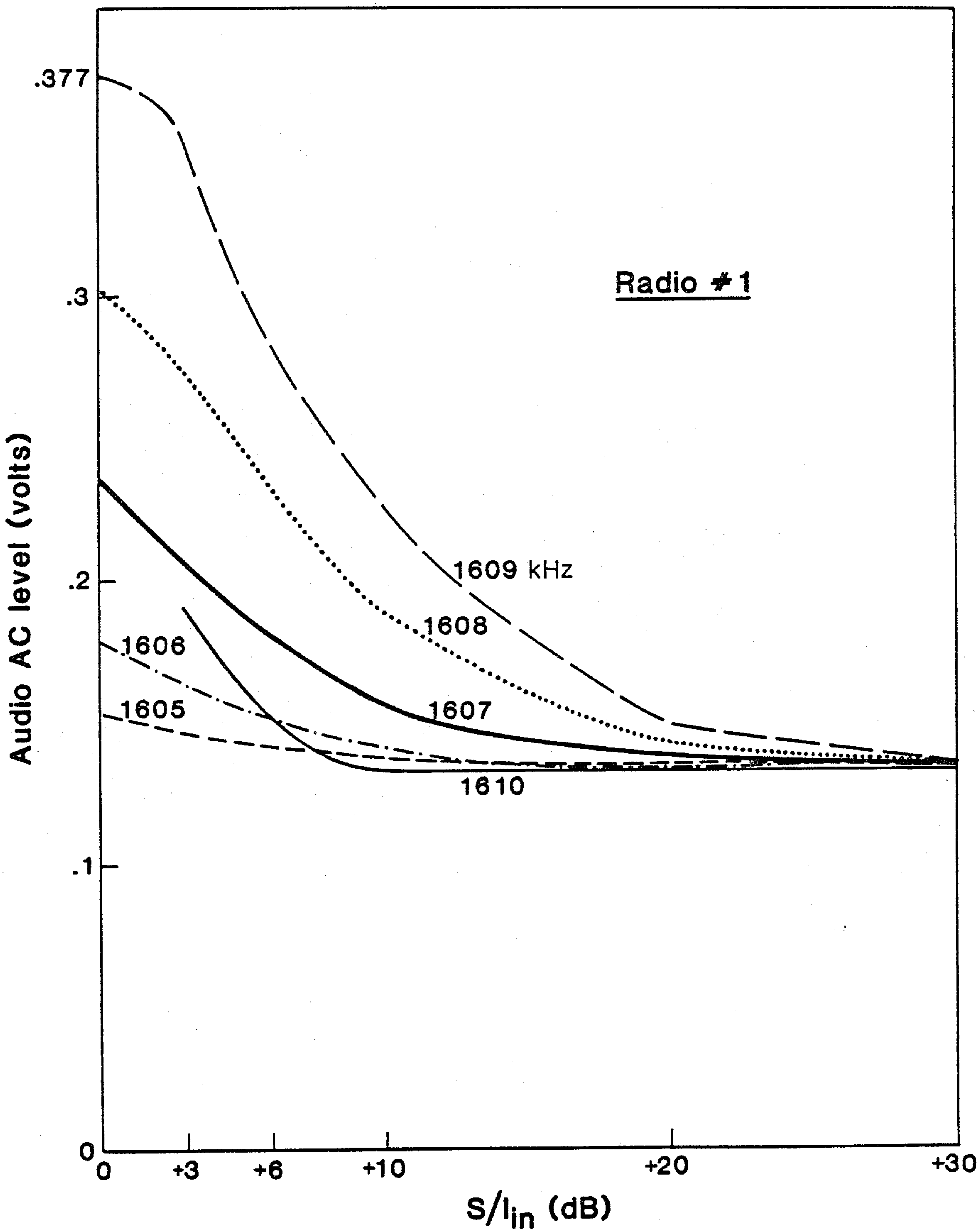


Figure 24. Audio output level vs. interference of test radio #1.

