NTIA REPORT 85-178

An Assessment of the Future of Travelers' Information Stations

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SEPTEMBER 1985

ABSTRACT

This report is a study of Travelers' Information Stations (TIS) operating in the 525-535 and 1605-1615 kHz bands. It was prompted by the expansion of the AM broadcasting band from 1605 to 1705 kHz. Included is information on rules and regulations, allocations, technical standards, frequency assignments, and system characteristics. Potential compatibility problems are identified and analyzed. Alternate approaches and policies for TIS users are identified and assessed. Conclusions are drawn and recommendations made on the potential for sharing in the AM and FM broadcasting bands.

KEY WORDS

AM Broadcasting Band
Electromagnetic Compatibility (EMC)
FM Broadcasting Band
525-535 kHz Band
1605-1615 kHz Band
Highway Advisory Radio
Nondirectional Beacons
Travelers' Information Stations (TIS)

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SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the radio spectrum allocated to the Federal Government. Part of NTIA's responsibility is to "...establish policies concerning spectrum assignment, allocation and use, and provide the various departments and agencies with guidance to assure that their conduct of telecommunications activities is consistent with these policies" (NTIA, 1985). In support of these requirements, the guidance provided by NTIA, with the assistance of the Interdepartment Radio Advisory Committee (IRAC), encompasses the areas of utilizing spectrum, identifying existing and/or potential electromagnetic compatibility (EMC) problems between systems of various departments and agencies, providing recommendations for resolving any compatibility conflicts, and recommending changes for more efficient and effective use of the spectrum and improved spectrum management procedures. This report considers spectrum use by Travelers' Information Stations (TIS), their present frequency assignments and future spectrum needs, and includes compatibility analysis.

In 1977, the Federal Communications Commission (FCC) revised Part 90 of its Rules and Regulations (FCC, 1977). In subsection 90.242, provisions were made for the TIS at 530 and 1610 kHz. The TIS was also authorized to operate, on a secondary basis to stations operating on a primary basis, in the 510-525 and 1615-1715 kHz bands. The TIS is designed to transmit only noncommercial voice information for automobile travelers regarding traffic and road conditions, availability of lodging, location of rest stops and service stations, and descriptions of local points of interest. These stations are restricted to use in the immediate vicinity of air, train, and bus transportation terminals, bridges, tunnels, and any intersections of a Federal interstate highway with any other interstate, Federal, state, or local highway.

As a result of WARC-79 agreements, the band from 1605-2000 kHz experienced changes in frequency allocation. The AM broadcasting service expanded from 1605 to 1705 kHz. The FCC released a first Notice of Inquiry (NOI) in General Docket No. 84-467, May 16, 1984 (FCC, 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 scheduled for 1986. In early January 1984, the IRAC formed an ad hoc committee (Ad Hoc 193) to help develop the position and proposal documents of the Executive Branch for the Region 2 Administrative Radio Conference.

Some comments received by the FCC suggest possible changes in the allocation of frequencies to TIS and the use of high-power AM broadcasting stations in the 1605-1705 kHz band. In a spectrum resource assessment (SRA) published in April 1985 (Thompson, 1985), the frequency band from 1605-1705 kHz was analyzed to determine the effects of cochannel and adjacent-channel AM broadcasting stations on TIS at 1610 kHz. The results showed a requirement for large separation distances between the two stations, particularly at night when skywave propagation is possible. Other problems with TIS operations in a shared environment with AM broadcasting were discussed at meetings of Ad Hoc 193. These discussions resulted in a memo from the Ad Hoc chairman to NTIA (Matos, 1984) requesting a thorough investigation of alternatives addressing the technical, economic, and administrative aspects of TIS and broadcasting operations. The memorandum states that the Federal Highway Administration (FHWA), although they have no TIS assignments, has the Federal Interstate Highway Systems represented by the various state departments of transportation as its constituency. The FHWA sponsored a conference on motorists information services where the Highway Advisory Radio (HAR--their name for TIS) played a major role in the presentations and discussions. Officials from various state highway departments indicated increasing requirements for TIS on both 530 and 1610 kHz.

The National Weather Service (NWS) is also contemplating the use of TIS along the nation's interstate highway system at the various rest stop areas to disseminate weather information--particularly severe weather watches. This could easily mean over a thousand new assignments depending on the feasibility and number of states covered. The largest Government user of TIS is the Department of Interior (DOI) with 153 assignments. The DOI projects their use of TIS will more than triple in the next five years to over 500 assignments.

The current use, proposed uses, changes in allocations in the 1605-1705 kHz band, which could affect TIS, and assistance to the IRAC in developing a national position for the upcoming Regional Administrative Radio Conference is the basis for this report.

OBJECTIVES

The objective of this task was to provide a technical and administrative basis for the development of plans and policies for future use of TIS.

APPROACH

In order to accomplish the objectives of this TIS study, the following approach was taken.

1. Existing and planned uses of TIS were documented along with a review of the Government Master File (GMF), the non-Government Master File (NGMF), recommendations of IRAC Ad Hoc 193, and contacts with concerned Federal, state, and local Government agencies to compile a reasonably comprehensive set of spectrum requirements.

2. Potential compatibility problems at the TIS frequencies were identified and analyzed.

3. Alternate approaches and policies for TIS users were identified and assessed, including the two exclusive TIS frequencies at 530 and 1610 kHz, the use of 1700 and 1710 kHz, TIS shared with FM broadcasting in the 88-108 MHz band, and TIS shared in the 535-1705 kHz band.

4. Specific changes to existing rules, regulations, and frequency management practices, which would improve overall management of TIS in the bands involved, are recommended.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS

Discussions with state and Federal agencies on the future use of TIS pointed to increased use in the near future. This increased use, as pointed out in Section 4, is likely to be dramatic in the next five years, with a possibility of more than doubling the present use. These estimates of growth could be greater yet if TIS were better known among the general population. As the public becomes more knowledgeable about TIS, the use and uses of this service should increase at a much faster rate over the next decade than it has over the past decade.

SPECIFIC CONCLUSIONS

Various options were considered for accommodating existing and future requirements of TIS. Specific conclusions are provided below for each of the options studied.

1. Conclusions concerning continued use of TIS on the frequencies 530 and 1610 kHz on an exclusive basis follow.

   a. TIS frequencies outside of large metropolitan areas are adequate to support present needs.

   b. TIS reception in large metropolitan areas where there are more broadcasting stations close to the TIS frequency at 1610 kHz often experiences unacceptable interference, particularly with automobile radios that are marginally capable of tuning to 1610 kHz.

   c. The experience of many operators of TIS shows that the power allowed for TIS at 530 kHz is not adequate for desired coverage.

   d. Unless very rigorous installation procedures of TIS equipment are followed (particularly for the antenna), poor coverage of the desired communication area results.

e. Approximately 99% of all existing TIS antenna installations use monopole antennas, rather than the "leaky cable" type.

f. Government agencies using TIS show a preference for the 1610 kHz frequency where 87% of the assignments are listed.

g. Future international use of high-powered broadcasting stations on the 1610 kHz frequency could result in substantial interference to TIS, particularly at night due to skywave propagation.

h. The need exists to retain the current exclusive allocation within the United States for the mobile service to support current and near-term TIS requirements.

i. This option requires no further national allocation changes.

j. There is a potential for interference between nondirectional radio beacons and TIS at 530 kHz.

2. Conclusions concerning continued use of TIS on the frequency 530 kHz, but long-term transition to the use of 1690, 1700, or 1710 kHz versus 1610 kHz follow.

a. On a long-term basis, interference to TIS at 1710 kHz will be less than at 1610 kHz because of less competition from cochannel and adjacent-channel broadcasting stations.

b. There is a preference for 1690 and 1700 kHz over 1710 kHz by TIS users who would much rather have frequencies at the top, but within the actual AM broadcasting band.

c. The existence of travelers with automobile radios capable of tuning to 1700 kHz will likely be 10-15 years away, which makes the use of the 1610 kHz TIS frequency critical for the near future.

d. The 1710 kHz frequency is in a band allocated to the mobile service.

e. Radiolocation, other mobile, and fixed service allocations in the 1705-1800 kHz band are of concern to potential TIS users if 1710 kHz were assigned to TIS, particularly since many radiolocation users may be coming to this band from the 1605-1705 kHz band.

3. The conclusion concerning the shared operation of TIS within the 535-1615 kHz and 1615-1705 kHz bands allocated nationally to the broadcasting service is that interference from US and international broadcasting stations, especially at night, would be likely to result in a very unreliable service.

4. The conclusion concerning the operation of TIS under the low-power rules in Part 15 of the FCC Rules and Regulations and Chapter 7 of the NTIA Manual is that this type of operation would have a very short range and would be generally limited to a small parking lot or similar applications and would not fulfill most TIS needs.

5. Conclusions concerning the use of TIS in the 88-108 MHz FM broadcasting band follow.

   a. Antenna-pattern coverage is easier to control at these frequencies than in the AM band.

   b. Antenna installations would be much simpler, and the overall cost of a station in this band would be less than the AM band.

   c. The shared use of the 20 channels from 88.1 to 91.9 MHz, used mostly by low-power, noncommercial, educational FM stations along with TIS spectrum allocations, would be adequate for TIS for the forseeable future.

   d. The 10 W power output limitation required of Class D noncommercial educational FM broadcasting stations would be adequate for TIS.

   e. TIS operations in this band would necessitate the use of a computer assignment scheme to assign TIS channels to assure protection of FM broadcasting stations from TIS interference. A disadvantage of TIS in this band is that not all automobiles have FM receivers.

6. Conclusions concerning the use of TIS under existing FCC Rules and Regulations (FCC, Part 90) follow.

   a. The TIS coverage needs at 5 to 8 km are not always realizable under present power and antenna height restrictions.

   b. Present required separation distances between TIS stations are not adequate if needed field intensities at 5 and 8 km are realized.

   c. The DOI recommended field strength requirements for adequate automobile radio reception at 5 to 8 km (330 μV/m at 530 kHz and 250 μV/m at 1610 kHz) are reasonable.

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.

1. The frequencies at 530 and 1610 kHz should remain available for TIS use in the United States until the phase-out of 1610 kHz and phase-in of 1700 kHz occurs. TIS use of 530 kHz should continue.

2. The United States should adopt a position for the Region 2 Medium Frequency Conference supporting a limit on power for broadcasting stations operating at 1700 kHz.

3. Provision should be made for the allocation and exclusive use of 1700 kHz TIS operations and appropriate technical standards to facilitate such use should be adopted.

4. The FM broadcasting band from 88-108 MHz should be made available for TIS operations throughout the band on a noninterference basis.

5. A "constant coverage" scheme should be developed for TIS, which provides adequate field strength for good reception at 5 and 8 km and allows antenna height and/or transmitter power to be adjusted to whatever level necessary to produce that field strength.

6. An addition to the NTIA Manual should be made providing rules, regulations, and recommendations for Government use of TIS.

7. TIS-to-TIS separation distance requirements for cochannel operations should be reviewed, and appropriate tables of distance separation given in the NTIA Manual.

8. Distance and/or frequency separation guidelines for nondirectional beacon stations and TIS at 530 kHz should be given in the NTIA Manual.

SECTION 3

RULES AND REGULATIONS

GENERAL

The current Federal Communications Commission (FCC) Rules and Regulations (FCC, Part 90) covering the TIS were initiated by the Federal Highway Administration (FHWA) and other interested Government agencies in the early 1970's. In 1971, the FHWA conducted a research effort on the Highway Advisory Radio (HAR), and a committee of the FCC/IRAC was formed to consider the requirements set forth by the FHWA, US Forest Service, and US Park Service. This resulted in the July 1975 FCC proposed rulemaking, Docket 20509, that would establish a TIS. Under this docket, HAR stations became recognized as TIS by the FCC. The TIS stations are authorized on a primary basis on the 530 kHz and 1610 kHz frequencies and secondary from 510-525 kHz and 1615-1715 kHz to stations designated as primary in those bands. A revised version of Docket 20509 (FCC, 1977), effective on July 29, 1977, allowed TIS to be installed on any interstate interchange. This rulemaking attracted over 100 comments with approximately half of them coming from the broadcast industry, which expressed itself as being totally opposed to the creation of TIS. The concern of the broadcasters appeared to be that HAR would compete with standard AM broadcast stations for listeners with a resulting loss of advertising revenue. In response to this, the FCC imposed a restriction prohibiting the identification of the commercial name of any business establishment, and placed strict limitations on permissible locations and zones of coverage. Separation distances are specified with respect to the protected contours of adjacent-channel broadcast stations.

INTERNATIONAL ALLOCATIONS

The international allocations are shown in TABLE 1, together with the footnotes applicable to the TIS. As a result of WARC-79, the 1605-1705 kHz band is allocated to the broadcast service in Region 2. In the Tables of

TABLE 1

POST WARC-79 NATIONAL AND INTERNATIONAL ALLOCATION TABLE

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
526.5-1606.5 BROADCASTING	525-535 BROADCASTING 477 AERONAUTICAL RADIONAVIGATION	526.5-535 BROADCASTING Mobile 479	525-535	US18 US221 US239	AERONAUTICAL RADIONAVIGATION (Radiobeacons) MOBILE	AERONAUTICAL RADIONAVIGATION (Radiobeacons) MOBILE	
	535-1605 BROADCASTING	535-1606.5 BROADCASTING	535-1605			BROADCASTING NG128	
478	1605-1625 BROADCASTING 480		1605-1615	US221 480	MOBILE	MOBILE	Traveler's Information Systems
1606.5-1625 MARITIME MOBILE FIXED/ LAND MOBILE/ 483 484	481	1606.5-1800 FIXED MOBILE RADIOLOCATION	1615-1625	US237 US299 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 US299 480	Radiolocation	BROADCASTING Radiolocation	

Footnotes pertaining to the Travelers' Information Service for the US and Region 2

477 In Region 2, in the band 525-535 kHz, the carrier power of broadcasting stations shall not exceed 1 kW during the day and 250 W at night.

480 In Region 2, the use of the band 1605-1705 kHz by stations of the broadcasting service shall be subject to a plan to be established by a regional administrative radio conference.

481 In Region 2, until the dates decided by the Regional Administrative Radio Conference referred to in No. 480, the band 1605-1705 kHz is allocated to the fixed, mobile and aeronautical radionavigation services on a primary basis and to the radiolocation service on a secondary basis.

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

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.

US239 Aeronautical radionavigation stations (radiobeacons) may be authorized, primarily for off-shore use, in the band 525-535 kHz on a noninterference basis to Travelers' Information Stations.

Frequency Allocations in Region 2, the 1605-1625 kHz band is allocated exclusively to the broadcast service, and the 1625-1705 kHz band is allocated to the broadcast service on a shared basis with other services. Also, the use of this band by the broadcasting service is subject to a broadcasting plan to be established by a Regional Administrative Radio Conference to be convened in 1986 and 1988 to establish a plan for the broadcasting service in the 1605-1705 kHz band in Region 2.

NATIONAL ALLOCATIONS

The US National allocations are also shown in TABLE 1 for comparison with the international allocations. As can be seen, the National allocations differ from the international allocations in only the 1605-1625 kHz band, which is broken down into a 1605-1615 kHz and 1615-1625 kHz band. The 1605-1615 kHz band is allocated to mobile service (TIS) on a primary basis. The 1615-1625 kHz band has been allocated to broadcasting on a primary basis, but implementation is subject to decisions of the 1986/88 Region 2 Administrative Radio Conference.

The 525-535 kHz band is allocated to aeronautical radionavigation and mobile services on a primary basis. The aeronautical radionavigation service is used for radiobeacons, and Footnote US239 states that the use is primarily for off-shore on a noninterference basis to TIS. The mobile service by Footnote US221 is limited to distribution of public service information from TIS operating on 530 or 1610 kHz.

TECHNICAL STANDARDS

The technical standards for non-Government TIS are set by the FCC in Part 90, Subpart J, and cover antenna requirements, transmitter modulation requirements, transmitter measurements, emission standards, licensing requirements, and coverage zones.

Coverage zone limitations are specified for two types of permissible antennas. The "leaky" or induction cable antennas are limited to 3 km (approximately 1.86 mi) in length and may not produce a field greater than 2 mV/m at a distance of 60 m (197 ft) normal to the cable. Vertically polarized radiators may not produce a field greater than 2 mV/m at a distance of 1.5 km (0.93 mi). In either case, the effect is to limit the field intensity of the antenna of a moving vehicle to a 2 mV/m, or greater, field to about 3 km of travel. At 55 mph, this amounts to about 2 minutes. The signal will drop off abruptly past the end of the cable, but may still be detectable by a good receiver for miles beyond the 2 mV/m contour of a vertically polarized antenna. However, because of the statistical spread of receiver characteristics of randomly selected automobile radios, it may not be possible to achieve coverage beyond the approximately 330 μV/m at 530 kHz and 250 μV/m at 1610 kHz according to a DOI study (McFadden and Shoaf, 1979). Also, the transmitter output power is constrained not to exceed 50 W for the "leaky" cable antenna systems and 10 watts for the monopole antenna systems and to be adjustable downward to enable the user to comply with the above specified field strength limits.

The complete set of applicable regulations extracted from Part 90 (Private Land Mobile Radio Services) of the Federal Communications Commission Regulations are given in the Appendix.

SECTION 4

SPECTRUM USAGE AND EQUIPMENT CHARACTERISTICS

INTRODUCTION

This section considers the present spectrum-assignment structure and equipment characteristics. Spectrum occupancy information is based on the current frequency assignments in the GMF and NGMF. Equipment characteristics are identified by the equipment type in use including possible new systems under consideration. Trends for future spectrum and system usage are included in this discussion, and projections are based on the best available information.

The authorization for TIS operations began in 1977. Equipment failures, mainly in the tape units, plagued the early TIS operations. The use of the two designated frequencies for TIS (530 and 1610 kHz) was less than anticipated in its first 2 years of operation, while potential users waited for better equipment to appear on the market. As equipment became more reliable, the use of TIS increased until recent Government and non-Government projections, discussed later in this section, show rapid growth over the next few years.

Although the TIS frequencies appear to have minimal interference problems, the impact of expanding the AM broadcasting band to 1705 kHz is not known at this time. Some organizations who answered the FCC NOI on this expansion of broadcasting services suggested the elimination of TIS as a primary service at 1610 kHz.

In light of the changes in band structure adjacent to the upper TIS frequency and the possible proliferation of TIS in the next 10 years, this section assesses both present and estimated future spectrum occupancy and system characteristics for a variety of TIS alternatives.

SPECTRUM USAGE

Frequency Assignments

TABLE 2 shows the Government assignments by agency for the two TIS frequencies at 530 and 1610 kHz. There are six Navy assignments at 530 kHz that are not TIS. Four assignments have a station class designation of FC which is a "Coast station: a land station in the maritime mobile service"; one assignment has a station class designation of MS which is a "Ship station: a mobile station in the maritime mobile service located on board a vessel which is not permanently moored, other than a survival craft station." and one assignment is for aeronautical radiobeacon stations. The Navy uses this frequency for ship-to-ship and ship-to-shore radiocommunications.

There are 222 assignments--216 of which are for TIS. Most of the Government TIS assignments (89%) are at 1610 kHz. When manufacturers and users of TIS equipment were questioned about the preference for 1610 kHz, the reason most often given was the higher cost equipment at 530 kHz. The antennas at the lower frequency are not as efficient, and the equipment must

TABLE 2

GOVERNMENT ASSIGNMENTS AT TIS FREQUENCIES
JANUARY 1985

Agency	Number of Assignments		
	1610 kHz	530 kHz	Total
Department of Interior	144	9	153
Department if Agriculture	41	7	48
Justice	4	0	4
Department of Transportation	2	1	3
Air Force	1	1	2
Army	1	1	2
Coast Guard	1	1	2
Federal Aviation Admin.	0	2	2
Navy	0	6 (not TIS)	6
TOTAL:	194	28	222

provide more power to the antenna to obtain the same coverage as equipment at 1610 kHz.

TABLES 3 and 4 show Government and non-Government TIS assignments by state. There are 29 states with Government assignments and 28 states with non-Government assignments. There are 39 states represented between the Government and non-Government TIS assignments.

Figures 1 and 2 show the geographic distribution of TIS assignments at 530 and 1610 kHz respectively from the GMF (includes non-Government assignments). Figures 3 and 4 show the geographic distribution of AM broadcasting stations at 540 and 1600 kHz respectively. These two frequencies are the first adjacent channel AM broadcasting frequencies to the TIS frequencies. These data are given here to help assess the potential adjacent channel interference problem . TABLE 5 shows the stations, locations, and transmitter power for AM broadcasting at 540 kHz. There are 15 stations; one transmits with a power of 50 kW, five at 5 kW, four at 1 kW, one at 500 W, and four at 250 W. There are 80 AM broadcasting transmitters at 1600 kHz--48 that are east of the Mississippi River as shown in TABLE 6. The highest power for transmitters at this frequency is 5000 W. There are 33 stations that broadcast 5000 W, and eight of these do not reduce power at night. The greatest number of stations (22) broadcast 1000 W in daytime only. Of the 80 stations at 1600 kHz, 52 (65%) are daytime only stations.

Since part of this study looks at alternatives for TIS, the FM broadcasting band from 88 to 108 MHz is being studied as a possible candidate; thus, the following statistics are provided for information. Figure 5 shows the frequency assignment distribution for FM broadcasting transmitters in the US. In general, the frequency with the highest number of assignments also represents low-power transmitters (3 kW or less). Figures 6 and 7 show the geographic distribution of FM broadcasting station transmitters in the continental US (CONUS). There are 6720 assignments of the 100 FM channels. However, most areas of the country have available channels that could be used for TIS, as shown in Section 5.