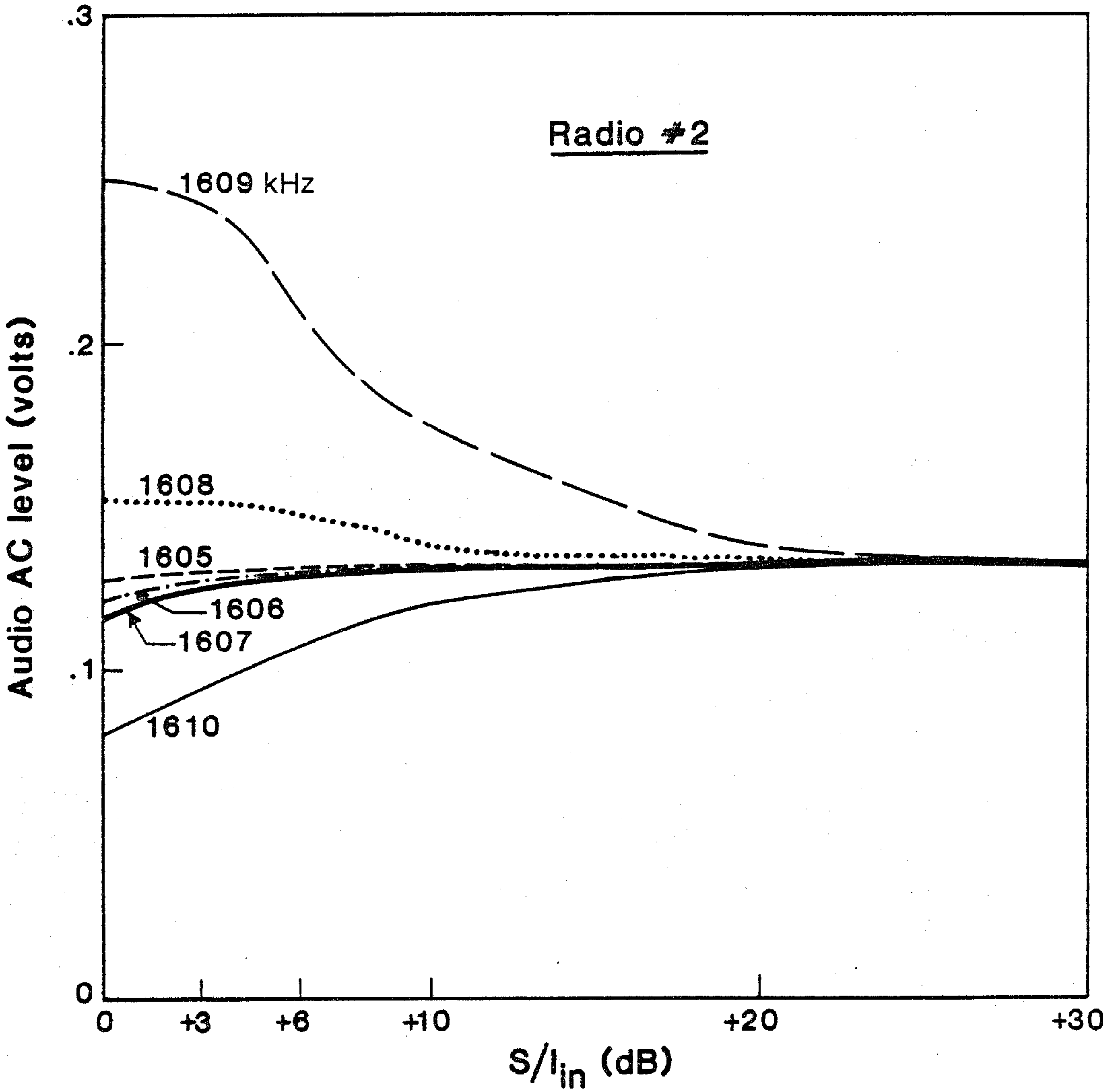


Figure 25. Audio output level vs. interference of test radio #2.

TABLE 18

BROADCAST AND RADIOLOCATION SEPARATION DISTANCE CONSIDERATIONS

AM BROADCAST STATION						RADIOLOCATION STATION (ANTENNA 50 mV/m, POWER 375 W)			TOTAL SEPARATION DISTANCE	
				DISTANCE TO PROTECTION LEVEL (mi)			DISTANCE TO PROTECTION LEVEL (mi)			
CLASS	POWER LEVEL	PROTECTION LEVEL	INTERFERENCE LEVEL	2 mmhos/m	15 mmhos/m	PROTECTION LEVEL	2mmhos/m	15 mmhos/m	2 mmhos/m	15 mmhos/m
I	50 kW	100 μV/m	5 μV/m	82	168	26 dB	55	126	137	294
(ANTENNA) (225 mV/M)			10 μV/m			20 dB	38	96	120	264
			31.6 μV/m			10 dB	23	59	105	227
II	50 kW	500 μV/m	25 μV/m	35	100	26 dB	26	66	61	166
(ANTENNA) (175 mV/m)			50 μV/m			20 dB	18	49	53	149
			158 μV/m			10 dB	10.6	30	45.6	130
III	5 kW	500 μV/m	25 μV/m	20	54	26 dB	26	66	46	120
(ANTENNA) (175 mV/m)			50 μV/m			20 dB	18	49	38	103
			158 μV/m			10 dB	10.6	30	30.6	84
IV	1 kW	500 μV/m	25 μV/m	13	35	26 dB	26	66	39	101
(ANTENNA) (150 mVm)			50 μV/m			20 dB	18	49	31	84
			158 μV/m			10 dB	10.6	30	23.6	65

NOTE - ANTENNA FIELD STRENGTHS GIVEN AT 1 MILE.

given in Part 73 of the FCC Rules and Regulations. The 20 dB level represents the protection needed for AM radios with below average interference rejection capabilities such as test radio #1 in the tests conducted in this report. The 10 dB level represents the S/I desired to protect AM radios with slightly better than average interference rejection capabilities such as test radio #2.

SHARING BETWEEN CORDLESS TELEPHONES AND GOVERNMENT SYSTEMS.

Radiolocation, radionavigation, and TIS are the principal Government services sharing the 1605-2000 kHz band with cordless telephones. The TIS assignments are principally located at national parks and consequently, assumed to be sufficient distance from populated centers to neither experience interference from cordless telephones nor interfere with them. Additionally, in accordance with an FCC Waiver, IRAC Document 22856/1-2.8.2.1/4.18, most cordless telephones manufactured after September 1982 are restricted to a frequency within the 1625-1800 kHz band, well above the 1610 kHz TIS assignment.

The radionavigation stations are mainly used by the Army in short-term tactical training exercises at temporary airfields (208 of the total 213 assignments are to the Army). Cordless telephones and the radionavigation service should suffer no mutual interference, because the airfields are usually located in remote areas where very few cordless telephones are likely to be used.

There is the potential problem, however, of cordless telephones interfering with radiolocation reception aboard dockside or nearby vessels when the radiolocation transmitters are at a considerable distance from the vessel.

Part 15.7 of the FCC Rules and Regulations limits the radiated field from a cordless telephone to 15 μV/m at any point to a distance of $\lambda/2\pi$ from the cordless telephone. However, after September 1982, FCC Waiver, Document 22856/1-2.8.2.1/4.18, deferred this requirement, upon a manufacturer's compliance, with certain conditions. Two of the conditions of interest to this SRA are: (1) the carrier current portion of the cordless phone shall operate on a frequency in the 1625 kHz to 1800 kHz band and (2) the RF currents on the power cord and telephone line of each cordless phone shall not exceed 90 mA on any single power conductor, 12 mA on the telephone line, and 12 mA where measuring all power cord conductors together, including the ground conductor.

Measured radiated fields from typical cordless telephones ranged from 130 μV/m to 6500 μV/m at 98.4 ft (30 m) with 98 percent of the measured field strengths less than, or equal to, 3000 μV/m. These measurements were made in the induction field of the cordless phone radiator, but since no farfield measurement data are available, the field strength value of 3000 μV/m was used as a basis to determine the required separation distance between a cordless telephone and a typical radiolocation system.

The minimum performance level criteria for a radiolocation system was determined from both theoretical considerations and private communications with system manufacturers and system users.