The FM broadcast band from 88-108 MHz has been divided into 100 channels of 200 kHz each, and each channel has been assigned a number between 200 and 300. For example, the frequency 88.1 MHz is designated FM channel 201, and frequency 107.9 MHz is designated FM channel 300. The channels are then

TABLE 3

GOVERNMENT TIS ASSIGNMENTS BY STATE

State	Number of Assignments	
	530 kHz	1610 kHz
Alaska		10
Arizona	4	10
California	1	26
Colorado	2	5
Florida	1	14
Hawaii		1
Idaho		1
Indiana	2	
Maine		2
Maryland		1
Massachusetts		2
Michigan		4
Missouri	1	5
Montana	1	20
Nevada		1
New Hampshire		1
New Mexico		10
North Carolina	2	8
Oklahoma		2
Oregon		8
Pennsylvania		3
Tennessee		9
Texas		2
Utah	1	7
Virginia	3	4
Washington	3	6
West Virginia		1
Wisconsin		2
Wyoming		29
WDC	1	
TOTAL:	29	194

TABLE 4

NON-GOVERNMENT TIS ASSIGNMENTS BY STATE

State	Number of Assignments	
	530 kHz	1610 kHz
Alabama		2
Arizona	2	1
California	10	1
Colorado	4	1
Florida	1	2
Georgia	8	
Idaho		2
Illinois	1	6
Indiana		1
Iowa		1
Kentucky	4	2
Louisiana	3	
Massachusetts	1	
Maryland	3	
Minnesota	4	4
Missouri	1	5
North Carolina	2	
New Jersey	1	
New York	1	
Ohio	2	6
Oklahoma	1	2
Oregon		1
South Dakota		1
Tennessee	1	1
Texas	3	2
Virginia	18	2
Washington	9	9
Wyoming	4	
TOTAL:	93	52

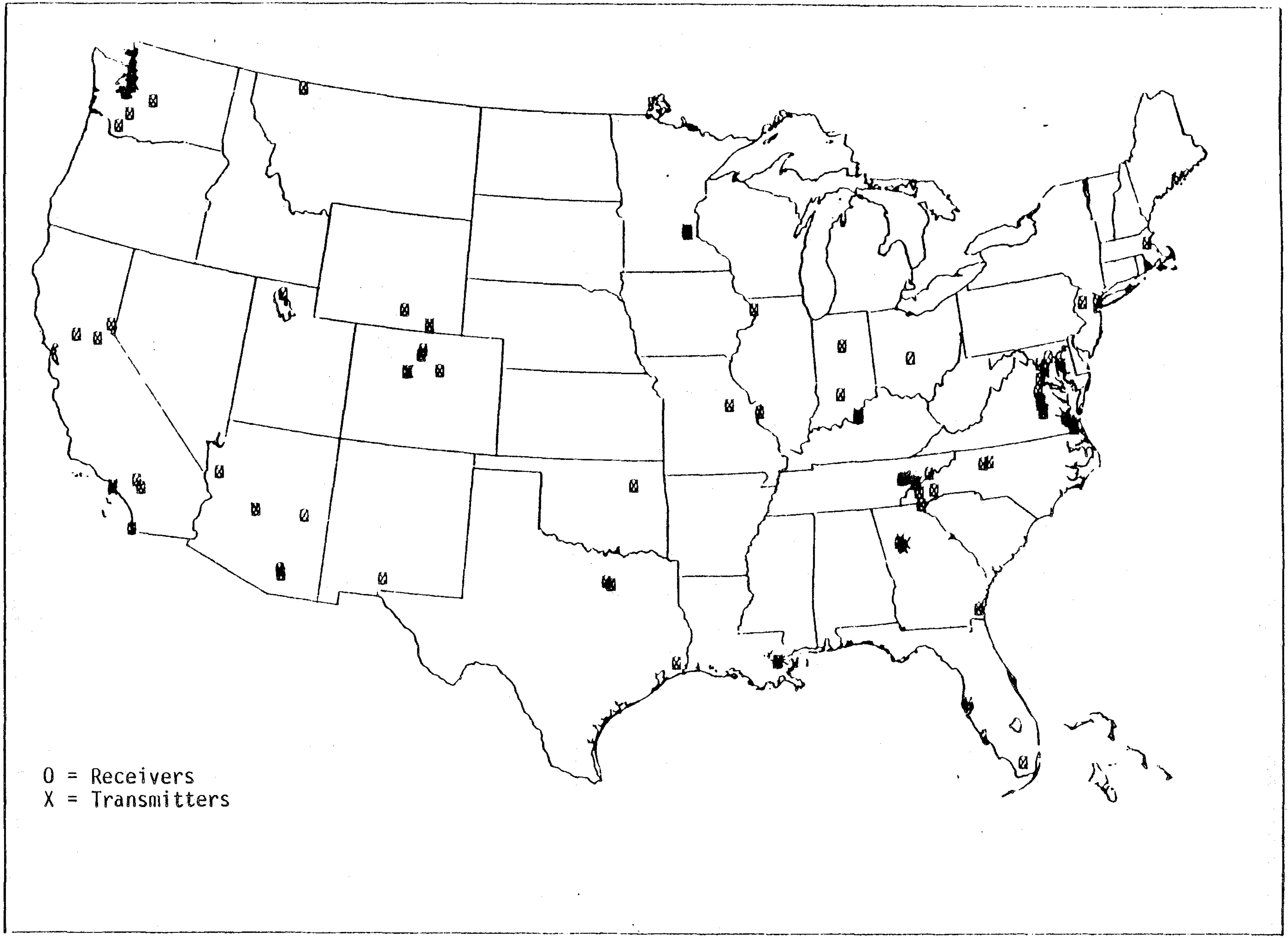


Figure 1. Geographic distribution of TIS assignments at 530 kHz as listed in the GMF.

Figure 2. Geographic distribution of TIS assignments at 1610 kHz. as listed in the GMF.

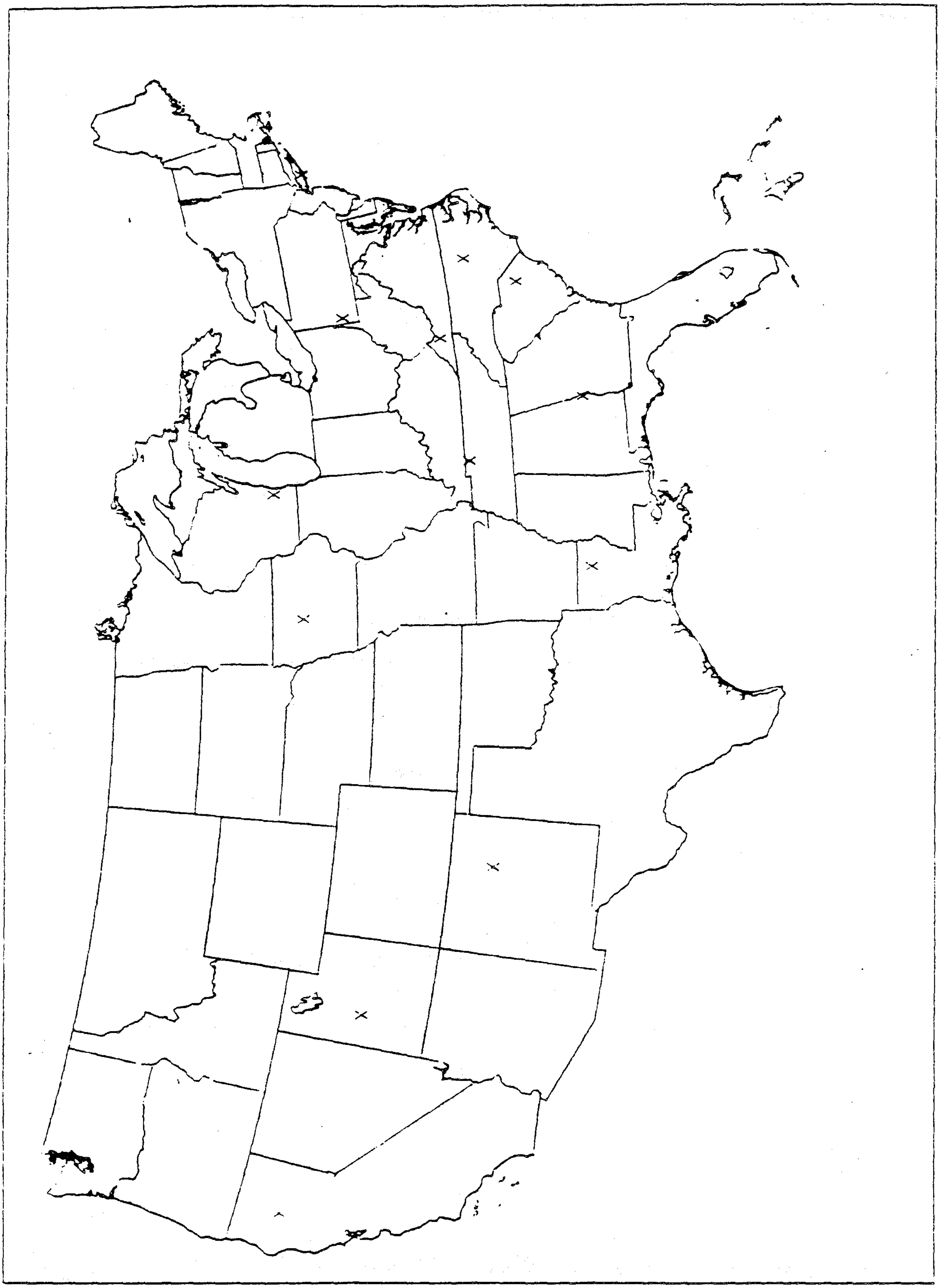


Figure 3. Geographic distribution of AM broadcasting stations at 540 kHz.

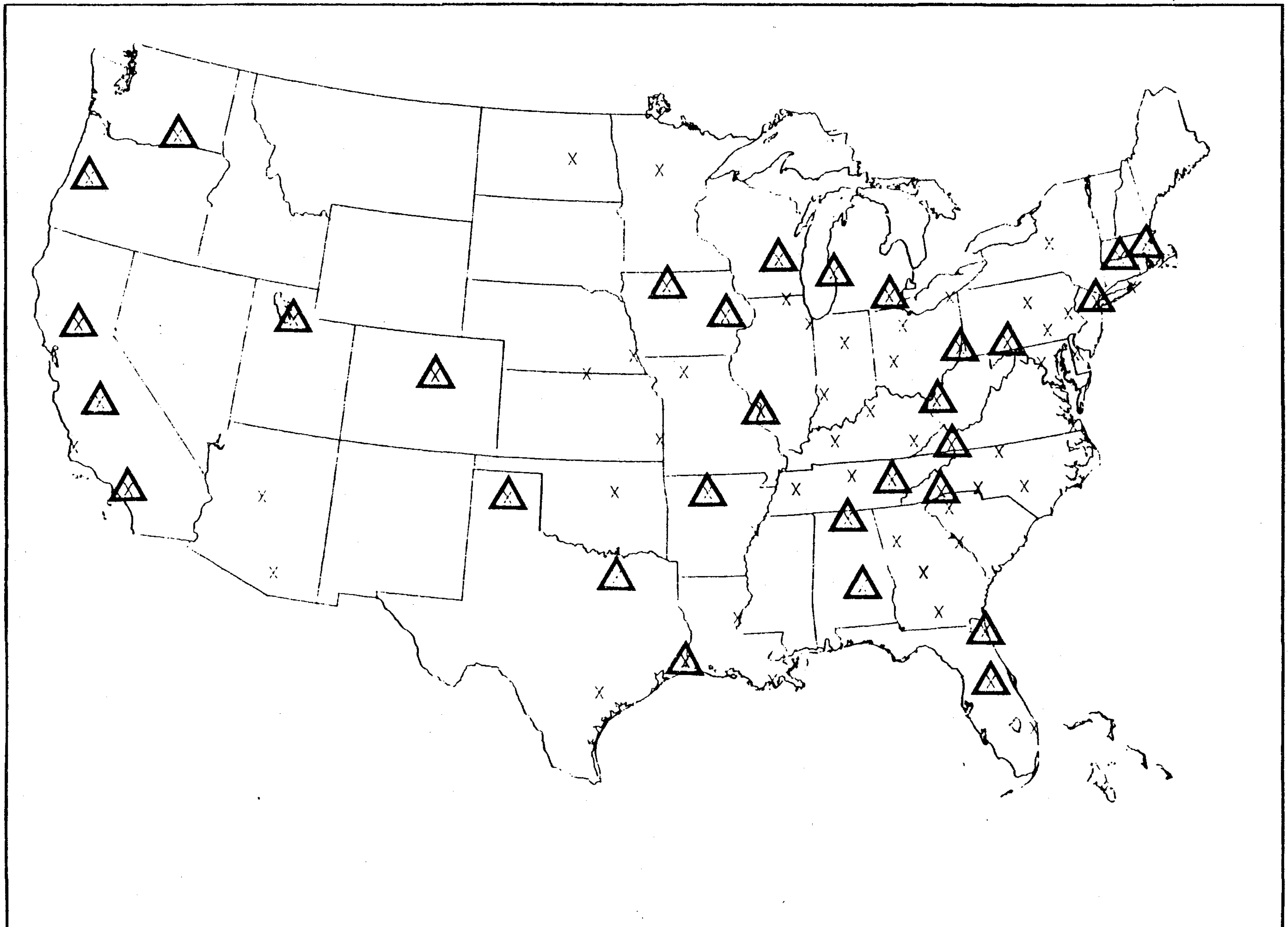


Figure 4. Geographic distribution of AM broadcasting stations at 1600 kHz.

TABLE 5

AM BROADCASTING TRANSMITTER SITES AT 540 KHZ

Location	Call Letters	Transmitter Power	
		Day (watts)	Night (watts)
Redding, CA	KVIP	1000	Daytime only
Cypress Gardens, FL	WGTO	50000	1000
Columbus, GA	WDAK	5000	1000
Fort Dodge, IA	KWMT	5000	Daytime only
Monroe, LA	KNOE	5000	1000
Pocomoke City, MD	WDMV	500	Daytime only
Wendell-Zebulon, NC	WETC	5000	"
Las Vegas, NM	KNMX	5000	"
Islip, NY	WLIX	250	"
Canonsburg, PA	WARO	250	"
Florence, SC	WYNN	250	"
Clarksville, TN	WDXN	1000	"
Delta, UT	KNAK	1000	"
Richlands, VA	WRIC	1000	"
Jackson, WI	WYLO	250	"

TABLE 6

AM BROADCASTING TRANSMITTERS AT 1600 KHZ

Transmitter Power			
Day (watts)	Night (watts)	Number of Stations	Number East of Mississippi River
5000	Daytime only	8	4
5000	2000	3	1
5000	1000	5	2
5000	500	3	1
2000	Daytime only	14	10
2000	1000	1	1
2000	500	1	1
1000	1000	3	1
1000	500	4	4
1000	Daytime only	22	13
500	Daytime only	16	10
TOTAL:		80	48

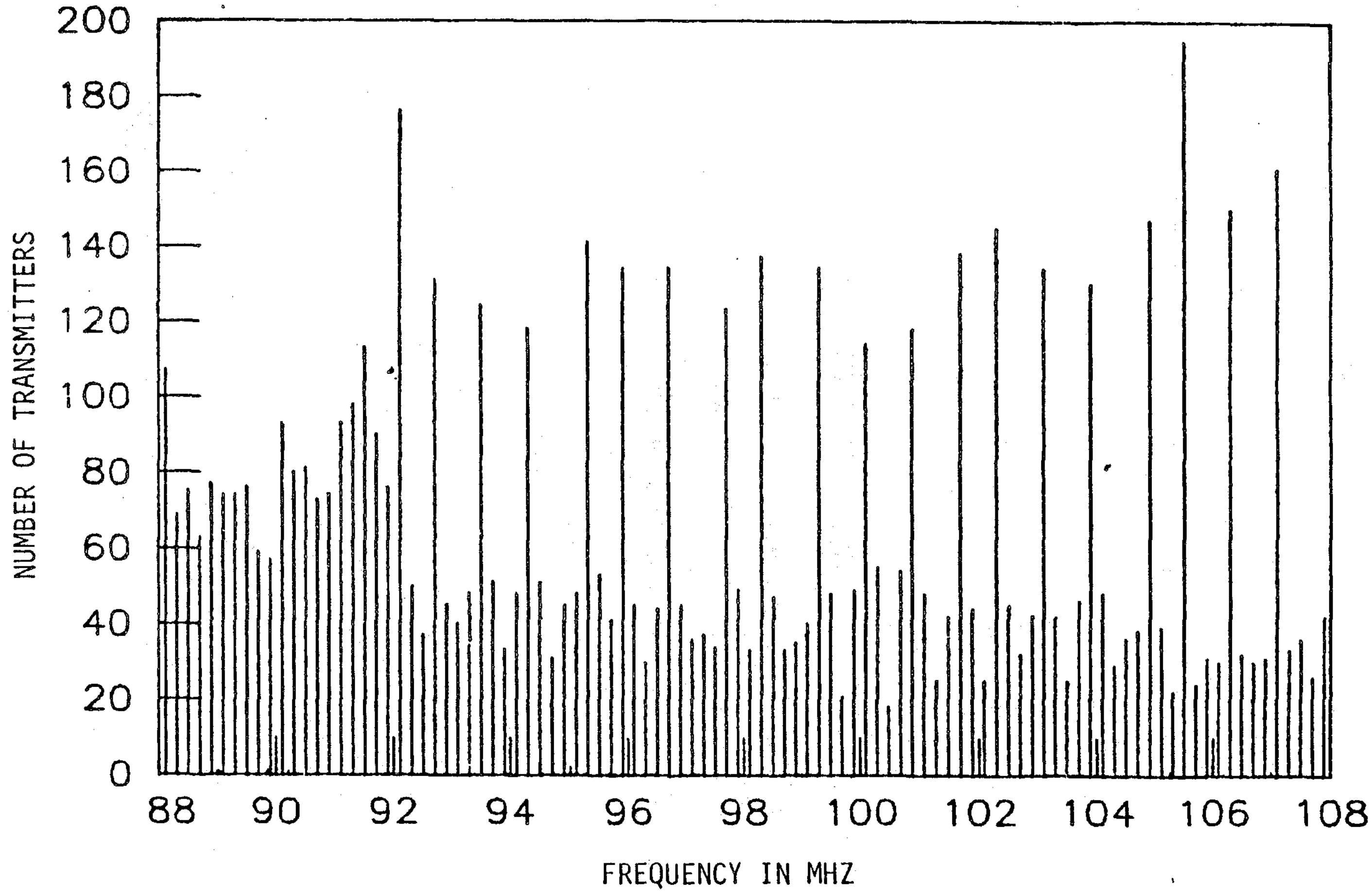


Figure 5. Number of FM transmitters per FM channel for the 88-108 MHz FM broadcasting band. (January 1985)

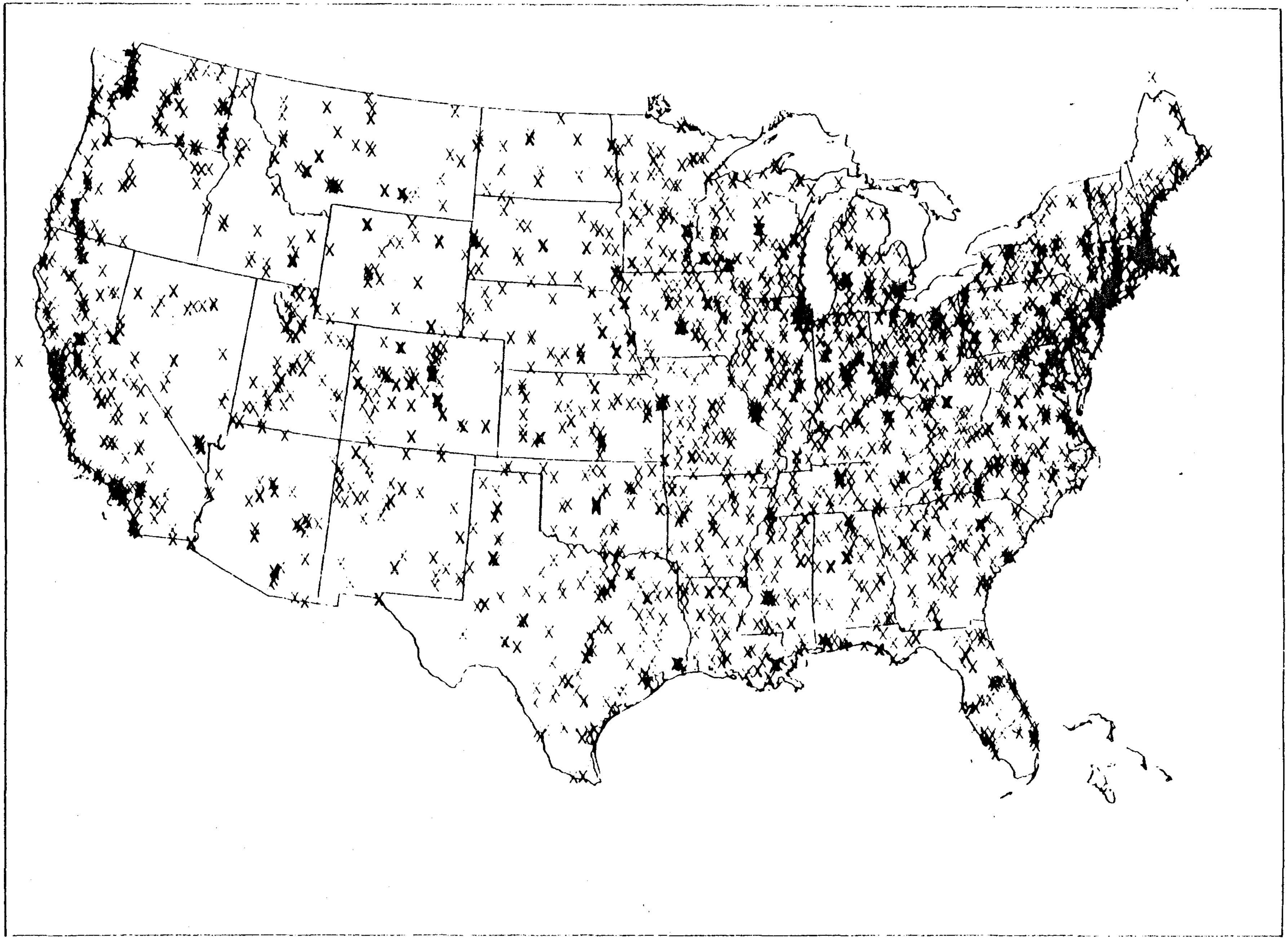


Figure 6. Geographic distribution of FM broadcasting stations from 88-98 MHz.

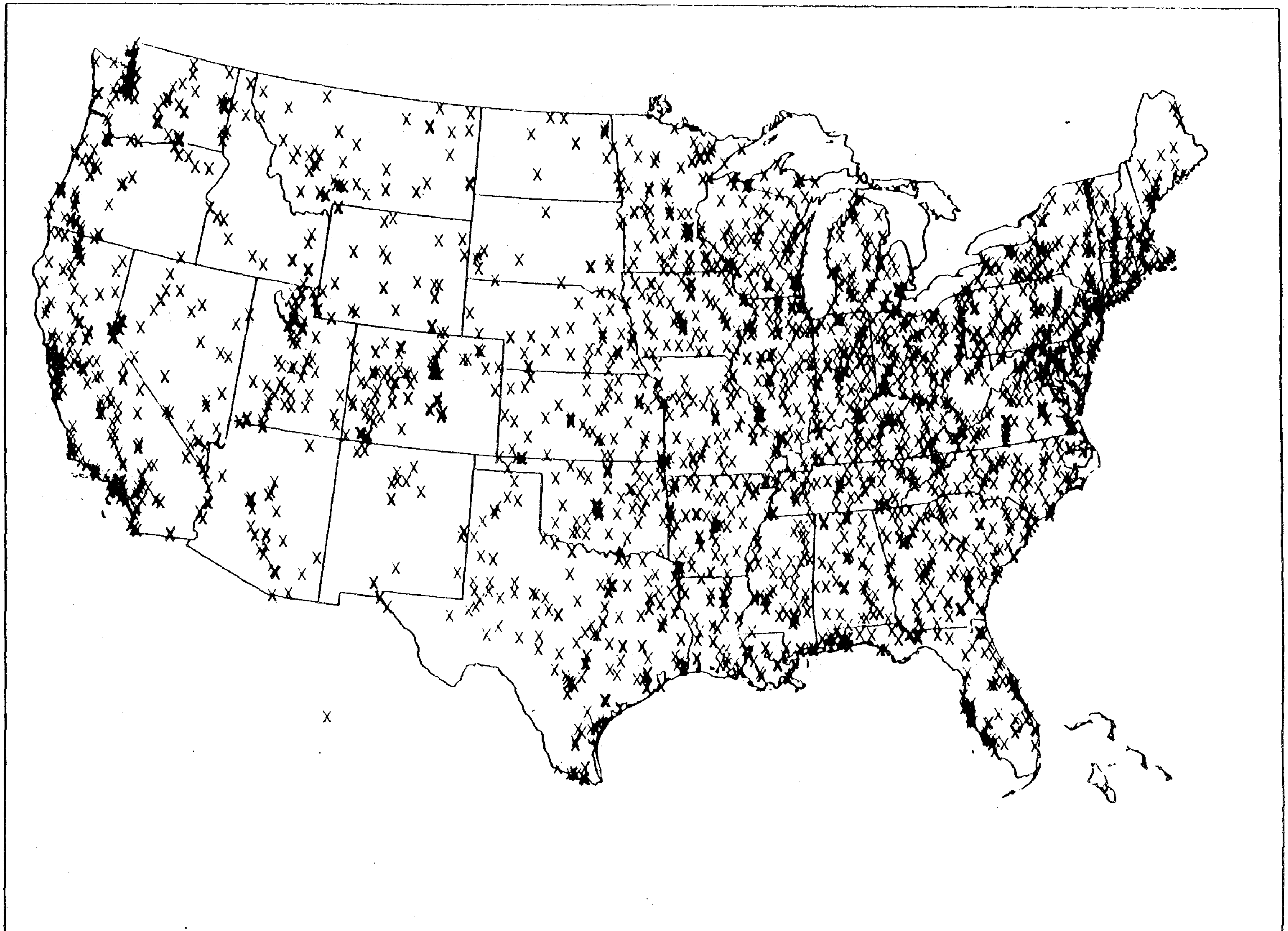


Figure 7. Geographic distribution of FM broadcasting stations from 98-108 MHz.

assigned by state and community in the US. The Table of Assignments is found in Part 73, #73.202, of the FCC Rules and Regulations (FCC, Part 73). The FM stations are also designated as Class A, B, C, or D stations. The US and certain of its territories are also divided into zones, as shown in Figure 8, for the assignment of FM stations by station class. Class A stations cannot have a coverage that exceeds that obtained from a 3 kW effective radiated power (erp) and an antenna height above average terrain of 300 ft (90.9 m). There are also 20 channels between 92.1 and 107.1 MHz which are designated Class A stations only. Class A stations may operate in any zone. Class B stations operate on B-C channels in Zones I and I-A (there are no Class B stations in Zone II). Class B stations cannot operate with an erp greater than 50 kW, and the coverage pattern cannot exceed that obtained from the 50 kw erp and an antenna height above average terrain of 500 ft (151.5 m). Class C stations operate on Class B-C channels in Zone II (there are no Class C stations in Zone I or I-A). Class C stations cannot operate with an erp greater than 100 kW, and the coverage can not exceed that obtained from a 100 kW erp and an antenna height above average terrain of 2000 ft (606.1 m).

There are 21 channels between 87.9 and 91.9 MHz, which are available for noncommercial educational FM broadcast stations. Class D educational stations operate on a secondary (noninterference) basis and operate with no more than 10 W transmitter power output. Many universities and vocational training schools use these stations for training purposes. Class A, B, and C noncommercial educational stations may be assigned to any of the channels designated for that use as stated above. These stations are designated as Class A, B, or C, depending on the erp and antenna height above average terrain and the zone in which the stations transmitter is located.

Minimum distance separations for FM stations are discussed in Section 5 along with analysis for possible sharing of the 88-108 MHz band with TIS.

EQUIPMENT CHARACTERISTICS

The equipment utilized to implement a TIS broadcasting station is generally categorized by the type of coverage desired. For those applications requiring omnidirectional coverage for a distance up to several miles, a monopole antenna is employed. Where coverage is to be limited to several

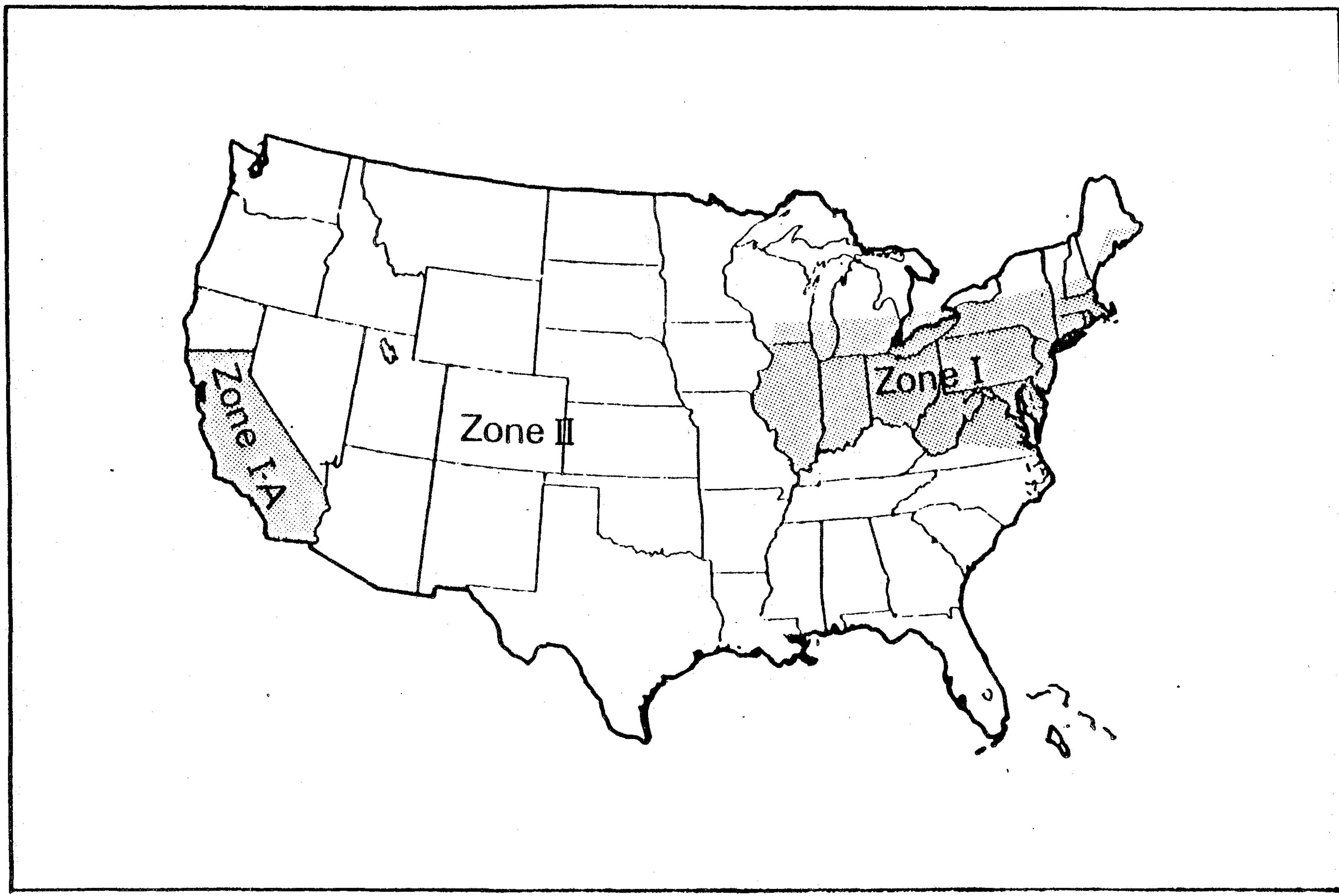


Figure 8. Map of United States showing the zones for FM broadcasting station assignment by station class.

hundred feet and extend for distances up to 3 km (1.86 mi), the "leaky" cable antenna system may be selected. Cost constraints and interference considerations also determine the final system that is selected.

Placement of TIS sites is restricted by distance required between cochannel TIS stations and distance from 500 μV/m daytime field intensity contours of adjacent channel broadcast station coverage areas. The 500 μV/m contour distance changes with ground conductivity and must be taken into consideration to ensure that proper protection levels are maintained for existing AM stations.

The TIS systems are generally composed of the following four basic units:

1. antenna
2. transmitter
3. audio
4. control.

These units vary depending on their specific application. Mobile applications are not addressed in this report. General unit characteristics are reviewed to demonstrate typical, or a range of, operations to familarize the reader with the basic equipment that can be used for TIS implementation.

Monopole Antenna System Equipment

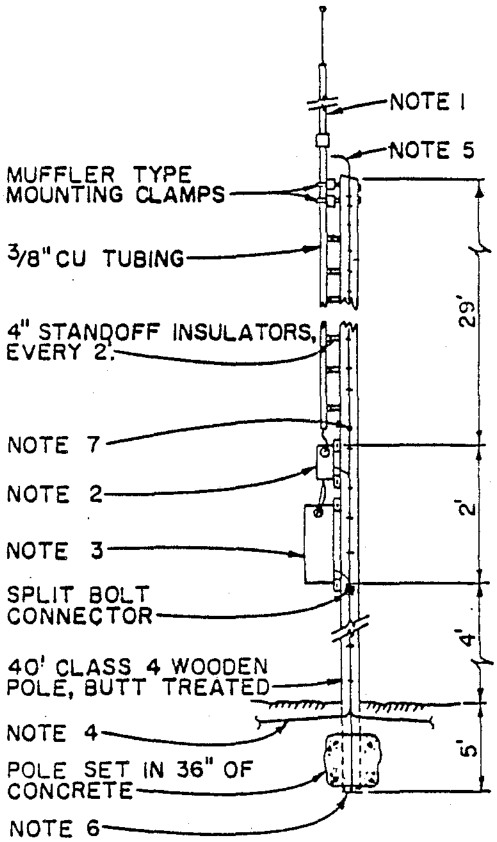
The typical TIS monopole antenna system is an electrically short radiator (0.0265 λ for 530 kHz and 0.0806 λ for 1610 kHz) mounted above a ground plane. The electrically short antenna occurs because of height limitation of the antenna which is limited to 15 m (49.2 ft) above ground level. The typical antenna has a tuning slug and loading coil to permit operation at 530 kHz or 1610 kHz. The antenna is usually attached to a post that is either buried and cemented in the ground or mechanically fixed to a building. Appropriate electrical insulators provide mechanical mounting and electrical isolation from the monopole antenna. A special spark gap is also provided for lightning protection.

The ground system for the monopole antenna consists of a group of radial conductors (usually copper) extending from the antenna base. The pattern for the ground plane is not fixed and can vary greatly depending on the available space and the desired radiation efficiency. These radials are usually buried to a depth not exceeding 45 cm (18 in). Increasing depth does not help the efficiency of the ground plane.

For regions that do not provide a good ground, it is necessary to attach grounding rods to the end of each radial. At the center, the radials are bonded together and attached to the antenna ground lead. Up to 20 radials can be used, but beyond this number, very little increase in efficiency can be obtained. More typical installations use a 30° or 45° spacing of the radials. The radials are rarely over 30.5 m (100 ft) and need not be larger than #12 AWG in diameter. Radials longer than 1 1/2 times the antenna height do not generally improve antenna efficiency. Typical antenna installations are shown in Figures 9 and 10 (McFadden, 1979). Increases in height and size of the ground plane generally improve the radiation effectiveness of the monopole system. The current field strength limitation of 2 mV/m at 1.5 km (0.93 mi) determines the practical limitation of the size of the antenna system and associated transmitter power setting.

Obtaining the 2 mV/1.5 km at the lower TIS frequency of 530 kHz, generally requires the full 15 m (49.5 ft) height and a relatively extensive ground plane to achieve the maximum field strength with the 10 watt transmitter limitation. In some cases, a "top hat" (radials mounted at the top of the antenna) is needed to improve the radiation efficiency. The current rules and restrictions do impose relatively severe constraints to obtain the field strength permitted. This is made worse by the fact that most car receivers require additional field strength at the low end of the band, as compared to operation at higher frequencies in the AM band. The maximum field strength at 1610 kHz is not as difficult to obtain because the wavelength is roughly three times shorter for the same height limitation. The effective increase in the electrical length of the antenna (with respect to a wavelength) increases the radiation efficiency.

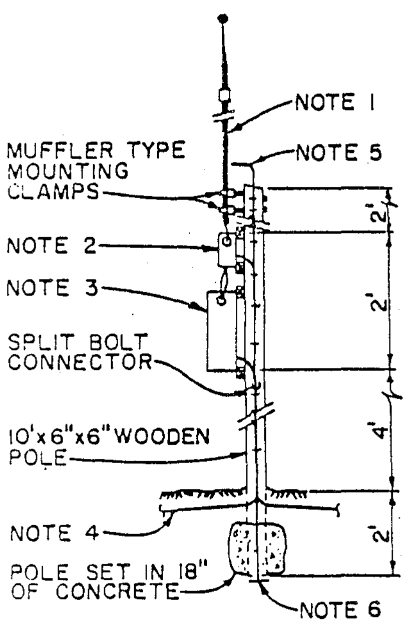
The transmitter is the next item to be considered in the TIS system or "type-accepted" unit for TIS use. For external transmitters, the enclosure



NOTES:

1. 530 KHz ANTENNA WITH LOADING COIL AND TUNING STUB. LATTER MUST BE ADJUSTED BY INSTALLING ENGINEER.
2. TRANSMITTER UNIT (SECURITY BOX ACCESSIBLE ONLY TO FCC LICENSED PERSONNEL).
3. TAPE PLAYER AND TRANSMITTER POWER SUPPLY
4. INSTALL COUNTERPOISE CONSISTING OF EIGHT 100' EQUALLY-SPACED RADIALS OF #12 (MIN) BARE COPPER WIRE BURIED 18" WHERE POSSIBLE (6" MIN. OR TO SOLID ROCK). SOLDER ALL RADIALS TO #6 COPPER GROUND WIRE. EXTEND ONE RADIAL TO ALL WATER LINES, METAL FENCES, POWER SYSTEM GROUNDS AND FUEL TANKS LYING LESS THAN 400' FROM POLE.
5. BEND 1/2"x6' COPPERWELD GROUND ROD WITH 6" RADIUS TO FORM LIGHTNING GAP. POINTED TIP SHALL BE 1/4" FROM ANTENNA. FASTEN TO POLE AND CONNECT TO #6 BARE COPPER GROUND WIRE BONDED TO CABINETS AND GROUND RADIALS RUNNING TO POLE BUTT. STAPLE GROUND WIRE TO POLE EVERY 2'.
6. SPIRAL 4' LENGTH OF #6 BARE COPPER WIRE AND STAPLE TO BUTT END OF POLE.
7. FORM 1/8" GAP IN GROUND WIRE ON SIDE OF POLE WHERE INDICATED.

Figure 9. Typical antenna installation for TIS at 530 kHz.



NOTES:

1. 1610 KHz ANTENNA WITH LOADING COIL & TUNING STUB. LATTER MUST BE ADJUSTED BY INSTALLING ENGINEER.
2. TRANSMITTER UNIT (SECURITY BOX ACCESSIBLE ONLY TO FCC LICENSED PERSONNEL.)
3. TAPE PLAYER & TRANSMITTER POWER SUPPLY
4. INSTALL COUNTERPOISE CONSISTING OF EIGHT 50' EQUALLY SPACED RADIALS OF #12 (MIN.) BARE COPPER WIRE BURIED 18" WHERE POSSIBLE (6" MIN. OR TO SOLID ROCK). SOLDER ALL RADIALS TO #6 COPPER GROUND WIRE. EXTEND ONE RADIAL TO ALL WATER LINES, METAL FENCES, POWER SYSTEM GROUNDS AND FUEL TANKS LYING LESS THAN 150' FROM POLE.
5. BEND 1/2"x 6' COPPERWELD GROUND ROD WITH 6" RADIUS TO FORM LIGHTNING GAP. POINTED TIP SHALL BE 1/4" FROM ANTENNA. FASTEN TO POLE & CONNECT TO #6 BARE COPPER GROUND WIRE BONDED TO CABINETS & GROUND RADIALS RUNNING TO POLE BUTT.
6. SPIRAL 4' LENGTH OF #6 BARE COPPER WIRE & STAPLE TO BUTT END OF POLE.

Figure 10. Typical antenna installation for TIS at 1610 kHz.

must be weather proof, provide some protection from vandalism, and permit access to only authorized personnel.

For the monopole antenna system, the transmitter power level is restricted to a maximum of 10 W into a nonreactive load of 50 ohms. The power level is usually continuously adjustable over the range of 2 to 10 W. The unit is powered by one of the following sources: 110 V, 60 cycle; solar cell/batteries; batteries; or thermoelectric power generation. Remoteness from conventional sources, mobility requirements, and economics dictate the power source to be used.

The frequency of the transmitter is crystal controlled with a tolerance of ±100 Hz over a temperature range of -30°C to 20°C when the relative humidity is as high as 90%. The transmitter may be modulated up to 100% with suitable audio protection to preclude distortion on audio peaks. Distortion should be less than 5% under 67% modulation conditions.

The sideband spectrum is limited to -25 dB at 5 kHz either side of the carrier, -35 dB at ±10 kHz, and 51 dB at ±20 kHz. The audio spectrum is limited to 300-3000 Hz with a 10 dB rolloff (attenuation) from 2500-5000 Hz.

Audio Unit

The FCC Rules and Regulations do not permit commercial messages or music to be transmitted on a TIS broadcast station. This means that an audio message must be present almost continuously because some signal needs to be present to permit tuning to the TIS frequency. A tone, even for a brief period, would be objectional to the traveler. The audio messages are usually timed so that the traveler can tune to the station and get the TIS message at least twice before leaving the coverage area of the TIS broadcasts. The message length can vary from 30 seconds to 10 minutes. The usual method of message storage is a continuous (endless) loop tape recorder or all solid-state voice storage. The all solid-state memory system has the advantage of no mechanical moving parts. Message lengths, however, are currently limited to less than three minutes. The message storage system must be very reliable and permit remote operation for extended periods of time. At some locations, it is necessary to provide more than just one message. It is also possible to have a microphone capability for live messages. The equipment enclosure must have controlled access to make certain that the TIS broadcast station conforms to FCC regulations.

Control Unit

The control unit can be set up to provide direct access to one broadcast station or remote control of several broadcast stations. The TIS broadcast station control and operation, transmitter power on or off, message selection, and line messages can be obtained by direct line, leased line, or telephone lines. Where the telephone line is used, special multifunction controller/decoder operation is needed to ensure that no unauthorized control can be exercised over station operation. The coder/decoder operation for remote stations provides control of the voice messages, recording of new messages, playback, and stop modes. The remote site must retain its "lost command" mode even under power outage conditions. General station operation conditions can also be sampled to determine states of remote operation.

Cable Antenna Systems

Cable antenna systems rely on the "losses" to provide a radiation field for the length of the cable. The typical methods for obtaining this radiation field are to have special coaxial cable that (1) has a slot in the outer conductor (Andrew Heliax), (2) has an outer conductor with a spiral conductive ribbon such that there is a uniform gap in the outer conductor (Halstead/Comscope), or (3) has a loose braid (open weave) outer conductor (Locrod NF-2) (Turnage, 1980). Cable lengths for leaky or lossey induction cable antennas are limited by FCC rules to 3 km (1.86 mi) in length and are limited to a field not to exceed 2 mV/m at a distance of 60 m (197 ft) perpendicular to the cable.

The advantages of the cable radiator include the following:

1. The radiation coverage is limited to a few hundred feet of the cable. This permits a very carefully controlled coverage area with minimum interference to nearby AM broadcast stations.

2. It can provide coverage in areas of tall buildings, under bridges or overpasses, and through tunnels.

3. The communication system is not visible to the traveler, and because the cable is usually buried, it is not subject to vandalism or weather. (Note that soil conductivity does not affect the radiation field to any great extent.)

4. Rapid deployment for special requirements is also a possibility. It is only necessary to unroll a cable in the area of concern and connect the transmitter. No matching network or tuning adjustments are needed (cable is terminated in its characteristic impedance).

Some of the associated disadvantages include the following.

1. It needs to be located very close to the highway.

2. The length of coverage is limited to 3 km (1.86 mi).

3. It must usually be buried to avoid vandalism and damage.

4. It is not easily installed where large quantities of concrete are located (intersections, etc.).

5. It is expensive for initial purchase and installation (cable burying costs and the need for more transmitter power for desired coverage).

The overall use of this type of antenna is based on the coverage requirements and the desirability of minimizing interference to adjacent-channel AM broadcast stations.

The associated message storage and system control can be the same as discussed for the monopole antenna system.

HIGHWAY ADVISORY SYSTEMS ABROAD

West Germany

The Federal Republic of Germany (FRG) has implemented an extensive network of radio traffic information broadcast stations. Blaupunkt-Warke GmbH of FRG has developed an Automatic Radio Information (ARI) system that enables the motorist to receive traffic information that is broadcast over the main channel of an FM radio station. These traffic data are transmitted every 15 minutes, and an unmodified receiver can receive the message. The Blaupunkt ARI system provides an automatic mode to alert the motorist of special messages. The messages are for a localized area or zone to minimize nonessential messages being relayed. The driver is is alerted to traffic conditions, construction, maintenance, or accidents.

The ARI unit automatically raises the volume to a preset level for a travelers advisory message when tuned to an ARI transmitting station. After the message is completed, the volume will return to the previously set level. The system can also interrupt a stereo cassette player for the duration of the special message and then resume playing at the point where the message started. The objective of these provisions is to get through to even the "nonlisteners." A driver who is actually listening to an ARI station will get the message as part of the regular program schedule. The traveler advisory message that is transmitted by the ARI station provides information that only applies to a specific zone of coverage. In this way, only messages that apply to a specific zone are transmitted. This greatly minimizes nonrelevant information for the driver. When the traveler goes into the next zone, it is necessary to tune to a new ARI station. Again, the ARI receiver unit has the ability to search out the new station and lock on. This operation is initiated by the driver when the boundary of a new zone is encountered. Zone information data are provided to the traveler in the form of a small map that highlights the zone boundary information.

This system uses a subcarrier control system (57 kHz) for activation of the automatic features on the ARI receiver. The location of the subcarrier is selected such that it does not impact normal station operation of either monoral or stereo transmission.

West Germany has provided nationwide ARI coverage since 1974. The ARI has been operating in most of Western Europe since the end of 1983. The ARI decoders are built into a very large percentage of car radios now sold in Germany. Blaupunkt plans to license the patented techniques to other automobile manufacturers. Today, approximately 70% of the FM staions in the FRG transmit ARI information.

England

The British Broadcasting Corporation has a dedicated broadcast TIS, called Carfax, for the "Greater London" area. This system uses low power transmitters programmed to broadcast traveler advisory data in consecutive time allocations on a single frequency. The low power transmitters serve a limited area or zone. The news bulletins that are transmitted are assigned to the time allocation for that particular area. Again, the idea is to provide only that information that is pertinent to the zone that is of interest to the driver based on the driver's location. Further information is only provided when traffic advisory data are necessary.

Three basic forms of receivers have been developed for testing purposes. These include an "add-on" for existing radios, a combination unit (radio and TIS), and a separate traveler advisory receiver. Depending on the unit selected, the motorist can have radio without traveler information, regular listening with traffic update interruptions, and traffic data only when it occurs.

The transmitters are placed throughout the area to provide complete coverage. There is no interference to be concerned with, as only one transmitter is transmitting at a given time. This system offers a rapid update of information, and control comes from one central point to coordinate all of the city's traffic problems.

Japan

The Japanese system is known as the Traffic Incident Information Subsystem. This system offers two types of messages. The first type is high-priority emergency information. When these messages are transmitted, the driver's radio is automatically switched on, and if they are tuned to a different station, the radio will be automatically tuned to the station with the emergency message. The second type includes more of a traffic update in terms of traffic tie-ups, construction impacting traffic, and anticipated travel times. The driver has the option of listening to this information or not.

This system utilizes a "leaky" coaxial antenna system that limits the area of coverage. The antenna system is located on key routes divided into zones. This permits specific information pertaining to its zone to be transmitted to drivers in that zone. The system is centrally controlled and has the capability for both automatic transmission and manual update throughout the system.

SECTION 5

SHARING PROBLEM ANALYSIS

BACKGROUND

Nationally and internationally, increased emphasis is being placed on providing an effective communication link to the traveling motorist. This communication link provides emergency and updated information on weather, highway conditions, and public and scenic attractions. The most convenient method of providing this information is through the traveler's car radio that generally has both AM and FM broadcast reception capability. The approach taken for this report is to assume that existing receiver capabilities will be used. There are several systems under development, but all require radio modifications such as subcarrier detectors, special automatic features to override operator selections, and frequency converters to accommodate other frequency bands. These techniques require additional investment by the automobile owner and may not be as readily accepted as present TIS systems.