Literature published by Offshore Navigation, Inc., a company that provides radiolocation services, describes a system the company has deployed around the Gulf of Mexico, Type N Raydist, as "...usually providing daytime ranges of several hundred miles." This publication also states, in a technical specification describing, three similar kinds of systems that the daytime range of all three systems (including Type N) is "...over 300 nautical miles."

The following analysis assumes a 100 W system operating at 1.6 MHz with a usable wintertime range of 300 nmi (556.8 km) for 4 hours, from 12 p.m. to 4 a.m., when the expected values of atmospheric radio noise is at the maximum daily value. Figure 26, from CCIR Report 322, is a world chart showing the expected median value of noise power (P_N) for this time block taken. Up the East Coast of the United States, around Florida, and into the Gulf of Mexico, the expected median value of noise from the chart is 70 dB above KTB (thermal noise) at 1 MHz and 65 dB at 1.6 MHz. Using median values is probably justified when comparing the noise powers in the six blocks. Four time blocks have lower noise values, and the received S/N during these time blocks will be much improved. So for two-thirds of the day the received signal may be described as better than adequate.

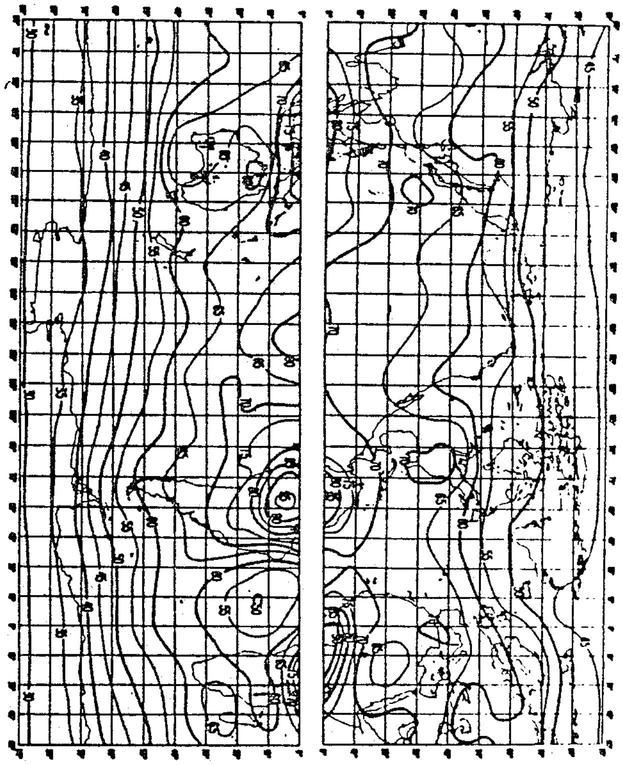
The P_N of a short vertical antenna over a perfectly conducting ground plane can be related to root mean square (rms) noise field strength (fS) in a 1 kHz bandwidth by:

$$fS\ rms = P_N \quad 65.5 + 20 \log_{10} F_{MHz}$$

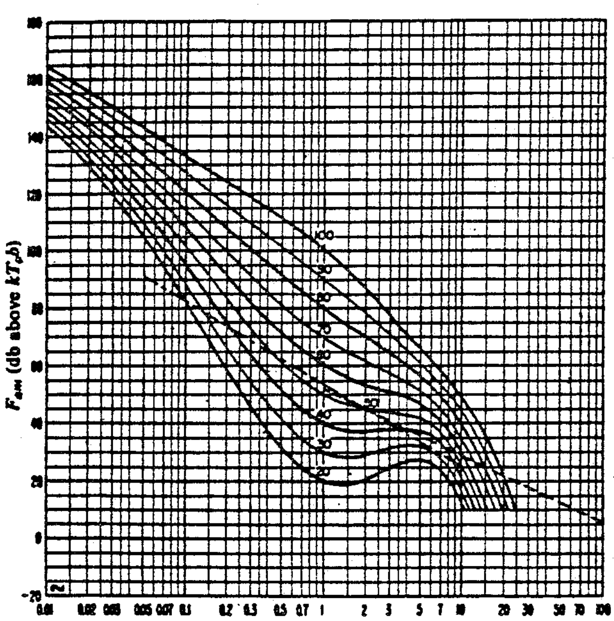
(CCIR Report 322), where F is the frequency pertinent to the noise power specification. The value of the field strength for any bandwidth (BW), in Hz, can be determined by adding the term ($10 \log_{10}$ BW - 30) to fS. The above equation then becomes

$$fS = P_N - 95.5 + 20 \log_{10} F_{MHz} + 10 \log_{10} BW$$

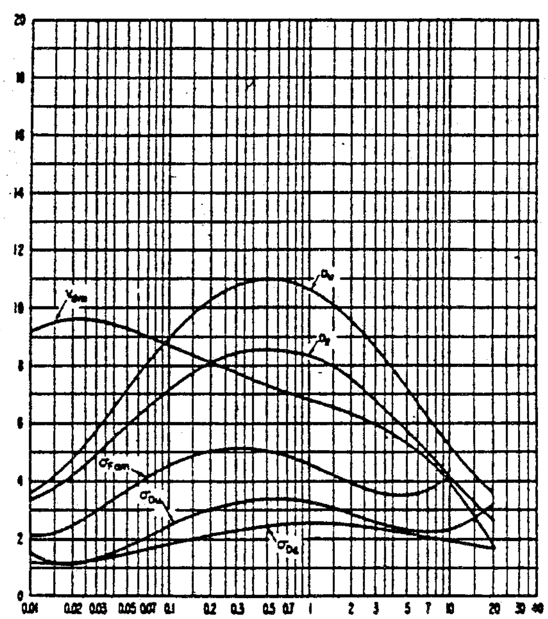
With a system bandwidth of 200 Hz, fS = 65 - 95.5 + 4.1 + 23 = -3.4 dB (μV/m) (see TABLE 19).



Expected values of atmospheric radio noise, F_{am}
(db above kT_0b at 1 Mc/s)
(Winter; 0000–0400 h.)



Variation of radio noise with frequency
(Winter; 0000–0400 h.)



Data on noise variability and character
(Winter; 0000–0400 h.)

——— Expected values of atmospheric noise
—·—·— Expected values of man-made noise at a quiet

$\sigma_{F_{am}}$ = Standard deviation of values of F_{am}
D_u = Ratio of upper decile to median value, F_{am}

Figure 26. World chart of noise power.

TABLE 19

WINTER, MIDNIGHT TO 4 AM NOISE POWER

SEASON & HOURS	P_N (dB) KTB		FS (dB) µV/m		S/N (dB)	
WINTER	MEDIAN	UPPER DECILE	MEDIAN	UPPER DECILE	MEDIAN	UPPER DECILE
Midnight-4 a.m.	65	75	-3	4	21	14

$F_{MHz} = 1.6$ BW = 200 Hz

The strength of the received signal at the radiolocation receiver may be determined, using Figure 8, for a separation distance of 300 nmi (345 statute miles, 556.8 km). Over a sea water path, the received signal strength will be 50 µV/m for a transmitter power of 1 kW and a radiating antenna efficiency such that the effective radiated field at 1 mi (1.6 km) is 100 mV/m. Since Figure 8 is based on a nominal transmitter power output of 1 kW, and the actual radiolocation transmitter output is 100 W, the value of 50 µV/m must be reduced by the square root of the power ratio, so $50/\sqrt{1000/100} = 15.8$ µV/m for a 100 W transmitter. If the radiolocation transmitting antenna is short, wavelength wise, and is located inland with a deficient ground system, the effective field at 1 mi (1.6 km) may be as low as 50 mV/m. With these antenna system deficiencies, the received signal at 300 nmi will become 15.8 (50/100) = 7.9 µV/m, and at the receiver, the S/N will be 20 log 7.9 - (-3.4) = 21.4 dB. If the radiolocation transmitting antenna is about $\lambda/4$ high over a fairly good ground plane that extends into the sea, the effective field at 1 mi (1.6 km) may be as high as 150 mV/m, resulting in a signal level at 300 nmi of 15.8 (150/100) = 23.7 µV/m and a S/N of 20 log 23.7 - (-3.4) = 30.9 dB.

Considering these two extreme antenna configurations are likely to bracket most of the antenna configuration in use, a S/N between 21.4 dB and 30.9 dB seems reasonable. Additionally, information received from some user agencies quotes measured receiver S/N requirements of about 25 dB.

Given a receiver sensitivity adequate to detect an atmospheric noise power level of -3.4 dB (μV/m), an approximate value for receiver sensitivity can be established if the receiver antenna factor is known. For a typical 8 ft (2.4 m) whip antenna over sea water, a computer program entitled HVD1 (input format shown in TABLE 20) (FitzGerrell (privite communication)) provides an antenna factor value of 35.5 dB, without antenna matching, and an antenna input impedance of about 0.05 -j 3600 Ω. With proper matching into 50 Ω, using an inductor with a Q of 50, the antenna factor will become about 5 dB. The antenna factor is expressed as

$$\text{antenna factor} = \frac{\mu V/m \text{ (incident field)}}{\mu V \text{ (V into 50 } \Omega)}$$

Since the incident noise field is (-3.4 dB) μV/m, the voltage into the 50 Ω expressed in logarithms) corresponds to:

$$20 \log \mu V = 20 \log \mu Vm(-3.4 \text{ dB}) - \text{antenna factor (5 dB)}$$

Then

$$\log \mu V = \frac{-8.4}{20} \text{ or } \quad 0.38 \ \mu V$$

The noise power input to the receiver is

$$\text{Power}_{in} = \frac{\varepsilon^2}{R} = \frac{(0.38 \times 10^{-6})^2}{50} = \frac{1.44 \times 10^{-13}}{50} = 2.89 \times 10^{-15} \text{ watts}$$

This result is then expressed in dB with respect to 1 mW

$$\text{Power}_{in} = -115 \text{ dBm}$$

When a radiolocation system performance is atmospheric noise limited in the winter, a cordless telephone radiation, with a received signal level above -3.4 dB(μV/m), 0.46 μV/m, at the radiolocation receiver, will reduce the S/N at the receiver below a value necessary for adequate location service.

The measured radiation data for cordless telephones were taken in the nearfield of the devices, where the field strength value decreases at the rate of the inverse of the square of the distance separating the radiator and the monitor point. When the distance is equivalent to several wavelengths (farfield), the field begins to decrease with the inverse of the distance. In this analysis, the

TABLE 20

VERTICAL ANTENNA PROGRAM

```
 82/09/23.  10.25.13
N O A A / E R L   170/750     82/09/05.       NOS 1.4  531/552.23
FAMILY:
          TERMINAL:    150.  TTY
RECOVER/  CHARGE:  CHARGE, Z7233180.Z
$CHARGE,Z7233180,Z.
/OLD
LE NAME:  HVD1
READY.
RUN

 82/09/23.  10.25.41.
PROGRAM   HVD1

TYPE THE REQUESTED DATA AFTER EACH ?
FREQUENCY, MHZ
?  1.6
ANTENNA HALF-LENGTH, M,  < LAMBDA/2
?  2.44
ANTENNA RADIUS,  M
?  .00635
GROUND CONDUCTIVITY, MILLIMHOS/M
?  0
IMPEDANCE OF T-LINE ATTACHED TO ANTENNA, OHMS
?  50
TYPE 1.  FOR HORIZONTAL POLARIZATION,  0 FOR VERTICAL
?  0
TYPE 1.  FOR DIPOLE OR 0 FOR MONOPOLE
?  0
INPUT IMPEDANCE =         .0523+J[  -3646.8843]OHMS
ENTER NEW HALF-LENGTH IF DESIRED, OTHERWISE ENTER 0
?  0
ANTENNA FACTOR ASSUMING A  50.00-OHM RECEIVER AND TRANSMISSION LINE ARE EMPLOYED =  35.53 DB
VSWR = 5084456.1201
MISMATCH LOSS =    61.0418 DB
PRESS RETURN FOR GAIN VS PHI, OTHERWISE TYPE STOP
  PAUSE

?
ELEV ANGLE INCREMENT FOR BELOW 10 DEG AND THE ADDITIONAL INCREMENT FOR ABOVE 10 DEG
?  2.
?  8.
E-PLANE ELEVATION ANGLE IN DEGREES AND GAIN IN DB VERTICAL POLARIZATION
          2.000                5.842
          4.000                5.826
          6.000                5.799
          8.000                5.762
         10.000                5.714
         20.000                5.306
         30.000                4.596
         40.000                3.530
         50.000                2.005
         60.000                -.177
         70.000               -3.476
         80.000               -9.364
         90.000             -120.000
- - - - - - - - - - - - - - - - - - - - -
```

cordless telephone is assumed to radiate a field of 3000 μV/m at 98.4 ft (30 m), and the farfield is assumed to begin at 1584 ft (480 m) where the field strength is about 12 μV/m.