AM Band Applications of TIS

The existing TIS operates at both ends of the AM broadcast band. The low frequency of 530 kHz is roughly one-third of the upper frequency of 1610 kHz. As such, there are some significant variations in operations at the two frequencies. Groundwave propagation for the low frequency is much better than the upper frequency. Both atmospheric and galactic noise is higher for the low-end frequency. With the height restrictions imposed on the transmitting antenna, the radiation efficiency is better for the higher frequencies. Receiving antennas (car antennas) have an increased electrical wavelength and usually increased efficiency for the higher frequency.

The Institute for Telecommunication Sciences' (ITS) MF propagation models (Berry, 1978) and the FCC data (FCC, 1980) were used to determine propagation effects for frequencies under consideration. The ITS model results will be used for a proposed expansion frequency. Figures 11 and 12 show the results of the ITS propagation model for 530 and 1700 kHz, respectively.

TABLE 7 gives the radius of coverage for 530 kHz, with a representative ground conductivity of 2 and 15 mmhos/m. The radius of coverage is determined from the antenna effectiveness and transmitter power limitation imposed on TIS. These data are derived by making the appropriate conversion from the propagation model or FCC propagation charts (Figure 13) that normalizes the data to 100 mV/m at 1 mi with a 1 kW transmitter. Since the TIS operations are specified to have no more than 2 mV/m at 1.5 km (0.93 mi), with a transmitter power level of 10 W, a conversion factor must be formulated. Field strength varies inversely with distance and also with the ratio of the specified field strength. The conversion factor then becomes the following.

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

For example, the radius of coverage for a 250 μV/m contour would be obtained by calculating the following:

$$250\ \mu\text{V/m} \times 53.8 = 13450\ \mu\text{V/m}.$$

Now, using Figure 13 and the above field intensity and selecting the 2 mmhos/m curve, the radius of coverage is found to be 7.2 km (4.8 mi).

Cochannel Protection Considerations

Cochannel interference should mainly come from other TIS operations; however, there is possible interference from nondirectional radiobeacons at 530 kHz. The FCC Rules and Regulations require a TIS separation of "15.0 km (9.3 mi) for the case when both stations are using conventional antennas." Again, using Figure 13, a rough approximation of the isolation protection during daytime conditions can be estimated. Information from the DOI (McFadden and Shoaf, 1979) indicates that 330 μV/m is needed for adequate signal reception for 530 kHz. From TABLE 7, the distance from transmitter to the travelers' receiver can be either 6.2 km (3.9 mi) or 8.6 km (5.4 mi),

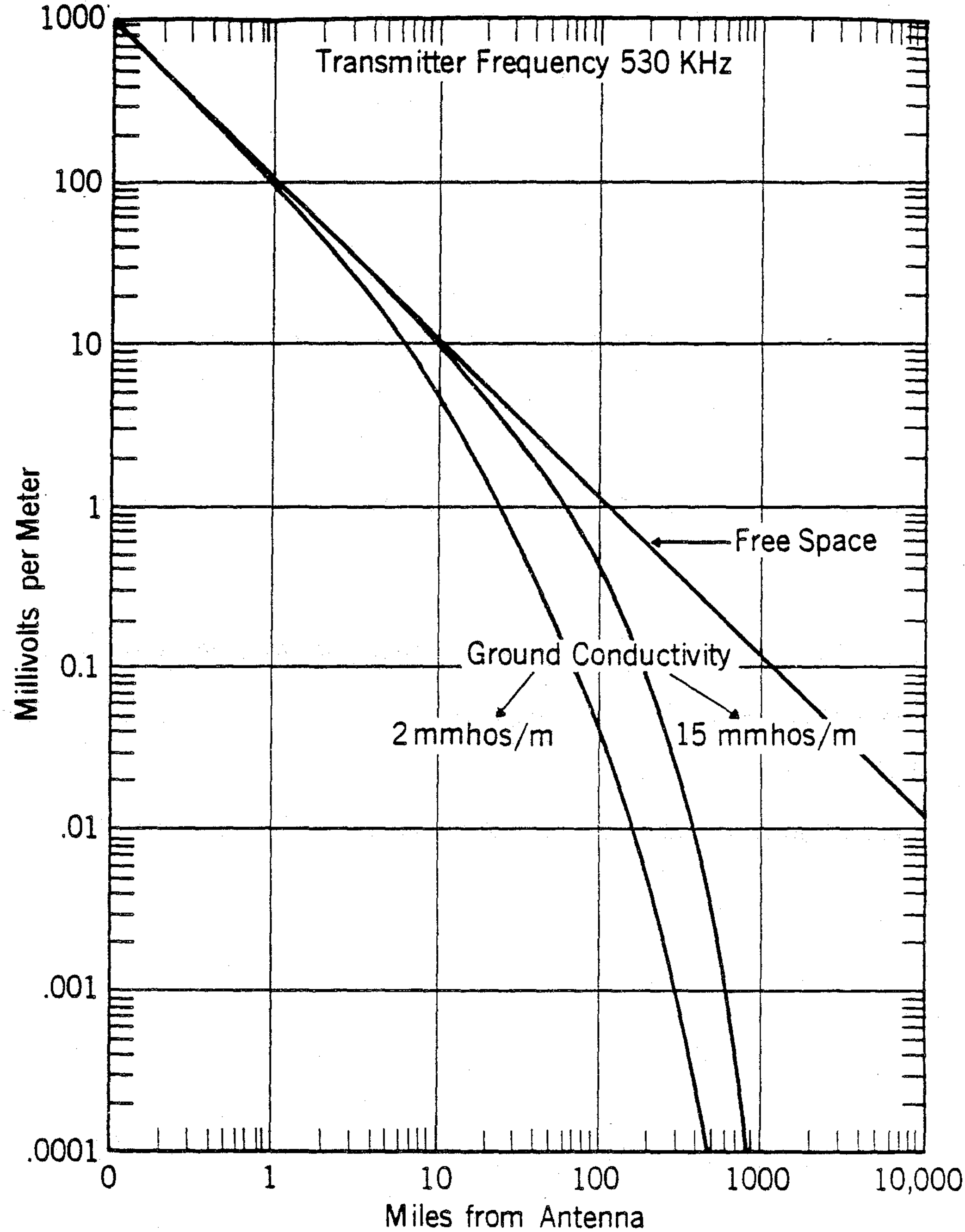


Figure 11. Field strength vs. distance for 530 kHz.

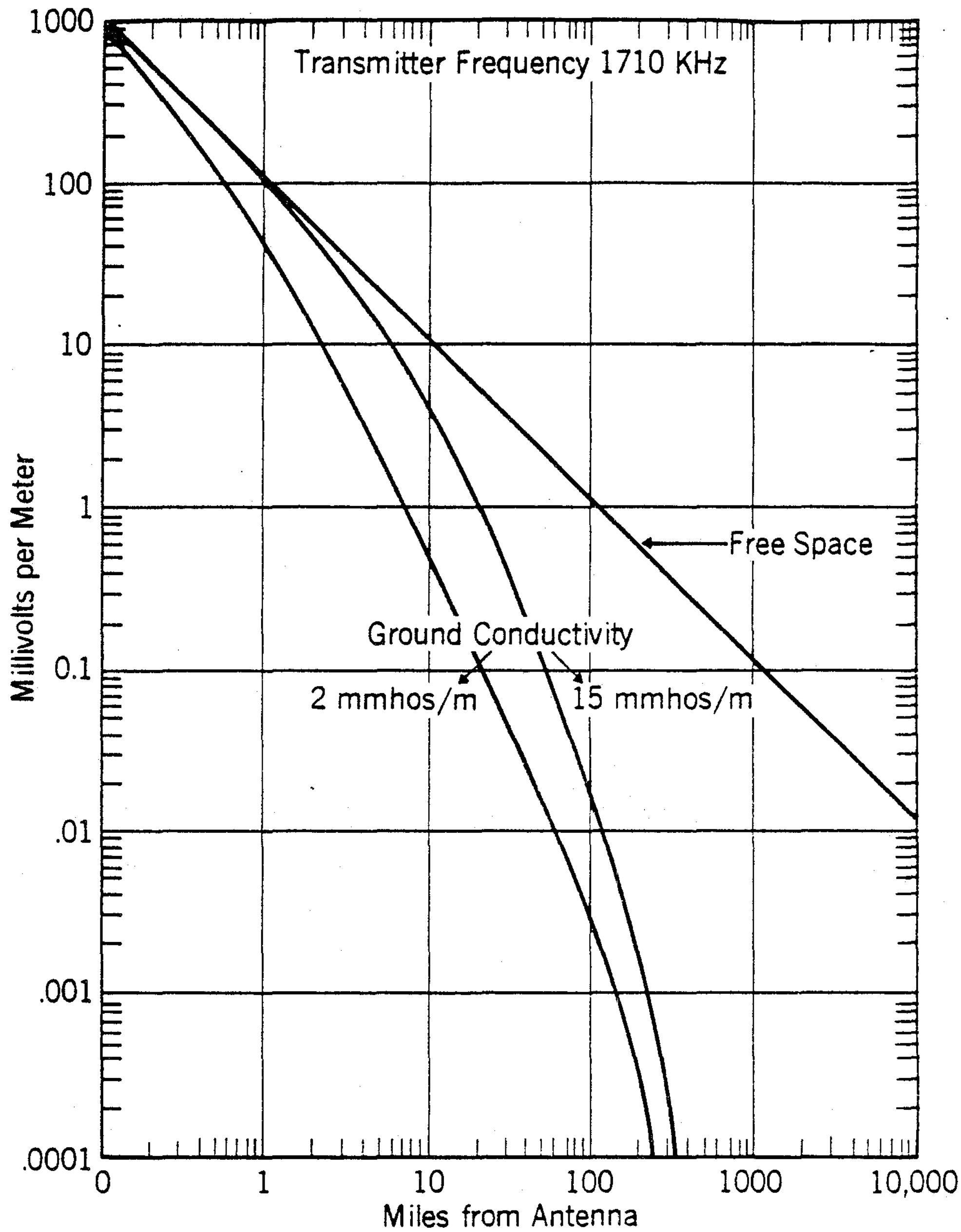


Figure 12. Field strength vs. distance for 1700 kHz.

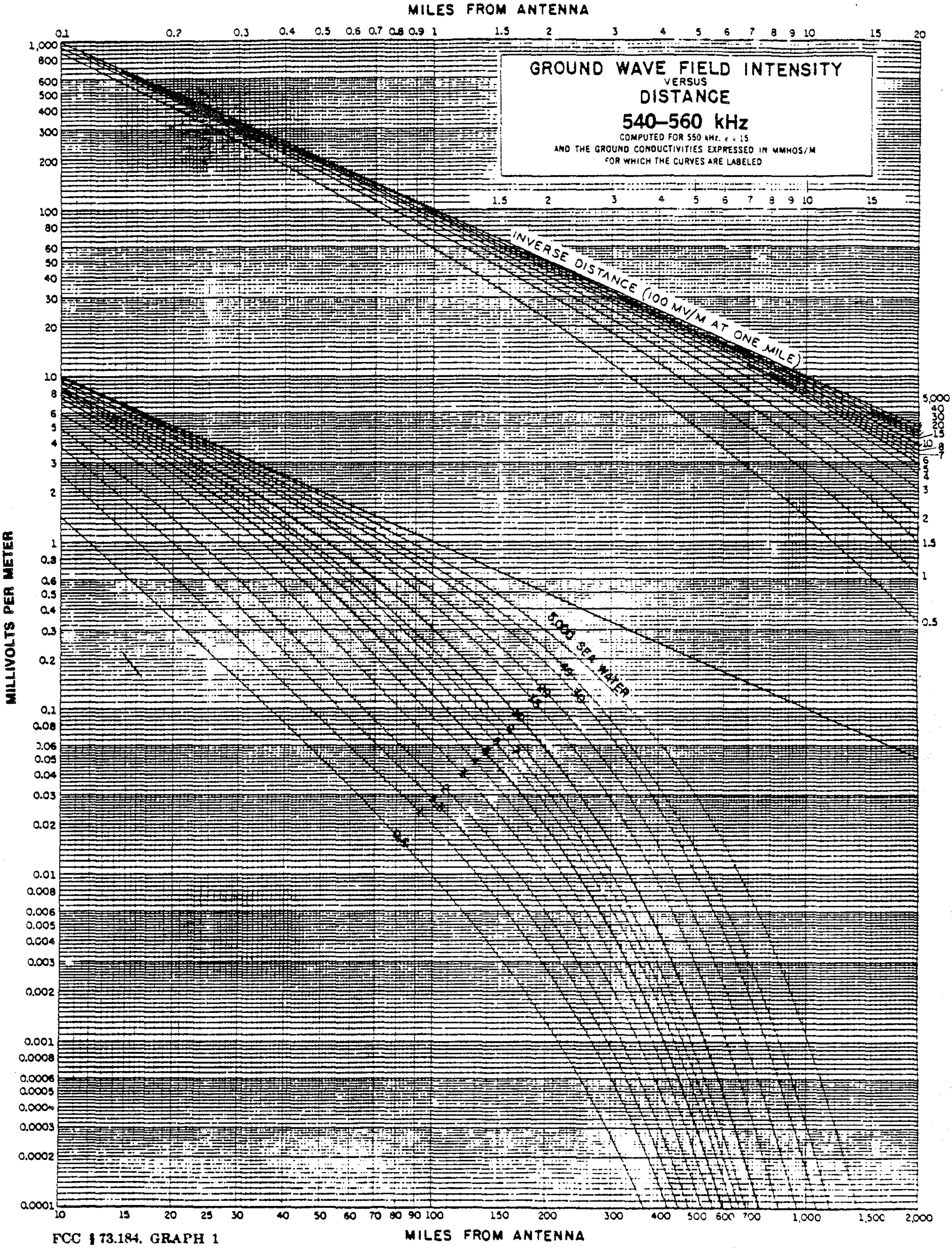


Figure 13. Groundwave field intensity.

TABLE 7

TIS RADII OF COVERAGE (DAYTIME) AT 530 KHZ

Field Strength Contours (μV/m)	Ground Conductivity (mmhos/m)	
	2	15
	Distance, km (miles)	
5.0	71.8 (44.0)	202.7 (126.0)
12.0	46.7 (29.0)	120.7 (75.0)
25.0	33.8 (21.0)	79.6 (49.5)
90.0	16.9 (10.5)	29.3 (18.2)
100.0	15.0 (9.3)	26.5 (16.5)
160.0	10.8 (6.7)	17.4 (10.8)
250.0	7.7 (4.8)	10.8 (6.7)
330.0	6.3 (3.9)	8.7 (5.4)
500.0	4.5 (2.8)	5.5 (3.4)

depending on the ground conductivity (2 mmhos/m and 15 mmhos/m, respectively). This means that a second transmitter located 15 km (9.3 mi) away can provide a signal strength of approximately 220 uV/m or 445 μV/m (depending on the ground conductivity) at the 330 μV/m contour of the first transmitter. This shows the isolation that results for this frequency under cochannel operation. This isolation is far less than what is required in the AM broadcast band cochannel protection that is normally 20:1. The TIS cochannel isolation would be less than 1:1 in the latter case. Both ratios can be categorized as unacceptable. The above TIS values of cochannel interference demonstrate the need to reassess the separation distance needed for the 530 kHz TIS frequency and establish more accurate values of protection levels and protection ratios that should be determined for TIS operation. This will become more of a problem as the usage of this frequency increases. Cochannel- and adjacent-channel considerations for radiobeacons are addressed later in this section.

TIS Adjacent Channel Considerations

Adjacent channel considerations must also be assumed to be a maximum of 1:1 (desired signal-to-interference signal). The FCC rules call for showing a measured or a calculated 500 μV/m field strength contour of any adjacent-channel AM broadcast station to a proposed TIS operation. To obtain the separation distance necessary to comply with this requirement or other selected field strengths, it is necessary to take the sum of the distance from the AM broadcast station to the selected protection contour level plus the distance from the TIS to the selected protection contour. This latter distance can be obtained from TABLE 7. The former distance can be determined from Figure 13, with the appropriate conversion factors. These conversion factors can be obtained by compensating for the variations in transmitter antenna efficiencies and transmitter power levels for the various class of AM broadcast stations. Figure 13 is based on an antenna efficiency that will provide 100 mV/m at 1.6 km (1 mi), with an input transmitter power of 1 kW. Minimum antenna effectiveness (efficiencies) at 1 mile for AM broadcast stations, are as follows:

1. Class I - 225 mV/m
2. Class II - 175 mV/m
3. Class III - 175 mV/m
4. Class IV - 150 mV/m

These classes of stations are also permitted to operate at several different power levels. To obtain the composite conversion factor for each of these cases, it is necessary to take the direct ratio of the antenna efficiency, multiply by the square root of the power ratio involved, and then multiply by the value of the selected protection contour desired. The calculation of the conversion factor for a Class I station operating at a power level of 10 kW and a protection contour of 500 μV/m would be obtained as follows:

$$\frac{100 \text{ mV/m}}{.225 \text{ mV/m}} \times \sqrt{\frac{1 \text{ kW}}{10 \text{ kW}}} \times 500 \text{ μV/m} = 70.3 \text{ μV/m}$$

Now, referring to Figure 13, using 2 mmhos/m conduction and 70.3 μV/m , the distance from the AM station to the 500 mV/m is approximately 120 km (75 mi). Taking the radius of coverage of the TIS, using the same conditions as above, this distance corresponds to 4.5 km (2.8 mi). Adding these two results (75 + 2.8 ≅ 78 mi) gives the required separation distance for this example. TABLE 8 gives a summary of separation distances for adjacent-channel AM broadcast operations for selected protection contour levels. This table shows that relatively large separation distances are required for adjacent channel operation. Class IV stations would provide the best protection for TIS including Canada and Mexico for the 1610 or 1700 kHz frequencies.

TIS Nighttime Operating Considerations

The next adjacent-channel operation consideration is that of nighttime operation. The area of concern here is the ionospheric reflection, or skywave propagation. This has the general effect of increasing the propagation distance. This effect greatly increases the nighttime interference for the TIS. Figures 14 and 15 are from the FCC Rules and Regulations, Part 73, and show how field strength varies with distance for a 10% skywave interference level. Again, these curves are drawn using a transmitter antenna efficiency of 100 mV/m at 1.6 km (1 mi) with 1 kW power input. The conversion factors previously determined are applicable to Figures 14 and 15 in the way shown previously. TABLE 9 gives the resulting separation distances for selected protection levels. The separation distances required are relatively large for all but the very lowest of transmitter power levels.

TABLE 8

ADJACENT-CHANNEL BROADCAST STATION COVERAGE RADII AT THREE CONTOUR LEVELS
(1:1 PROTECTION RATIO) AT 530 kHz
(TRANSMITTER SEPARATION DISTANCES, DAYTIME)

Field Strength Contours (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, km (miles)															
100	241 (150)	589 (366)	311 (193)	710 (441)	164 (102)	404 (251)	198 (123)	508 (316)	224 (139)	549 (341)	291 (181)	677 (421)			140 (87)	380 (236)
250	169 (105)	446 (277)	225 (140)	542 (337)	98 (61)	277 (172)	137 (85)	373 (232)	153 (96)	414 (257)	208 (129)	518 (322)			93 (58)	261 (162)
330	154 (96)	418 (260)	216 (134)	531 (330)	85 (53)	241 (150)	119 (74)	338 (210)	138 (86)	386 (240)	195 (121)	491 (305)			82 (51)	232 (144)
500	126 (78)	356 (221)	174 (108)	454 (283)	72 (45)	201 (125)	100 (62)	285 (177)	116 (72)	320 (199)	156 (97)	420 (261)			68 (42)	187 (116)

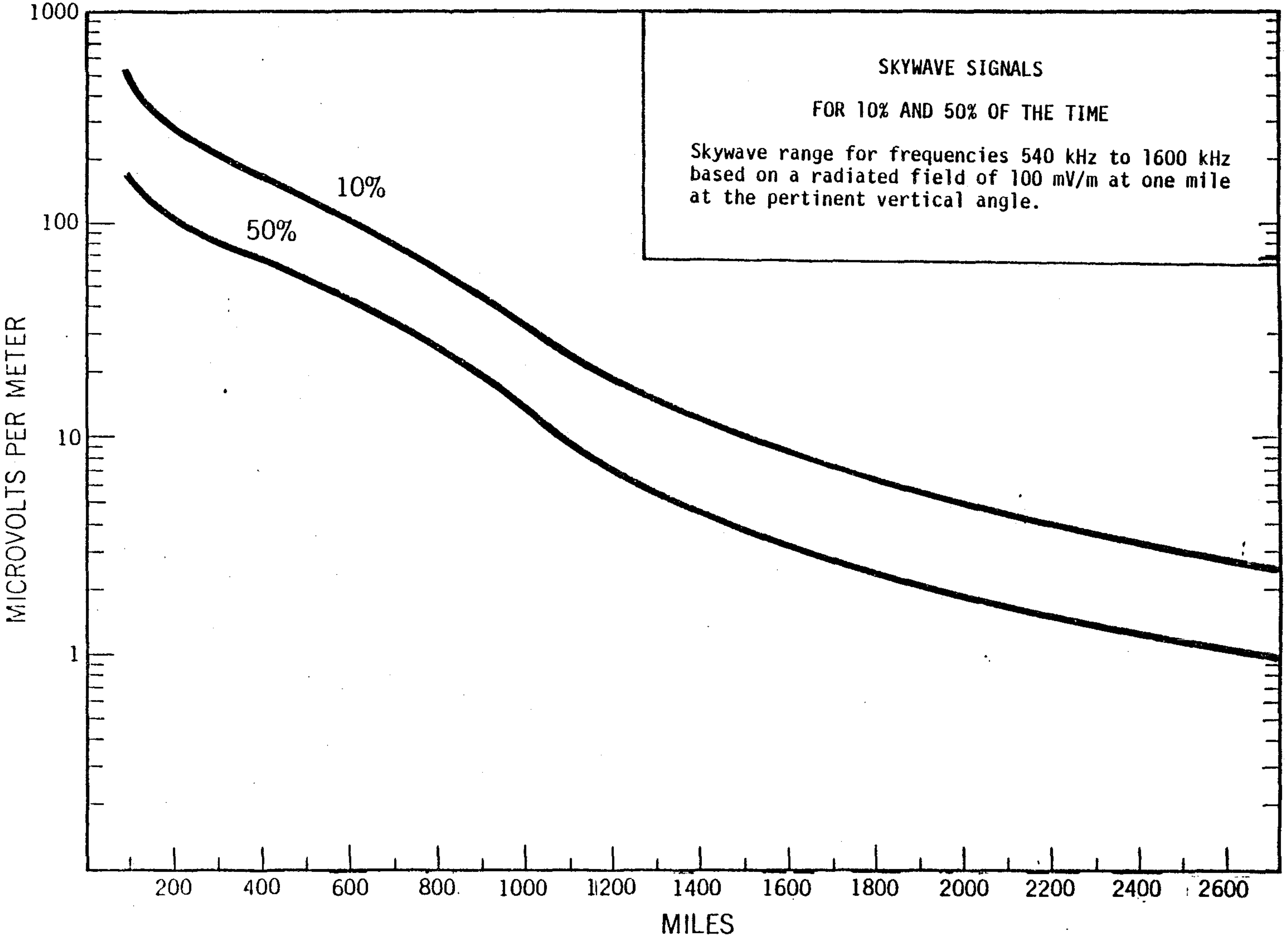


Figure 14. Field strength vs. distance for skywave signals from Class I broad-casting stations.