Hence, based on the above conditions, a cordless telephone separated by line-of-sight distance, greater than 5.3 mi (8.5 km) from the radiolocation receiver, will not adversely affect the performance of the location system.

SECTION 7.
SPECTRUM MANAGEMENT ISSUES

The effects of WARC-79 on the 1605-2000 kHz band are significant. The characteristics of the band will undergo great change in the next 5 to 10 years. The major spectrum management issues are discussed in the following paragraphs.

TRAVELER'S INFORMATION STATIONS (TIS).

The TIS has been allocated the 1605-1615 kHz portion of the band in the new allocation table. However, it would seem more consistent with past allocations to have TIS at the top of the AM broadcast band at 1700 kHz rather than remaining at the present 1610 kHz. This would help the frequency management aspects by keeping the broadcast band continuous, and with only a few low power Government and non-Government assignments around 1700 kHz, the compatibility problems may be eased. Additionally, the slightly lower value of groundwave attenuation at 1610 kHz, compared to 1700 kHz, favors the use of 1610 kHz for broadcasting.

The NTIA Manual contains no rules or regulations for Government use of TIS. Since there are 172 Government assignments to TIS, it would be appropriate to either make a statement to the applicability of the FCC Rules and Regulations or to list some rules and regulations pertaining to these assignments.

As shown in Section 6, separation distances for nighttime TIS operation are very large for broadcasting stations operating at power levels in excess of 1 kW for cochannel operations. Adjacent-channel separation distances are also large, so special consideration will need to be given to adjacent channel operation. It should be noted that the data in TABLES 15 and 16 represent a minimum separation. Antennas used throughout the analysis of Section 6 represent the minimum requirements. Nighttime operations of TIS on a Primary basis will pose significant separation requirements for broadcast station (cochannel or adjacent channel). Using Class IV stations and a cochannel and off-channel sharing plan on a case-by-case basis could result in compatible operations between the two services.

Another alternative to TIS broadcasting sharing would be to move the TIS to the FM bands. The following paragraphs address this approach.

THE FM BROADCASTING BAND AS AN ALTERNATIVE FOR TIS IMPLEMENTATION.

The AM broadcasting band is currently planned for expansion as a result of WARC-79 decisions. This planned expansion could cause additional operational problems for TIS with current restrictions and interference problems normally associated with the AM band. It should also be noted that expansion of the TIS service also includes portable applications for temporary services, and all of these items constitute increased services and areas for operation. The increased flexibility and access to more areas within the United States necessitates a review of possible alternatives to meet the increased demands for both the AM broadcasting service and the planned growth of TIS.

Currently, the most convenient method of providing information to the traveler is with existing car radios. Requiring modifications to existing car radios would limit the number of travelers that would have ready access to the TIS service. A review of sales information shows a steady increase in the number of new cars that have FM reception capability. Sales of car radios for update or replacement also show an increase in FM reception. With a large percentage of cars with FM receivers, the FM broadcast band offers an interesting alternative means of providing TIS service.

FM BAND GENERAL CHARACTERISTICS.

From a technical viewpoint, the 88-108 MHz band offers some attractive characteristics for TIS application. One main feature of the FM band is that the radio propagation is generally referred to as line-of-sight. For this mode of propagation, the reception distance is generally limited to the radio horizon. The actual coverage obtained is a function of many variables, such as the radio refractive index, terrain obstructions, earth conductivity, and multipath. At distances beyond the radio horizon, diffraction and forward scatter exist; however, in these regions, the signal attenuates very rapidly. This serves to restrict coverage beyond the radio horizon and thus minimize interference to adjacent areas. It should also be noted that FM coverage is not affected appreciably by diurnal effects like the AM broadcasting band.

A typical example of propagation loss can be obtained from the National Telecommunications and Information Administration (NTIA) Master Propagation System Users' Manual, using the included "NLAMBDA Propagation Model." This propagation model computes a theoretical estimate of the median value of the transmission loss over a smooth, spherical, and imperfectly conducting earth. Antenna heights can be located very near the earth's surface for this model, which would be the planned application for TIS operation. The model includes propagation mechanisms such as surface wave, direct wave, reflected wave, and the diffraction wave. The predicted loss values depend on the user-input values of ground conductivity, atmospheric refractivity, and path distance.

For example, this propagation model is used with the following parameters: a transmitter height of 50 ft (15.2 m), a receiver antenna at 4 ft (1.2 m) above the earth's surface (assumed effective height of a car-mounted antenna), vertical polarization (again a typical car-mounted antenna), 5 mhos earth conductivity is the selected relative permittivity and the surface atmospheric refractive index of 301 N(units). The propagation loss between isotropic antennas at 100 MHz is shown in Figure 27. The lower curve shows the estimated median path loss from the NLAMDA model, where the upper curve is the corresponding line-of-sight or free-space path loss. Note the significant difference of the NLAMBDA model and the free-space loss. The model attenuation rate (slope) is also much more rapid than the free-space attenuation. The attenuation rate also shows an increase in the region near the radio horizon. This increased attenuation can effectively minimize cochannel and adjacent-channel interference problems.

The FM modulation and receiver system also offer some interesting differences from the AM commercial system. The FM systems have the capability of trading bandwidth for improvements in system output S/N. Additionally, wideband FM systems (the maximum frequency deviation of the carrier is several times the modulation frequency) have certain inherent noise and interference reduction properties not found in AM systems. The penalty for this improved system performance is the increased transmission bandwidth requirement. Currently, FM stations utilize approximately 150 kHz bandwidth and operate with 200 kHz channel spacing.

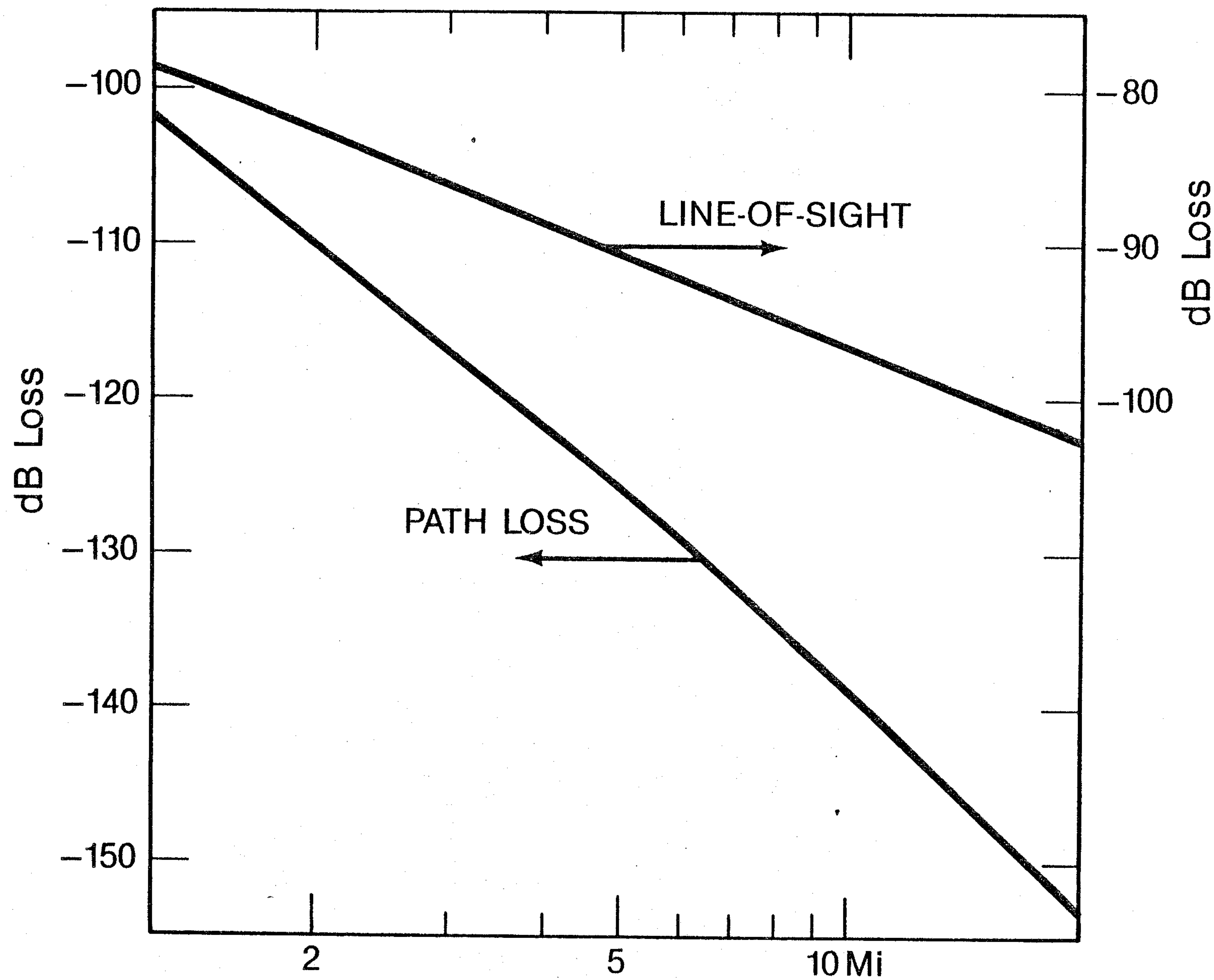


Figure 27. FM path loss.

The FM demodulation systems exhibit a signal capture effect. This signal capture effect occurs with an increasing S/N after the initial improvement threshold has been reached (i.e., the FM system begins to exceed AM output S/N performance); refer to Figure 28. This improvement threshold is a function of the system bandwidth and the modulation frequency. In current systems, this can vary from about a 9 to 13 dB carrier-to-noise ratio (C/N). Increasing the C/N above this initial threshold results in an approximately 3 dB improvement in S/N output for each S/N decibel increase. Note the S/N improvement of FM compared to AM, as shown in Figure 28. The FM improvement obtained is a function of the modulation index. Once full FM improvement is obtained, the slope of S/N output increases 1 dB for each dB increase of C/N input until saturation is reached.

This capture effect is also exhibited for low C/N. In this case, the noise acts to suppress the signal. When deemphasis is used to compensate for the nonuniform noise of the FM system, the signal is suppressed approximately 2 dB for each dB decrease in C/N.

FM systems typically provide a marked improvement in output S/N once the C/N input is above the initial threshold. The FM system also exhibits less sensitivity to noise such as AM noise components. Below initial FM thresholds, noise captures the receiver system and suppresses weak signals, thus minimizing weak signal interference. These characteristics are very beneficial for TIS, where a limited coverage area is all that is normally needed.

SYSTEM PERFORMANCE CONSIDERATIONS.

After a brief review of some basic FM characteristics, it is now necessary to review the overall details of the system (i.e., antennas, transmitter power requirement, and receiver) to determine the general broadcast station parameters.

For example, an FM system will be formulated to provide a coverage radius of approximately 8 mi (12.9 km). The median transmission loss is -134 dB, which is determined from Figure 27. A representative receiving system is assumed to have a nominal 14 dB noise figure, 150 kHz IF bandwidth (B_{IF}), and a -4 dB antenna gain. With this information, the receiver sensitivity can be determined by equation (3).