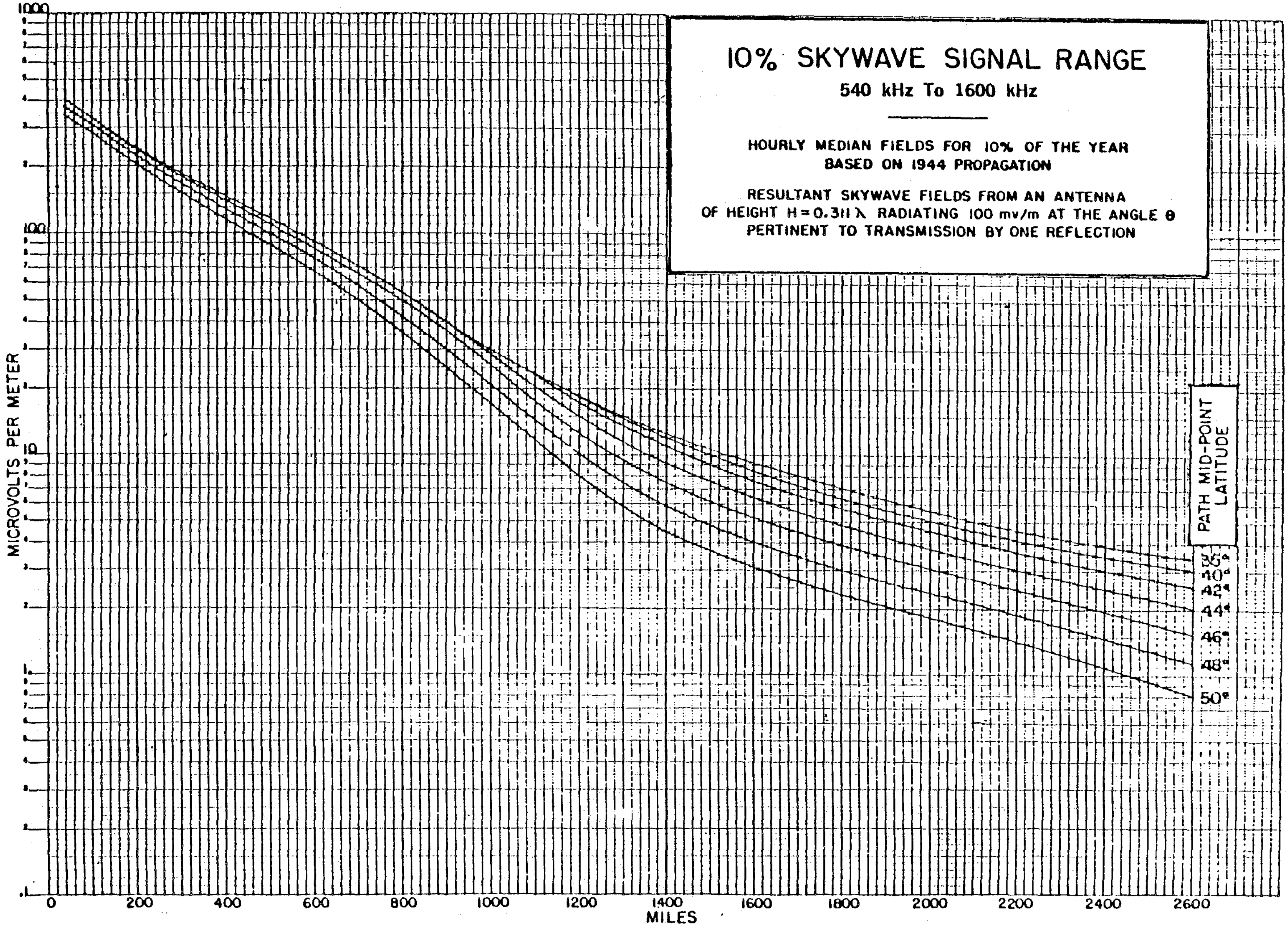


Figure 15. Field strength vs. distance for 10% skywave signals from Classes II, III, and IV stations.

TABLE 9

ADJACENT BROADCAST STATION SKYWAVE COVERAGE RADII FOR FIVE CONTOUR LEVELS (NIGHTTIME)

Field Strength Contours (μV/m)	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, km (miles)							
100	2140 (1330)	2896 (1800)	1062 (660)	1271 (790)	1706 (1060)	1931 (1200)	2607 (1620)	740 (460)
160	1818 (1130)	2414 (1500)	724 (450)	965 (600)	1448 (900)	1609 (1000)	2253 (1400)	402 (250)
250	1561 (970)	1995 (1240)	418 (260)	676 (420)	1191 (740)	1384 (860)	1850 (1150)	161 (100)
330	1480 (920)	1850 (1150)	290 (180)	499 (310)	1046 (650)	1239 (770)	1673 (1040)	<64 (<40)
500	1191 (740)	1641 (1020)	<64 (<40)	225 (140)	740 (460)	965 (600)	1448 (900)	<64 (<40)

A recent NTIA report (Thompson, 1985) provides a technical review of TIS at 1610 kHz. This report provides a similar set of information concerning TIS operation and separation requirements that have been provided for 530 kHz. TABLES 10 through 14 are taken from this report to provide a comparison. The data in the tables was taken from the FCC field strength vs. distance curve for 1560 to 1640 kHz (Thompson, 1985).

Proposed AM Band Expansion Impact on TIS

With the planned expansion of the AM broadcast band, it is also necessary to consider the possibility of TIS operation at 1700. This would be the highest frequency assignment in the proposed AM band expansion. TIS coverage for selected signal strengths are shown in TABLE 15. These data were derived from the ITS model. It should be noted that relatively small changes in propagation characteristics exist between 1610 kHz and 1700 kHz. However, there is an approximate 3:1 increase in coverage for 530 kHz for the same field strength.

TABLE 10

TIS RADII OF COVERAGE FOR 1610 KHZ (DAYTIME)

Field Strength Contours (μV/m)	Ground Conductivity (mmhos/m) 2	15
	Distance, km (miles)	
5.0	23.2 (14.4)	64.4 (40.0)
12.5	14.8 (9.2)	43.4 (27.0)
25.0	10.8 (6.7)	31.4 (19.5)
90.0	5.8 (3.6)	16.1 (10.0)
100.0	5.5 (3.4)	15.0 (9.3)
160.0	4.2 (2.6)	11.1 (6.9)
250.0	3.4 (2.1)	8.0 (5.0)
500.0	2.3 (1.4)	4.7 (2.9)

TABLE 11

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, km (miles)			
5.0	265 (165)	442 (275)	330 (205)	515 (320)
12.5	209 (130)	354 (220)	257 (160)	451 (280)
25.0	167 (104)	314 (195)	217 (135)	378 (235)
90.0	98 (61)	220 (137)	137 (85)	278 (173)
100.0	93 (58)	209 (130)	129 (80)	265 (165)
160.0	76 (47)	180 (112)	108 (67)	233 (145)
250.0	61 (38)	151 (94)	88 (55)	203 (126)
500.0	43 (27)	113 (70)	64 (40)	158 (98)

TABLE 12

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, km (miles)							
5.0	175 (109)	330 (205)	228 (142)	412 (256)	251 (156)	423 (263)	309 (192)	494 (307)
12.5	126 (78)	261 (162)	169 (105)	322 (200)	193 (120)	354 (220)	241 (150)	418 (260)
25.0	93 (58)	211 (131)	130 (81)	270 (168)	151 (94)	298 (185)	206 (128)	362 (225)
90.0	51 (32)	130 (81)	76 (47)	179 (111)	87 (54)	204 (127)	124 (77)	267 (166)
100.0	50 (31)	122 (76)	71 (44)	169 (105)	82 (51)	193 (120)	119 (74)	251 (156)
160.0	39 (24)	101 (63)	58 (36)	142 (88)	66 (41)	163 (101)	97 (60)	219 (136)
250.0	32 (20)	82 (51)	47 (29)	117 (73)	55 (34)	137 (85)	79 (49)	187 (116)
500.0	24 (15)	63 (39)	32 (20)	85 (53)	39 (24)	101 (63)	58 (36)	142 (88)

TABLE 13

CLASS IV BROADCAST STATION RADII OF COVERAGE (DAYTIME)

Field Strength Contours (μV/m)	Station Power: 1 kW	
	Ground Conductivity (mmhos/m)	
	2	15
	Distance, km (miles)	
5.0	169 (105)	322 (200)
12.5	116 (72)	249 (155)
25.0	87 (54)	201 (125)
90.0	47 (29)	121 (75)
100.0	45 (28)	116 (72)
160.0	35 (22)	95 (59)
250.0	29 (18)	76 (47)
500.0	23 (14)	60 (37)

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, km (miles)													
100	98 (61)	224 (139)	134 (83)	280 (174)	55 (34)	137 (85)	76 (47)	183 (114)	87 (54)	208 (129)	124 (77)	265 (165)	50 (31)	130 (81)
250	64 (40)	159 (99)	92 (57)	211 (131)	35 (22)	90 (56)	50 (31)	126 (78)	58 (36)	145 (90)	82 (51)	195 (121)	32 (20)	84 (52)
500	45 (28)	117 (73)	66 (41)	163 (101)	26 (16)	68 (42)	34 (21)	90 (56)	40 (25)	106 (66)	60 (37)	146 (91)	24 (15)	64 (40)

TABLE 15

TIS RADII OF COVERAGE FOR 1700 KHZ (DAYTIME)

Field Strength Contours	Ground Conductivity (mmhos/m)	
	2	15
	Distance, km (miles)	
5.0	22.2 (13.8)	57.9 (36.0)
12.5	14.5 (9.0)	39.4 (24.5)
25.0	10.1 (6.3)	29.3 (18.2)
90.0	5.3 (3.3)	15.0 (9.3)
100.0	5.1 (3.2)	14.3 (8.9)
160.0	4.0 (2.5)	10.5 (6.5)
250.0	3.1 (1.9)	7.7 (4.8)
330.0	2.7 (1.7)	6.3 (3.9)
500.0	2.1 (1.3)	4.5 (2.8)

Cochannel Separation Considerations

Again, for purposes of comparison at the upper end of the band, the 15 km (9.3 mi) separation requirement for TIS cochannel operation isolation can be determined for 1700 kHz. At the higher end of the band, DOI (McFadden and Shoaf, 1979) has indicated that 250 μV/m is needed as a minimum acceptable signal value for average car reception. The distance to the 250 μV/m contour from the TIS antenna is 3 km (1.9 mi) and 7.7 km (4.8 mi) for 2 and 15 mmhos/m ground conductivity respectively from TABLE 15.

In the first case (2 mmhos/m), the second cochannel TIS has a field strength at 12 km [15 km (9.3 mi) - 3 km (1.9 mi) = 12 km (7.4 mi)] of approximately 20 μV/m. This corresponds to an isolation ratio of 250/20 or 12.5:1. This is still below the 20:1 ratio required in the AM band, but is a much more reasonable ratio. The field strength (using 15 mmhos/m) at 7.2 km [15 km (9.3 mi) - 7.7 km (4.8 mi) = 7.2 km (4.5 mi)] is approximately 275 μV/m , which results in less than a unity isolation ratio. This example further confirms results in less than a unity isolation ratio. This example further confirms the need to review TIS cochannel separation requirements to provide adequate interference-free signals. Present separation distances as given in Part 90 of the FCC Rules and Regulations do not seem to be adequate.

Adjacent Channel Separation Considerations

Coverage distances for the various station classes and associated transmitted power levels are provided in TABLES 16, 17, and 18. Adjacent-channel AM broadcast station separation distances for selected contour levels are provided in TABLE 19. It can be seen that adjacent-channel separation distances are still relatively large. This is especially true for moderate to high transmitter power levels.

Nighttime operation has a greatly extended operating range because of the skywave propagation. This mode of propagation is not appreciably affected by frequency changes in the AM broadcast region (Al'Pert, 1963). Many parameters affect the propagation, such as seasonal variations, ionospheric conditions (sun spot activity), latitude, time of night, and, in some cases, the direction of propagation. However, the FCC has established curves that show the signal strength versus distance for nighttime propagation for the AM band as given previously in Figures 14 and 15. If an interfering signal does not exceed a certain level 10% of the time, this constitutes the signal's interference value that will be tolerated. Field strengths from distant transmitters can increase very rapidly during the onset of night. Factors of several hundred fold increase have been observed. This increased field intensity at night is the principal reason for requiring large separation distances for AM broadcast stations. TABLE 20 shows the resulting separation distance for adjacent-channel operation for selected values of field strength and the various classes of AM transmitters. Separation distances become relatively large for any transmitter over the 1 kW power level. Data developed for TABLE 20 utilize the 40° latitude curve as being representative for the central portion of the US. TIS will be greatly constrained and adversely affected at nighttime if adjacent-channel AM broadcasting transmitters are permitted to operate above the 1 kW power level.

TABLE 16

CLASS I BROADCAST STATION RADII OF COVERAGE FOR 1700 KHZ (DAYTIME)

Field Strength Contours (μV/m)	Station Power: 10 kW, Ground Conductivity (mmhos/m) 2	10 kW, 15	50 kW, 2	50 kW, 15
	Distance, km (miles)			
5	248 (154)	389 (242)	299 (186)	457 (284)
25	145 (90)	274 (170)	193 (120)	331 (206)
90	87 (54)	188 (117)	121 (75)	241 (150)
100	84 (52)	183 (114)	116 (72)	233 (145)
160	68 (42)	154 (96)	97 (60)	203 (126)
250	55 (34)	130 (81)	79 (49)	177 (110)
500	40 (25)	100 (62)	58 (36)	137 (85)

TABLE 17

CLASSES II AND III BROADCAST STATION RADII OF COVERAGE FOR 1700 KHZ (DAYTIME)

Field Strength Contours (μV/m)	Station Power: 1 kW, Ground Conductivity (mmhos/m) 2	1 kW, 15	5 kW, 2	5 kW, 15	10 kW, 2	10 kW, 15	50 kW, 2	50 kW, 15
	Distance (Miles)							
5	154 (96)	290 (180)	204 (127)	346 (215)	228 (142)	370 (230)	282 (175)	434 (270)
25	82 (51)	182 (113)	116 (72)	233 (145)	134 (83)	257 (160)	177 (110)	314 (195)
90	47 (29)	114 (71)	68 (42)	153 (95)	79 (49)	177 (110)	108 (67)	222 (138)
100	43 (27)	108 (67)	64 (40)	146 (91)	74 (46)	169 (105)	105 (65)	217 (135)
160	35 (22)	90 (56)	51 (32)	124 (77)	60 (37)	140 (87)	87 (54)	188 (117)
250	29 (18)	76 (47)	42 (26)	105 (65)	50 (31)	117 (73)	71 (44)	161 (100)
500	21 (13)	58 (36)	31 (19)	79 (49)	35 (22)	90 (56)	51 (32)	122 (76)

TABLE 18

CLASS IV BROADCAST STATION RADII OF COVERAGE FOR 1700 KHZ (DAYTIME)

Field Strength Contours (μV/m)	Ground Conductivity (mmhos/m) 2	15
	Distance, km (miles)	
5	146 (91)	277 (172)
25	77 (48)	172 (107)
90	43 (27)	106 (66)
100	42 (26)	101 (63)
160	34 (21)	84 (52)
250	27 (17)	71 (44)
500	19 (12)	53 (33)

TABLE 19

ADJACENT-CHANNEL BROADCAST STATION COVERAGE RADII FOR 1700 KHZ AT THREE CONTOUR LEVELS (1:1 PROTECTION RATIO)

Field Strength Contours (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, km (miles)													
100	88 (55)	198 (123)	121 (75)	248 (154)	48 (30)	122 (76)	69 (43)	161 (100)	79 (49)	183 (114)	109 (68)	232 (144)	47 (29)	116 (72)
250	58 (36)	138 (86)	82 (51)	185 (115)	32 (20)	84 (52)	45 (28)	113 (70)	53 (33)	126 (78)	74 (46)	169 (105)	31 (19)	79 (49)
500	42 (26)	105 (65)	60 (37)	142 (88)	23 (14)	63 (39)	32 (20)	84 (52)	37 (23)	95 (59)	53 (33)	127 (79)	21 (13)	58 (36)

TABLE 20

ADJACENT-CHANNEL BROADCAST STATION SKYWAVE COVERAGE RADII
AT FOUR CONTOUR LEVELS (NIGHTTIME)

Field Strength Contours (μV/m)	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, km (miles)							
100	2140 (1330)	2896 (1800)	1062 (660)	1271 (790)	1706 (1060)	1931 (1200)	2607 (1620)	740 (460)
160	1818 (1130)	2414 (1500)	724 (450)	965 (600)	1448 (900)	1609 (1000)	2253 (1400)	402 (250)
250	1561 (970)	1995 (1240)	418 (260)	676 (420)	1191 (740)	1384 (860)	1850 (1150)	161 (100)
500	1191 (740)	1641 (1020)	≤64 (≤40)	225 (140)	740 (460)	965 (600)	1448 (900)	≤64 (≤40)

Current Limitations on TIS Coverage

Coverage for the current TIS is one of the main areas of concern. Adjacent-channel operations by other AM broadcasting stations, having as a minimum a 1 kW transmitter power level during daytime hours, can limit TIS coverage by interference. Even the smaller AM stations have a 100:1 power advantage over the current TIS transmitters. This disadvantage is made even more lopsided when the typical antenna efficiencies are also compared to TIS.

Antenna installation is one of the main areas of concern for TIS. With the current installation limitations for an antenna height of 15 m (49.2 ft), the radiation effectiveness is very low because the resultant antenna is electrically very short. One of the major problems experienced for installations of this type is finding a suitable transmitter site location and providing an adequate ground system. For example, mounting the antenna on an existing building would essentially preclude providing a centered circular ground plane at the base of the building. Providing an adequate ground plane is a key ingredient necessary to obtaining the allowable field intensity currently specified in the FCC Rules and Regulations.

Desired Coverage Considerations

For TIS to be effective, it will need to provide a 5 to 8 km (3 to 5 mi) radius of consistent coverage. The mechanics of turning the radio on, tuning to the TIS frequency (which is not a common AM frequency), and allowing adequate time for a message to be repeated once when the car is traveling at highway speeds (message times for TIS tend to be between 1 and 4 minutes) dictate the minimum coverage distance. If the system does not provide this minimum coverage, TIS will not be effective.

Coverage is very sensitive to ground conductivity, antenna effectiveness, and transmitter power levels. An appropriate solution to providing adequate coverage may be to make selected measurements on various TIS installations and determine the most cost-effective method of providing the desired minimum coverage distance. Providing a trade-off analysis of the antenna constraints, power restrictions, and variations due to ground conductivity may dictate specifying the desired field strength at the desired coverage boundary rather than the approach currently taken. Transmitter power, antenna height, and the field strength allowed at 1.5 km are all specified and often are not mutually achievable.

Providing needed consistent distance (radius) of coverage could be achieved by changing the antenna height restrictions and/or transmitter power limitations. For example, if the power level were allowed to change to provide a 500 μV/m level at either 5 or 8 km (3 or 5 mi) for consistent coverage, TABLE 21 would show the resultant power levels as a function of frequency and ground conductivity. All of the data in TABLE 21 assumes no changes to the antennas employed. Combinations of power levels and antenna improvements could also be investigated. TABLE 21 has been provided only for illustrative purposes. It can be seen that power levels rapidly increase as the radius of consistent coverage increases modestly. Also, the power levels are very

TABLE 21

TRANSMITTER POWER LEVEL NEEDED TO PROVIDE A 500 μV/M FIELD INTENSITY AT INDICATED DISTANCES

Consistent Coverage (km)	Transmitter Power Level (watts)					
	Frequency (kHz)					
	530		1610		1710	
	Ground Conductivity (mmhos/m)					
	2	15	2	15	2	15
5	11.6	7.1	157.5	11.1	189.0	12.6
8	42.7	20.1	1234.5	41.6	1487.2	45.6

TABLE 22

TRANSMITTER POWER REQUIRED FOR CONSISTENT COVERAGE OF 5 KM (3 MI) AS A FUNCTION OF PROTECTION

Consistent Coverage (μV/m)	Transmitter Power Level (watts)					
	Frequency (kHz)					
	530		1610		1710	
	Ground Conductivity (mmhos/m)					
	2	15	2	15	2	15
250	-	-	44	3	54	3
330	6	3.5	-	-	-	-
500	13	8	177	12	215	13

sensitive to ground conductivity. Low conductivity regions require more transmitter power to obtain the desired field intensity.

It appears that the 5 km (3 mi) coverage should provide a minimally adequate coverage area. The 5 km (3 mi) coverage would permit a message length of approximately 3 minutes for a car traveling at highway speeds (allowing time for a complete message-repeat cycle). Also, power levels can be adjusted downward if the field strength is reduced from the 500 μV/m value used in TABLE 21. The 5 km (3 mi) consistent coverages should have a very minimal impact on current AM band operations. TABLE 22 shows the transmitter power levels required for the 5 km (3 mi) coverage. However, cochannel operation distances (TIS to TIS) will have to be increased (refer to TABLE 23 for representative protection boundaries and protection ratios). The availability of two frequencies and possibly a third at 1700 kHz would permit added flexibility to implementing a system that could provide the variety of services needed in a relatively high-use region. This does point out the necessity of having several frequencies available in high usage areas to comply with the separation requirements in TABLE 23.

Again, the final selection of the best combination of antenna effectiveness, transmitter power levels, protection boundaries, and protection ratios needed to provide consistent coverage will need further definitive study.

TIS Sharing in the AM Broadcast Band

To complete the study of TIS in the AM band, it is necessary to review the conditions that would permit sharing. TIS would need to have a minimal impact on the operations of current AM stations. TIS, of course, would only be considered on a secondary basis.

The nighttime operation can be readily addressed. The nighttime separation distance requirements shown in TABLE 20 illustrate that very long separation distances are required for adjacent-channel operation. This separation distance is predicated on a protection ratio of one-to-one at the 500 μV/m boundary. For cochannel operation, this protection ratio would have to be increased a minimum of approximately ten-to-one (signal-to-interference). This would require a further increase in the separation distances. The problem with cochannel TIS operation is not the impact on AM broadcast stations (which is minimal), but rather the impact on TIS operation. With the current power and antenna restrictions on TIS, there are virtually no areas where interference is low enough to permit TIS operation at nighttime. AM broadcast cochannel operation is then essentially eliminated

TABLE 23

TIS-TO-TIS SEPARATION DISTANCES FOR 5 KM (3 MI)
CONSISTENT COVERAGE

Frequency of Operation (kHz)	Selected Protection Level (μV/m)	Protection Ratio Signal-to-Interference (μV/m)	Separation Distance, km (mi) Ground Conductivity (mmhos/m) 2		Separation Distance, km (mi) Ground Conductivity (mmhos/m) 15	
530	330	2.5:1 (130)	17.5	(10.9)	26	(16.0)
		5:1 (66)	25.0	(15.4)	42	(26.0)
		10:1 (33)	34.0	(21.0)	69	(43.0)
	500	2.5:1 (200)	14.0	(8.8)	19	(11.6)
		5:1 (100)	20.0	(12.5)	31	(19.4)
		10:1 (50)	28.0	(17.5)	51	(32.0)
1610	250	2.8:1 (90)	10.0	(6.5)	21	(12.9)
		5:1 (50)	12.5	(7.8)	27	(16.8)
		10:1 (25)	15.0	(9.6)	36	(22.4)
	500	2.8:1 (179)	8.7	(5.4)	15	(9.3)
		5:1 (100)	10.0	(6.3)	20	(12.4)
		10:1 (50)	12.5	(7.8)	27	(16.9)
1710	250	2.8:1 (90)	10.0	(6.3)	20	(12.3)
		5:1 (50)	12.0	(7.5)	25	(15.8)
		10:1 (25)	15.0	(9.3)	34	(21.0)
	500	2.8:1 (179)	8.5	(5.3)	14.5	(9.0)
		5:1 (100)	10.0	(6.2)	19	(11.8)
		10:1 (50)	12.0	(7.5)	25	(15.7)

for nighttime operation consideration. Again, consistent coverage is the key to successful TIS operations.

Cochannel TIS operation during daylight hours also needs to be reviewed. The AM broadcast band provides coverage from 535 to 1605 kHz with 107 channels. The main area of concern is finding a frequency that is not in use and available for TIS operation for a specific area. Daytime coverage distances for Class I through Class IV AM broadcasting stations, with the various power levels and frequencies of 530, 1610, and 1700, are shown in TABLES 24, 25, and 26. These frequencies give representative values of coverages for the end points of the AM band and the proposed expansion. Within the AM band, the 500 μV/m boundary must not receive interference in excess of 1/20 of this value or 25 μV/m TABLES 24 through 26 also show other values of field strength for comparitive purposes. It can be seen that the separation distances at the high end of the band are appreciably less than the lower end of the band.

The daytime use of the AM band would be applicable to low density (AM station density) areas of the country. A special study would need to be conducted to establish specifically those areas and frequencies that could be used for daytime TIS operation. This does appear to be an area that could provide an additional resource for TIS services. With the limited power levels of TIS, the impact on AM stations would have to be evaluated, but it is anticipated that the impact caused by TIS would be minimal.

Nondirectional Radio Beacons and TIS Interference Considerations

An NTIA Report (Fraizer, 1978) shows the frequency/distance sharing criteria between nondirectional radiobeacons (NDB) and TIS in the 525-535 kHz band. The following paragraphs and figures are taken from that report.

Analysis results were presented for both NDB to TIS and TIS to NDB interference interactions and are presented on the frequency/distance (F/D) curves in Figures 16 through 19. Present data show that the most realistic value for the AM broadcasting receiver is S/I = 20 dB which relates favorably with both the National Park Service and measured results.

TABLE 24

COCHANNEL BROADCAST STATION COVERAGE RADII AT THREE CONTOUR LEVELS FOR 530 KHZ
(20:1 PROTECTION RATIO)

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, km (mi)															
100	545 (339)	1056 (656)	626 (389)	1184 (736)	385 (239)	750 (466)	465 (289)	959 (596)	513 (319)	1007 (626)	610 (379)	1136 (706)			377 (234)	805 (500)
250	433 (269)	880 (547)	523 (325)	1017 (632)	298 (185)	684 (425)	378 (235)	800 (497)	410 (255)	848 (527)	507 (315)	977 (607)			282 (175)	663 (412)
500	359 (223)	777 (483)	439 (273)	906 (563)	233 (145)	560 (348)	302 (188)	687 (427)	335 (208)	697 (433)	417 (259)	858 (533)			220 (137)	539 (335)

TABLE 25

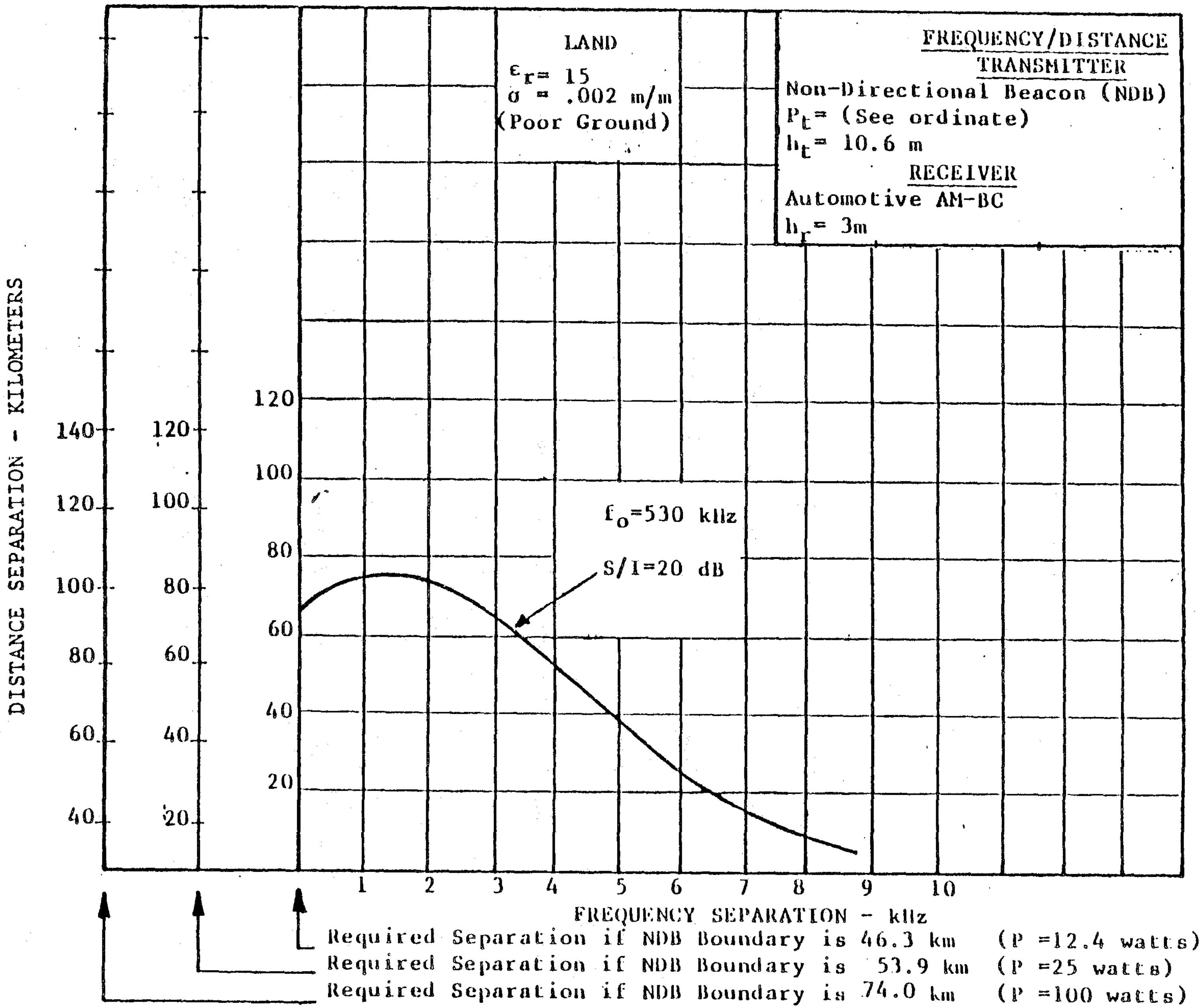
TIS COCHANNEL BROADCAST TRANSMITTER SEPARATION DISTANCE AT THREE CONTOUR LEVELS FOR 1610 KHZ
(20:1 PROTECTION RATIO, DAYTIME)

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, km (mi)													
100	270 (168)	457 (284)	335 (208)	529 (329)	180 (112)	344 (214)	233 (145)	426 (265)	256 (159)	438 (272)	314 (195)	508 (316)	174 (108)	336 (209)
250	212 (132)	368 (229)	261 (162)	465 (289)	129 (80)	269 (167)	172 (107)	330 (205)	196 (122)	362 (225)	245 (152)	426 (265)	121 (75)	264 (164)
500	169 (105)	319 (198)	219 (136)	383 (238)	95 (59)	216 (134)	132 (82)	275 (171)	153 (95)	302 (188)	208 (129)	367 (228)	88 (55)	206 (128)

TABLE 26

COCHANNEL BROADCAST STATION COVERAGE RADII AT THREE CONTOUR LEVELS FOR 1700 KHZ
(20:1 PROTECTION RATIO)

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, km (mi)													
100	253 (157)	404 (251)	304 (189)	471 (293)	159 (99)	304 (189)	209 (130)	360 (224)	248 (145)	385 (239)	286 (178)	449 (279)	151 (94)	291 (181)
250	190 (118)	330 (205)	241 (150)	389 (242)	113 (70)	235 (146)	153 (95)	290 (180)	172 (107)	311 (193)	224 (139)	373 (232)	106 (66)	225 (140)
500	146 (91)	278 (173)	195 (121)	336 (209)	84 (52)	187 (116)	117 (73)	238 (148)	135 (84)	262 (163)	179 (111)	319 (198)	79 (49)	177 (110)



Figre 16. Frequency/distance curves for NDB transmitter to AM receiver.

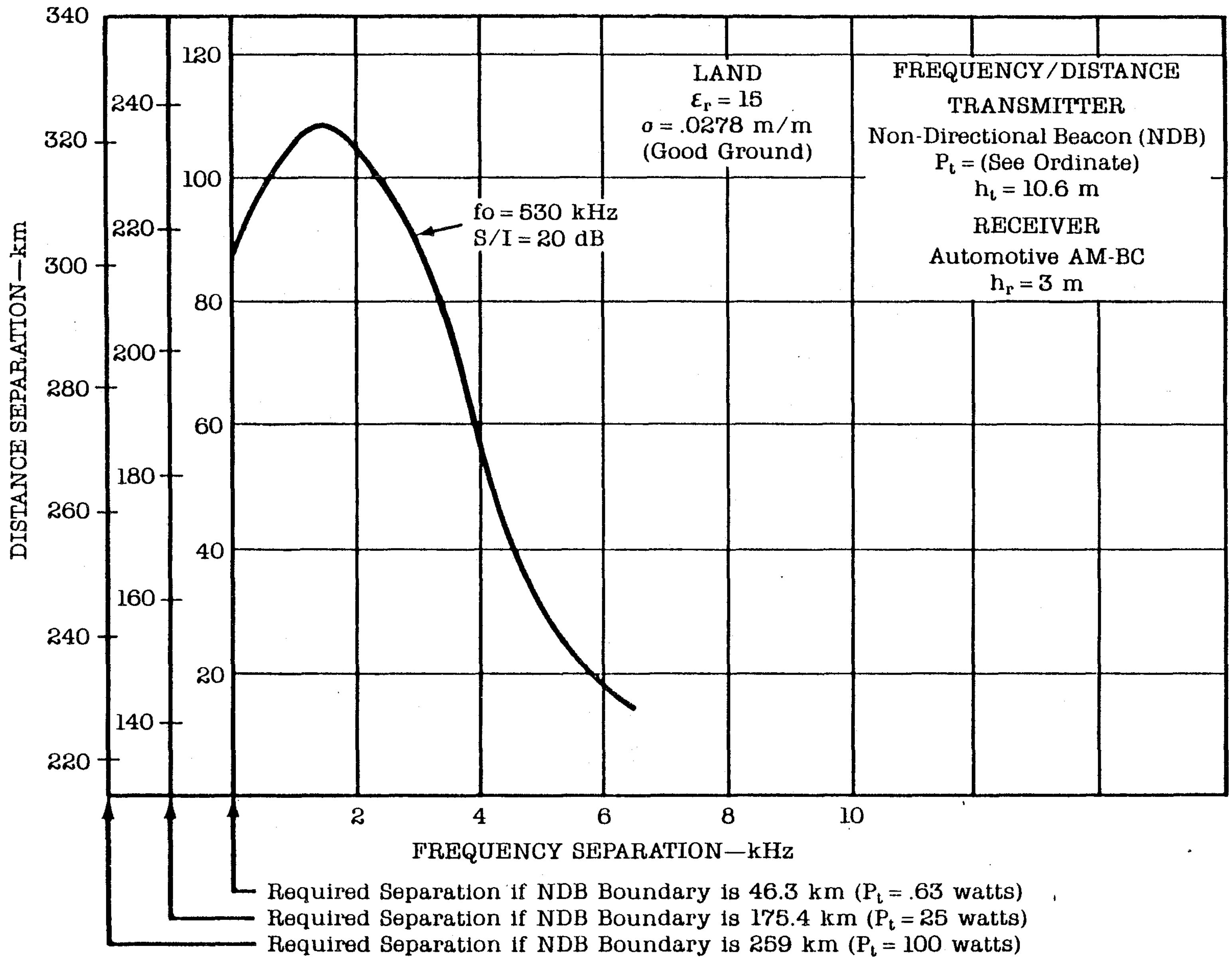


Figure 17. Frequency/distance curve for NDB transmitter to AM receiver.

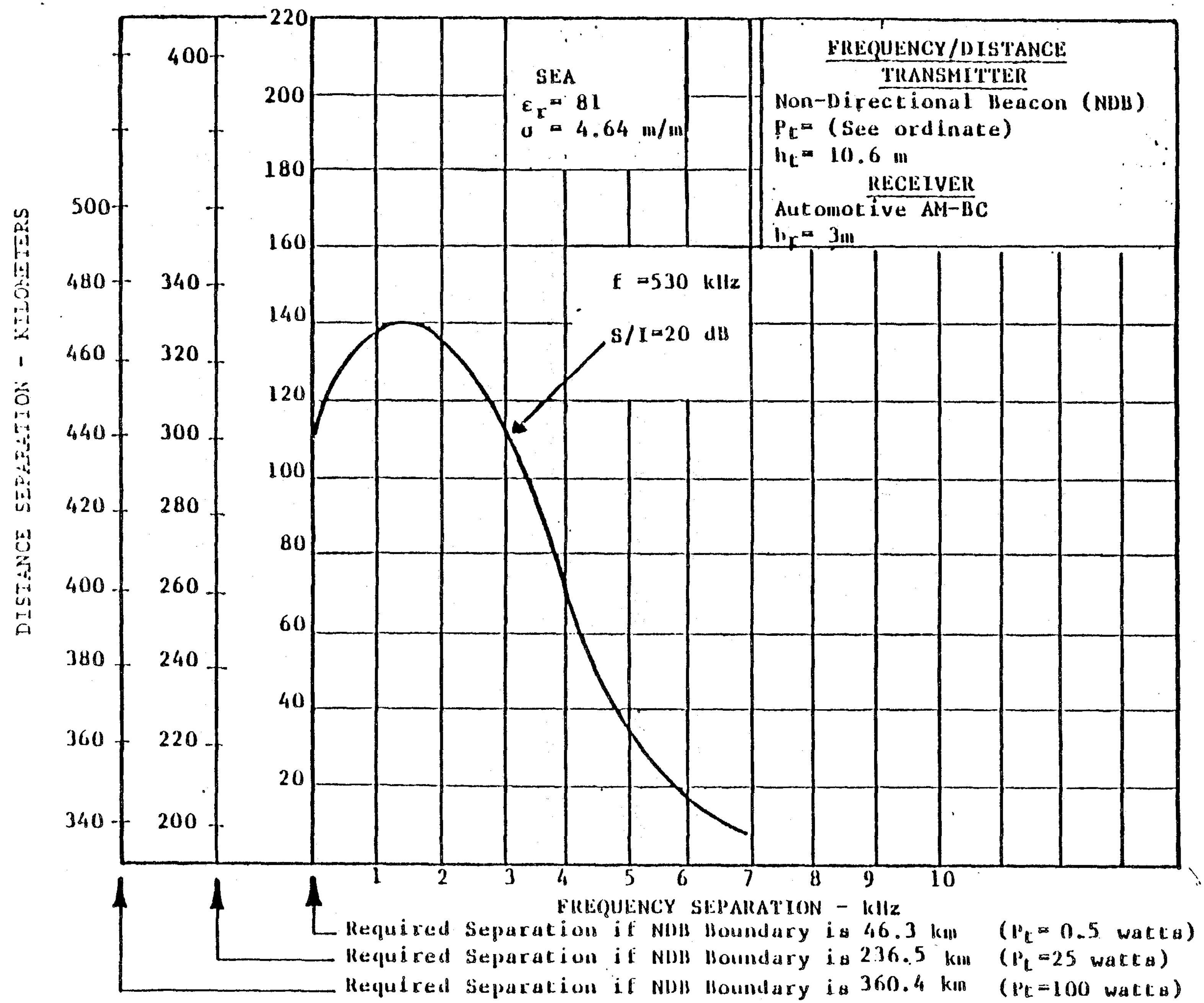


Figure 18. Frequency/distance curves for NDB transmitter to AM receiver.

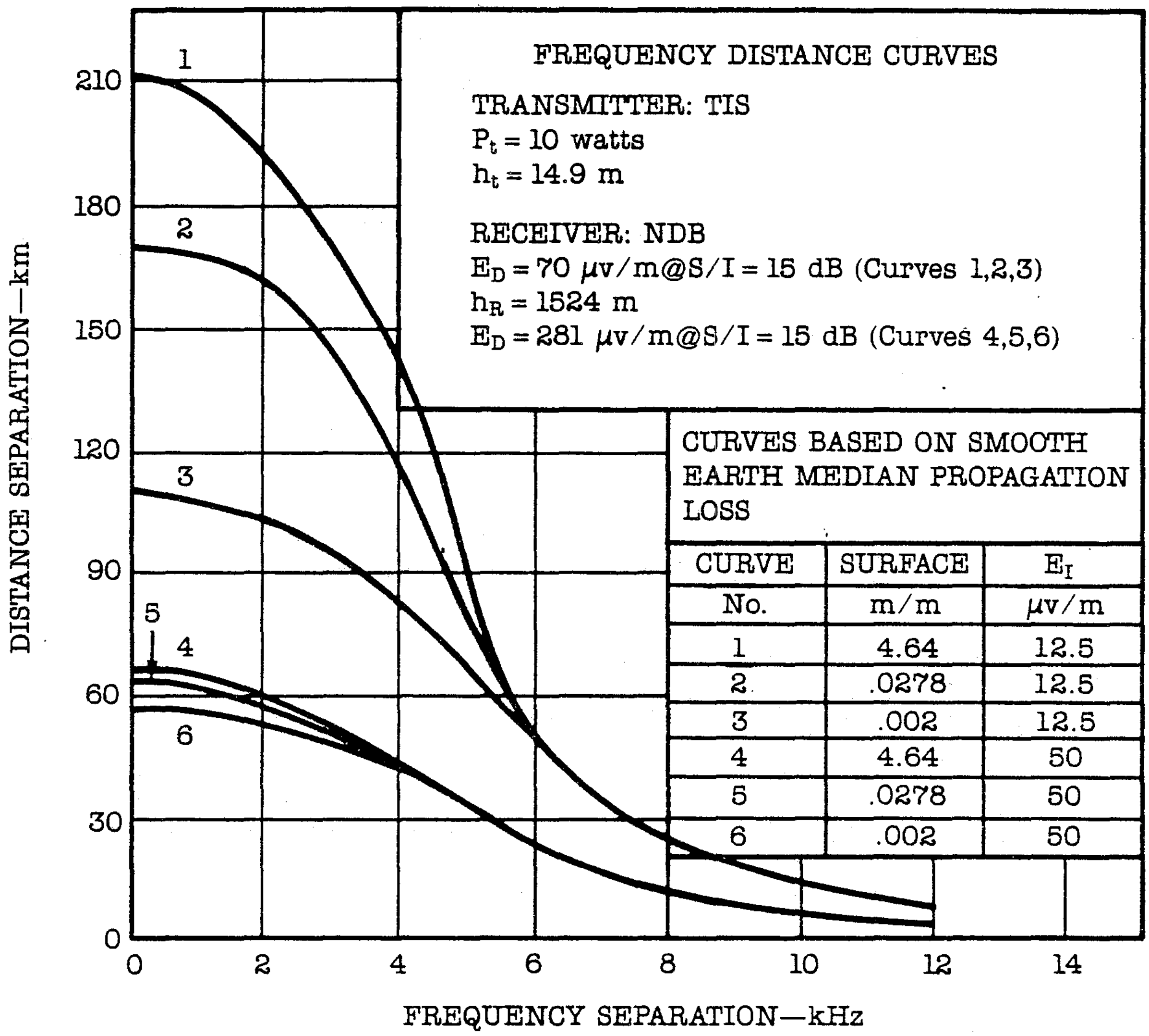


Figure 19. Frequency/distance curves for TIS transmitter to NDB receiver.

The analysis of the AM BC (TIS) receiver is based on desired signal field strength of E_D = 330 μV/m and 500 μV/m at the receiver antenna. The desired signal of 500 μV/m is reportedly sufficient to provide intelligible reception to about 95% of the automobile AM radios (Robertson, 1976) while the National Park Service as stated earlier indicates that 300 uV/m is sufficient for TIS area coverage.

The F/D curves (Figures 16 through 18) for the NDB transmitter to the TIS receiver are given for a variety of powers, field strengths, and surface conductivities. The first ordinate of each curve is based on a signal strength of 70 μV/m at 46.3 km (28.8 m), which is the minimum required field strength and the minimum NDB boundary distance for FAA land based NDB transmitters. Having determined the field strength required at a definite distance, it is possible to calculate the transmitter output power required for assumed values of antenna gain. The FAA Handbook (FAA, 1972) gives antenna efficiency levels which indicate that NDB transmitter antenna gains vary between -22 dBi to -17 dBi. Since the median level is approximately -19 dBi, this value was used for estimating the ordinate scales on Figures 16, 17, and 18, based on NDB boundary distances other than 46.3 km. As indicated on Figure 17, if the ground conductivity is assumed to be 0.0278 mhos/m for good land, the NDB service boundary of 70 μV/m at 46.3 km can be satisfied with a 0.63 W transmitter which is matched to an antenna of -19 dB gain. However, if the ground conductivity is assumed to be 0.002 mhos/m for poor land, the required transmitter power rises to 12.4 W as indicated on Figure 16. If this same transmitter output power was raised to 25 W, the 70 service boundary would increase to approximately 174.5 km (109 mi) over good land, 53.9 km (33.5 mi) over poor land, and 236.5 km (147 mi) over sea. If the transmitter power was increased further to the maximum of 100 W allowed by the 8th NOI (FCC, 1977), the NDB boundary distances increase to approximately 259 km (161 mi) over good land, 74 km (46 mi) over poor land, and 360.4 km (224 mi) over sea. The large differences in required separation distances between land paths for good land and poor land and between land and sea paths are caused by propagation attenuation differences. Propagation attenuation at frequencies in the 150-535 kHz bands is highly dependent upon the conductivity of the surface.

The frequency/distance relationship required for compatible band sharing operation of a TIS transmitter and an NDB receiver is shown on Figure 19. The receiver performance criteria of $(S/I)_I$ = 15 dB used in the analysis corresponds to a maximum interference field at the antenna field of 12.5 μV/m while the desired signal field at the antenna is 70 μV/m The upper curves indicate a required distance separation of 167 km (104 mi) over good land and 206 km (128 mi) over sea paths for interference-free cochannel operation. This may be reduced to less than 11 km (7 mi) for 12 kHz frequency offset. The lower curves are provided to exhibit the large distance separations required at $(S/I)_I$ = 15 dB, even for a high desired signal level of 281 μV/m.

The analysis results indicate that the required separation distances predicted for the 525-535 kHz band are highly dependent upon the ground conductivity of the path between the transmitter and the receiver.

A frequency separation of at least 3 kHz is needed between an NDB transmitter and an AM receiver in order to realize any reduction in the required separation. Furthermore, if the NDB were placed at the lower band edge, f = 525 kHz, and provided 70 μV at 46.3 km (29 mi), the required separation distance over good land would be approximately 30 km (19 mi) (Figure 17). For an 8 kHz frequency separation (NDB at 522 kHz), the required separation distance would probably be less than 10 km (6 mi) for the same path.