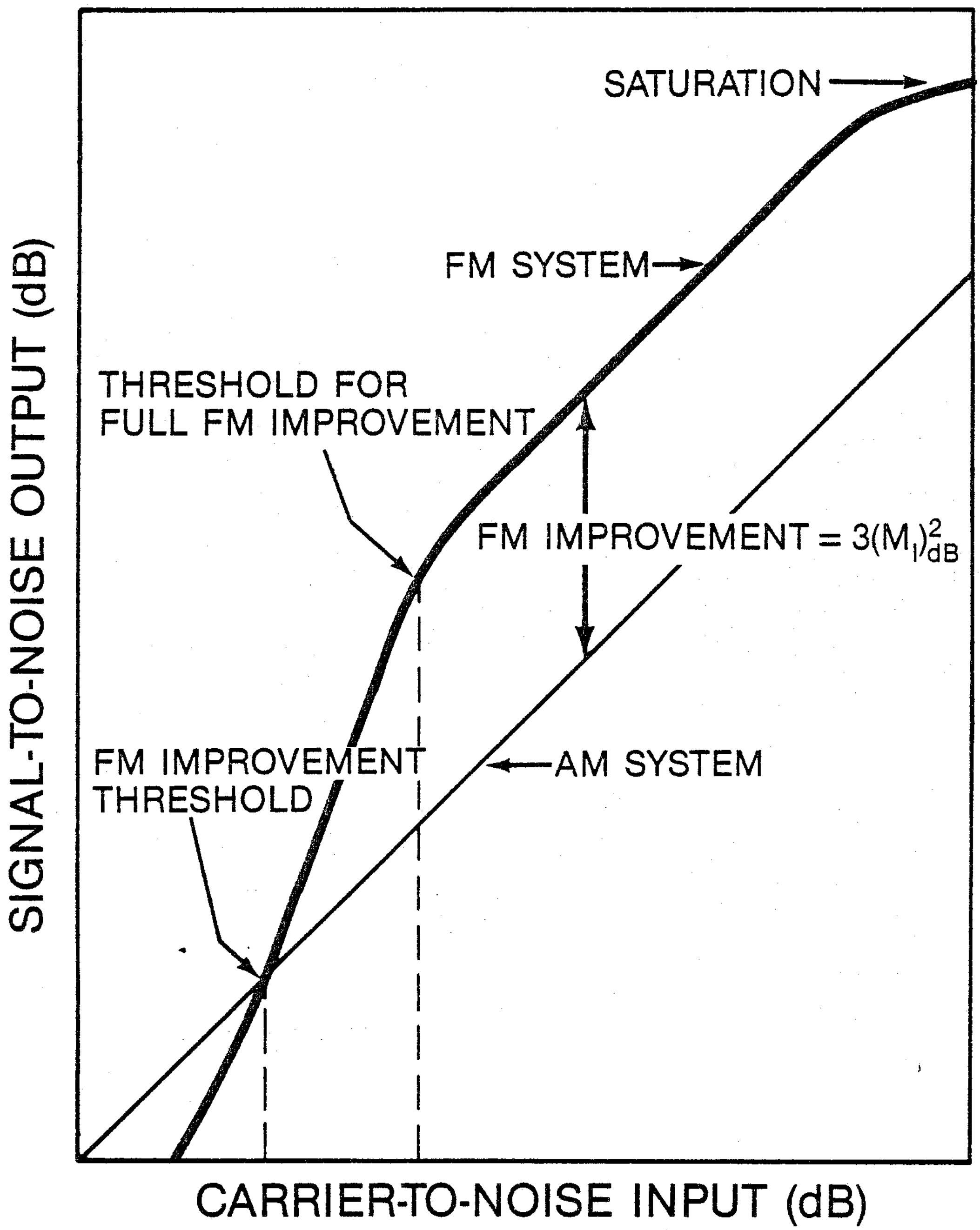


Figure 28. FM system characteristics.

$$\text{Input sensitivity} = -204 \text{ dB} + NF + 10 \log B_{IF} \quad . \tag{3}$$

For this example,

$$\text{Input sensitivity} = -204 + 14 + 51.8 = -138.2 \text{ dBW} \quad .$$

The transmitter antenna will provide approximate hemispherical coverage and hence is assumed to have a +3 dB antenna gain over isotropic.

Transmitting antenna	+ 3 dB
Space loss	-134 dB
Receiver antenna	- 4 dB
Net loss	-135 dB

The difference between the signal level required for proper operation of the FM receiver and the net propagation loss determines the transmitter power level requirement. The minimum signal level needed for the FM receiver is determined by the signal needed for full FM improvement. This value is determined from the receiver sensitivity, plus the initial FM threshold, plus the added signal increased and needed for full FM improvement. The initial FM improvement occurs in the region of 9-13 dB S/N. For this example, 13 dB is selected. FM improvement is determined theoretically by $3(M_I)^2$ dB. M_I corresponds to the modulation index (M_I = deviation of the RF carrier/modulation frequency) and is expressed in dB. For a typical FM system, this corresponds to $3(75 \text{ kHz}/15 \text{ kHz})^2 = 75$ or approximately 18.7 dB. This improvement comes at the expense of increased S/N above the initial FM threshold. In the region between the initial and full FM improvement, the output S/N increases approximately 3 dB for a 1 dB increase in input C/N. Thus, an additional (18.7/3) = 6.2 dB C/N signal will be needed as well as the 13 dB just mentioned or 19.2 dB above receiver threshold for minimum system operation.

Knowing the receiver sensitivity, system loss, and the antenna gains for the transmitter and receiver, it now is necessary to determine the transmitter power level needed for system operation.

Receiver sensitivity	- 140.2 dBW
Carrier to noise	(+) 19.2 dB
Required carrier level	- 121.0 dBW
System loss	+ 137.0 dB
Required power level	16.0 dBW (approximately 40 watts)

If the coverage requirement is reduced from 8 mi (12.9 km) to 5 mi (8.1 km), the transmitter calculation would be done as shown above. Figure 27 would be used for determining the path loss, and using the same system parameters would result in requiring a transmitter power level of approximately 5.6 watts. These examples demonstrate that for moderate power levels it is relatively easy to obtain the desired limited coverage for TIS operations.

The FM threshold serves to provide a relatively controlled boundary for signal reception. Once the signal starts to get weak (traveling away from the transmitter), very little added distance is required to get virtually total signal loss. With antenna height control, system threshold effects, and ease of providing directional antennas in this frequency band, it should be relatively easy to provide a prescribed coverage capability.

Interference considerations for FM stations for either cochannel or adjacent channel operations can generally be controlled by providing proper spacing and by using directional antennas. This spacing requirement is considerably less than what would be required for AM. Power levels and nighttime considerations are not restrictive for FM when compared to AM.

The FM band provides for 100 assignable channels. This quantity of potential station availability should more than meet TIS requirements, since FM frequency reuse does not require nearly the same separation distances that AM channels require. The potential areas of concern are the dense metropolitan areas, which may use virtually all channel allocations, and some areas where increased coverage is obtained by virtue of locating transmitting antennas on mountain peaks. However, for low density areas, which includes a very large percentage of the United States, the FM band offers a very good means of support for TIS operation.

Sales of automobile FM radios have increased rapidly over the past few years. The Radio Advertising Bureau (RAB) has published the following results as shown in TABLE 21. It should also be noted that cars with AM only are steadily decreasing. Data also show that 95 percent of the cars currently in operation have radios.

TABLE 21

CAR RADIO TRENDS

Year	Car Sales with AM Only	Car Sales with AM/FM	Percentage of Cars having FM Radios
1983	1,513,000	10,568,000	70%
1982	1,882,000	10,424,000	68%
1981	2,598,000	10,000,000	64%
1980	2,575,000	7,017,000	59%

The FM approach appears to be a suitable alternative from a technical viewpoint, especially in low population density areas. This approach also virtually eliminates the AM nighttime operation constraints. Further study may be needed to establish interference levels for cochannel and adjacent channel constraints. This preliminary technical analysis shows the use of the 88-108 MHz band to be a possible approach for TIS. Additional factors of present band utilization, projected growth of FM stations, and growth of the TIS service would have to be factored into an effective spectrum management plan before a conclusive decision on the use of this band could result.

RADIOLOCATION AND THE BROADCAST SERVICE.

According to WARC-79, in Region 2, broadcasting will become exclusive in the 1605-1625 kHz segment of the band and Primary in the 1625-1705 kHz segment of the band. Exclusion of the radiolocation service from the 1605-1625 kHz band will not seriously affect the service since few systems are assigned frequencies below 1625 kHz. The problem arises when the 1625-1705 kHz allocation to the broadcast service is implemented and radiolocation becomes Secondary in this portion of the band, where most of the radiolocation systems are assigned.

There are some kinds of radiolocation systems that require use of frequencies that are harmonically related. In the Government allocations, these are now assigned within 1650-1655 kHz and 3300.4-3310.4 kHz. Based on Section 6 of this report, it is possible to assign radiolocation frequencies in both a cochannel and off-channel sharing plan on a case-by-case basis to be compatible with the broadcast service. This, however, assumes that the transmitters can be geographically separated far enough. Sufficient distances can be obtained if the broadcast assignments are confined to Class IV stations.

RADIONAVIGATION.

The WARC-79 allocations in the 1605-2000 kHz band for Region 2 do not include allocations for the radionavigation service, which is principally used by Army aircraft during tactical and training missions. There are presently 215 Government assignments for radionavigation within the 1605-1750 kHz band. During 1981-82, the Army purchased 566 new radionavigation systems with transmitters designed to operate in either of two bands, 200-535.5 kHz or 1605-1750.5 kHz.

To provide the necessary spectrum for these requirements, the post WARC-79 Government and non-Government allocation table has a Footnote US240, which states: "The bands 1715-1725 kHz and 1740-1750 kHz are allocated on a Primary basis and the bands 1705-1715 kHz and 1725-1740 on a Secondary basis to the aeronautical radionavigation service (radiobeacons)." The Army has stated that these frequencies are only used for training purposes in CONUS, being used mainly for temporary field location for helicopters in tactical situations. Their equipment is to be phased out of this band in the 1990s.

CORDLESS TELEPHONE AND THE RADIOLOCATION SERVICES.

In the past, cordless telephones have utilized frequencies throughout the 1600-2000 kHz band in a more or less random manner with each manufacturer making a frequency choice. After September 1982, cordless telephone manufacturers had to confine their frequency choices within the 1625-1800 kHz band in order to comply with a condition of an FCC Waiver, FCC Part 15.7. This waiver provides a practical standard by which the manufacturer can measure cordless telephone output power. Currently, available information indicates that nearly all manufactured cordless telephones do not comply with the provisions of Section 15.7 (FCC Rules and Regulations) that govern the radiated field from the telephones. In general, the radiated field value is much higher than the allowable value.

As an increasing number of cordless telephones are sold (10 million units are predicted by 1987), the interference potential is likely to be severe. Government radiolocation receivers aboard vessels at dockside in an urban environment will be very susceptible if the radiolocation transmitter is several hundred miles away.

Cordless telephones could not be manufactured for use in the 1605-2000 kHz band after October 1, 1984. However, millions had been sold by that date that were using this band.

SECTION 8

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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 is a spectrum resource assessment of the 1605-2000 kHz band. It includes information on rules, regulations, allocations, technical standards, frequency assignments, system characteristics, and applicable compatibility analyses pertinent to the 1605-2000 kHz band. Major issues are discussed concerning changes in the allocation tables due to WARC-79 decisions. Parts of the 1605-2000 kHz band are in transition from radiolocation service use to broadcasting service use. Major problems in this band are the sharing among travelers' information stations, radiolocation, and broadcasting and the proliferation of the cordless telephone. This report analyzes the possibility of sharing between broadcasting and travelers' information stations and radiolocation, along with addressing the problems associated with cordless telephones.

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

1605-2000 kHz, Broadcasting Service, Cordless Telephone, Electromagnetic Compatibility, Radiolocation Service, Radionavigation Service

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