The F/D curves on Figure 19 indicate that a 10 W TIS transmitter on good land (σ = 0.0278 m/m), using a monopole antenna, could be detected by an airborne NDB receiver at a distance of about 167 km (104 mi) for cochannel operation with a receiver $(S/I)_I$ = 15 dB (12.5 μV/m). However, if the NDB were off-tuned 5 kHz for band-edge operation at 525 kHz, the required separation distance could be reduced to about 80 km (50 mi) for paths over good land. For 10 kHz off-tuning (NDB at 515 kHz), the required separation distance would be less than 16 km (10 mi) for paths over either land or sea.

Results of the interference analysis indicated that the TIS and NDB services can share the 525-535 kHz band if strict guidelines are followed and site-by-site frequency engineering is applied. Many difficulties in sharing exist as a result of the limited available spectrum in the 525-535 kHz band, the restrictive nature of the NDB and AM broadcasting receiver degradation criteria, and the excellent propagation characteristics of frequencies around 530 kHz. These factors impose large distance separations for on-tuned and near adjacent-channel operations and thus minimizes the options for resolving potential bandsharing problems.

Special attention should be given to avoiding interference problems for TIS applications in airport environments. TIS systems are well suited as an aid to vehicle traffic in air terminals, and thus increased use is expected in airport environments. Since small airports may use NDB's as end of runway markers, interference problems could possibly occur for cochannel or near adjacent-channel operation near airports.

Coverage Considerations for Low-Power Communication Devices

Low-power communication devices may operate on any frequency between 510 and 1600 kHz, subject to the condition that the emission of RF energy on the fundamental frequency or any harmonic or other spurious frequency does not exceed the field strength of

$$\frac{24000}{\text{Frequency in kHz}}\ \mu\text{V/m at 30.5 m (100 ft)}$$

Also in lieu of meeting this requirement of §15.111 of the FCC Rules and Regulations, a low-power communication device must meet the following requirements (§15.113):

1. the power input to the final radio stage must not exceed 100 mW
2. the emissions below 510 kHz or above 1600 kHz must be suppressed 20 dB or more below the unmodulated carrier
3. the total length of the transmission line plus the antenna and the ground lead must not exceed 3 m (10 ft).

Using either of these two regulations results in an extremely limited distance for a usable signal when applied to TIS. Usually, vehicles would have to be within approximately 3 m (10 ft) of the antenna or "leaky" cable system to receive a usable signal. There are difficulties associated with energizing a "leaky" cable antenna or making certain that the specified signal strengths are not exceeded at the feedpoint or any place along the antenna.

The above specifications for low-power communication devices severely limit their use for TIS. A possible application of this device might be in a tunnel. However, this category of a communicating device does not seem suitable for TIS operation.

Considerations for Implementing TIS in the FM Broadcast Band

The FM band offers an interesting technical approach for TIS operation. The FM band operates from 88 to 108 MHz. In this frequency region, the electromagnetic propagation is characterized as being line-of-sight. Although atmospheric refraction, surface diffraction, and forward scattering can provide beyond-the-horizon coverage, these parameters do not radically alter the relatively short propagation coverage associated with TIS requirements. In short, the FM band offers predictable coverage areas that are independent of diurnal (daytime and nighttime effects) and weather conditions.

Equipment Implementation. General considerations for equipment implementation are very favorable. To obtain coverages of 5 to 8 km (same as AM band example), only modest power is required. The antenna requirements are greatly simplified for FM as compared to AM installations. One major advantage is that no special ground plane systems are required. The physical size of the antenna can be kept relatively small. A relatively large number of antenna types can be used for the TIS application. Antenna gain can be provided up to a maximum of 15 dBi. Directional capability could be employed to concentrate the TIS information in a given direction. The antenna gain also serves to minimize interference to adjacent station operation and control the desired area of coverage. Variations in antenna height and transmitter power levels serve to provide a very flexible method of obtaining the desired consistant coverage.

General FM Band Operations. The FM broadcasting band provides 100 channels between 88 and 108 MHz. The first channel starts at 88.1 MHz and then each succeeding channel is spaced 200 kHz apart. The channels are assigned to the following classes: A, B, C, or D. Frequency assignments, station classification, and channel numbers are shown in TABLE 27.

Only Class A stations can operate on Class A frequencies. Class A stations are primarily for relatively small communities, cities, or towns, and surrounding rural areas. A Class A station can have a maximum transmitter power level of 3 kW at a maximum antenna height above the average terrain of 91.4 m (300 ft).

Class B stations can operate on Channels 222 to 300, but must exclude all Class A frequencies. Class B stations are assigned for use in Zones I and IA only (refer to Figure 8). Class B stations are designed to serve a sizable community, city, or town, or the principal city or cities of an urbanized locale and its surrounding area. The Class B station is authorized to operate with a transmitter power level not to exceed 50 kW, with a maximum antenna height above the average terrain of 152.4 m (500 ft).

Class C stations operate on the same channels as Class B stations; hence, the class designation of B-C as noted in TABLE 27. Class C stations are assigned for use in Zone II only (see Figure 8). Class C stations are authorized to operate with a transmitter power level not to exceed 100 kW at a maximum antenna height above the average terrain of 609.5 m (2000 ft).

Minimum radiated power requirements are as follows (dB referenced to 1 kW):

Class A	100 watts (-10 dBk)
Class B	5 kW (7 dBk)
Class C	25 kW (14 dBk)

No minimum antenna height above average terrain is specified. For those conditions where the antenna height will exceed the specified maximum value, a reduction in transmitter power is required (see Figure 16). The zone where the FM transmitter is located determines the minimum and maximum operating requirements.

Noncommercial educational stations are permitted to operate on Channels 201 through 220 (see TABLE 27). A Class D noncommercial educational station

TABLE 27

FM CHANNEL ALLOCATIONS BY FREQUENCY, TYPE, AND CHANNEL NUMBER

Frequency (MHz)	Class	Channel No.	Frequency (MHz)	Class	Channel No.	Frequency (MHz)	Class	Channel No.	Frequency (MHz)	Class	Channel No.	Frequency (MHz)	Class	Channel No.
88.1	D	201	92.1	A	221	96.1	B-C	241	100.1	A	261	104.1	B-C	281
88.3	D	202	92.3	B-C	222	96.3	B-C	242	100.3	B-C	262	104.3	B-C	282
88.5	D	203	92.5	B-C	223	96.5	B-C	243	100.5	B-C	263	104.5	B-C	283
88.7	D	204	92.7	A	224	96.7	A	244	100.7	B-C	264	104.7	B-C	284
88.9	D	205	92.9	B-C	225	96.9	B-C	245	100.9	A	265	104.9	A	285
89.1	D	206	93.1	B-C	226	97.1	B-C	246	101.1	B-C	266	105.1	B-C	286
89.3	D	207	93.3	B-C	227	97.3	B-C	247	101.3	B-C	267	105.3	B-C	287
89.5	D	208	93.5	A	228	97.5	B-C	248	101.5	B-C	268	105.5	A	288
89.7	D	209	93.7	B-C	229	97.7	A	249	101.7	A	269	105.7	B-C	289
89.9	D	210	93.9	B-C	230	97.9	B-C	250	101.9	B-C	270	105.9	B-C	290
90.1	D	211	94.1	B-C	231	98.1	B-C	251	102.1	B-C	271	106.1	B-C	291
90.3	D	212	94.3	A	232	98.3	A	252	102.3	A	272	106.3	A	292
90.5	D	213	94.5	B-C	233	98.5	B-C	253	102.5	B-C	273	106.5	B-C	293
90.7	D	214	94.7	B-C	234	98.7	B-C	254	102.7	B-C	274	106.7	B-C	294
90.9	D	215	94.9	B-C	235	98.9	B-C	255	102.9	B-C	275	106.9	B-C	295
91.1	D	216	95.1	B-C	236	99.1	B-C	256	103.1	A	276	107.1	A	296
91.3	D	217	95.3	A	237	99.3	A	257	103.3	B-C	277	107.3	B-C	297
91.5	D	218	95.5	B-C	238	99.5	B-C	258	103.5	B-C	278	107.5	B-C	298
91.7	D	219	95.7	B-C	239	99.7	B-C	259	103.7	B-C	279	107.7	B-C	299
91.9	D	220	95.9	A	240	99.9	B-C	260	103.9	A	280	107.9	B-C	300

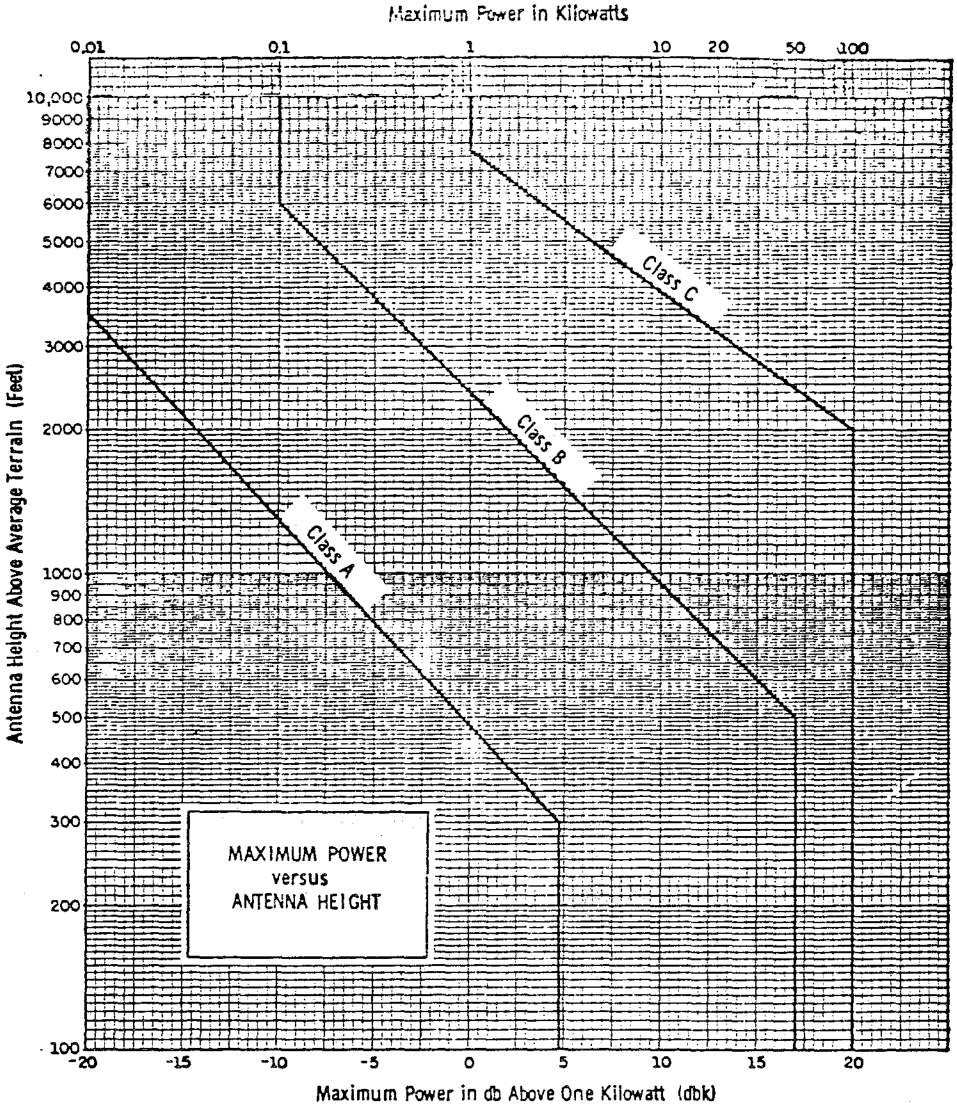


Figure 16. Maximum power permitted for Classes A, B, and C FM broadcast stations as a function of antenna height above average terrain (FCC § 73.333).

is one that operates with a maximum of 10 watts of transmitter power output. Noncommercial educational stations that operate with more than 10 watts of transmitter power output are classified as Class A, B, or C, according to the effective radiated power, antenna height above average terrain, and zone in which the transmitter operates. Classes A, B, and C noncommercial educational stations may be assigned to Channels 201 through 220. There are some restrictions in border agreements between Mexico and Canada. Special assignment restrictions also apply to Alaska and New York. These are specified in Part 73 of the FCC Rules and Regulations for FM broadcast stations.

FM Station Separation Requirements

Of major concern for TIS operations is the cochannel and first, second, and third adjacent-channel separation constraints. In the FCC Rules and Regulations §73.207, the minimum separation distances between FM stations are specified. TABLE 28 shows the minimum required separation distances. Separation distance requirements for stations separated in frequency by 10.6 or 10.8 MHz (53 or 54 channels) are shown in TABLE 29. This requirement comes from the fact that most FM receivers operate with an intermediate frequency (IF) of 10.7 MHz. The separation distances in TABLE 29 are designed to minimize this interference problem.

Frequency Considerations in the FM Band for TIS Operation

The selection of a specific frequency or set of frequencies for TIS operation is relatively involved and is dependent on the desired area of operation. Consideration must not only be given to a frequency that may not be in use for a given area, but also the first, second, and third adjacent channels on either side of the frequency being considered.

The frequency region from Channels 221 to 300 (92.1 to 107.9 MHz) provides for commercial operations. This frequency region is where the majority of FM broadcasting channels (80%) are authorized to operate. Figure 5 shows the frequency usage for the entire FM band. Note that the stations showing the highest usage are Class A frequency assignments. Class B-C frequencies

TABLE 28

SEPARATION REQUIREMENT BETWEEN SPECIFIC CLASSES OF FM STATIONS

Class to Class	Separation Distances, km (mi)			
	Cochannel	1st Adjacent (±200 kHz)	2nd Adjacent (±400 kHz)	3rd Adjacent (±600 kHz)
A to C	209 (130)	- -	- -	- -
A to B	177 (110)	- -	- -	- -
D to C	201 (125)	153 (95)	105 (65)	105 (65)
D to B	169 (105)	97 (60)	64 (40)	64 (40)
D to A	97 (60)	48 (30)	24 (15)	24 (15)
D to D	18 (11)	10 (6)	5 (3)	5 (3)

TABLE 29

SEPARATION DISTANCES REQUIRED TO MINIMIZE IF INTERFERENCE

Class to Class	Separation Distances, km (mi) Required Spacing in km (mi)
A to A	8 (5)
B to A	16 (10)
B to B	24 (15)
C to A	32 (20)
C to B	40 (25)
C to C	48 (30)
C to D	24 (15)
B to D	16 (10)
A to D	8 (5)
D to D	3 (2)

show usage that is as low as 17 to a high of 55 assignments per channel. Frequency usage from 88.1 to 91.9 MHz is somewhat higher, but on the average, the transmitter power levels are very much lower.

Some general observations about separation distances are in order. The supposition is made that TIS will operate similar to present Class D classification because of the limited coverage needed. Thus, a 10 W power rating is sufficient to provide 5-8 km (3-5 mi) coverage for TIS operation (Thompson, 1985). The separation distance given in TABLE 28 for Class D to C cochannel operation is the largest (201 km (125 mi)). This distance decreases to 153 km (95 mi) for the first adjacent channel and to 105 km (65 mi) for the second and third adjacent channels. These distances would virtually rule out cochannel operation in any metropolitan area. This is also essentially true for Class B stations, since the separation distances are not greatly different from Class C. Class B-C frequencies could only effectively be used for TIS at significantly large distances from population concentrations where they normally operate. Note also that the first, second, and third adjacent channels significantly restrict TIS operation. Because of the relatively large number of stations that normally operate in a metropolitan area, there are a very limited number of frequencies that would permit TIS operation without numerous interfering signals. The selection of one of the limited number of frequencies would be extremely dependent on the specific area of consideration. A computer program could be developed to assist in the frequency selection process for TIS. This would require an indepth and up-to-date data base that would be especially important if transportable TIS operations were to be considered. Field measurements could also be utilized to validate the frequency selection process.

Class A frequencies (except 92.1 MHz) are flanked on both sides with Class B-C frequencies. Cochannel separation distances, in this case, can be less than the adjacent-channel separation requirements. These separation distances would serve to restrict TIS operations. Note that separation distances for Class A to A are not specified in TABLE 28. This is because of the inherent spacing (frequency separation) and the dominating factor of adjacent-channel separation for Class A frequencies. Again, frequency or channel availability would be very limited and area dependent.

For example, the FM stations received by two FM car radios near Boulder, CO (Denver metropolitan area), are shown in TABLE 30. A review of this listing shows there are approximately 10 frequency assignments that would permit insertion of a TIS. Note also the relatively large power levels associated with the assignments from 92.1 to 107.9 MHz. Also associated with these high power levels is the effect of "punch through" on the car receiver. This causes the receiver to receive the high power signal even when it is tuned to the first and second adjacent channels. This is due to the inability of the receiver selectivity to eliminate high-power adjacent-channel interference. This effect necessitates having approximately 3 to 5 contiguous channels that do not have high power stations in operation in order to provide effective coverage with a low power TIS. However, for TIS operations in a given area, perhaps the few frequencies available would meet the demand as long as they did not violate the required separation distances of Table 28.

Class D to D separations are relatively small (see TABLE 28). With spacing requirements ranging from 18 km (11 mi) to 5 km (3 mi), this frequency region (88.1-91.9 MHz) that is limited to noncommercial educational stations looks very attractive. This is further enhanced by the fact that 20 channels are available in this frequency region. Frequency usage for the noncommercial educational channels averages approximately 80 stations per FM channel (Figure 5). However, under the October 1982 FCC Rules and Regulations, Part 73, Subpart C, §73.512, Class D stations are supposed to move to available commercial channels, if possible, as their present licenses expire. This means that higher power educational FM stations (Class A, B, or C) will most likely be replacing the existing Class D stations over the next decade or so in the 88.1-91.9 MHz portion of the band. There may not be any advantage for TIS operating in the 88.1-91.9 Mhz portion of the band in the future if large numbers of high-power stations are allowed to operate there since such stations would experience the same separation distance competition as in the 92.1-108 MHz portion of the band. There would still be some advantage in using the first 20 FM channels since there would probably always be fewer stations assigned per channel than the commercial channels. This would also require a more detailed study to establish procedures for frequency usage and coverage constraints.

TABLE 30

FM STATIONS RECEIVED ON TWO FM CAR RADIOS AT BOULDER, COLORADO (DENVER METRO AREA)

(Page 1 of 2)

Frequency	Reference NGMF,1983	Radio	Power kW	Station[a] Class	Owner	Location ° N '	° W '
88.5	?	KGNU			Boulder		
90.1	x	KCFR	26.5	BCFE	Univ. of Denver	39-43	105-15
90.7	x	KCDC	0.01	BCFE	St. Varain School	40-14	105-03
	x	"	0.001	BCFE	District Longmont	40-08	105-07
91.1	x	KWBI	6.0	BCFE	Western Bible College Morrison	39-36	105-12
91.5	x	KUNC FM	50.0	BCFE	Univ. of Northern Colo. Greeley	40-38	104-49
92.1	x	KRKY	0.72	BCFC	Baker Broad. Company Castle Rock	39-25	104-52
92.5	x	KGRE	25.0	BCFC	O'Kieffe Broad. Company Greeley	40-22	104-49
93.3	x	KTCL	100.0	BCFC	Wren Broad. Company Ft. Collins	40-32	105-11
93.9	x	KILO	83.0	BCFC	Kilo Broad. Company Colorado Springs	38-44	104-51
94.7	x	KBVL	30.0	BCFC	Bld. Valley Broad. Company Boulder	39-57	105-12
95.1	x	KRDO FM	96.0	BCFC	Pikes Peak Broad. Company Colorado Springs	38-44	104-51
95.7	x	KPKE KXKX	100.0	BCFC	Doubleday Broad. Company Denver	39-43	105-14
96.1	x	KGBS	100.0	BCFC	Colorado RG Inc. Greeley	40-38	104-49
96.5	x	KKFM	23.0	BCFC	Sky Hi Inc. Colorado Springs	38-44	104-51
97.3	x	KBCO	33.0	BCFC	Centennial Wireless Boulder	40-04	105-21
97.9	x	KCCY	100.0	BCFC	Kennebec-Colo. Broad. Com. Pueblo	?	?
98.5	x	KIMN FM KYGO	100.0	BCFC	Jefferson Pilot Broad. Com. Denver	39-43	105-14
99.1	x	KUAD FM	100.0	BCFC	KUAD-FM Inc. Windsor	40-38	104-49
99.5	x	KVOD	100.0	BCFC	Capital City Broad. Company Denver	39-41	105-00
100.3	x	KLIR	100.0	BCFC	Duffy Broad. Corp. of Colo. Denver	39-41	105-04
100.7	x	KZLO	100.0	BCFC	United Comm. Inc. Pueblo	38-22	104-32
101.1	x	KOSI	100.0	BCFC	Westinghouse B/C and Cable Aurora	39-43	105-14

TABLE 30

FM STATIONS RECEIVED ON TWO FM CAR RADIOS AT BOULDER, COLORADO (DENVER METRO AREA)

(Page 2 of 2)

Frequency	Reference NGMF,1983	Radio	Power kW	Station Class	Owner	Location ° N '	° W '
101.7	x	K269E	?	BCFR	Capital City Broad. Company Boulder	39-57	105-12*
102.3	x	KLOV FM	3.0	BCFC	KLOV AM/FM Inc. Loveland	40-09	107-57
103.1	x	K276BJ	?	BCFR	Wren Broad. Company, Inc. Fort Collins	40-04	105-21**
103.5	x	KOAQ	100.0	BCFC	General Electric B/C Co. Schenectady, N.Y.	39-43	105-14
104.3	x	KLMO FM	28.00	BCFC	Radio Longmont Inc. Longmont	40-11	105-07***
104.3	x	KLMO FM	100.00	BCFC	" " "	40-05	105-08
105.1	x	KADX KBRQ FM	100.00	BCFC	Den. Great Epire B/C Co. Wichita, Kansas	39-40	104-52
105.9	x	KBPI	99.00	BCFC	Rocky Mt. Radio Inc.	39-43	105-14
106.7	x	KAZY	94.00	BCFC	Group One B/C Company Denver	39-43	105-14
107.5	x	KPPL	91.00	BCFC	Outer Banks Cablevision Cleveland, Ohio	39-41	105-09
107.9	x	KCOL FM	100.00	BCFC	Beef Empire B/C Company Ft. Collins	40-40	104-56

* Translator KVOD
** KTCL Translator
*** Translator

[a]Station Class Definitions:

BCFC - Commercial FM broadcast station
BCFE - Noncommercial FM broadcast station
BCFR - FM translator station

FM Leaky-Cable Considerations

The leaky-cable approach has little or no application in the FM frequency band. The first consideration is that the cable cannot be buried without suffering a very high attenuation to the broadcasted signal. This would necessitate mounting the cable above ground. This would also greatly add to the cost of the system and make it susceptible to vandalism. Tunnels or very localized areas (a few feet) are the only plausible application for the leaky-cable system. This approach is not recommended for further consideration at this time.

SECTION 6

SPECTRUM MANAGEMENT ISSUES

This study of TIS has raised the following spectrum management issues.

1. Should TIS allocations at 530 and 1610 kHz remain exclusive?

2. Should the upper TIS frequency move to 1700 or 1710 kHz when AM broadcasting phases into the 1605-1705 kHz band?

3. Are power and antenna height limits now imposed on TIS reasonable?

4. Can TIS operate effectively on FCC Rules and Regulations, Part 15 limitations?

5. Can TIS operate successfully in the 540-1600 kHz band on a secondary basis?

6. Can TIS operate compatibly in the 88-108 MHz FM band?

7. Should TIS be upgraded to Travelers Information <u>Service</u> in light of its expanding role?

In the following discussions that address the issues above the suggestions and input from various documents generated by IRAC Ad Hoc 193 dealing with the future of TIS are incorporated.

<u>TIS Allocations</u>

The TIS is presently allocated two frequency bands for their exclusive use. These are 530 $\pm$ 5 kHz and 1610 $\pm$ 5 kHz, at the bottom and top of the present AM broadcasting band, respectively. In light of the expanding use of the TIS in the near future by both Government and non-Government, these frequencies should continue to be exclusive. However, there may be good reason to consider moving the upper frequency 1610 kHz to 1700 kHz (1690 kHz also desired) (Subgroup on Radio Spectrum Allocations, 1985) when the expansion of the broadcasting service to 1705 kHz is implemented. The 1610 kHz frequency will have adjacent AM broadcasting assignments at 1600 and 1620 kHz. Since the allowed station classes for the expanded broadcasting band are yet to be determined, the potential interference impact on TIS can not be totally assessed at this time, but at best would limit the use of the 1610 kHz frequency in many areas. This of course assumes that TIS would remain exclusive at 1610 kHz. If AM broadcast stations are allowed to be cochannel at this frequency, the use for TIS would be even more restrictive as discussed in Section 5.

After discussing this situation with users of TIS, it was determined that it may be beneficial for TIS to move to 1700 kHz when automobile receivers can tune the expanded band. There was a definite preference by the TIS community for 1700 kHz rather than 1710 kHz. The reasoning behind this preference was mainly due to experience at 1610 kHz. At present, the 1610 kHz TIS frequency is just above the AM broadcasting band, which ends at 1600 kHz. There are still many automobile radios that cannot tune the 1610 kHz TIS frequency or cannot tune it close enough to discriminate against stations at 1600 kHz. There are presently few assignments at 1710 kHz, but this will change rapidly as displaced users of the 1605-1705 kHz band move into this frequency area. As 1710 kHz is used more, most likely by the radiolocation service, compatibility problems with TIS will also grow. It is then felt that TIS should have an exclusive channel at 1700 kHz. The discussions with both Government and non-Government users of TIS also surfaced a desire for an additional channel at 1690 kHz for future expansion.

In light of the expanding use of TIS, it is still desirable to have both the 530 and 1610 kHz exclusive frequency allocations with a phase out period for 1610 kHz and a phase in of the 1700 kHz exclusive frequency. As long as automobile radio manufacturers are going to be expanding the tuning range of the AM receivers, it would be desirable to request them to design radios to cover the range from 530 to 1705 kHz. There are still some receivers that cannot tune the 530 kHz frequency.

TIS Rules and Regulations

At present, the rules and regulations governing the TIS antenna heights, transmitted power, and field intensity at a given distance are not always adequate for needed coverage. The problem is not with the TIS designated

2 mV/m at 1.5 km field intensity, but being able to achieve that value at lower ground conductivity levels with the allowed antenna heights (restricted to 15 m or less) and the transmitter power (10 W or less for monopole antennas and 50 W for leaky-cable antennas) as shown in Section 5.

It is suggested that the adoption of a constant coverage approach be considered. With a constant coverage philosophy, the controlling facter is the allowed field intensity at a given distance from the antenna as the main criteria. For example, if the presently allowed field of 2 mV/m at 1.5 km is adequate (it seems to be for most cases), then allow either antenna height adjustment or power output adjustment, or a combination of both, to achieve the desired field strength at the constant coverage distance. The systems now are too dependent on antenna installation procedures and local ground conductivity. The antenna ground planes, particularly at 530 kHz, are absolutely necessary and critical to proper coverage. These ground planes must be well designed and installed and maintained properly to obtain desired coverage. Experience shows that ground planes are not always installed and maintained properly. This is due in part to existing landscaping where proper ground radials are difficult, if not impossible, to install and/or mounting the antenna on a building or other structure where a sufficient number of ground radials (see Figures 9 and 10) are impossible to install. One installation that was checked showed a measured field intensity at 1.5 km of 30 μV/m which was not adequate for the desired coverage. The antenna system was mounted on a building for convenience and had no ground radials (building ground was used).

The constant coverage approach would only designate the maximum field intensity at a given distance, and the installing agency would be responsible for the measurements required to show compliance. It should be noted that field intensity requirements for proper reception at a given distance from the antenna were greater at 530 kHz than at 1610 kHz according to a DOI study (McFadden, 1978). Perhaps the field intensity would be given as 500 μV/m at 8 km, which would meet the needs of most Government TIS stations.

Referring back to the Section 5 analysis for the TIS frequencies, it is noted that at the preferred boundary where good reception is desired (5 and 8 km were the two most often quoted coverage distance needs by agencies using TIS) and using the DOI required field intensity for good reception (330 μV/m at 530 kHz and 250 μV/m at 1610 kHz), the required distance separation between

TIS stations as given in the FCC Rules and Regulations may not be adequate for interference free reception at the boundaries and should be reviewed for possible change.

TIS in the AM Broadcasting Band and Under FCC Rules and Regulations, Part 15

As shown in Section 5, the separation distances and nighttime interference potential in the AM broadcasting band from 540-1605 kHz betweeen broadcasting stations and TIS would be of such magnitude that little use could be made of TIS in this band.

Under FCC Rules and Regulations, Part 15, Subpart D, Low Power Communication Divices, the provisions for operation are such that use by TIS would not be practical. For example, the field strength at 30 m cannot exceed approximately 45 μV/m at 530 kHz and 15 μV/m at 1600 kHz. Most automobile radios would have trouble receiving a signal at this level. There are few uses for TIS where the listener would have to be stopped and within a few meters of the transmitter.

TIS in the 88-108 MHz FM Band

Perhaps the most promising band for future TIS operations would be the 88-108 MHz FM broadcasting band. Of particular interest are the 20 channels from 88.1-91.9 MHz set aside for noncommercial educational stations. The majority of station assignments in this subband at present are low power (under 1 kW). There are few of these stations in remote areas where Government TIS tend to be located. The antenna installations and overall system would be somewhat simpler and less expensive than current AM systems for the desired coverage. The 10 W maximum power restriction for existing Class D, FM stations would be adequate for TIS. A computerized frequency assignment plan for CONUS should be fairly simple to set up and in fact may be only an expansion of an existing program for assigning noncommercial educational FM stations now in use by the FCC.

TIS as a Type of Service

The expanding role of TIS both within the Government and the private sector would seem to dictate a more important status to these stations. The expansion from the few hundred assignments now in use to a few thousand assignments that are possible by the year 2000 would seem to justify this as a class of service to the public. It is suggested as an outcome of this study and findings of IRAC Ad Hoc 193 that the TIS acronym stand for Travelers' Information Service rather than Travelers' Information Stations.

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APPENDIX

RULES AND REGULATIONS FOR TIS

90.7 DEFINITIONS

BASE STATIONS

A land station at a specified site authorized to communicate with mobile stations.

TRAVELERS' INFORMATION STATION

A base station in the Local Government Radio Service used to transmit noncommercial, voice information pertaining to traffic and road conditions, traffic hazard and travelers' advisories, directions, availability of lodging, rest stops, and service stations, and descriptions of local points of interest.

90.17 Local Government Radio Service

(a) Eligibility. Any territory, possession, state, county, city, town, and similar governmental entity, including a district and an authority, but not including a school or park district or authority is eligible to hold authorizations in the Local Governmental Radio Service to operate radio stations for transmission of communications essential to official activities of the licensee.

(b) Frequencies Available. The following table indicates frequencies available for assignment to stations in the Local Government Radio Service, together with the class of station(s) to which they are normally assigned and the specific assignment limitations which are explained in paragraph (c) of this section.

Frequency or Band MHz	Class of Station(s)	Limitations
0.530	Base	23
1.610	Base	23

(23) This frequency is available for use by Travelers' Information Stations in accordance with 90.242.

90.119 APPLICATION FORMS. The following application forms shall be used:

(a) Except as provided for in paragraph (c) of this section, Form 400 shall be used to apply:

(1) For new base, fixed, or mobile station authorizations govern in this part.

90.149 LICENSE TERM

(a) Licenses for stations authorized under this part will normally be issued for a term of five years from the date of original issuance, modification, or renewal, except that, in some instances, a term of 1-5 years will be applied, the term varying as may be necessary to permit the orderly scheduling of renewal applications.

(b) Authorizations for stations engaged in developmental operation under Subpart P of this part will be issued upon a temporary basis for a specific period of time, but in no event to extend beyond one year from date of original issuance, modification, or renewal.

90.155 TIME IN WHICH STATION MUST BE PLACED IN OPERATION

(a) All stations authorized under this part must be placed in operation within 8 months from the date of grant or the authorization shall be invalid and must be returned to the Commission for cancellation.

(b) For Local government entities only, a period longer than eight months for placing a station in operation may be authorized by the Commission on a case-by-case basis, where the applicant submits a specific schedule for the completion of each portion of the entire system, along with a showing that the system has been approved and funded for implementation in accordance with that schedule.

90.203 TYPE ACCEPTANCE REQUIRED

(a) Each transmitter utilized for operation under this part of each transmitter marketed as set forth in 2.803 (of Part

2) must be of a type which is included in the Commission's current Radio Equipment List as type accepted for use under this part, or, be of a type which has been type accepted by the Commission for use under this part in accordance with the procedures in subparagraph (2) of this paragraph.

(1) The Commission periodically publishes a list entitled "Radio Equipment List, Equipment acceptable for Licensing." This list includes type accepted equipment and also, until such time as it may be removed by Commission action, other equipment which appeared in this list on May 16, 1955.

(2) Any manufacturer of radio transmitting equipment (including signal boosters) to be used in these services may request type acceptance of such equipment following the procedures set forth in Subpart J of the FCC Rules and Regulations, Part 2. Type acceptance for and individual transmitter or signal booster also may be requested by an applicant for a station authorization by following the procedure set forth in the FCC Rules and Regulations, Part 2. Such equipment is type accepted and will not normally be included in the Commissions "Radio Equipment List" but will be individually enumerated on the station authorization.

90.211 MODULATION REQUIREMENTS

(a) The maximum audio frequency required for satisfactory radio telephone intelligibility in these services is considered to be 3000 hertz per second.

(b) When amplitude modulation is used for radiotelephony, the modulation percentage shall be sufficient to provide efficient communication and normally shall be maintained above 70 percent on peaks, but shall not exceed 100 percent on negative peaks.

(c) Each transmitter shall be equipped with a device which automatically prevents modulation in excess of that specified in this subpart which may be caused by greater than normal audio levels.

This requirement shall not be applicable to transmitters authorized to operate as mobile stations with a maximum output power of two watts or less.

90.215 TRANSMITTER MEASUREMENTS

(a) The Licensee of each station shall employ a suitable procedure to determine that the carrier frequency of each transmitter authorized to operate with an output in excess of two watts is maintained within the tolerance prescribed in 90.213. This determination shall be made, and the results entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed.

(2) When any change is made in the transmitter which may affect the carrier frequency or its stability.

(b) The licensee of each station shall employ a suitable procedure to determine that the transmitter output power of each transmitter authorized to operate with an output power in excess of two watts does not exceed the maximum figure specified on the current station authorization. This determination shall be made, and the results thereof entered in the station records, in accordance with the following:

(1) When the transmitter is initially installed.

(2) When any change is made in the transmitter which may affect the transmitter power input.

(c) The licensee of each station shall employ a suitable procedure to determine that the modulation of each transmitter, which is authorized to operate with an output power in excess of two watts does not exceed the limits specified in this part. This determination shall be made and the following results entered in the station records in accordance with the following:

(1) When the transmitter is initially installed.

(2) When any change is made in the transmitter which may affect the modulation characteristics.

(d) The determinations required by paragraphs (a), (b), and (c) of this section may, at the option of the licensee, be made by a qualified engineering measurement service, in which case the required record entries shall show the name and address of the engineering measurement service as well as the name of the person making the measurements.

90.242 TRAVELERS INFORMATION STATIONS

(a) The frequencies 530 kHz and 1610 kHz may be assigned in the Local Government Radio Service for operation of Travelers' Information Stations subject to the following conditions and limitations:

(1) For Travelers' Information Station applications only, eligibility requirements as set forth in 90.17 (a) are extended to include part districts and authorities.

(2) Each application for a station or system shall be accompanied by:

(i) A statement certifying that the transmitter site of the Travelers' Information Station will be located at least 15.0 km (9.3 miles), measured orthogonally, outside the measured 0.5 mV/meter daytime contour of any AM broadcast station operating on a first adjacent channel (540 kHz or 1600 kHz). If the measured contour is not available, then the calculated 0.5 mV/m field strength contour shall be acceptable. These contours are available for inspection at the concerned AM broadcast station and FCC offices in Washington, D.C.

(ii) In consideration of possible cross-modulation and intermodulation interference effects which may result from the operation of a Tavelers'

Information Station in the vicinity of an AM broadcast station on the second or third adjacent channel, the applicant shall certify that he has considered these possible interference effects and, to the best of his knowledge, does not foresee harmful interference occurring to broadcast stations operating on 550 kHz, 560 kHz, 1580 kHz, of 1590 kHz.

(iii) A map showing the geographical location of each transmitter site and an estimate of the signal strength at the contour of the desired coverage area. For a cable system, the contour to be shown is the estimated field strength at 60 meters (197 feet) from any point on the cable. For a conventional radiating antenna, the estimated field strength contour at 1.5 km (0.93 mi) shall be shown. A contour map comprised of actual on-the-air measurements shall be submitted to the Commission within 60 days after station authorization or completion of station construction, whichever occurs later. A sufficient number of points shall be chosen at the specified distances (extrapolated measurements are acceptable) to adequately show compliance with the field strength limits.

(iv) For each transmitter site, the transmitter's output power, the type of antenna utilized, its length (for a cable system), its height above ground, distance from transmitter to the antenna, and the elevation above sea level at the transmitting site.

(3) Travelers' Information Stations will be authorized on a secondary basis to stations authorized on a primary basis in the bands 510-535 kHz and 1605-1735 kHz.

(4) A Travelers' Information Station authorization may be suspended, modified, or withdrawn by the Commission without prior notice of right to hearing if necessary to resolve interference conflicts, to implement agreements with foreign governments, or in other circumstances warranting such action.

(5) The transmitting site of each Travelers' Information Station shall be restricted to the immediate vicinity of the following specified areas: air, train, and bus transportation terminals, public parks and historical sites, bridges, tunnels, and any intersection of a Federal Interstate Highway with any other Interstate, Federal, State, or local highway.

(6) A Travelers' Information Station shall normally be authorized to use a single transmitter. However, a system of stations, with each station in the system employing a separate transmitter, may be authorized for a specified area provided sufficient need is demonstrated by the applicant.

(7) Travelers' Information Stations shall transmit only non-commercial voice information pertaining to traffic and road conditions, traffic hazard and travel advisories, directions, availability of lodging, rest stops and service stations, and descriptions of local points of interest. It is not permissible to identify the commercial name of any business establishment whose service may be available within or outside the coverage area of a Travelers' Information Station. However, to facilitate announcements concerning departures/arrivals and parking areas at air, train, and bus terminals, the trade name identification of carriers is permitted.

(b) TECHNICAL STANDARDS

(1) The use of 6A3 emission will be authorized, however, A0 emission may be used for purposes of receiver

quieting, but only for a system of stations employing "leaky" cable antennas.

(2) A frequency tolerance of 100 Hz shall be maintained.

(3) For a station employing a cable antenna, the following restrictions apply:

(i) The length of he cable antenna shall not exceed 3.0 km (1.9 miles).

(ii) Transmitter RF output power shall not exceed 50 watts and shall be adjustable downward to enable the user to comply with the specified field strength limit.

(iii) The field strength of the emission on the operating frequency shall not exceed 2 mV/m when measured with a standard field strength meter at a distance of 60 meters (197 feet) from any part of the station.

(4) For a station employing a conventional radiating antenna(s) (ex. vertical monopole, directional array) the following restrictions apply:

(i) The antenna height above ground level shall not exceed 15.0 meters (49.2 ft).

(ii) Only vertical polarization of antennas shall be permitted.

(iii) Transmitter RF output power shall not exceed 10 watts to enable the user to comply with the specified field strength limit.

(iv) The field strength of the emission on the operating frequency shall not exceed 2 mV/m when measured with a standard field strength meter at a distance of 1.50 km (0.93 miles) from the transmitting antenna system.

(5) For co-channel stations operating under different licenses, the following minimum separation distances shall apply:

(i) 0.50 km (0.31 miles) for the case when both stations are using cable antennas.

(ii) 7.5 km (4.66 miles) for the case when one station is using a conventional antenna and the other is using a cable antenna.

(iii) 15.0 km (9.3 miles) for the case when both stations are using conventional antennas.

(6) For a system of co-channel transmitters operating under a single authorization utilizing either cable or conventional antennas, or both, no minimum separation distance is required.

(7) An applicant desiring to locate a station that does not comply with the separation requirements of this section shall coordinate with the affected station.

(8) Each transmitter in a Travelers' Information Station shall be equipped with an audio low-pass filter. Such filter shall be installed between the modulation limiter and the modulated stage. At audio frequencies between 3 kHz and 20 kHz this filter shall have an attenuation greater than the attenuation at 1 kHz by at least:

$$60 \log_{10} (f/3) \text{ decibels}$$

where "f" is the audio frequency in kHz. At audio frequencies above 20 kHz, he attenuation shall be at least 50 decibels greater than the attenuation at 1 kHz.

90.403 GENERAL OPERATING REQUIREMENTS

(g) The radiation of the transmitter shall be suspended immediately upon detection or notification of a deviation from the technical requirements of the station authorization until such deviation is corrected. For transmission concerning the immediate safety-of-life or property, the transmissions shall be suspended as soon as the emergency is terminated.

90.419 POINTS OF COMMUNICATION

(e) Travelers' Information Stations are authorized to transmit certain information to members of the traveling public (see 90.241).

90.425 STATION IDENTIFICATION

(a) Except as provided in Paragraph (d) of this section, the required identification for stations in these services shall be the assigned call signal.

90.427 PRECAUTIONS AGAINST UNAUTHORIZED OPERATION

Each transmitter shall be so installed and protected that it is not accessible to or capable of operation by persons other than those duly authorized by and under the control of the licensee. Provisions of this part authorizing certain unlicensed persons to operate stations, or authorizing unattended operation of stations in certain circumstances shall not be construed to change or diminish in any respect the responsibility of station licensees to maintain control over the stations licensed to them (including all transmitter units thereof), or for the proper functioning and operation of those stations and transmitter units in accordance with the terms of the licenses of those stations.

90.429 CONTROL POINT AND DISPATCH POINT REQUIREMENTS

(a) Control point required. Unless permitted to be operated on an unattended basis, each station shall be provided with a control point.

(b) A control point is an operating position:

(1) Which must be under the control and supervision of the licensee.

(2) Where a person immediately responsible for the operation of the transmitter is stationed.

(3) Where the monitoring facilities required by this part are installed.

(c) Control point location. The location of the control point will be specified in the station license and will be assumed to be the same as that of the transmitting equipment unless an application for a different location has been approved by the Commission.

(d) Control point facilities required. At each point, the following facilities shall be installed:

(1) A carrier operated device which will provide continuous visual indication when the transmitter is radiating, or, a pilot lamp or meter which will provide continuous visual indication when the transmitter circuits have been placed in a condition to produce radiation:

(4) Facilities which will permit the person responsible for the operation of the transmitter to turn the transmitter carrier on and off at will.

90.433 OPERATOR LICENSE REQUIREMENTS

No operator license or permit is required for the operation of stations licensed under this part except as follows:

(a) Maintenance and tests. All transmitter adjustments or tests during the installation, servicing, or maintenance of a radio station which may affect the proper operation of such station shall be made under the immediate supervision and responsibility of a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph, who shall be responsible for the proper functioning of the station equipment.

(c) Transmitter with external controls. Transmitters so designed that during the course or normal rendition of service may result in off-frequency operation or in unauthorized radiation, and transmitters whose controls, which may cause off-frequency or improper operation or radiation, are readily accessible shall be operated by a person holding a first- or second-class commercial radio operator license, either radiotelephone or radiotelegraph, as may be appropriate for the type of emission being used.

90.437 POSTING STATION LICENSES

(a) The current original authorization for each station shall be retained as a permanent part of the station records but need not be posted.

90.439 INSPECTION OF STATIONS

All stations and records of stations in these services shall be made available for inspection at any reasonable time and any time while the station is in operation upon reasonable request of an authorized representative of the Commission.

90.443 CONTENTS OF STATION RECORDS

Each licensee of a station in these services shall maintain records in accordance with the following:

(a) For all stations, the results and dates of the transmitting measurements required by 90.215 of this part and the name of the person or persons making the measurements.

(b) When service or maintenance duties are performed on stations, the responsible operator shall sign and date an entry in the station record giving:

(1) Pertinent details of all duties performed by and under the supervision of the operator.

(2) The operator's name and address.

(3) The class, serial number and expiration date of the operator's license. Information stipulated in subparagraphs (2) and (3) of this paragraph need be entered only once in the station record at any station where the responsible operator is employed on a full-time basis and an operator's license is properly posted.

90.445 FORM OF STATION RECORDS

(a) Station records shall be kept in an orderly manner and in such detail that the date required are readily available. Key letters or abbreviations may be used if proper meaning or explanation is set forth in the record.

(b) Each entry in the records shall be signed by a person qualified to do so having actual knowledge of the facts to be recorded.

(c) No record or portion thereof shall be erased, obliterated, or willfully destroyed within the required retention period. Any necessary correction may be made only by the persons originating the entry who shall strike over the erroneous portion, initial the correction made, and indicate the date of the correction.

90.447 RETENTION OF STATION RECORDS

Records required by this part shall be retained by the licensee for at least one year.

FORM NTIA-29 (4-80)

U.S. DEPARTMENT OF COMMERCE
NAT'L. TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

BIBLIOGRAPHIC DATA SHEET

	1. PUBLICATION NO.	2. Gov't Accession No.	3. Recipient's Accession No.
	NTIA REPORT 85-178		

4. TITLE AND SUBTITLE
AN ASSESSMENT OF THE FUTURE OF TRAVELERS' INFORMATION STATIONS

5. Publication Date
SEPTEMBER 1985

6. Performing Organization Code
NTIA

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Department of Commerce
National Telecommunications & Information Administration
Institute for Telecommunication Sciences
Boulder, Colorado 80303

9. Project/Task/Work Unit No.
9014103

10. Contract/Grant No.

11. Sponsoring Organization Name and Address
U.S. Department of Commerce
National Telecommunications & Information Administration
179 Admiral Cochrane Drive
Annapolis, MD 21401

12. Type of Report and Period Covered
TECHNICAL

13.

14. SUPPLEMENTARY NOTES

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

This report is a study of Travelers' Information Stations (TIS) operating in the 525-535 and 1605-1615 kHz bands. It was prompted by the expansion of the AM broadcasting band from 1605 to 1705 kHz. Included is information on rules and regulations, allocation, technical standards, frequency assignments, and system characteristics. Potential compatibility problems are identified and analyzed. Alternate approaches and policies for TIS users are identified and assessed. Conclusions are drawn and recommendations made on the potential for sharing in the AM and FM broadcasting bands.

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

AM Broadcasting Band; Electromagnetic Compatibility (EMC); FM Broadcasting Band; 525-535 kHz Band; 1605-1615 kHz Band; Highway Advisory Radio; Nondirectional Beacons; Travelers' Information Stations (TIS)

17. AVAILABILITY STATEMENT	18. Security Class. *(This report)*	20. Number of pages
☒ UNLIMITED.	UNCLASSIFIED	116
☐ FOR OFFICIAL DISTRIBUTION.	19. Security Class. *(This page)* UNCLASSIFIED	21. Price: