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METEOR BURST SYSTEM COMMUNICATIONS COMPATIBILITY

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ABSTRACT

The technical and operating characteristics of meteor burst systems of importance for spectrum management applications are identified. A technical assessment is included which identifies the most appropriate frequency subbands within the VHF spectrum to support meteor burst systems. The electromagnetic compatibility of meteor burst systems with other equipments in the VHF spectrum is determined using computerized analysis methods for both ionospheric and groundwave propagation modes. It is shown that meteor burst equipments can cause and are susceptible to groundwave interference from other VHF equipments. The report includes tables of geographical distance separations between meteor burst and other VHF equipments which satisfy interference threshold criteria.

KEY WORDS

Compatibility
Interference
Meteor Burst
Spectrum Management

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SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA), the Executive Branch agency principally responsible for the development of both domestic and international telecommunications policy, is also responsible for managing the Federal Government's use of the radio frequency spectrum. NTIA establishes policies concerning spectrum assignment, allocation and use, and provides the various federal departments and agencies with guidance to ensure that their conduct of telecommunications activities is consistent with these policies.[1] In support of these requirements, NTIA has completed a number of spectrum resource assessments (SRAs). The objectives of these assessments are to evaluate spectrum use, identify existing or potential compatibility problems, provide recommendations to promote efficient use of the radio frequency spectrum, and improve spectrum management procedures. This assessment documents the electromagnetic compatibility of meteor burst systems in the VHF spectrum.

Recently, there has been increased interest in utilizing meteor burst systems for long range VHF beyond the line-of-sight (BLOS) communications and telemetry. The lower ionosphere is daily bombarded worldwide by billions of small meteors which, as they burn up in the upper atmosphere, create short-lived ionized trails. These trails are able to provide a BLOS ionospheric propagation path between ground-based transmitters and receivers. A meteor trail is available to provide a transmission channel between two BLOS locations once every 4 to 20 seconds. The lifetime of the channel is short (1/2 second duration) allowing only enough time for a "burst" of information to be transmitted before the meteor trail decays.

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[1]NTIA, Manual of Regulations and Procedures for Federal Radio Frequency Management, U.S. Department of Commerce, National Telecommunications and Information Administration, Washington, DC, revised September 1988.

The existence of meteor reflections at VHF frequencies has been known for several decades and there has been several past experimental programs to explore the usefulness of meteor reflections for communication purposes. The renewed interest in meteor burst communications stems from the recent availability of solid state memory devices which has made it possible to store information and transmit this information in a packetized digital bit stream "burst" when a meteor trail channel opens.

Meteor burst systems operate in the lower VHF band in the frequency range 30-100 MHz. The greatest use of meteor burst systems is expected to be in the 30-50 MHz frequency range. This spectrum is allocated predominantly to the fixed and mobile services. Both conventional and spread spectrum systems are in the band utilizing both analog and digital modulations.

OBJECTIVES

The objective of this study was to respond to a request of the Spectrum Planning Subcommittee (SPS) of the IRAC to assess the impact that expanded use of the meteor burst communication systems will have on the government VHF spectrum and identify approaches towards effective spectrum management of this technology.

APPROACH

1. The technical and operational characteristics for present and expected future meteor burst communications systems were defined. Current usage and regulatory issues were documented both in the government and commercial common carrier sectors.

2. The technical and operational characteristics of conventional VHF government communication equipments were defined, and an assessment was made of the available government VHF spectrum to support meteor burst applications.

3. Meteor Trail Channel Compatibility - An analysis was made of possible interference from signals reflected from ionized meteor trails.

4. Groundwave Compatibility - Although meteor burst probe transmitters provide communication by intermittent meteor reflections, the meteor burst equipment also continuously propagates groundwave signals. An analysis was made of the interference potential of the meteor burst groundwave signal to cochannel and adjacent channel receivers in the geographical area of the meteor burst transmitter. Also, the possible interference effects of reflection from high flying aircraft was examined.

5. Ionospheric Compatibility - The "footprint" and received signal from a meteor reflection are quite small. Thus, there is but a small chance of incompatible operation from the meteor scattering itself. However, during certain solar conditions, e.g., Sporadic E, blanketing Sporadic E, F_2 reflection VHF signals intended for meteor burst will also be reflected from the background ionosphere. During these conditions, the received signal strengths may be significantly larger and persistent relative to the 1/2-second duration meteor burst returns. The interference effects of these modes were assessed.

6. Sharing criteria were developed to help ensure at VHF frequencies compatible operation between meteor burst systems, as well as other radiocommunication equipments.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The conclusions of this study are grouped into three areas: frequency use, compatible operations, and others.

FREQUENCY USE

1. Meteor burst systems operate in the frequency range 30-100 MHz. It is generally acknowledged that the optimum band for normal operation of meteor burst systems is 40-50 MHz. This optimality stems from the ionospheric reflection properties of meteors.

2. The U.S. Government allocated subbands in the band 40-50 MHz are 40-42 MHz, 46.6-47 MHz and 49.6-50 MHz. The advantages of operating meteor burst systems in the lower subband 40-42 MHz, rather than the upper bands 46/49 MHz, are a somewhat larger meteor scatter signal return and greater channel throughput (see Section 4.1).

3. Nonlicensed consumer devices, such as cordless telephones, operate (unprotected and on a noninterference basis) along with government systems in the upper subbands 46 and 49 MHz. Forty percent of the bandwidth in these bands, (see Figure 17), is available for use by these unlicensed devices. Meteor burst systems operating cochannel may receive interference when located as far as 10 km away from these devices (see Figure 13).

4. When there is auroral absorption, meteor burst systems may advantageously make use of the upper subbands 46.6-47 MHz and 49.6-50 MHz. Moreover, during severe ionospheric disturbances and accompanying increased ionospheric absorption, meteor burst systems operate above 50 MHz. The only government allocated band in the frequency range 50-100 MHz which

permits transmitter power greater than 1 watt is 74.8-75.2 MHz. This band is allocated to the Aeronautical Radionavigation Service and is not appropriate for meteor burst operations. However, government operations may employ frequencies in nongovernment allocated bands between 25-2400 MHz for tactical and training purposes in accordance with the NTIA Manual.[2] (See APPENDIX C.)

5. Although the optimum band for meteor burst systems is 40-50 MHz, the bands 36-37 MHz and 38.25-39 MHz might also be considered for government meteor burst system use. Based on electromagnetic compatibility considerations, use of these bands is a consideration only when the meteor burst signal returns from other ionospheric modes is not likely to cause interference and groundwave compatibility is also assured.

COMPATIBLE OPERATIONS

6. The ionospheric signal returns from meteor burst stations have a small probability of causing an interference outage. When interference does occur, most likely during a sunspot maximum, real time equipment adjustments such as power, frequency or antenna changes are required to eliminate the interference.

7. Meteor burst master stations may be both a source (probe signals) and receptor to VHF groundwave interference. The separation distances between equipments for compatible cochannel sharing (joint simultaneous operation) with land mobile operations are in the range 90-320 km. When the equipments are on adjacent channels the separation distances are in the range 7-60 km. TABLES 7 and 8 of this report include numerical values for these separation distances for a variety of interference situations.

[2] Ibid., Section 7.15.3.

8. Meteor burst remote stations are susceptible to groundwave interference from other VHF equipments. The separation distances for cochannel use are 90-250 km and for adjacent channel use 10-38 km. See TABLE 8 of the report for the required separation distances for simultaneous operation. The signals transmitted from remote meteor burst stations are intermittent and unlikely to affect the intelligibility of other VHF systems. Thus, they are not judged to be an interference problem.

9. Adaptive data rate meteor burst systems, when they extend their bandwidths into adjacent channels, are more likely to encounter interference. This will be particularly true if the adapted bandwidth expands into an unlicensed device (e.g., cordless phone) channel.

10. The video IF frequency in U.S. television receivers is at 45.75 MHz with a bandwidth of 6 MHz (43.75-48.75 MHz) and the audio IF is at 41.25 with a 200 kHz bandwidth. Interference from meteor burst systems to television has not been reported but is of concern (see Section 5.7). It is also noted that the Allocation Table (see APPENDIX A) does not protect TV frequencies for government bands in 40-50 MHz.

11. The 20 kHz channeling plan for the 30-50 MHz band (NTIA Manual,[3] see Appendix C) is a good guide for meteor burst probe signals to follow and helps assure electromagnetic compatibility with other systems using the VHF spectrum. The intermittent meteor burst signals which have adaptive bandwidths greater than 20 kHz are an appropriate exception to the channeling plan (see Section 7.1).

OTHER

12. At the present time, within the United States, there are several operational meteor burst systems and a number of experimental and training

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[3]Ibid., Section 4.3.6.

systems. The applications, usage, and technology for meteor burst systems are undergoing continual change and improvement.

13. The SNOwpack TELemetry (SNOTEL) meteor burst system is an example of an effective and efficient use of the spectrum. Daily, data transfer from 550 remote terminals to a master station is accomplished by time shared use of a single frequency. Meteor burst systems are also being effectively used in Alaska for communication purposes.

14. There is expected to be much greater use of meteor burst systems outside the United States. Meteor burst systems can be used advantageously at geographical locations where the infrastructure of telecommunication equipments is not fully developed.

RECOMMENDATIONS

The following are recommendations based on the findings of this report. NTIA management will evaluate these recommendations to determine if they can or should be implemented from a policy, regulatory, or procedural viewpoint. Any action to implement these recommendations will be via separate correspondence modifying established rules, regulations and procedures. The recommendations are as follows.

1. The Spectrum Planning Subcommittee (SPS) and the Frequency Assignment Subcommittee (FAS) should utilize the conclusions and results of this study when assessing spectrum management situations involving meteor burst systems.

2. The SPS should continue to monitor meteor burst system usage and technology.

3. NTIA should use this study in the planning of frequency bands that support meteor burst communication systems.

SECTION 3

TECHNICAL CHARACTERISTICS OF METEOR BURST SYSTEMS

3.1 INTRODUCTION

This section describes the operation of a meteor burst system. Those technical characteristics which may affect the electromagnetic compatibility and spectrum management of meteor burst systems are discussed and explained. These include power, frequency, emission spectrum, and protocols of operation.

3.2 METEOR TRAIL ELECTROMAGNETIC CHARACTERISTICS

Every day, billions of meteors enter the Earth's upper atmosphere (around 100 km) and burn up. The burning up of each meteor produces an ionized trail. Radio waves with frequencies in the lower VHF spectrum (30-100 MHz) can be reflected from these meteor trails as a beyond the line-of-sight (BLOS) propagation mode for distances up to 2000 km. To provide a communication channel between two stations, the meteor trail must be spatially located in the common volume of the antenna patterns of two stations. The antennas used with meteor burst systems usually have half-power beamwidths of about 30 degrees.

A meteor burst communication link functions in the following manner. A probe signal is sent repeatedly into the upper atmosphere from a master station. A remote station waits and listens for the probe to be reflected by a meteor trail. When the remote station receives the probe signal it sends a message back to the master that a communication channel is open. The master acknowledges the remote and the "handshake" is complete. The master and remote commence communication in half or full duplex mode and continue to operate until the meteor trail decays and the channel closes (approximately 1/2-second duration). The master then returns to transmitting the probe signal, beginning the process anew.

The magnitude of the signal received from an underdense meteor trail reflection, see Sugar 1964,[4] is

$$P_R(t) = \frac{P_T G_T G_R}{f^3} S(\xi) \exp\left[-T(\xi) f^2\right] \exp(-2t/t_o) \qquad (1)$$

where

$P_R(t)$ = received power

P_T = transmitter power

G_T, G_R = antenna gain

f = frequency

$S(\xi)$, $T(\xi)$ = geometric and physical dependent factors

$t_o = \frac{U(\xi)}{f^2}$ and $U(\xi)$ = geometric and physical dependent factors.

The time dependence e^{-2t/t_o} in Equation (1) accounts for the observed fact that the shape of the meteor return is a decaying exponential in time. The Equation (1) shows that the factors which determine the signal return for a meteor burst system are P_T, G_T, G_R, f, and geometric and physical dependent factors. Operationally, some representative values for the parameters in Equation 1 are P_T = 300 watts, $G_T = G_R$ = 10 dBi and f in the range 40-50 MHz. The communication performance depends not only on $P_R(t)$, but is also dependent upon the required (E_b/N_o) for the particular digital modulation utilized and N_o the noise level in the vicinity of the receiver. Examples of the modulations used are PSK and FSK both coherent and incoherent.

Examples of peak returns from underdense meteor scatter, shown in Weitzen and Ralston,[5] vary from -112 dBm to -95 dBm. A typical return from an

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[4]Sugar, G.R. Radio Propagation by Reflection from Meteor Trails, Proceedings IRE, Vol. 52, pp. 116-136, 1964.

[5]Weitzen, J. A. and W. T. Ralston, Meteor Scatter: An overview, IEEE Transactions on Antennas and Propagation, December 1988.

individual underdense meteor for this study will be assumed to have a return of -110 dBm. Typical noise powers for a 16 kHz occupied bandwidth in the 40-50 MHz frequency range are: man-made suburban (-106 dBm), and galactic noise (-120 dBm). Since the man-made noise and the typical meteor burst signal are comparable in magnitude, whenever possible, meteor burst receivers are placed at low noise sites.

The times between available meteor channel openings are random and distributed exponentially with time as a Poisson process. The coherence bandwidth of the meteor scatter is quite large, up to 1 MHz. Some meteor burst systems take advantage of this large coherence bandwidth and during a burst expand their transmit and receive bandwidth to optimize the throughput possible during the burst. A diagram of a meteor burst system is shown in Figure 1. The diagram shows the ray paths to the meteor trail along with ray paths to other ionospheric reflectors which may be prevalent at VHF frequencies. The maximum range for a meteor burst path is 2000 kilometers. This maximum distance is fixed by the ray path geometry over a curved earth to a meteor trail at an altitude of 100 km. Meteors can be categorized as either underdense (electron densities < 10^{14} electrons/meter) or overdense (electron densities > 10^{14} electrons/meter). The underdense meteors are more common and provide the majority of the communication channels.

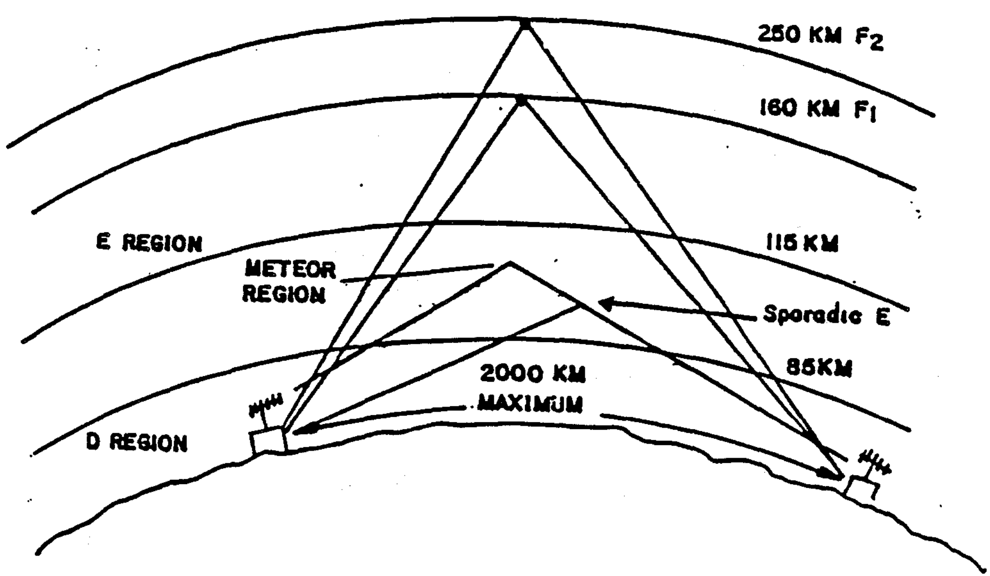

Figure 1. Meteor Burst System Geometry. Figure 1 shows ray paths to the meteor scatters along with ray paths to other ionospheric reflectors at VHF frequencies.

3.3 METEOR BURST SYSTEM PROTOCOLS

There are at present three basic equipment configurations for meteor burst systems. These are one-to-one communication, networking, and broadcast. For both one-to-one and networking the master station transmits repeatedly a probe signal of frequency f_1. The remote station listens for the master and when it detects a signal intended for it, sends back a signal (at frequency f_1 or a different frequency f_2) to the master station. The master detects the signal and returns an acknowledgment to the remote. This completes the handshake and communications can proceed. In the "broadcast" mode, the master sends a message repeatedly without acknowledgment from the remotes. The message is repeated a sufficient number of times to, hopefully, assure reception.

It is apparent that for all equipment configurations the duty cycle (on-time) for the master station is quite high and the duty cycle for the remotes is small (one-to-one and networking) or zero (broadcast modes).

The above describes the general operating principle for a meteor burst system. Based upon these general principles, along with certain variations in operation, at least five different operating protocols have been considered to effectively utilize meteor burst channels for communication. TABLE 1 lists these protocols and their characteristics. Protocol (1) is used for data acquisitions such as determining snow depth at a remote site. Meteor burst systems operating with this protocol after the handshake has taken place operate on a half-duplex basis. Protocol (2) is a communication system protocol. Once the handshake has taken place, communication on two frequencies takes place in a full duplex manner. The communication consists of individual packets of a digital message which might be voice. A variation on protocol (2) is that found in protocol (3). In this protocol, before the handshake takes place, both the master and remote are continually transmitting probe signals. The advantage of such a system is that data transmission can start quicker and the channel is used more effectively. However, this requires the remote to be on continually. It is our understanding that this protocol is not being used in the United States but may be under consideration for use elsewhere is the world. This protocol shall not be considered further here.

Protocol (4) is applicable to adaptive data rate systems. In an adaptive data rate system, during the handshake and afterwards, a quantitative measure is made of the magnitude of the signal from the meteor trail. Based upon this measure, the data rate (Kb/s) and the transmitter and receiver bandwidth are altered to send the optimum data rate the meteor trail can support. The use of adaptive data rates and a correspondingly larger bandwidth has the potential to improve the throughput for a meteor burst system by a factor of 10 (see Reference 5 on page 9). Both adaptive and non-adaptive system operations are identical prior to a handshake. Once this handshake has taken place, the protocol (4) included the ability to adapt the system parameters such as bandwidth and data rates.

Protocol (5) is a broadcast meteor burst mode. The protocol (1) to (4) are one-to-one. In protocol (5), the master station repeatedly transmits its message, on a single frequency f_1 to N remotes hoping that over a sufficient time period, a meteor burst channel will open to all N of the remotes. The remotes are in a receive mode only.

TABLE 1

METEOR BURST SYSTEM PROTOCOLS

Protocol	Purpose	Before Handshake	After Handshake
1.	Data Acquisition Half-Duplex f_1, f_2 $\lvert f_1 - f_2 \rvert \cong 1$ MHz	Master on Remote off	Master on but alternating Remote on but alternating
2.	Communication Full-Duplex f_1, f_2 $\lvert f_1 - f_2 \rvert \cong 1$ MHz	Master on Remote off	Master on Remote on
3.	Communication Full-Duplex f_1, f_2 $\lvert f_1 - f_2 \rvert \cong 1$ MHz	Master on Remote on	Master on Remote on
4.	Communication Full-Duplex Adaptive Data Rate	In 20 kHz channel Master on Remote off Beyond 20 kHz channel Master off Remote off	In 20 kHz channel Master on Remote on Beyond 20 kHz channel Master on Remote on
5.	Broadcast	Master on Remote off	Master on Remote off

SECTION 4

FREQUENCY BANDS AND EMISSION CHARACTERISTICS FOR METEOR BURST COMMUNICATION SYSTEMS

4.1 FREQUENCY BANDS

The general bounds on the frequency of operation for meteor-burst systems fall in the range 30-100 MHz. The complete international and national frequency allocations for this frequency range are included in APPENDIX A of this report. Additional rules and regulations from the NTIA Manual relating to frequency use for systems in this range are found in APPENDICES B and C. Under normal ionospheric conditions (including auroral absorption), the optimum frequency band for meteor burst systems is 40-50 MHz. The optimum frequency range (40-50 MHz) is thus a 10 MHz frequency segment. Within this optimum band, the U.S. Government subbands are 40.0-42.0 MHz, 46.6-47 MHz, and 49.6-50 MHz.

The peak signal power return from a meteor trail varies as f^{-3} and the average time duration of a meteor reflection varies as f^{-2}. Combining these two factors together and including the fact that galactic noise (which determines the required threshold signal) varies as $f^{-2.3}$, the information duty cycle (I_c) for a meteor burst system has a frequency dependence of

$$I_c \sim f^{-2.7} \qquad (2)$$

where I_c = information duty cycle (CCIR Report 251-4)
= proportion of time a given signal/noise ratio is exceeded.

Figure 2 plots together each of these frequency dependent terms over the optimum frequency range 40-50 MHz. Each of the terms in Figure 2 has been normalized to a value of 1 at f=40 Megahertz so that a comparison can be made among the variability of the terms in the range 40-50 MHz. It can be seen

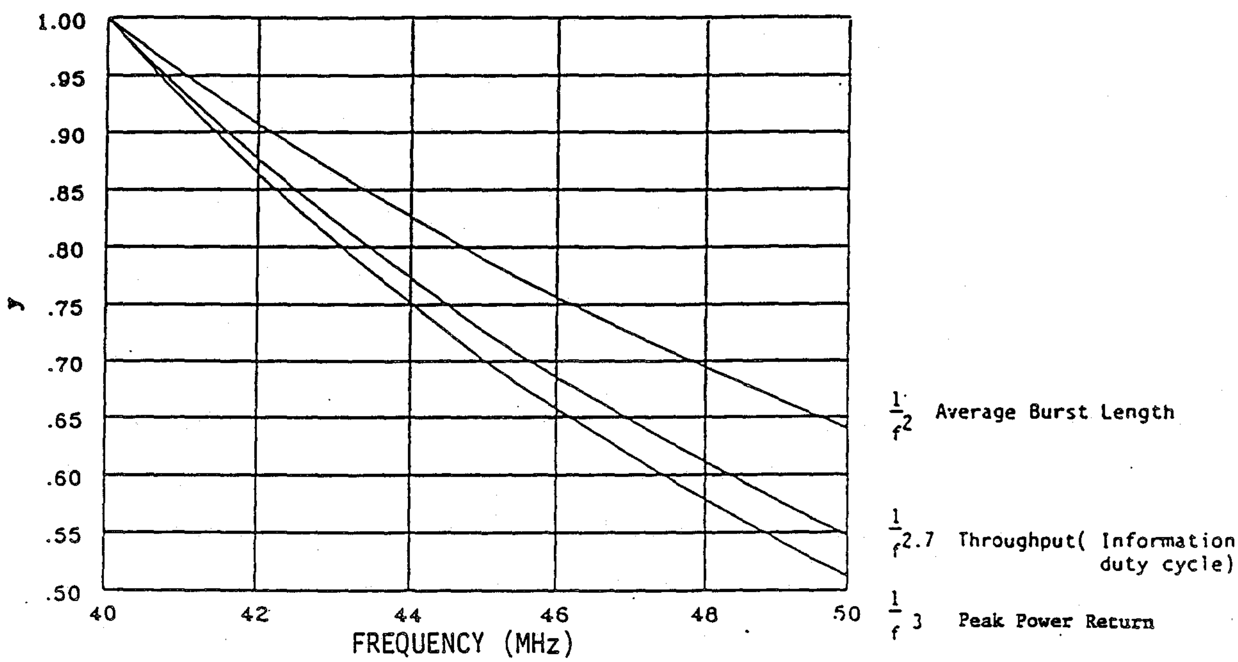

Figure 2. Frequency Dependent Terms in the range 40-50 MHz.

that the Information Duty Cycle, I_C, which is directly related to the throughput of the meteor channel is about two times larger at 40 MHz than the throughput at 50 MHz. The peak signal power level is also about two times larger at 40 MHz than at 50 MHz. Similarly, the average time duration of a meteor signal is about $1\frac{1}{2}$ times larger at 40 MHz than at 50 MHz. Thus, under regular ionospheric conditions and considering those parameters of meteor burst systems which are frequency dependent, it can be concluded that it is advantageous to operate in the lower ranges of the 40-50 MHz band.

As discussed earlier, there are cases when nonregular and disturbed ionospheric conditions dictate the use of higher frequencies. One example is the occurrence of auroral scatter in high latitude operations (e.g., Alaska).[6] When occasional auroral scatter is present, there is considerable fading and multipath. These auroral effects can usually be overcome by operating at higher frequencies.

The transmission equations for the meteor burst process itself yield a throughput $\sim f^{-2.7}$ signal return $\sim f^{-3}$ and average burst length $\sim f^{-2}$. This would suggest, for an undisturbed ionosphere, the use of as low a frequency as possible, i.e., below 40 MHz. However, when frequencies below 40 MHz are used other ionospheric modes such as Sporadic E, ionscatter, and F region reflection become more likely. These modes have a much greater possibility of occurrence as frequency decreases below 40 MHz. When these modes are prevalent, their signal strengths will tend to exceed or mask the meteor signal return. These modes, although a bonus, are characterized by multipath effects which are oftentimes less than advantageous for reliable communications. Nevertheless, the operation of meteor burst systems at frequencies below 40 MHz should be considered. From an interference perspective, the best times are those when other ionospheric propagation modes are less likely to occur.

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[6]Weitzen, J.A., M.J. Sona and R.A. Scofidio, "Characterizing the Multipath and Doppler Spreads of the High-Latitude Meteor Burst Communication Channel," IEEE Transactions on Communication, Vol. COM-35, No. 10, October 1987.

The COMET system operated successfully in the early 60's using frequencies between 35-40 MHz.[7] The government bands in the range 35-40 MHz are the fixed and mobile bands 36-37 MHz and 38.25-39 MHz. Although the optimum band for meteor burst is generally agreed to be 40-50 MHz, these bands between 35-40 MHz should be considered for meteor burst use, particularly if there is frequency congestion and groundwave interference in the 40-50 MHz frequency region.

The operation of a meteor burst system at frequencies above 50 MHz results in less throughput and longer wait times for transmission of a message. Under most ionospheric conditions, the deleterious effect on meteor burst systems of D region absorption is under 1 dB and not even included in determining system parameters for a meteor burst system. During the times of a severely disturbed ionosphere significant D region absorption prevails. The absorption has a f^{-2} frequency dependence which means that the use of higher VHF frequencies will have less loss due to absorption. Thus during a severely disturbed (man-made or natural) ionosphere, meteor burst systems will operate above 50 MHz. In the frequency range 50-100 MHz, the only government band permitted with transmitter powers greater than 1 watt is 74.8-75.2 MHz. This band is allocated to the Aeronautical Radionavigation Service and is not appropriate for meteor burst system use. However, government operations may employ frequencies in non-government allocated bands between 25-2400 MHz for tactical and training purposes in accordance with the NTIA Manual (see Ref. 1), Sections 7.15.3-7 (see APPENDIX C).

4.2 SPECTRUM STANDARDS

Digital modulations are used for meteor burst systems. The necessary bandwidths for these modulations are found in Appendix J of the NTIA Manual. For a given class of emission (modulation type) the necessary bandwidth is the width of the frequency band which is just sufficient to ensure the

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[7] Bartholome, Pierre J. and Irmfried M. Vogt, "Comet - A New Meteor Burst System Incorporating ARQ and Diversity Reception," IEEE Trans. on Comm., Vol. COM-16 No. 2, pp. 268-278, April 1968.

transmission of information at the rate (bits/second for digital modulation) and with the quality required.

Another measure of bandwidth is the occupied bandwidth. The occupied bandwidth for telecommunication equipment is the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage B/2 of the total mean power of a given emission. Unless otherwise specified by the CCIR, the value of B/2 should be taken as 0.5%. In practice, all reasonable effort shall be afforded to maintain the occupied bandwidth as close to the necessary bandwidth as practical. Meteor burst system designers have inquired what spectrum properties of meteor burst signals are of importance for electromagnetic compatibility. Each probe signal for a meteor burst station should follow the NTIA channeling plan for assignments in the 30-50 MHz band (NTIA Manual (see Ref. 1) Section 4.3.6, APPENDIX (C) of this report). Probe signals can fit into one channel of the 30-50 MHz channel plan. Each channel has a frequency width of 20 kHz. The probe signal spectrum, outside the channel bandwidth, should obey the constraints shown in TABLE 2.

TABLE 2

ADJACENT CHANNEL SPECTRUM

f_d	Attenuation
5 kHz < f_d < 10 kHz	83 log (fd/5) dB
10 kHz < f_d < 250% BW	29 log (fd^2/11) or 50 dB, whichever is less
fd > 250% BW	Land, Fixed, Mobile 50 + 10 log (unmodulated carrier power) dB
	Portable 43 + 10 log (unmodulated carrier power) dB

where f_d = deviation from carrier frequency.

These constraints are designed to limit adjacent channel interference from and to mobile systems. Also, land (fixed and mobile) receivers in the 30-50 MHz frequency region have for adjacent channel selectivity a standard in the NTIA Manual of 80 dB.

SECTION 5

METEOR BURST AND OTHER VHF SYSTEMS

5.1 INTRODUCTION

The use of meteor burst systems are either for telemetry or for communications. Meteor burst telemetry systems are used to transmit from a remote station back to a master station environmental and other data measured at the remote station. Communication meteor burst systems provide a low data rate BLOS link between the master and remote stations. In the United States, the major users of the VHF spectrum in the frequency range 30-100 MHz are land mobile, broadcasting and aeronautical radionavigation. Also using the VHF spectrum are unlicensed low power communication devices such as cordless telephones which operate in accordance with Part 15 of the FCC Rules and Regulations.

5.2 METEOR BURST TELEMETRY SYSTEMS

Probably the largest meteor burst system is the SNOWPACK Telemetry System (SNOTEL) operated by the Soil Conservation Service of the United States Department of Agriculture. This system, begun in 1977, measures and transmits, on a daily basis, snowpack and precipitation data from locations throughout the West. About 550 stations are in operation with the remote sites powered by solar panels. Master stations are in Boise, Idaho and Ogden, Utah. The SNOTEL system is an example of an effective and efficient use of the VHF spectrum since only a single frequency is used to communicate with all 550 remote stations.

Another system used to gather telemetry data is the Alaska Meteor Burst Communication System (AMBCS). This system is used by five government agencies to gather data: National Weather Service (remote weather data), Bureau of Land Management (surveying camps), Soil Conservation Service (water resources data), U.S. Geological Survey (stream and water gauging), and the Corps of Engineers (accumulate environmental data). The master station is in

Anchorage, Alaska. The transmitter and receiver frequencies are separated about 1 MHz to permit full duplex operation.

Another possible future use of the meteor burst system may be to monitor pipelines. These environmental data gathering meteor burst operations usually operate with 300-500 watt master stations and 300 watts remote. They operate in the lower part of the 40 MHz band with 20 kHz bandwidth channels.

5.3 METEOR BURST EMERGENCY COMMUNICATIONS

The Federal Emergency Management Agency (FEMA) has developed the concept for a Meteor Burst Warning/Communications Subsystem (MBWCS). The FEMA MBWCS concept, which is complementary to the landline oriented National Warning System (NAWAS), is to include 10 regional meteor burst (MB) master station terminals (MST), MB transceivers at the Emergency Operations Centers (EOC) of the 48 contiguous states, and MB warning receivers at 5000 designated warning points (including 2600 current NAWAS warning points) throughout the Nation. Coded national warning messages, injected by HF radio or landline from the National Warning Center (NWC) or Alternate NWC, will be acknowledged, automatically converted to short preformatted messages, and broadcast to adjacent master stations, State EOCs, and warning receivers. The MBWCS also will provide two-way point-to-point communications between adjacent master stations, and master stations and State EOCs within designated areas. The system is nonadaptive.

The equipment characteristics for the system are:

Transmitters: Master Stations - 10
State EOCs - 48 (Transceivers)
Power - 1 kW
Modulation - Bi-phase shift keyed (BPSK)
Warning-Omni - Communications (Pt-Pt)

Receivers: At Master Stations sites - 2-4 (approx. 24 total)
State EOCs - 48 (Transceivers)
At Warning Points - 5000

Messages: Data Rate - 4000 bps
Format - ASCII coded teletype (Pt-Pt) Binary (Warning)

Frequency: 40-50 MHz (Three frequencies for the system; each MST will transmit on one and receive on two frequencies. Each EOC will use one transmit and one receive frequency.

5.4 METEOR BURST COMMUNICATION SYSTEMS

Meteor burst communication systems operate by transmitting packets of digitized information during the channel openings. The advantage of meteor burst is that it can provide reliable communications for low-rate data and slow teletypes to and from remote sites where other modes of communication (satellite, microwave, and telephone) are unavailable or may be lost in an emergency. Previously, HF has been used in these circumstances, but HF frequencies must be changed regularly and at times HF signals can be unavailable for long periods of time due to the variances of the ionospheric properties. Meteor burst systems, although intermittent, utilize a reliable stationary communication channel.

Meteor burst system users choose transmitter power antenna size, receiver threshold, frequency, and data rate depending upon the communication requirement. For example, lower data rates are used when the message waiting time is more important than the amount of data to be transmitted in a given amount of time.

Meteor burst systems have found a place in Alaska to provide a thin route low data rate communication system for private users. The company, Alascom, provides long distance communication links across Alaska. The company operates a meteor burst communication system as a satellite back-up. The FCC (1988) provision on the use are the allowed frequencies 42.4, 44.10, 44.2, and 45.9 MHz. The base station power is limited to 2000 watts for base stations and 500 watts for remote stations. Cochannel base stations of different licensees are to be located 150 miles apart. (A waiver of the distance separation requirements is possible if a cooperative sharing arrangement can be reached.) The emission is to allow for PSK or FSK keying and the maximum authorized bandwidth is 20 kHz.

Meteor burst research is proceeding towards improving the understanding of the propagation mechanism and improving the technology and techniques (see Reference 5). There is currently considerable testing of meteor burst systems to determine the bounds on the communication capabilities (e.g., throughput, wait time) of meteor-burst systems. Some of the testing experiments have been carried out at high latitudes since meteor burst technology has both applications and advantages at high latitudes. Another subject of interest is the application of meteor burst scatter for short range BLOS communication distances less than 400 km.[8]

Meteor burst communication systems in 1987 have advanced to include the communication capabilities shown in TABLE 3.[9]

TABLE 3

METEOR BURST SYSTEM CHARACTERISTICS
(SOURCE: See Reference 9)

Adaptive Data Rates
Forward Error Correction
Networking
8000 Character Message Lengths
Average Throughput: 300 Words Per Minute
Message Wait Time: 1.5 Minutes

The meteor burst technology is continually improving and much has happened during the past five years. It is therefore difficult to extrapolate

[8]Weitzen, J.A., Communicating Via Meteor Burst at Short Ranges, IEEE Transactions on Communications, Vol. COM-35, No. 11, November 1987.

[9]Morgan, E.J., "Meteor Burst Communications: An Update," Signal, pp. 55-61, March 1988.

into the future the expected numbers and uses for meteor burst systems in the United States. One area in which progress has been made is in the size and complexity of the meteor burst equipment. Backpack terminals with easy set up are now feasible. Another application is to provide two-way communication with trucks (see Mickelson, 1989).[10] The FCC has authorized such a system to be operated on motor carrier service frequencies. The number of mobile units is expected to be in the tens of thousands.

5.5 VHF SYSTEMS

The U.S. VHF spectrum from 30-110 MHz is divided into 26 bands. These bands generally alternate between exclusive government and exclusive non-government bands as seen in APPENDIX A. There are only two bands that are shared between government and nongovernment from 30 to 50 MHz, and these are shared radio astronomy allocations. From 50-110 MHz, there are four shared bands, which are all in the 73-75.4 MHz spectrum region. These shared bands between government and nongovernment include radio astronomy from 73-74.6 MHz, fixed and mobile between 74.6 and 74.8 MHz and 75.2 to 75.4 MHz, and aeronautical radionavigation from 74.8 to 75.2 MHz.

In the 30 to 40 MHz band, the greatest use by government is for land mobile systems. The station class ML (a land mobile station) has the greatest number of assignments. In the 40 to 50 MHz band, the greatest number of assignments for a given station class is to ML. The meteor burst communication system, which is comprised of the Department of Agriculture's SNOTEL network, makeup the major assignments for the second most used station class in this band--FXH. The FXH designator is a fixed station used for the automatic transmission of either hydrological or meteorological data, or both. Most uses in this band are for land mobile systems, although aeronautical mobile and maritime mobile are also in use.

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[10] Mickelson, K. D. Tracking 64,000 vehicles with meteor scatter radio, Mobile Radio Technology, pp 24-38, January 1989.

In the band from 50 to 100 MHz, the major use is by the private sector, with amateur, TV broadcasting, and FM radio broadcasting being major spectrum allocations. The major government requirement in this band is for aeronautical radionavigation in the sub-band 74.8-75.2 MHz (78 percent of assignments) to the RLA station class, which is for aeronautical marker beacon stations. Various types of mobile stations make up the greatest portion of the remaining assignments.

Nongovernment allocations from 30 to 40 MHz are mainly to land mobile (six subbands) and one subband to exclusive radio astronomy and one secondary allocation also to radio astronomy shared with land mobile primary. There is a wide variety of communication services in these bands. There are four service types under the land mobile allocation that assignments are made to in the 30 to 40 MHz band. These are industrial, land transportation, public safety, and domestic public.

Assignments under industrial include businesses such as construction companies, plumbing companies, well drilling companies, petroleum and gas pipeline companies, companies involved in forest products, and almost any business that has a radio dispatched vehicle. There are a few assignments in the 30-40 MHz band to land transportation services. However, assignments to land transportation include bus lines, rapid transit systems, metro area transit authorities, trucking companies, and air transit companies. Assignments to domestic public services include radio paging systems, radio telephone systems, and telephone answering services. Assignments under public safety include police and highway patrol, emergency vehicles such as ambulances and paramedic teams, city and rural fire departments, highway maintenance vehicles, state parks and recreation areas, and local government vehicles. There are Federal Government assignments in some of these public safety subbands, particularly those departments and agencies with law enforcement responsibilities so they can communicate with local and state law enforcement personnel and offices.

The 40 to 50 MHz band for nongovernment allocations is to land mobile in two subbands from 42 to 46 MHz and from 47 to 49.6 MHz. The assignments are to the same four activities under land mobile as given above for the 30 to 40 MHz band. There are assignments in this band to the land transportation services and to power companies under the industrial allocation. There are also assignments to the experimental station classes such as experimental development, experimental research, and experimental contracts that are used mainly for new system development. The 40 to 50 MHz band is used extensively by the public safety services including local police departments, highway patrol, fire station vehicles, ambulances, and highway maintenance vehicles.

There is an allocation to industrial, scientific and medical (ISM) equipment in the subband 40.66-40.70 MHz. Industrial heating equipment emits radiation in the band 40.66-40.70 MHz. Meteor burst receivers operating in industrial areas may be in close proximity to these industrial devices.

Also allocated in portions of the band 40-50 MHz are low power unlicensed communication devices. These include cordless telephones and child monitors. Cordless telephone use is increasing dramatically. For example, 3,343,511 cordless telephones were imported in 1985; in 1986 the number increased to 5,377,999; and in 1987 the total number imported was 8,666,473.[11]

The 50 to 100 MHz band is divided into ten subbands; six are to exclusive nongovernment use and four are shared with government. From 50 to 73 MHz is exclusively non-government with amateur allocations from 50 to 54 MHz, television broadcasting from 54 to 72 MHz, and fixed and mobile from 72 to 73 MHz.

The spectrum from 73 to 75.4 MHz is shared equally between government and non-government. From 73 to 74.6 MHz, the allocation is to radio astronomy. From 74.6 to 74.8, the allocation is to fixed and mobile coequal primary. The subband from 74.8 to 75.2 MHz is allocated to aeronautical radionavigation, and the subband from 75.2 to 75.4 MHz is allocated to fixed and mobile again coequal primary.

The spectrum from 75.6 to 108 MHz is allocated to non-government exclusive services. From 75.4 to 76 MHz, the allocation is to non-government fixed and mobile coequal primary; 76 to 88 MHz is allocated to television broadcasting; and 88 to 108 MHz is allocated to FM radio broadcasting.

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[11]Bureau of the Census, private communication, 1988.

Nongovernment uses are varied and include public safety, industrial, and experimental from 50 to 57 MHz with many TV assignments at 57 MHz. Between 57 and 63 MHz, there are about the same distribution of assignments as in the 50 to 57 MHz subband with many TV assignments at 63 MHz. From 63 to 69 MHz, the assignments are mainly to industrial business with some experimental development assignments. There are many TV assignments at 69 MHz. From 69.1 to 74.6 MHz, there are many assignments to the industrial manufacturing. There are also many assignments to public safety services including police, highway patrol, firefighting vehicles, and other emergency vehicles. At 75 MHz, there are many assignments to the AR station designator which is assigned for aeronautical radionavigation. From 75.1 to 78.5, the assignments are to industrial, public safety, domestic public, land transportation, and experimental. At 79 MHz there are a number of TV assignments, and from 79.1 to 84.5, the assignments are mainly to industrial services. From 85 to 88 MHz, the assignments are to TV stations, and from 88 to 108 MHz, the assignments are to the Broadcasting service for FM radio stations.

Frequencies in the band 40.66-40.70 MHz may be authorized to government and nongovernment stations on a secondary basis for the tracking of, and telemetering of scientific data from ocean buoys and wildlife (U.S. Footnote 210). The operation in this band is subject to the technical standards specified in (a) Section 8.2.42 of the NTIA Manual (see APPENDIX C for the text) or Section 5.108 of the FCC's Rules.

The frequencies 36.25 and 41.71 MHz may be authorized to government and nongovernment stations in the Petroleum Radio Service for oil spill containment and cleanup operations. The use of these frequencies is limited to the inland and coastal waterway regions. (See APPENDIX C for the text.)

5.6 SYSTEM CHARACTERISTICS

Major systems in the 30 to 100 MHz band are mainly land mobile and other fixed and mobile types for both government and nongovernment. Concerning VHF technical parameters, receiver sensitivities are around 0.5 μV/m for most land mobile systems. Powers range from tenths of a watt for certain remote control and remote sensing systems to 100 W for land mobile systems (a few higher) with meteor burst systems running up to 10,000 W. There are a few specialized radar systems used by NOAA for research in wind studies and auroral scatter that range in power from 10 to 40 kW. NASA has a system that operates around 50 MHz that can transmit 400 kW and supports its deep space probes. The NSF has a 200 kW transmitter at Arecibo, Puerto Rico, used to support research experiments.

5.7 TELEVISION RECEIVER INTERMEDIATE FREQUENCIES (IF)

The video IF in U.S. televisions is at 45.75 MHz with a bandwidth of 6 MHz (43.75-48.75 MHz) and the audio IF is at 41.25 MHz with a 200 KHz bandwidth.

The FCC in its Report and Order 83-348 authorizing meteor burst operations in Alaska noted that the meteor burst transmitter frequencies they were proposing to authorize fell within the passband of television IF frequencies.[12] Accordingly, they decided to issue meteor burst grants on a developmental grant basis. The FCC stated in the Report and Order that "while it is true that no reported interference complaints have been received regarding Government or experimental nongovernment operations in Alaska, our experience with this band indicates that it is possible to have interference to television receivers as was developed in FCC docket 80-189."[13]

Interference to television is of concern, but it is also noted that the Allocation Table (APPENDIX A) does not protect TV receiver IF frequencies.

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[12]FCC, Report and Order 83-348 Amendment of Parts 2, 22, and 90 of the FCC Rules and Regulations to Provide for the Use of Meteor Burst Communications, July 22, 1983.

[13]FCC Docket 80-189 Authorized the Use of Certain 40-50 MHz Frequencies for One-Way Signaling (Meteor Burst), July 28, 1981.

SECTION 6

IONOSPHERIC COMPATIBILITY

6.1 INTRODUCTION

This section is the compatibility assessment for ionospheric propagated modes.

CCIR Report 259-6 identifies those ionospheric reflected signals which may lead to interference at frequencies between 30 and 300 MHz.[14] The most prevalent of these interference signals are reflections or scatter from: (1) meteor ionization, (2) Sporadic E reflection and scatter, and (3) regular F-layers. Because the maximum propagation range of these types of ionospheric signals can extend to ranges of 500-4000 km, there is the potential for interference over large geographical areas. The most likely occurrences of each of these interference sources is time (e.g., diurnal, seasonal, and yearly) dependent and also spatially dependent (i.e., low-latitude, temperate, equatorial). The actual times of occurrences of each of these interference signals can only be predicted statistically. Each of these different types of ionospheric propagated interference signals will be considered separately.

6.2 METEOR IONIZATION

Experimentally, it has been found that typical received signals from meteor trails reflection have signal magnitudes of -110 dBm with returns separated on an average of 4 to 20 seconds. The average duration of a signal is .58 seconds.[15] During the times of meteor showers, the average time between meteor reflection is less.

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[14]CCIR Report 259-6, VHF Propagation by Regular Layers, Sporadic E or other Anomalous Ionization, Doc. XVI Plenary, (1986a).

[15]Oetting, J.D., An Analysis of Meteor Burst Communications for Military Applications, IEEE Transactions on Comm. COM-28, pp. 1591-1601, September 1980.

Based upon the above signal characteristics, it is apparent that an interfering signal from a meteor trail is short lived and might cause at most a short interruption to a wanted signal. Miller and Licklider have determined the impact of short interruption on percent word articulation index.[16] The impact depends upon two parameters; the noise time fraction which is the duty factor of the noise and the number of interruptions per second. The typical meteor burst signal described above has a noise time factor = (.58/4) = .12 and the number of interruptions/second = (1/4) = .25. The percent word articulation index for this interference would be about .95 which is more than acceptable for most, if not all, communication purposes. Moreover, the typical signal return of -110 dBm is a relatively weak signal on a par with galactic noise levels and is unlikely to cause interference to other VHF systems such as land mobile. The possibility of interference is further reduced since each meteor acts as a directional antenna and focuses the energy it radiates to the ground in a small "footprint" with dimensions of 5 x 40 km. It is concluded that meteor scatter signals are not a likely source of interference to other users of the VHF spectrum.

6.3 SPORADIC E REFLECTIONS

The potential for meteor burst station signals which are reflected from Sporadic E ionization to cause interference can be assessed by use of the CCIR recommended Sporadic E field strength calculation method.[17] This calculation method was used to compute expected signal returns from Sporadic E ionization for the equipment parameters: P_T = 10 kw, $G_T = G_R$ = 10 dBi. Figure 3 plots the calculated expected received power as a function of transmitter frequency and separation distance between the transmitter and receiver. The critical frequency of Sporadic E was 13 MHz for the calculations. Figure 3 shows that the signal powers from Sporadic E returns are of the same order of magnitude (i.e., -110 dBm) as meteor trail returns.

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[16] Miller and J. C. Licklider, Intelligibility of Interrupted Speech, Journal Acoustical Society of America, Vol. 22, No. 2, March 1950.

[17] CCIR Recommendation 534-2, Methods for Calculating Sporadic-E Field Strength, Doc. XVI Plenary, 1986b.

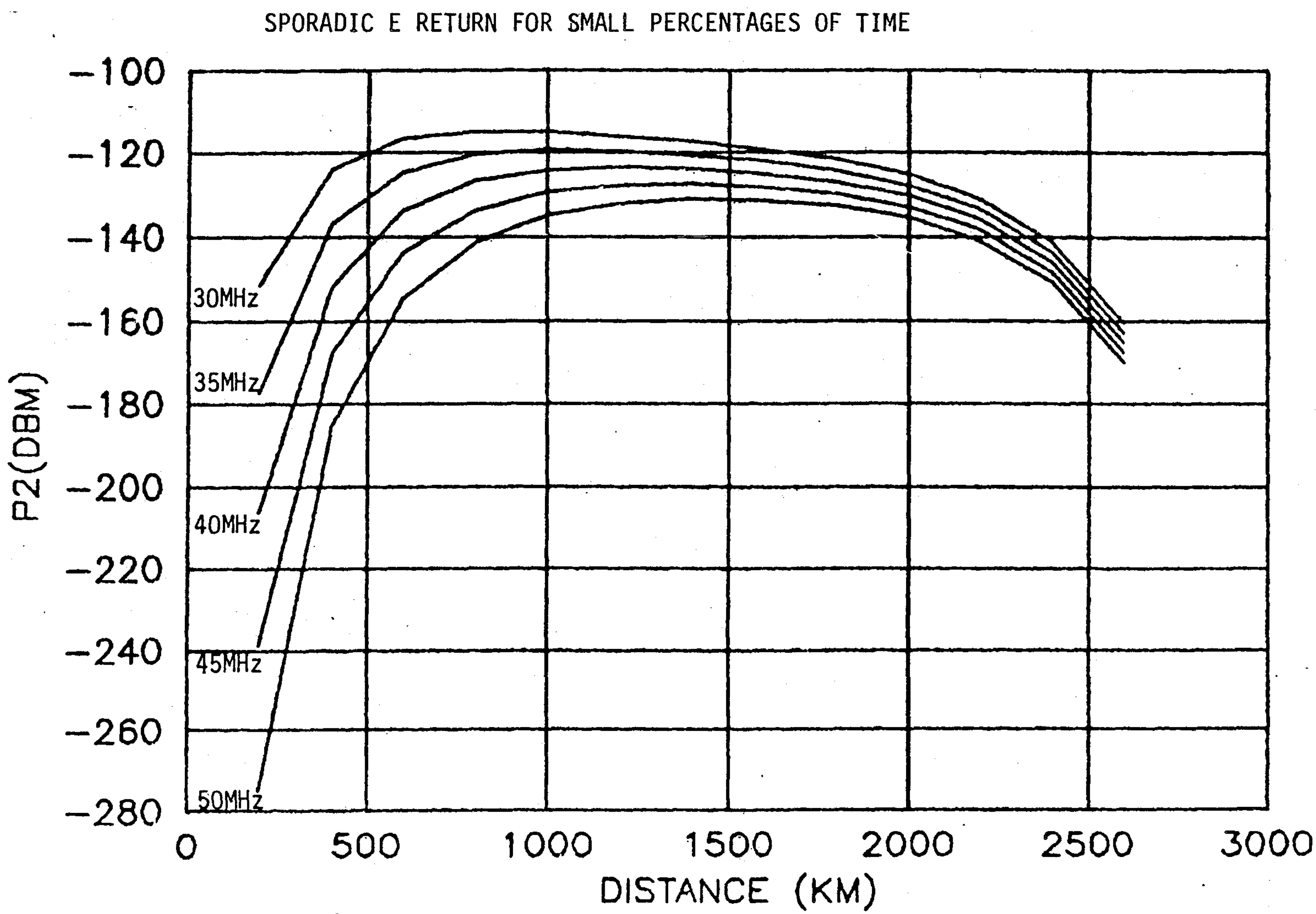

Figure 3. Received power vs. distance separation between transmitter and receiver. 10,000 watt transmitter $G_T = G_R = 10$ dBi, ionosphere $f_0 = 13$ MHz

The maximum percentage of time for Sporadic E reflections at VHF frequencies is in the range of 1 to 8% with the probability of occurrence decreasing with frequency. Weitzen, et al., has characterized Sporadic E returns as an unstable, slowly fading high throughput channel which is best considered as a "bonus" channel to the more stable meteor burst channel (see Reference 6).

6.4 REGULAR F REGION REFLECTIONS

When the solar cycle is at a maximum, VHF signals up to 60 MHz can propagate to long distance via reflection from F1 and F_2 layers in both temperate and low latitudes (see Reference 14). These ionospheric signals can originate from a number of interference sources including VHF-TV, land mobile, and meteor burst. The duration of interference from F reflections can range up to a couple of hours. However, the occurrence times are random and the time percentage of occurrence is small, (about 1%), making it difficult to develop spectrum management procedures for this kind of interference. Some outage time due to ionospheric interference must be expected.

6.5 SUMMARY OF VHF IONOSPHERIC INTERFERENCE

The common quality of ionospheric interference for frequencies above 30 MHz is that the times of occurrence are random with a relatively low probability of causing a communication outage. The probability of interference will be greatest during the times of high sunspot activity. It is concluded that it is not necessary to develop specific compatibility criteria for ionospheric propagated VHF interference to or from meteor burst equipment. Real time equipment adjustments such as power, frequency or antenna changes are required to solve these interference problems.

6.6 AIRPLANE REFLECTIONS

The significance of aircraft reflections of meteor burst signals is brought into question intuitively when it is considered that commercial television pictures commonly flutter when aircraft approach a receiver antenna location. Commercial channels 2, 3, 4, 5, and 6 are approximately in the same frequency range as meteor burst systems.

At distances less than 160 kilometers, interference signals from meteor burst probe transmitters may be received from airplane reflections. These signals, due to the movement of the airplane, have a great amount of fading and last for just seconds. The number and how often these airplane echoes occur will depend upon the density of aircraft in the sky and their trajectories. It is concluded that, in general, airplane reflections are not a significant interference problem.

SECTION 7

GROUNDWAVE COMPATIBILITY

7.1 INTERFERENCE PATHS AND CONDITIONS

Interference to and from meteor burst systems propagate as groundwave signals. Figure 4 shows the possible groundwave interference paths between meteor burst and other common equipments in the 30-50 MHz band. Each path includes an arrow showing the direction of the interference from source to receptor. These equipments can be grouped with respect to interference as shown in TABLE 4.

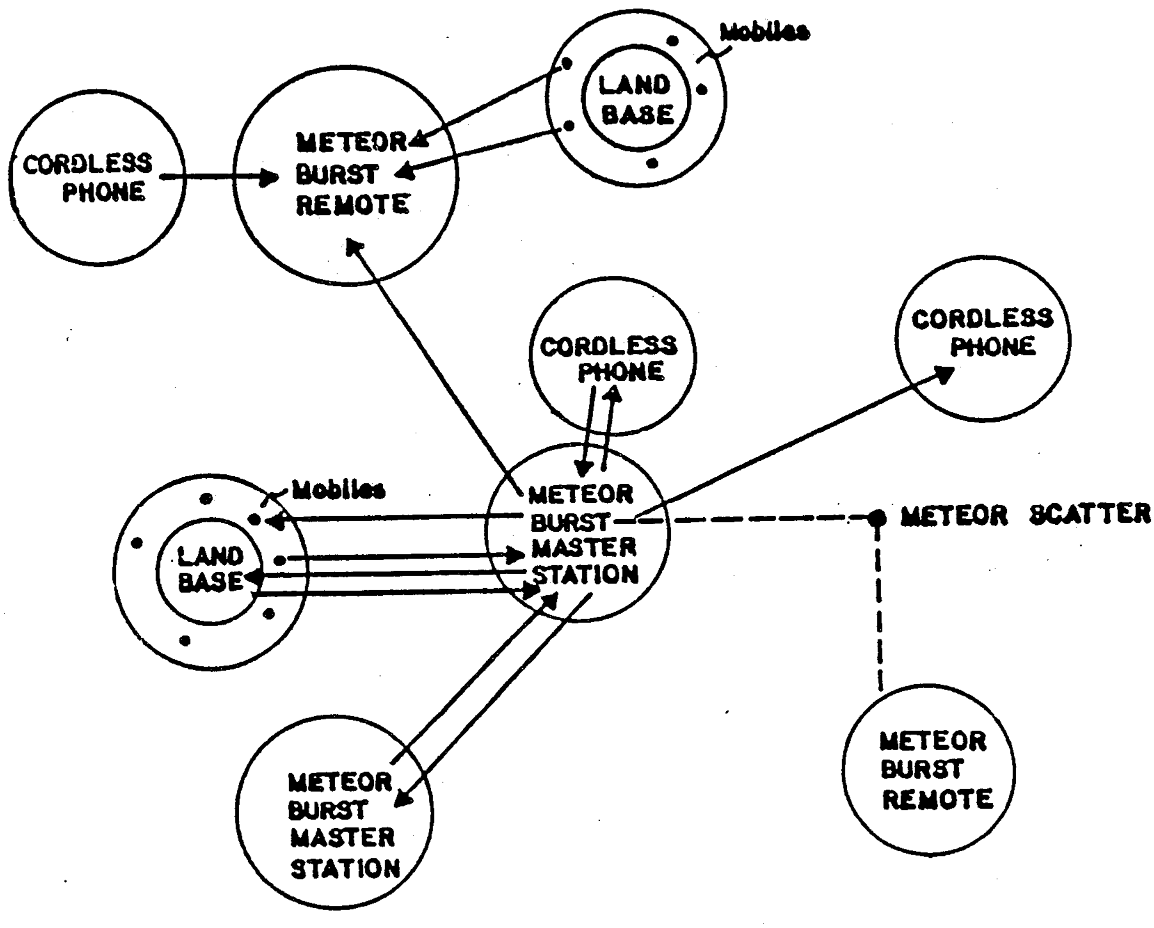

Figure 4. Groundwave interference paths between meteor burst and other equipments in the 30-50 MHz band. The dashed path (via the meteor scatter) is the wanted path.

TABLE 4

EQUIPMENTS

Equipments Susceptible to Meteor Burst Master Station (Probe Signal) Interference
Land Mobile Base Station Receivers
Land Mobile Mobile Station Receivers
Cordless Telephone Receivers
Master and Remote Station Meteor Burst Receivers
Equipment Which May Cause Interference to Meteor Burst (Master or Remote) Receivers
Land Mobile Base Station Transmitters
Land Mobile mobile Station Transmitters
Cordless Telephone Transmitters
Master Station Meteor Burst Transmitters (Probe Signals)

Transmissions from meteor burst remote terminals are not included in TABLE 4 as a source of VHF interference. Meteor burst remote stations transmit only when addressed and only during the short time periods of meteor burst trails. Based on the work of Miller and Licklider (see Reference 16), these signals will not affect the intelligibility of other VHF signals.

The signal characteristics for adaptive data rate meteor burst systems have already been described. The probe signals for adaptive data rate systems are expected to be included in a VHF 20 kHz channel. The probe signals for both adaptive and non-adaptive meteor burst systems are identical and have the same interference characteristics. When the signal adapts to the characteristics of the meteor trail channel, it expands its bandwidth. The expanded signal outside the channel bandwidth of the probe satisfies the Miller and Licklider criteria for intelligibility and is, therefore, not considered a possible source of interference.

TABLES 5 and 6 show the technical parameters for the meteor burst and land mobile equipments used later in the simulations. The antenna gain for the meteor burst transmitter signals in the groundwave direction depend upon the radiation angle Δ of the meteor burst antennas. A meteor burst antenna for a 1000 km path and directed to meteors at 100 km altitude will utilize a radiation angle Δ of about 9 degrees. The beamwidth of the meteor burst antenna is ± 15 degrees. Thus, the meteor burst antenna gain for groundwave signals can be well approximated by the meteor burst mainbeam gain of 10 dB.

TABLE 5

METEOR BURST SYSTEM

Transmit Power	300, 1000, 2000, 10000 watts
Antenna Gain	$G_T = G_R = 10$ dBi, Sidelobe = 0 dBi
Wanted Signal	-110 dBm, $E_b/N_o = 10$ dB
Protocol	Master: continuous operation Remote: Transmit when probed
Channel Bandwidth	16 kHz necessary bandwidth 20 kHz channel spacing (probe signals)
Modulation	Digital, e.g., PSK, FSK
Transmitter Height	15 meters

TABLE 6

LAND MOBILE SYSTEM (30-50 MHz)

Base Transmitter Power	100 watts
Mobile Transmitter Power	50 watts
Antenna Gain	$G_T = G_R = 0$ dBi
Operation	Half-Duplex
Channel Bandwidth	16 kHz necessary bandwidth
Modulation	Analog frequency modulation Maximum Frequency deviation = ±5 kHz
Successful Communication	$P(\frac{S}{N} \geq 17 \text{ dB}) = 90\%$ at r = 28 km
Transmitter Height-Base	10 meters
Transmitter Height-Mobile	3 meters

The dominant propagation mode for a meteor burst system operated at high elevation angles and for correspondingly shorter distances (less than 200 km) would be by troposcatter and not meteor reflection. The interference characteristics of systems which are intended for troposcatter propagation modes are not considered further in this report since under these conditions the systems cease to be intended for meteor burst communications and become instead troposcatter systems.

7.2 LAND MOBILE COMMUNICATION SERVICE AREA

Government land mobile systems in the 30-50 MHz band usually are a base station communicating with mobile stations which are moving randomly around the base station. The communication range, $r_m = R$, of the land mobile system is typically defined as the radial distance, r_m, from the base station where the probability of the base station's signal achieving a S/N $\geq$ = 17 dB is 90%. Mathematically this is

$$P\left(\frac{S}{N} \geq 17\right) = 90\% \quad \text{at } r_m = R \tag{3}$$

The 17 dB S/N threshold is the combination of an unfaded 11 dB RF protection ratio and 6 dB to account for Rayleigh fading. It was found using both the PRODSIR (see APPENDIX D) simulation and reference to typical mobile system operational ranges that a representative value for R is 28 kilometers. In the simulations to account for this communication range, all mobiles are confined to operate between the radii r_m = 1 to r_m = 28 kilometers. It has been reported that somewhat larger communication ranges are utilized by some Government systems. A somewhat larger communication range would have only a slight effect on the later results of this study.

7.3 INTERFERENCE CRITERIA

The interference RF protection ratio for land mobile systems used in the simulations is an S/I = 17 dB. The value of the protection ratio is 17 dB, since the digital signals from the meteor burst transmitter are assumed to have the interference characteristics of noise. The criteria for compatible communication for the land mobile system in meteor burst interference is

$$P\ (S/I \geq 17\ \text{dB}) = 90\%\ \text{over the coverage area}\ r_m = 1\ \text{to}\ 28\ \text{km} \qquad (4)$$

A different interference criteria is used for meteor burst receivers. The interference threshold is

$$\bar{I} = \bar{S} - (\bar{S}/\bar{I}) \quad \text{dB} \qquad (5)$$

where

$\bar{S},\bar{I}$ = mean values of S (signal) and I (interference)

$(\bar{S}/\bar{I})$ = required $\bar{S}/\bar{I}$ in interference

The analysis in Section 3 has shown that a typical usable received peak power, $P_r(t=0)$, return for meteor burst operation is -110 dBm. A usable $\overline{S}/\overline{N}$ is approximately 10 dB for QPSK, BER = 10^{-3}, and $\overline{N}$ the threshold noise power. $\overline{N}$(dBm) = $\overline{S}$ - ($\overline{S}/\overline{N}$) or -110 dBm - (10 dB) = -120 dBm.[18] The compatibility criteria is an assurance that the received interference power is substantially below the noise power. This is achievable with an I/N = -6 dB and a corresponding interference threshold = -120 dBm - 6 = 126 dBm. Thus, when determining separation distances to protect meteor burst receivers, the interference criteria is to assure that the magnitude of the mean interference does not exceed the threshold -126 dBm.

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[18] Cox, D.C., Universal Digital Portable Radio Communications, Proceedings of the IEEE, pp. 436-476, April 1987.

When meteor burst and land mobile systems operate on adjacent channels, the equipments can be placed geographically closer together due to the Off Frequency Rejection associated with operation on adjacent channels.[19] When the signal is analog and the interference is digital (i.e., meteor burst to land mobile interference) the interference is reduced 56 dB to account for Off Frequency Rejection OFR (Δf = 20 kHz) = 56 dB.[20] Conversely, when the signal is digital and the interference is analog (i.e., land mobile to meteor burst interference) the OFR is 80 dB.

7.4 METEOR BURST SYSTEM COMPATIBILITY WITH LAND MOBILE SYSTEMS

An electromagnetic environment which includes both a land mobile system and meteor burst equipment is illustrated in Figure 5. The base and meteor burst station are separated a distance D. The minimum distance separation which permits both systems to operate without interference is $D=D_S$.

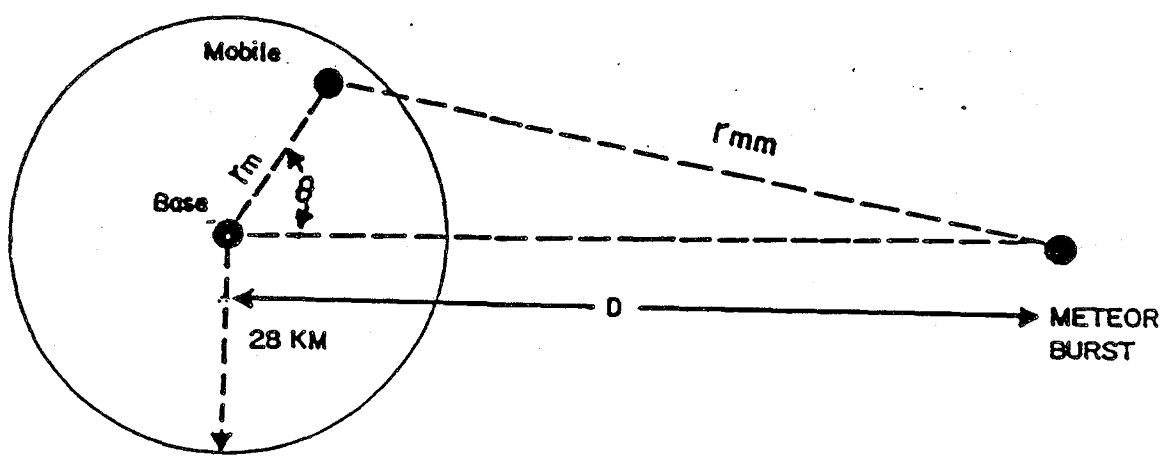

Figure 5. Electromagnetic Environment which includes both a land mobile and meteor burst system. When $D = D_S$ interference protection is provided.

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[19]CCIR Report 654-2, Methods for Calculating Interference Power in Adjacent Bands and Channels, Doc. XVI Plenary, 1986e.

[20]CCIR Report 903-1, Digital Transmission in the Land Mobile Service, Doc. XVI Plenary, 1986d.

Computer models were used to simulate the electromagnetic environments to find values of D_s for various interference situations. Four interference situations are possible and each situation has a different required minimum separation distance, D_s. These are: (1) meteor-burst master station transmitter interference to a mobile base receiver, (2) meteor-burst master station transmitter interference to a mobile station receiver, (3) base station transmitter interference to a meteor-burst receiver (master or remote), and (4) mobile station transmitter interference to a meteor-burst receiver.

The PRODSIR computer model (see APPENDIX D for a description) developed by L. A. Berry,[21] was used to simulate the above interference situations and compute the probabilities in equations 3-5. The propagation model is described in APPENDIX E. The PRODSIR model used as inputs the technical parameters found in TABLES 5 and 6 to compute the probabilities P(S/N) and P(S/I).

Case 1 Meteor Burst Master Station Transmitter Interference to a Base Station Receiver

The desired signal, S, in this case is the signal from a randomly located mobile station received at the base station. The mobile is located in the range $1 \leq r_m \leq 28$ km. The interfering signal, I, is the groundwave signal from the meteor burst transmitter. The meteor burst transmitter and the land mobile base station are separated a distance D (see Figure 5).

The PRODSIR simulation model first calculates the probability density function (pdf) of the path length, r_m, from the mobile to the base. Then, after performing some intermediate calculations (see Figure 24, APPENDIX D), the PRODSIR model computes the probability $P(\frac{S}{I} \geq 17 \text{ dB})$.

There are two possible interference conditions depending upon the radiation direction of the mainlobe of the meteor burst antenna relative to the land mobile system. The base station receiver is either in the mainlobe (G_t = 10 dB) or sidelobe (G_t = 0 dB) of the meteor burst antenna. Figure 6

[21] Berry, L.A., Probabilistic Tradeoff for Efficient Spectrum Use with a "CB" Example, OT Report 77-117, Office of Telecommunications, 1977.

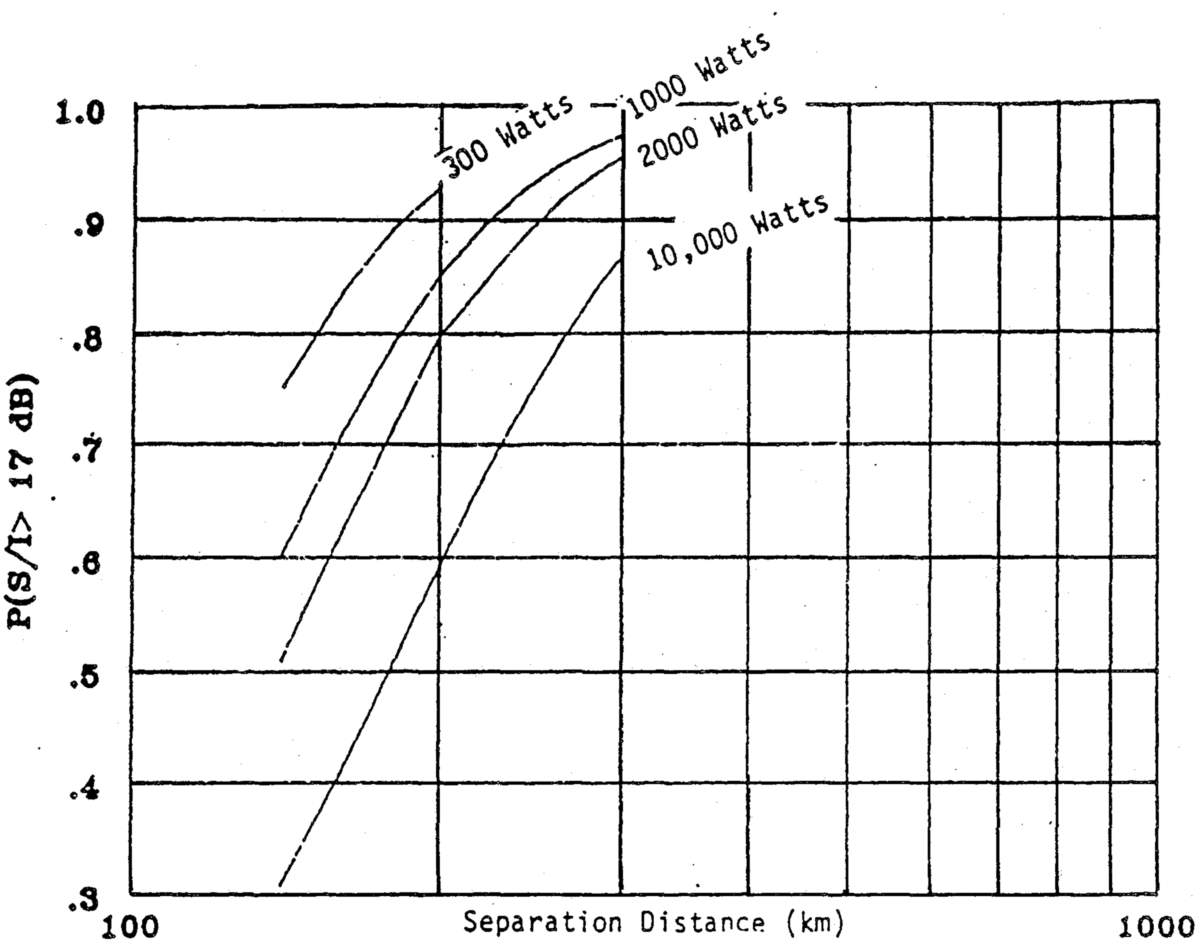

Figure 6. Meteor Burst to Land Mobile Base Station.
Mainlobe Meteor Burst

plots $P(\frac{S}{I} \geq 17$ dB) for the mainbeam case and for meteor burst transmitter powers of 300, 1000, 2000, and 10,000 watts as a function of separation distance D. The criteria for successful communication in the meteor burst digital interference is $P(\frac{S}{I} \geq 17$ dB) = .9. For this interference criteria, the minimum separation distances, $D = D_s$, can be read from Figure 6 for each of the meteor burst transmitter powers. These are: 300 watts, D_s = 180 km; 1000 watts, D_s = 220 km; 2000 watts, D_s =250 km, and 10,000 watts D_s = 320 km.

Figure 7 shows $P(\frac{S}{I} > 17$ dB) = .9 for the same situation except the land mobile system is in the sidelobe of the meteor burst antenna pattern. The meteor burst transmitter powers and their associated separation distances for this situation are: 300 watts, D_s =130 km; 1000 watts, D_s =150 km; 2000 watts, D_s =175 km, and 10,000 watts D_s = 220 km.

Another interference possibility is when the interfering digital meteor burst station is on the adjacent channel to the land mobile station receiver. From Section 7.3 the Off-Frequency Rejection (OFR) is 56 dB for this situation. This OFR was accounted for in the computer modeling by reducing the interfering power from the meteor burst transmitter by 56 dB and then simulating the environment using the PRODSIR model. The probability $P(\frac{S}{I} \geq 17$ dB) is shown in Figure 8 for the various meteor burst power and antenna pointing directions. The adjacent channel separation distances D are obtained from Figure 8 and are listed in TABLE 7.

Case 2 Meteor Burst Master Station Transmitter Interference to a Mobile Receiver

The desired signal, S, for this case is the signal from the base station transmitter to a mobile receiver at a radius $r = r_m$. The interference, $I(r_{mm})$, is the signal at the mobile from the meteor burst transmitter. The propagation distance, r_{mm}, (see Figure 5) from the meteor burst station to the mobile station receiver is

$$(r_{mm})^2 = D^2 + r_m^2 - 2Dr_m \cos \theta \qquad (6)$$

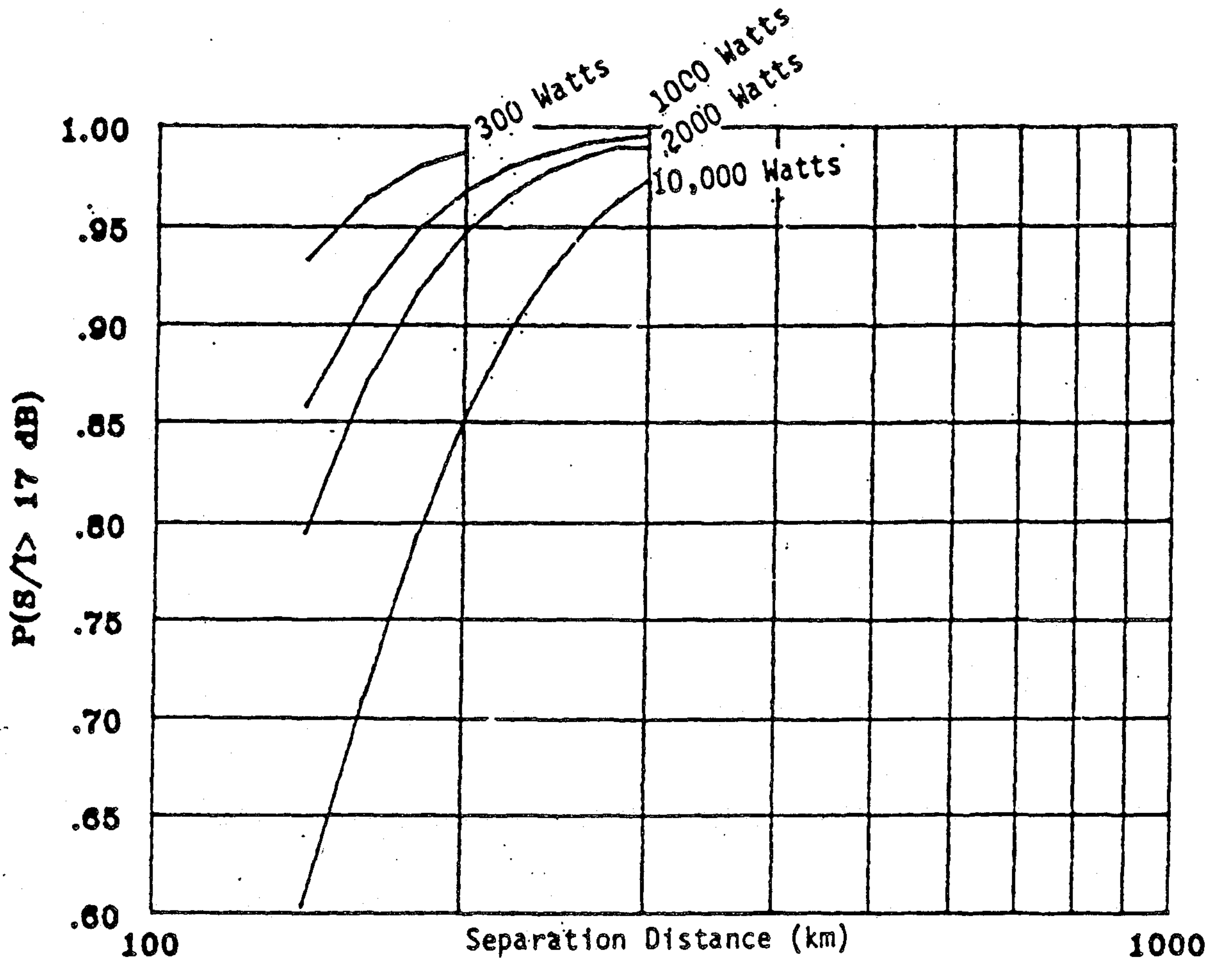

Figure 7. Meteor Burst to Land Mobile Base Station
Sidelobe Meteor Burst

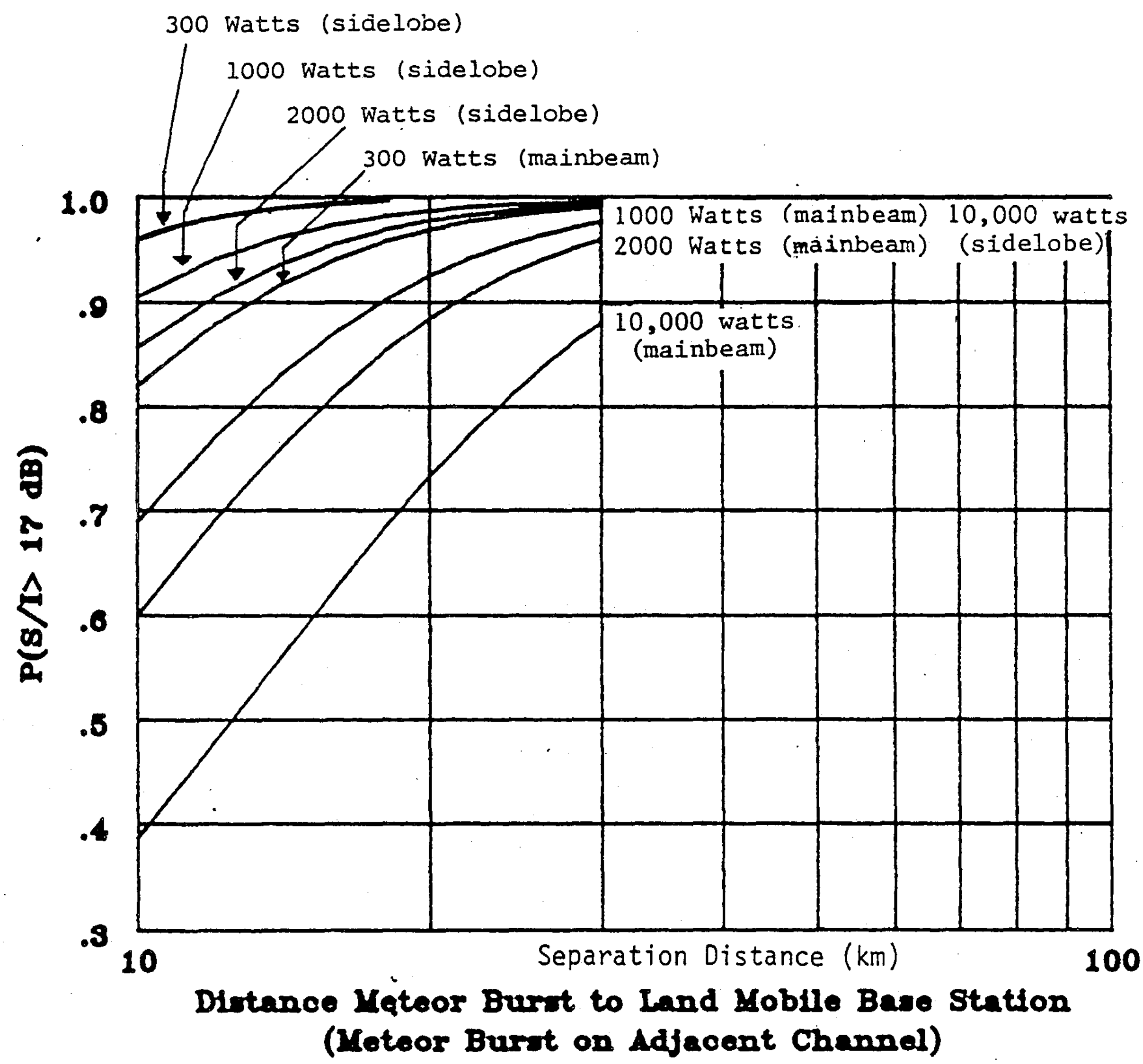

Figure 8. Interference from Meteor Burst to Base Receiver.

TABLE 7

DISTANCE SEPARATION (D_S, METEOR TO BASE) TO PROVIDE INTERFERENCE PROTECTION TO MOBILE SYSTEMS

		Distance Separation Cochannel	Distance Separation Adjacent Channel
Case 1A	Meteor Burst Master Station (Main Beam) Interference to Base Station Receiver		
	300 watts	180 km	14 km
	1000 watts	220 km	18 km
	2000 watts	250 km	22 km
	10000 watts	320 km	32 km
Case 1B	Meteor Burst Master Station (Sidelobe) Interference to Base Station Receiver		
	300 watts	125 km	7 km
	1000 watts	160 km	10 km
	2000 watts	175 km	12 km
	10000 watts	220 km	18 km
Case 2A	Meteor Burst Master Station (Main Beam) Interference to Mobile Station Receiver		
	300 watts	150 km	42 km
	1000 watts	190 km	46 km
	2000 watts	200 km	50 km
	10000 watts	250 km	60 km
Case 2B	Meteor Burst Master Station (Sidelobe) Interference to Mobile Station Receiver		
	300 watts	110 km	35 km
	1000 watts	130 km	38 km
	2000 watts	150 km	40 km
	10000 watts	190 km	46 km

where

D = the separation distance between the base and meteor burst stations

r_m = radial distance base to mobile

Θ = angle between D and r_m (See Figure 5)

The PRODSIR model includes a Monte Carlo subroutine to calculate the probability density function (pdf) of r_{mm}. The pdf of the base to mobile transmission distance, r_m, is also determined in the PRODSIR program. The basis for the determination of the pdfs is the assumption that the probability that an area contains a mobile station is proportional to the size of the area.

Using these pdfs, the PRODSIR model was used to calculate the probability $P(S/I \geq 17\ dB)$ shown in Figure 9. Using the criteria $P(S/I \geq 17\ dB) = .9$ as a basis for successful communication, the separation distances for the various examples of meteor burst transmitter power are 300 watts, D_s = 150km;, 1000 watts, D_s =190 km; 2000 watts, D_s = 200 km, and 10,000 watts, D_s = 250km. When the mobile receiver is in the sidelobe of the meteor burst antenna pattern, the probability shown in Figure 10 is $P(S/I \geq 17\ dB)$ and the minimum separation distances for the interference criteria $P(S/I \geq 17\ dB) = .9$ are 300 watts D_s = 110 km, 1000 watts, D_s = 130 km, 2000 watts, D_s = 150 km and 10,000 watts D_s = 190 km. The separation distances, D_s, to protect mobile systems are summarized in TABLE 7.

A different interference protection criteria is applied when the meteor burst transmitter and the mobile receiver are on adjacent channels. The adjacent channel separation distances between meteor burst transmitters and mobile receivers are approximately the same distances determined in Case 1 above for a base station receiver. The required separation distance D_s (base to meteor burst distance, (see Figure 5) to provide interference protection to a mobile receiver located at the maximum communication range (28 km) is found by adding the Case 1 adjacent channel distances to 28 km. For example, the separation distance for a 1000 watt meteor burst transmitter (mainbeam) is 18 km + 28 km = 46 km. Other distance separations are listed in TABLE 7.

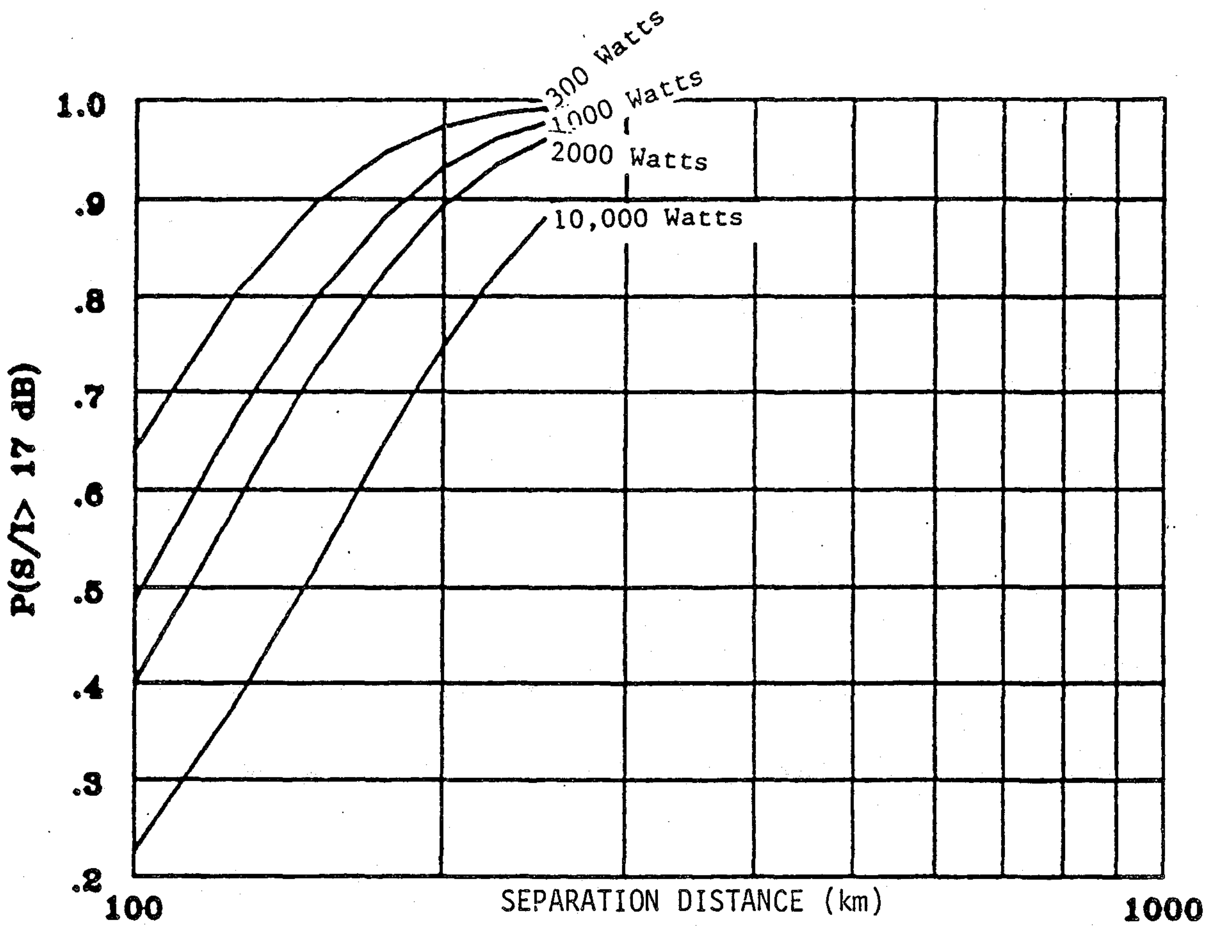

Figure 9. Distance Meteor Burst to Base Station.
Interference to Mobile Receiver
(Mainbeam)

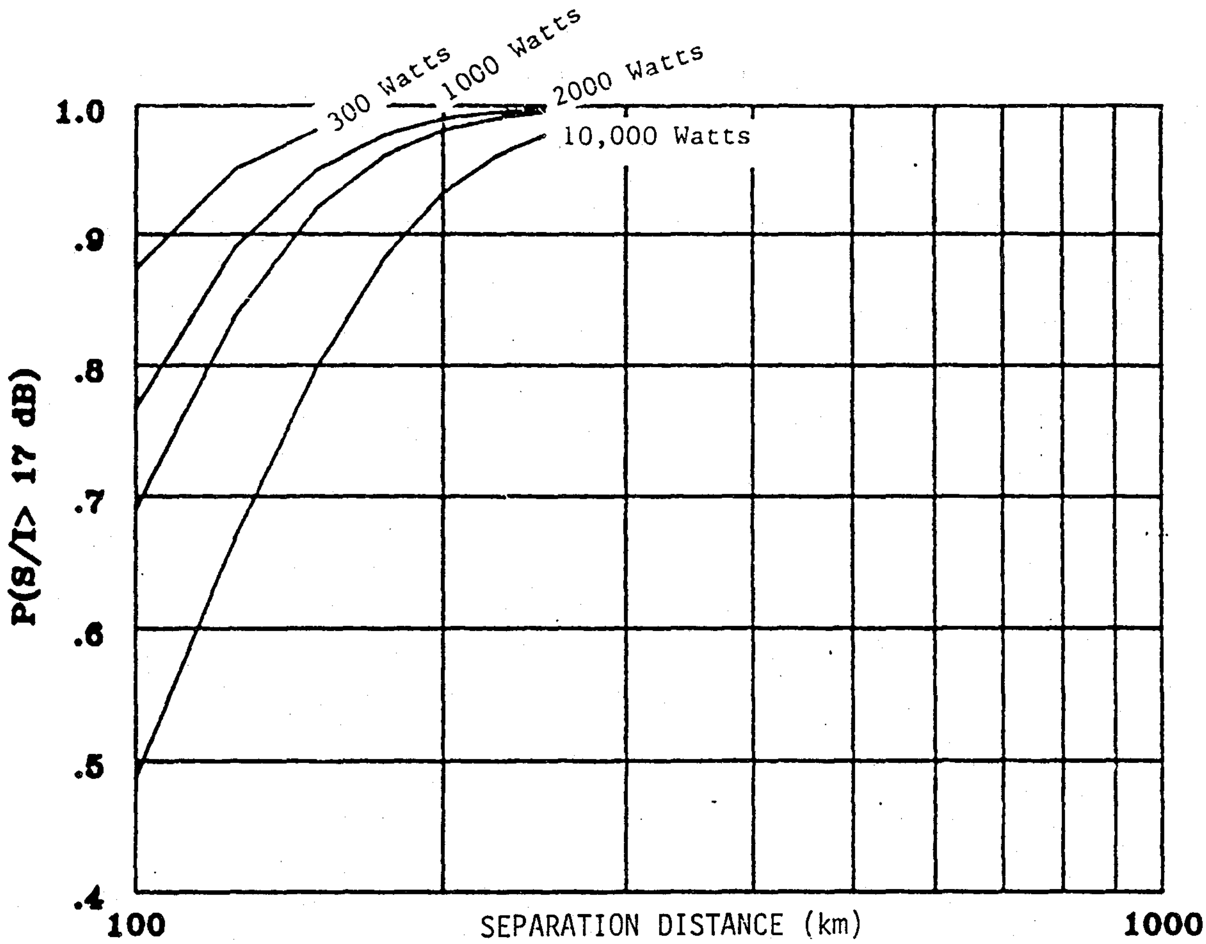

Figure 10. Distance Meteor Burst to Base Station Interference to Mobile Receiver (Off-Axis)

Case 3 Base Station Interference to a Meteor Burst Receiver

Cases 1 and 2 involve interference from a meteor burst transmitter to mobile and base station receivers. Cases 3 and 4 consider the opposite situation which is interference from land mobile equipments to a meteor burst receiver (see Figure 5). The wanted signal for Cases 3 and 4 is the typical meteor burst peak return = -110 dBm.

The interference signal, I, in Case 3 is the unwanted groundwave signal from a land mobile base station received at the meteor burst station. From Equation 5, the interference threshold for a meteor burst receiver is a mean peak interference signal, $\overline{I}_m$ = -126 dBm.

Figure 11 plots the mean peak received interference, $\overline{I}_m(D)$, when the interference is received in the mainbeam of the meteor burst antenna. D is the separation between the base station and the meteor burst station. The minimum separation $D = D_S$ is when $\overline{I}_m$ = -126 dBm. Reading from the figure D_S = 350 kilometers. Figure 11 also plots $\overline{I}_m(D)$ for the condition of reception of the interference in the sidelobe of the meteor burst antenna. From the figure, the minimum separation distance is D_S = 225 km.

When the digital meteor burst receiver and the analog base station transmitter are on separate but adjacent channels, there is an adjacent channel off frequency rejection of 80 dB and the interference threshold is (-120 dBm) + 80 dBm = -40 dBm. Applying this interference threshold, the required separation distances, D_S, for adjacent channel operation are less than 10 km for all cases (mainbeam or sidelobe).

Case 4 Mobile Transmitter Interference to a Meteor Burst Receiver

The wanted signal, S, for this case, as in Case 3, is a meteor reflected signal with magnitude I = -110 dBm. The interference signal, I, is the groundwave signal transmitted from a mobile station received at the meteor burst station (see Figure 5). The interference distance, r_{mm}, from mobile to meteor burst is given in Equation 6. The threshold for interference is a mean peak interference signal, $\overline{I}_m$ = -126 dBm. The PRODSIR model was used to

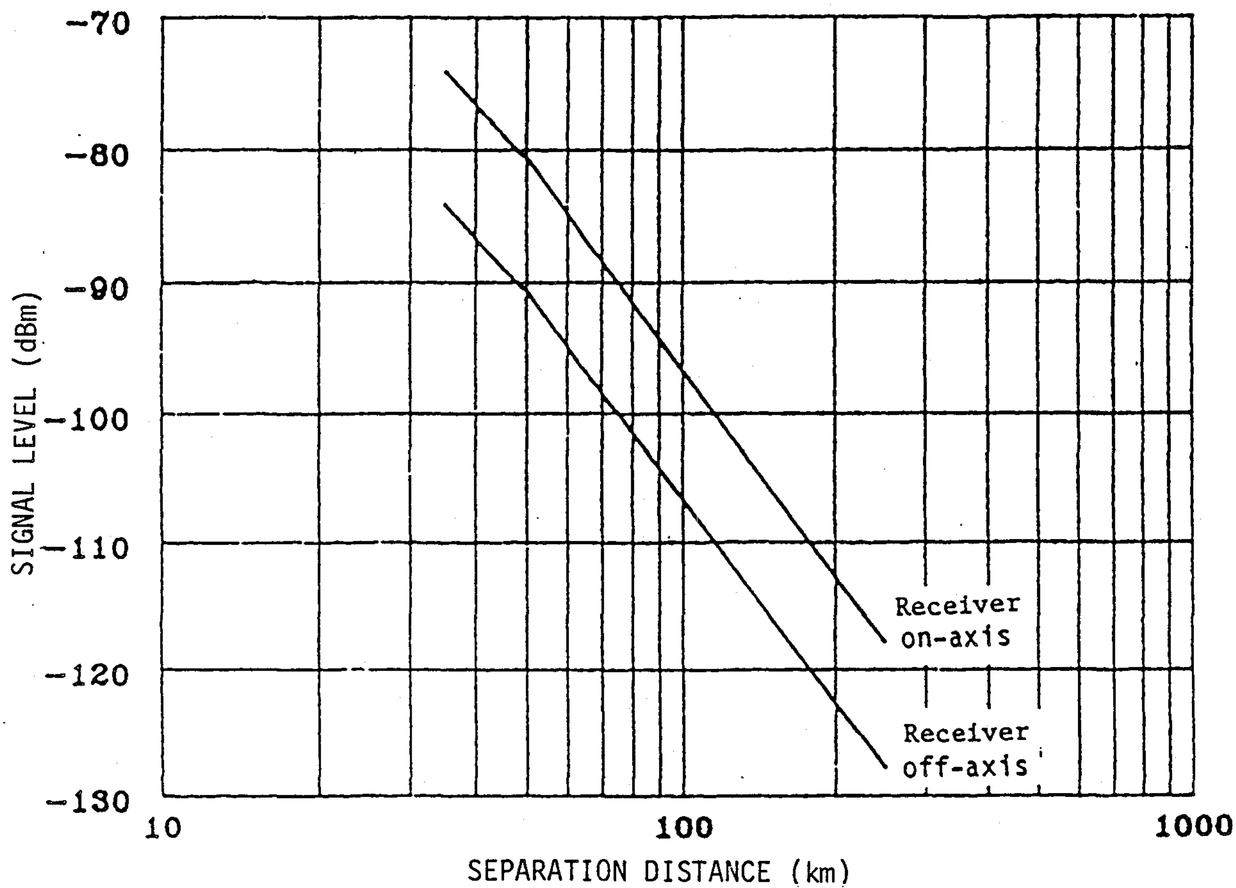

Figure 11. Land Mobile Base Station to Meteor Burst Receiver.

calculate $\bar{I}_{mm}$ versus the separation distance, D, between the base and meteor burst stations. The $\bar{I}_{mm}$ is computed by taking into consideration all possible values of r_m and Θ in the respective ranges $1 \leq r_m \leq 28$ and $0 \leq \Theta \leq 2\pi$. Figure 12 plots the mean interference, $\bar{I}_{mm}$, from the mobile under the condition that all mobiles are in the mainbeam receiving pattern of the meteor burst. The off axis plot in Figure 12 is for the same mobile meteor burst configuration, except that all mobiles are in the sidelobe of the meteor burst receiving pattern. The separation distances, $D=D_S$, when $\bar{I}_{mm} = -126$ dBm are for the mainbeam D_S = 150 km and D_S = 100 km for the sidelobe condition.

The separation distances, D_S, for adjacent channel operation are determined using a different interference protection criteria. The criteria is based on providing interference protection to the meteor burst receiver from a mobile transmitter located at the maximum communication range r = 28 km. When a mobile transmitter and a meteor burst receiver are on adjacent channels the interference threshold for the meteor burst receiver is -126 dBm + (80 dBm) = -46 dBm. The mobile to meteor burst separation distance which satisfies this interference threshold is 10 km or less for both mainbeam and sidelobe conditions. Adding the two distances together (see Figure 5) the separation distance D_S (base to meteor burst distance) is 28 + 10 = 38 km. The separation distances for Cases 3 and 4 are tabulated in TABLE 8.

7.5 CORDLESS TELEPHONES and CHILD MONITORS

The cordless telephone industry in the United States has been granted use of ten 20 kHz channels in the 46.6-47.0 MHz band and ten 20 kHz channels in the 49.6-50.0 MHz band. These bands are allocated for government use and the cordless telephones operate on the condition of not causing interference to the government services nor receiving protection from them.

The technical parameters for a cordless telephone assumed for this study are shown in TABLE 9. The loss factor (-7 dB) is considered to be the minimum value expected for this parameter.

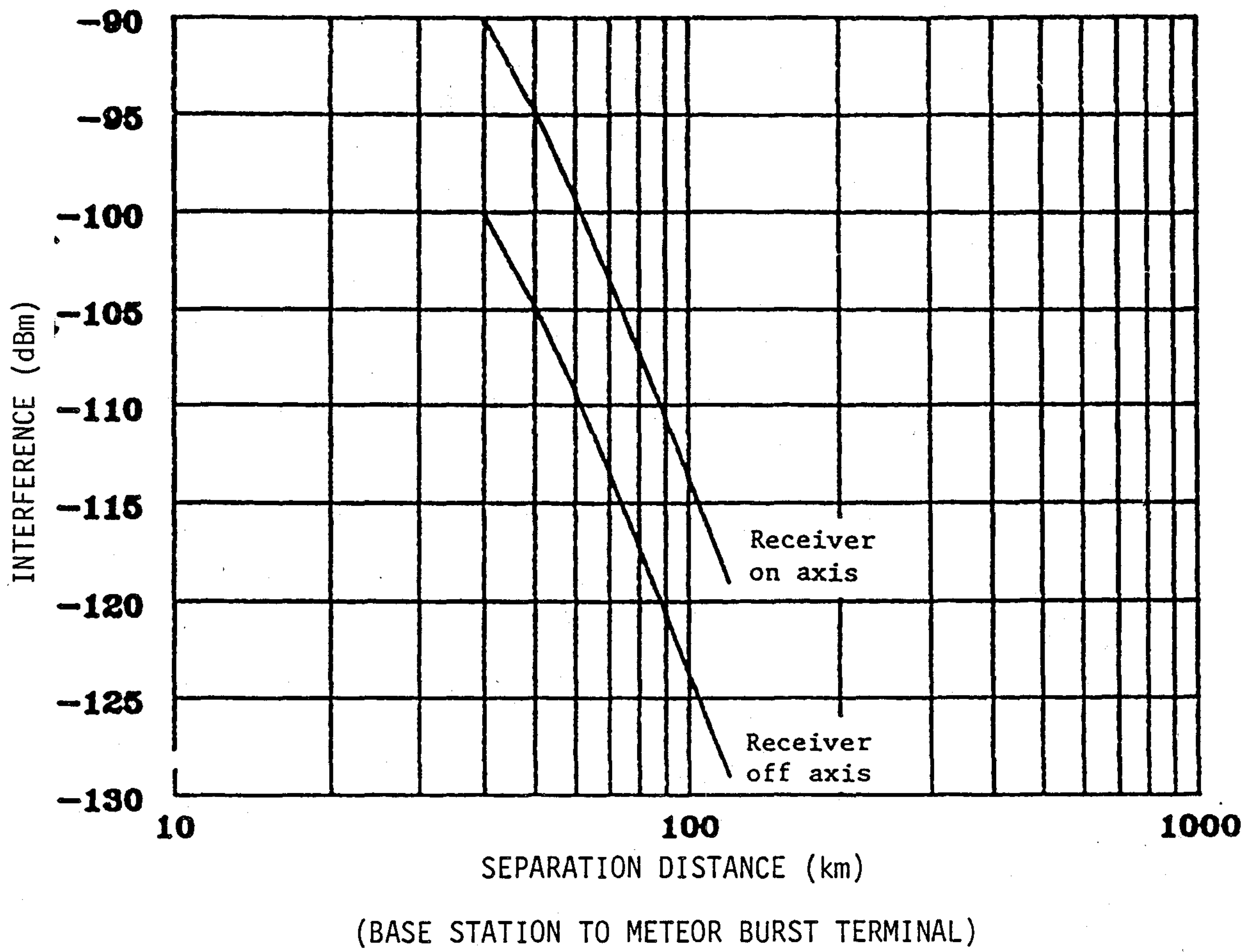

Figure 12. Mean Interference Signal, $\bar{I}_{mm}$, Mobile Transmitter to Meteor Burst Receiver.

TABLE 8

DISTANCE SEPARATION (D_S METEOR TO BASE) TO PROVIDE INTERFERENCE PROTECTION TO METEOR BURST RECEIVERS

		Distance Separation Cochannel	Distance Separation Adjacent Channel
Case 3A	Base Station Interference to a Meteor Burst Receiver through its Mainbeam	350 km	10 km
Case 3B	Base Station Interference to a Meteor Burst Receiver through its Sidelobes	225 km	10 km
Case 4A	Mobile Transmitter Interference to a Meteor Burst Receiver through its Mainbeam	150 km	38 km
Case 4B	Mobile Transmitter Interference to a Meteor Burst Receiver through its Sidelobe	100 km	38 km

TABLE 9

CORDLESS TELEPHONE TECHNICAL PARAMETERS

Power	10 mW
Antenna Gain $G_T = G_R$	-10 dBi
Loss Factor (Building, Foliage)	-7 dB
Mean Propagation Loss .01 km < $D_s \leq$ 10 km	35 + 85 log (D_s)
Propagation Loss σ	σ = 7 dB

The technical specifications and other regulations pertaining to cordless telephones are contained in Section 15.223-15.237 of the FCC Rules. The FCC Rules state that cordless telephones may not interfere with radio communications and must accept any interference received, including that which may cause undesirable operation. The FCC Rules do not specify a maximum operating power but instead specify that the field strength of the carrier frequency shall not exceed 10,000 μV/m at 3 meters.

The NTIA Rules and also the FCC Regulations also permit at certain frequencies in the 49.82-49.90 MHz low power communication devices to operate. (See APPENDIX C of this report for the NTIA regulatory rules relating to the use of low power communication equipments in this band.) Like cordless telephones, emissions on the carrier frequency are not permitted to exceed 10,000μV/m measured at 3 meters. The particular frequencies are 49.83, 49.845, 49.860, 49.875, and 49.890 MHz. A typical equipment of this type is a child monitor. In addition to possible interference to meteor burst systems, an additional problem is that of interference between cordless telephones and child monitors.

The CCIR lists a typical power of 10 mW for cordless telephones and this was used in simulation models to determine separation distances.[22] Figure 13 plots the expected signal received from a cordless telephone transmitter or child monitor. They are received either by the main beam (Curve A) or sidelobe (curve B) of the meteor burst antenna. The plots were made using the PRODSIR model and the parameters found in Table 9. The received power is plotted as a function of the distance separation, D, between the cordless telephone and meteor burst. Figure 13 shows that a cordless telephone or child monitor signal may exceed the meteor burst interference threshold of -120 dBm when the cordless telephone is located at a distance up to 10 km away from the meteor burst receiver. The minimum separation distance is thus D =10 km.

Hirst,[23] while undertaking a meteor burst experimental program encountered interference at 49.89 MHz. Extensive tests revealed that the source of interference was a child monitor located 1.6 to 3.2 km (1-2 miles) from the meteor burst receiver. The measured received power from the child monitor was -97 dBm with a 6 meter receiver antenna. During the measurements, in an effort to maximize the interference, the meteor burst receiver antenna was raised to 12 meters and its azimuth (bearing) varied to obtain the strongest return. Under these conditions, the received signal moved up to -85 dBm. This measured data has been plotted (over the indeterminate range between 1.6 to 3.2 km.) on the Figure 13. The measured data and simulation results are similarly suggesting that the simulation is an appropriate model.

To aid in the technical assessment of interference probability, it was decided to measure at NTIA/ITS the radiation characteristics of a cordless telephone and a nursery monitor. Representative off-the-shelf models of cordless telephones and nursery monitors were used in the measurements. The measurement sites were two fields south of the Radio Building at the Department of Commerce in Boulder, CO, and the field strength meter (Potomac Instruments) was selected because of availability. The center of the vertical

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[22] CCIR, Technical and Operational Characteristics of Cordless Telephones, Doc. XVI Plenary, CCIR Report AM/8.

[23] Hirst, Private Communication, MITRE Corporation, 1988.

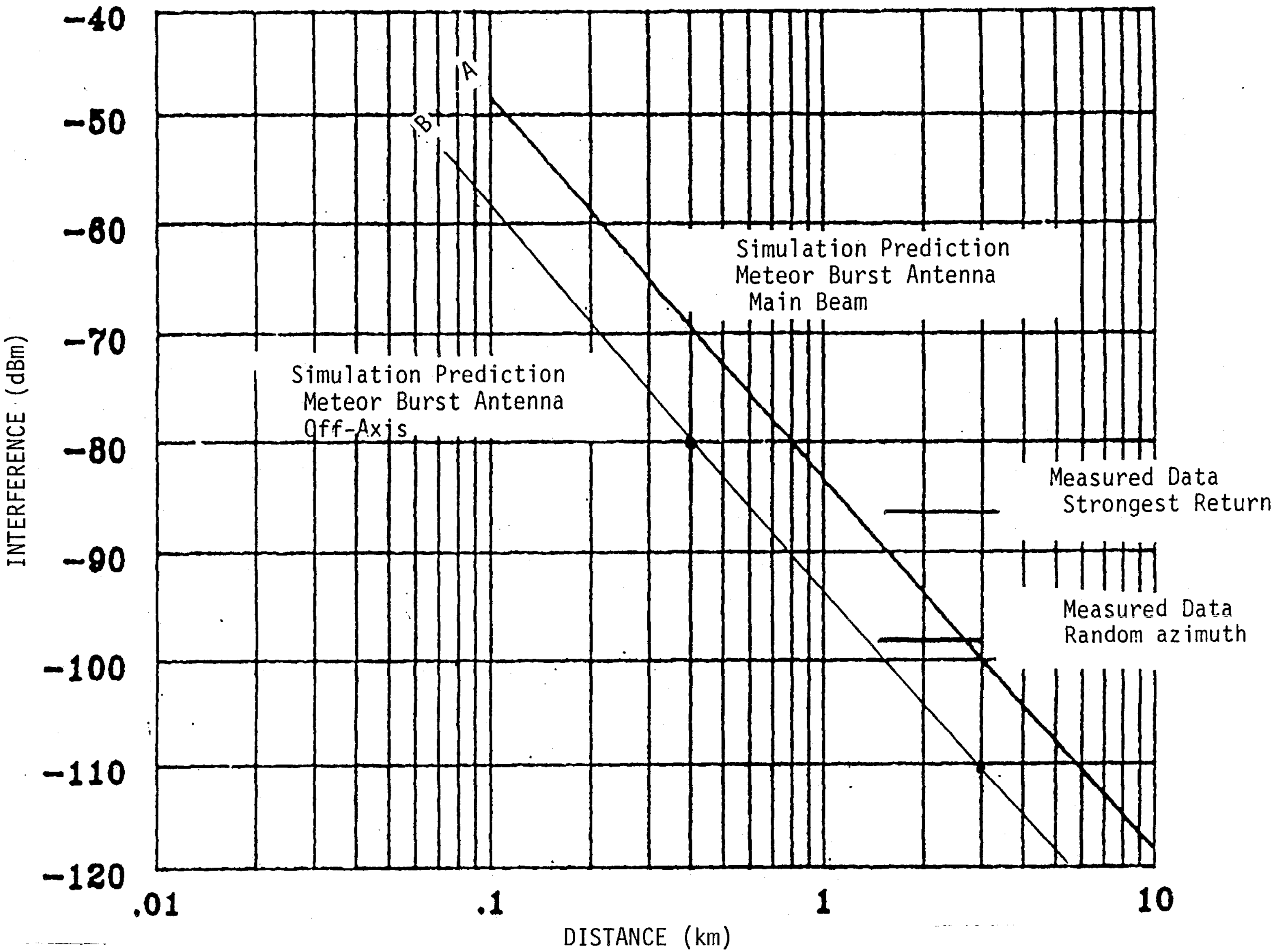


Figure 13. Comparison Measured and Simulation Prediction interference level for a cordless telephone. Plot A is the computer prediction for mainbeam and Plot B is for the Sidelobe of the meteor burst antenna. The horizontal lines are measured data bounds.

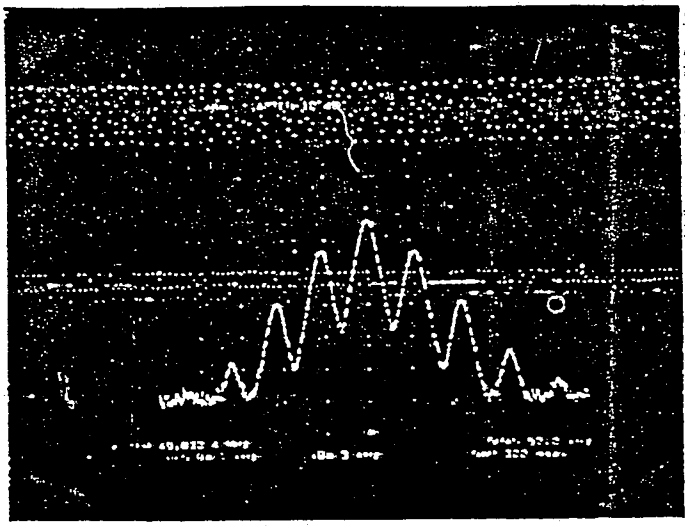
receiving (measurement) dipole was maintained about 2 meters above the ground as was the vertical monopole of the cordless telephone (to reduce coupling or reflection interference). In order to determine near region characteristics, measurements were made at approximately 1 meter path increments out to 30 meters. In addition, measurements were performed at 1000 meters in order to obtain information on range limits.

The measurements for both the cordless telephone and the child monitor at close range display variations due to 1/R, $1/R^2$, and $1/R^3$ components. At distances greater than a few meters, the spatial variation smooths out.

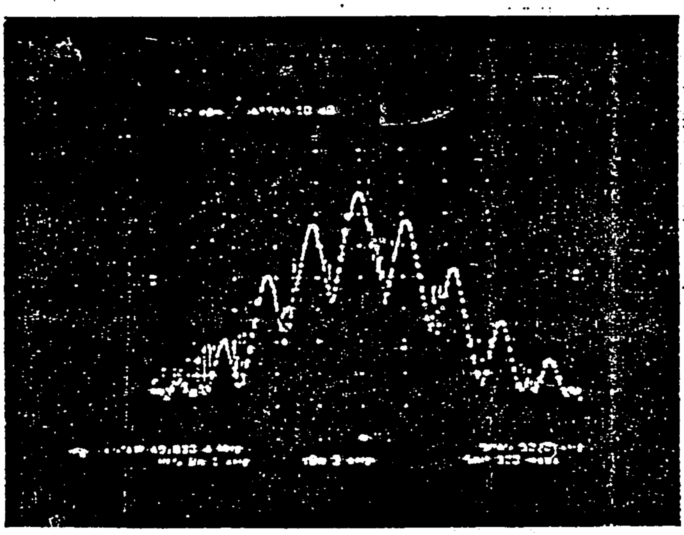
The measured field strength from the cordless telephone at 1000 meters was for a series of measurements from 2 to 6 uV/m. The cordless phone was clearly audible at this range. At this range, the PRODSIR model for a 10 mW transmitter (G_t = -10 dB) predicts (converting the reduced powers at a separation distance of one km in Figure 13) the received field strength by a meteor burst station to be in the range 3-9-uV/m. The predicted and measured results are similar.

The field strength from the child monitor at 1000 meters was measured under two operating conditions. Initially, the power cord was wound into a coil of 3 centimeters in diameter. Under this condition (5 repeated attempts), no signal was audible or could be separated from noise. When the power cord was suspended into a vertical position (length about a meter), the monitor was clearly audible and the field strength was observed to be slightly over 1 uV/m. It is conjectured that the power cord when extended acted as an antenna and a consequential greater received power.

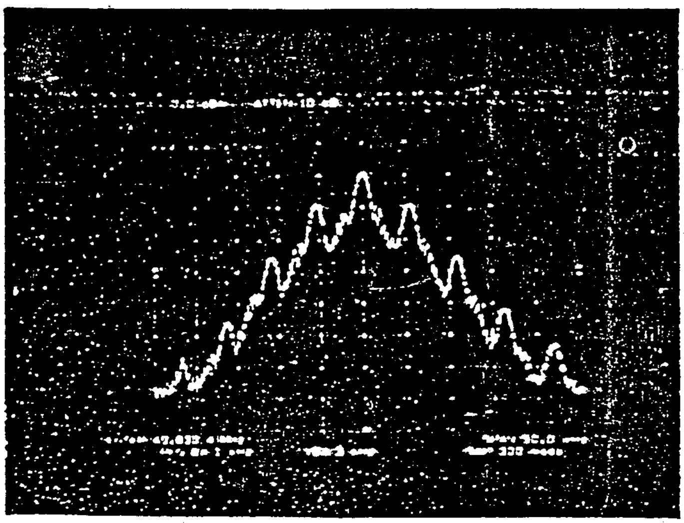
To further provide information for assessment of potential interference by cordless telephones, two different models were coupled (antenna separations about 30 cm) to a spectrum analyzer. The emission spectra obtained are shown in Figures 14, 15, and 16. Figure 14 shows the emission spectra of the first model giving the carrier frequency and side frequency peaks with and without modulation. Peak frequencies are separated by about 5.3 and 5.4 kHz, and peak levels are separated by about 9 to 20 dBm when there is no modulation. It is interesting that with dialing or voice modulation relative peak values are similar, although values between peaks change noticeably. In Figure 15 the



CARRIER ONLY

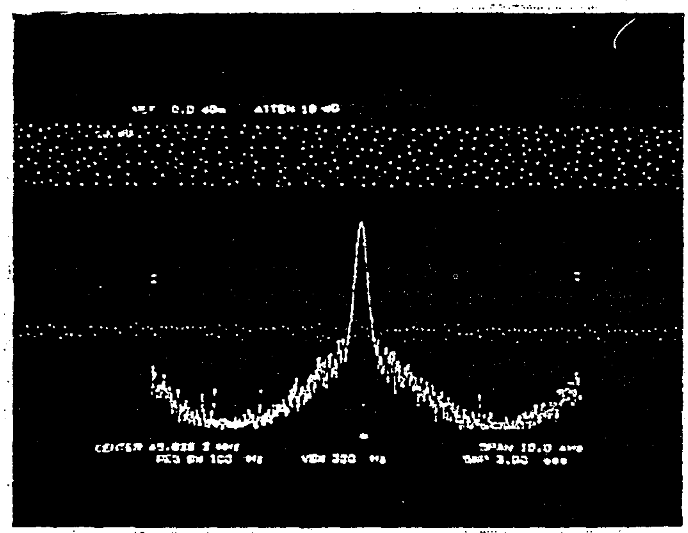


WITH DIALING

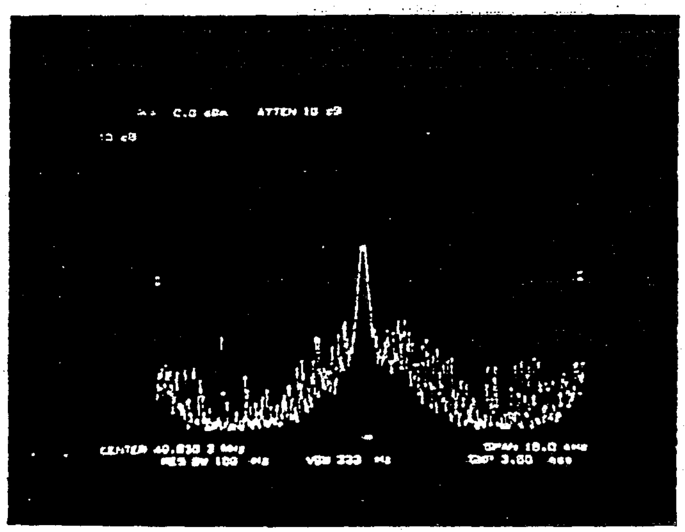


WITH VOICE MODULATION

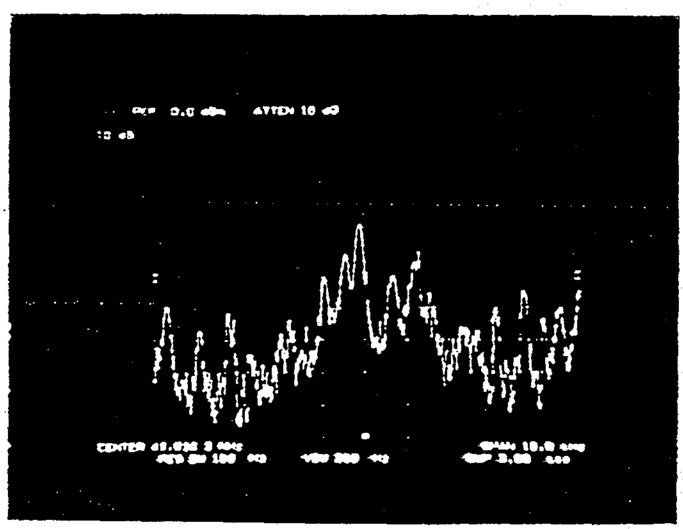
Figure 14. Cordless telephone emission spectra for Model 1. The The spectra include the carrier frequency and side frequency peaks with and without modulation (50 kHz span).



CARRIER ONLY

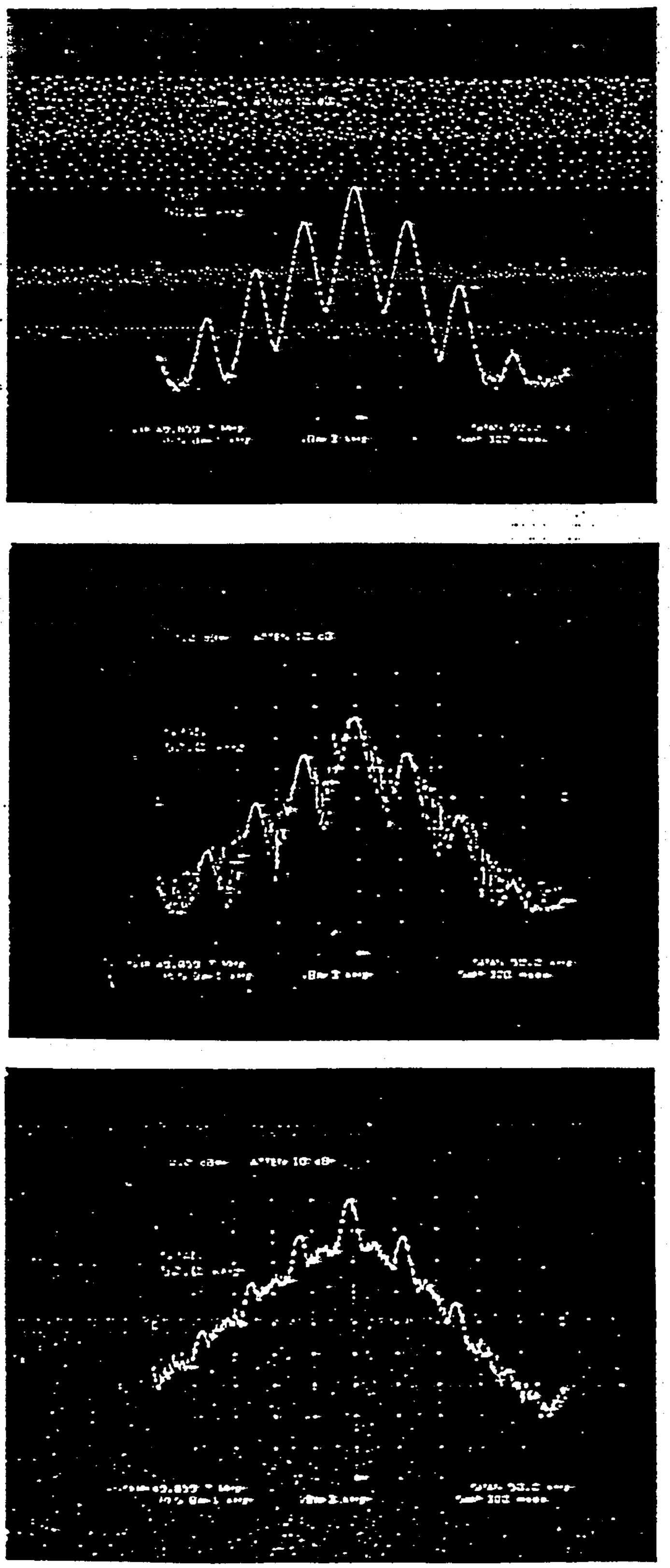


WITH DIALING



WITH VOICE MODULATION

Figure 15. Emission spectra for Model 1. The frequency span has been decreased from 50 kHz to 10 kHz.



CARRIER ONLY

WITH DIALING

WITH VOICE MODULATION

Figure 16. Emission spectra for Model 2. The frequency span is 50 kHz.

emission spectra of only the center peak frequency is shown. Here the resolution bandwidth has been changed from 1 kHz to 100 Hz and the span has been decreased from 50 to 10 kHz. The effects of voice modulation are quite evident here.

The emission spectra of model 2 is shown in Figure 16. Frequency peaks are separated by 5.5 to 5.9 kHz, and frequency peak levels are separated from 10 to 20 dBm. Modulation effects by dialing or voice are similar to those observed with the first model.

The operation of meteor burst equipment in the United States is often found in remote areas such as Alaska and non-urban areas where it is less likely for low power communication equipment to be operating. However, with increasing widespread use of cordless telephones it becomes more likely that even in remote areas, meteor burst systems will experience interference signals from unlicensed devices. The cordless frequency channeling plan is shown in Figure 17. Forty percent of the spectrum in the bands 46 and 49 MHz is occupied by cordless operations.

Consider, an adaptive meteor burst system transmitting in 46/49 MHz with a probe signal occupying a non-cordless channel. When a meteor channel becomes available, the meteor burst transmitter and receiver will adaptively extend their bandwidth, for example, to 100 kHz. This extension will most likely include one of the cordless channels which are often occupied. Thus, if cordless operations are within the 10 km separation distance from the meteor burst receiver, it becomes probable that adaptive rate operation will encounter interference from one or more cordless telephones.

Cordless telephones and other low power equipments cannot claim protection from meteor burst interference. Nevertheless, it was of interest to simulate the interference impact of a meteor burst transmitter on nearby low power communication devices. Figure 18 shows as a function of separation distance, D, the expected cordless phone received signal power from meteor burst transmitters with power 300-10,000 watts.

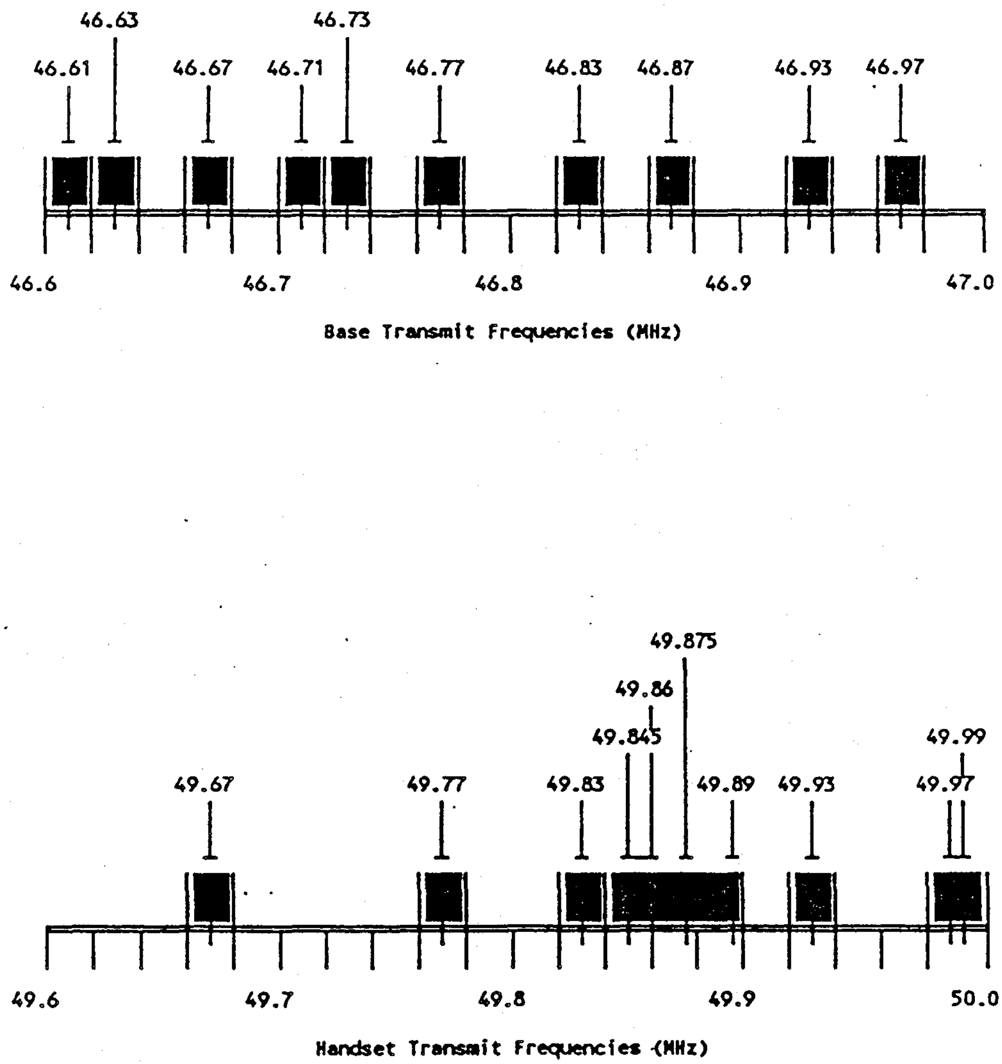


Figure 17. Cordless Phone Channels.

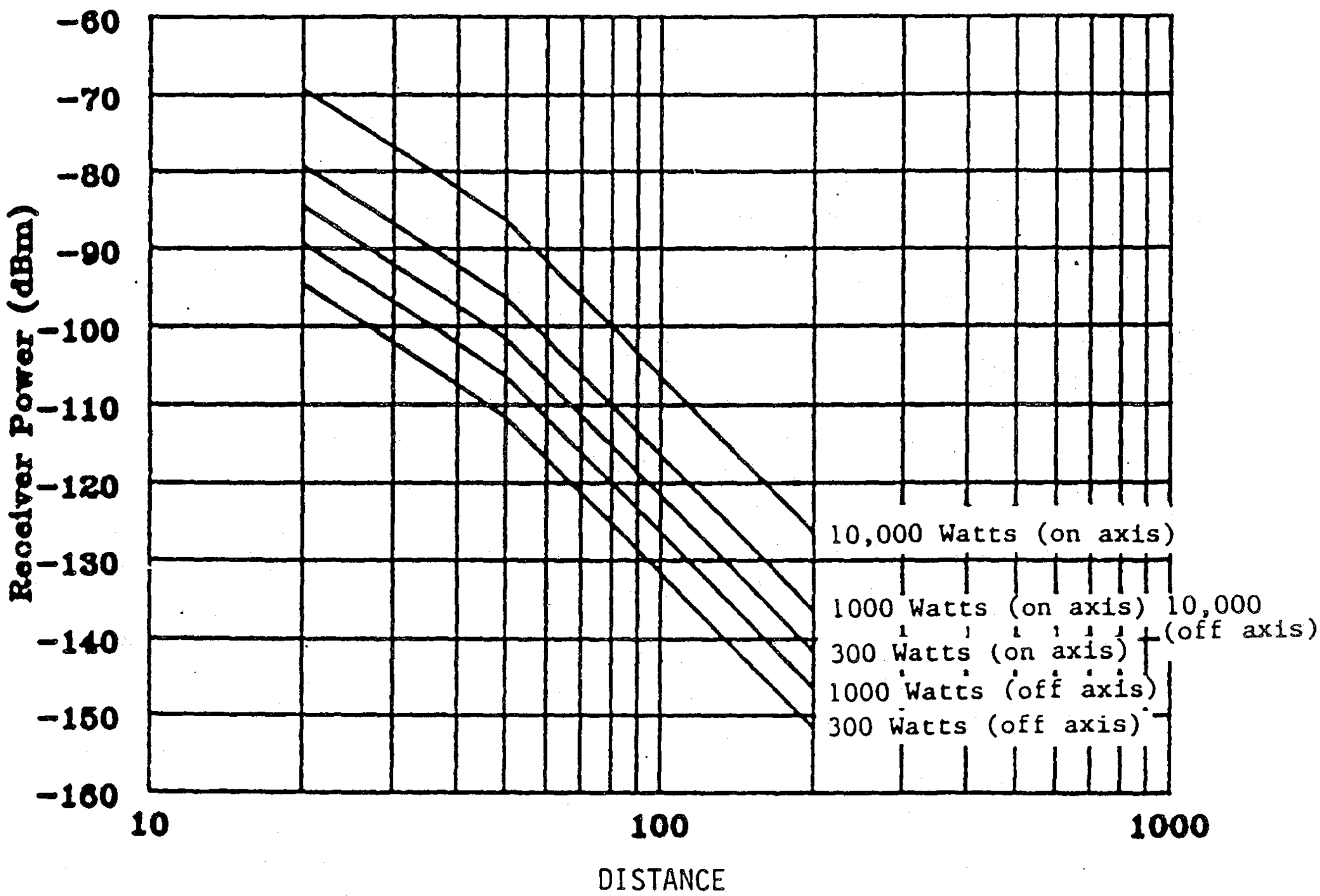


Figure 18. Interference to a Cordless Telephone from a Meteor Burst Transmitter.

The power, W, delivered to a receiver with no loss and a VSWR of 1 is

$$W = \frac{E^2 G}{f^2 (480\pi^2)} \qquad (7)$$

where
E = field strength
f = frequency
G = receiver antenna gain

Assuming the sensitivity of a cordless phone is .5 μV/m and using Equation 7, the noise threshold for a cordless telephone is -94.51 dBm. The interference threshold for a cordless phone is assumed to be equal to the noise threshold -94.51 dBm. Figure 18 shows the required separtion distances $D = D_S$ to avoid possible interference. The separations are:

Meteor Burst Power	Separation Distance
300 watts (off axis)	20 km
1,000 watts (off axis)	30 km
300 watts (on axis)	40 km
1,000 watts (on axis)	55 km
10,000 watts (on axis)	75 km

It should be remembered that up to 40 dB additional signal attenuation would be realized if the cordless telephone receiver is located inside a building rather than outside or adjacent to an outside wall.

7.6 METEOR BURST TO METEOR BURST COMPATIBILITY

One possible frequency assignment strategy would be to make available one or more frequency channels for meteor burst use. The FCC has already implemented this for the State of Alaska. Within Alaska, the FCC has made available the frequencies 42.40, 44.10, 44.20, and 45.90 MHz for assignment for meteor burst communications to fixed stations in the Rural Radio Service.[24] The maximum transmitter power is limited to 2,000 watts for a central office. In order to assure compatible cochannel operations, these central office stations (unless a waiver is granted) must be located at least 150 miles apart (240 km).

Meteor burst systems, if operated on the same frequency channel, whether dedicated or not, require distance separation, D_s, to avoid mutual groundwave interference.

The simulation model was used to calculate mean received powers as a function of separation distances for three meteor burst to meteor burst coupling conditions: (1) mainbeam to mainbeam coupling (Figure 19), (2) mainbeam to sidelobe coupling (Figure 20), and (3) sidelobe to sidelobe (Figure 21). The technical parameters used in the simulations, as before, are found in TABLE 5. The interference threshold is a mean signal level = -126 dBm.

TABLE 10 shows the required separation distances for the range of transmitter power 300 watts to 10,000 watts.

[24]FCC, Rules and Regulations, Section 22.601 and Section 1.106.

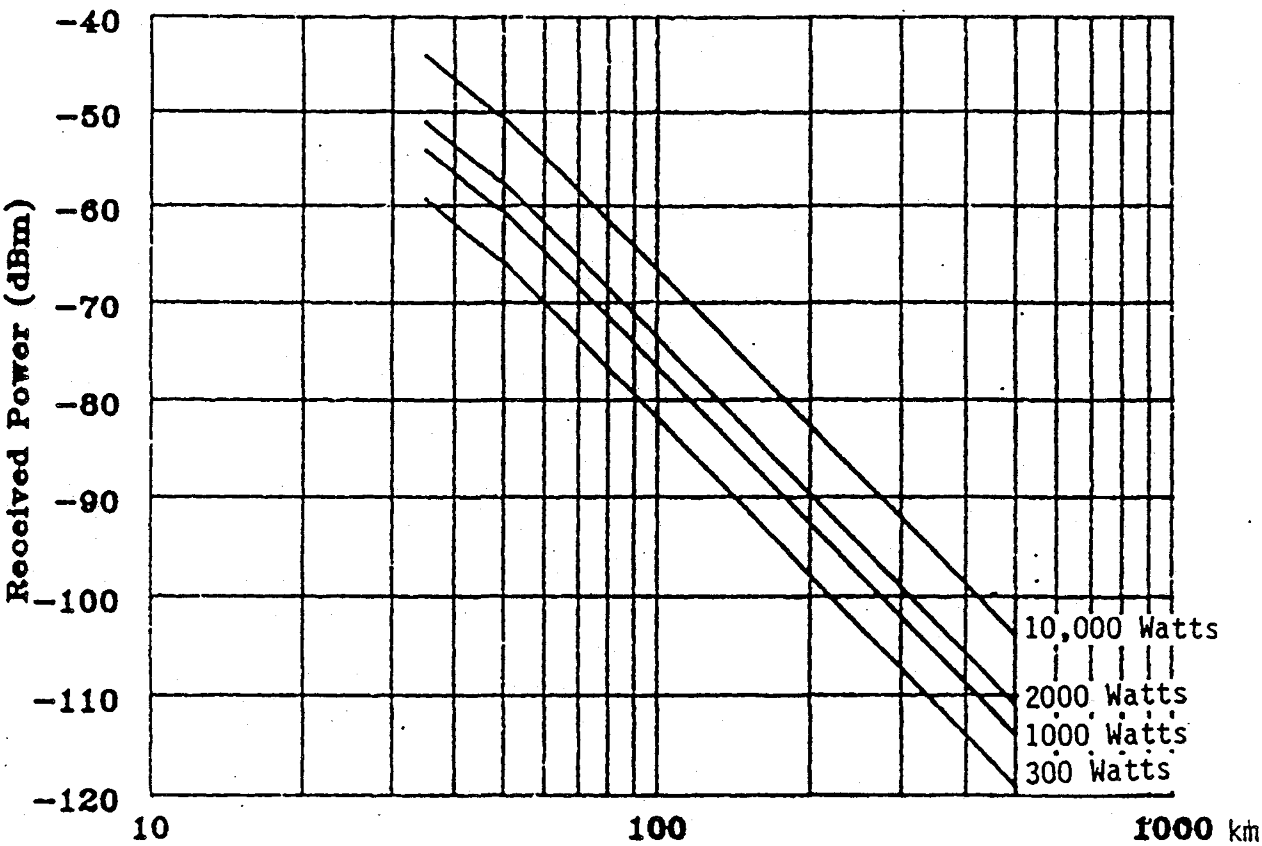


Figure 19. Received Power from Meteor Burst Transmitter, Mainbeam to Mainbeam, Meteor Burst to Meteor Burst.

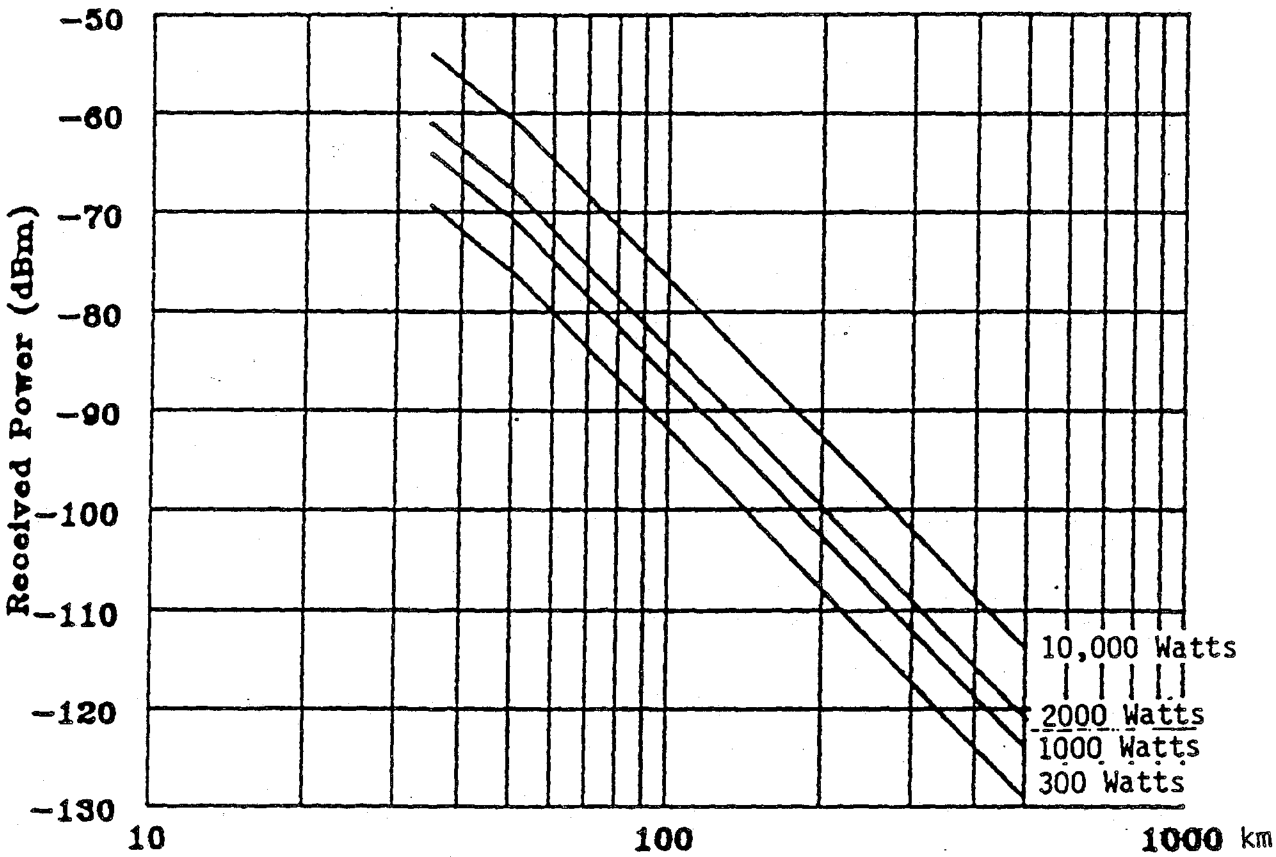


Figure 20. Received Power from Meteor Burst Transmitter, Mainbeam to Sidelobe, Meteor Burst to Meteor Burst.

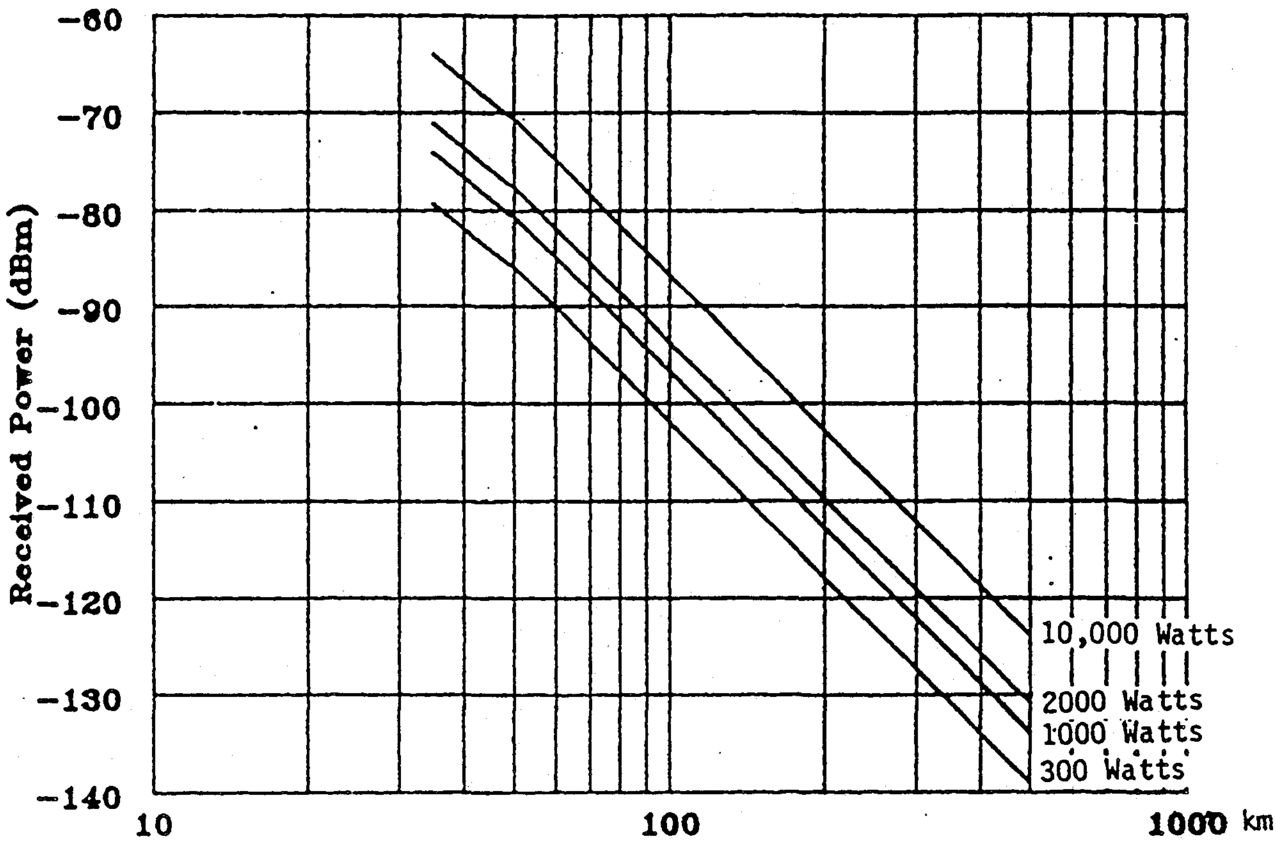


Figure 21. Received Power from Meteor Burst Transmitter, Sidelobe to Sidelobe, Meteor Burst to Meteor Burst.

TABLE 10

COCHANNEL SEPARATION DISTANCES (METEOR BURST TO METEOR BURST)

Transmitter Power	Coupling	Separation Distance (km)
300 watts	Mainbeam to Mainbeam	800 km
1,000 watts	Mainbeam to Mainbeam	900 km
2,000 watts	Mainbeam to Mainbeam	1000 km
10,000 watts	Mainbeam to Mainbeam	1200 km
300 watts	Mainbeam to Sidelobe	400 km
1,000 watts	Mainbeam to Sidelobe	600 km
2,000 watts	Mainbeam to Sidelobe	800 km
10,000 watts	Mainbeam to Sidelobe	1000 km
300 watts	Sidelobe to Sidelobe	300 km
1,000 watts	Sidelobe to Sidelobe	350 km
2,000 watts	Sidelobe to Sidelobe	400 km
10,000 watts	Sidelobe to Sidelobe	600 km

SECTION 8

APPLICABLE RULES AND REGULATIONS

8.1 ALLOCATIONS

The International Telecommunication Union (ITU), Geneva, Switzerland, regulates international radio frequency utilization which, for administrative purposes, has been divided into three geographic regions as shown in Figure 22. Within the United States, NTIA regulates frequency usage for government agencies, and the Federal Communications Commission (FCC) performs this function for nongovernment radio frequency users. The current international and national radio frequency allocation table for the 30 to 100 MHz and adjacent bands is given in APPENDIX A with appropriate footnotes in APPENDIX B.

Internationally, the 30 to 100 MHz band is divided into 15, 22, and 18 subbands in regions 1, 2, and 3, respectively. Throughout the three regions, primary allocations to fixed and mobile predominate, followed by primary allocations to broadcasting. In addition, there are some primary allocations to amateur, space research/operation, radio astronomy, and aeronautical radionavigation. Secondary allocations are to radio astronomy and to fixed and mobile. The international regulations also include footnotes which provide, in certain instances, additional primary allocations to broadcasting, fixed, mobile, aeronautical radionavigation, and amateur services. Some secondary allocations are made to fixed and mobile, and protection is given to radio astronomy.

Within the United States, the 30 to 100 MHz band is divided into 29 subbands for both government and nongovernment allocations. Within the government, the fixed and mobile allocations are primary in some subbands and secondary in others. Government has no allocations in 13 of the 29 subbands. U. S. footnotes provide for protection to radio astronomy, for telemetering services in connection with ocean buoys and wildlife, and for stations in the petroleum radio service.

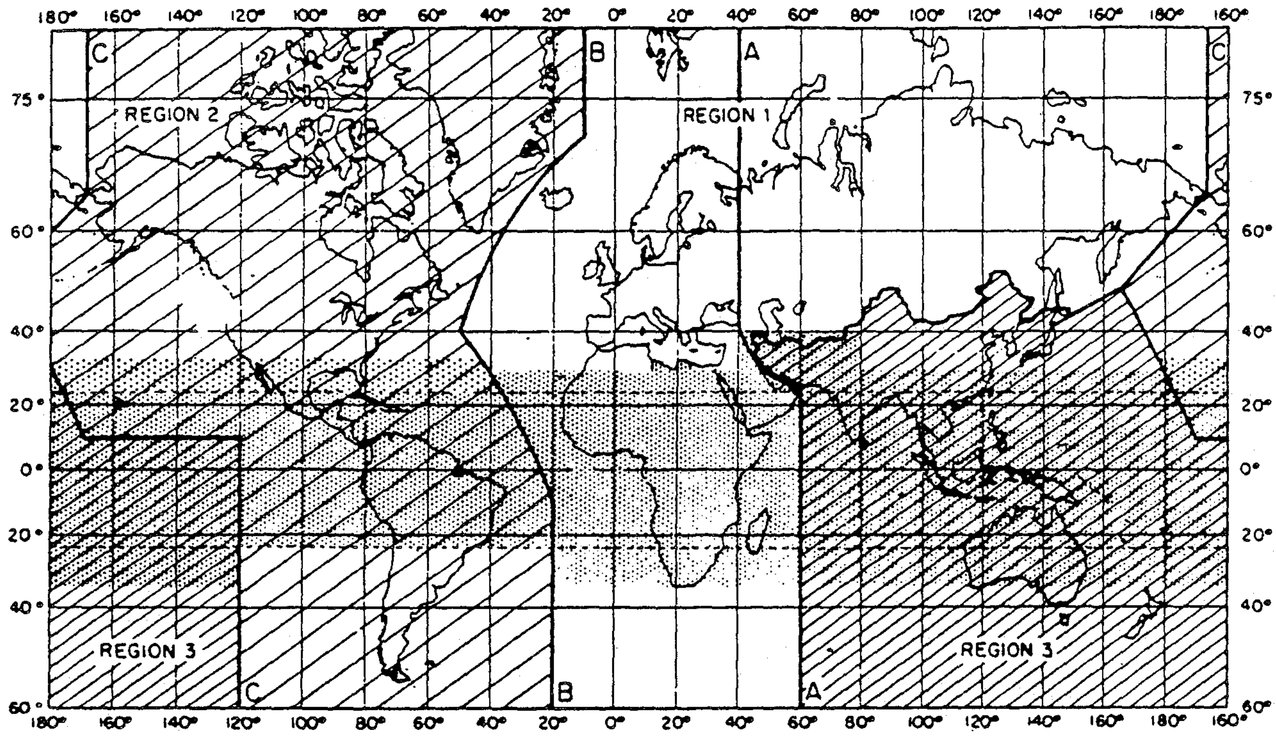


Figure 22. ITU International Radio Frequency Utilization divided into Three Geographic Regions.

Nongovernment primary allocations are to land mobile, broadcasting, fixed and mobile, aeronautical radionavigation, radio astronomy, and amateur. The only secondary allocation is to radio astronomy. Out of 29 subbands, 7 have no nongovernment allocations. Footnotes provide for such services as facsimile, remote control, public safety radio, fixed service on a secondary basis, and for meteor burst communications in Alaska on a primary basis.

8.2 TECHNICAL STANDARDS

All government radio systems adhere to certain technical standards. Technical standards for government are given in Chapter 5 of the NTIA Manual. APPENDIX C, which has been extracted from the manual, gives frequency tolerances and levels of unwanted emissions that are applicable to the 30 to 100 MHz band. Technical standards for wildlife and ocean buoy tracking and telemetry are given in APPENDIX C. To avoid harmful interference with U.S. Army testing, signals at 20 to 54 MHz must not exceed 50 MV per meter within a 25 km (15 mi) radius of Ft. Huachuca, AZ.

8.3 CHANNELING PLAN

The channeling plan for the 30 to 50 MHz band, as it appears in Chapter 4 (Section 4.3.7) of the Manual (see Reference 1) is given in APPENDIX C. The channels are 20 kHz wide allowing a necessary bandwidth for both analog and digital signals of 16 kHz. Assignments with necessary bandwidths up to 40 kHz may be authorized under certain conditions. The necessary bandwidth is a measure of the bandwidth necessary to transmit the signal and is the width of the frequency band which is just sufficient to ensure transmission of information at the rate and with the quality required.

8.4 DEFINITION OF METEOR BURST SYSTEMS

The NTIA Manual (Section 6.1.1) and the FCC Rules and Regulations define Meteor Burst Communications as communications by the propagation of radio signals reflected by ionized trails.

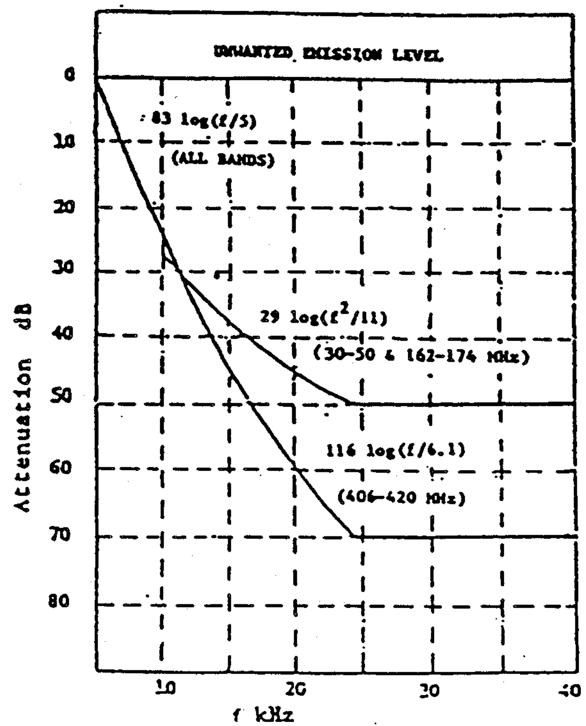
8.5 ADJACENT CHANNEL EMISSIONS (UNWANTED EMISSIONS)

An important consideration for land-mobile operations is that land-mobile operations in adjacent channels do not interfere. This is accomplished by limiting the emission spectrum (power spectral densities) of land mobile operation in adjacent channels. Section 5.6 of the NTIA Manual includes a chart and Table (see Figure 23) defining the limits in the band 30-50 MHz on the power of any unwanted emission on a frequency removed from the center of the authorized bandwidth a displacement f_d.

f_d	Attenuation (30-50 MHz)
5 kHz < $f_d \leq$ 10 kHz	83 log (f_d/5) dB
10 kHz < $f_d \leq$ 250% BW	29 log (f_d^2/11) or 50 dB, whichever is less

8.6 BILATERAL INTERNATIONAL AGREEMENTS

By mutual agreement, the United States and Canada coordinate the use of radio frequencies from 32 to 50 MHz along their mutual borders. The terms of their agreements are given in arrangement D of Chapter 3 in the NTIA Manual and in ITU RR222.



A(dB) = 83 LOG(f/5) FOR 5 < f ≤ 10 kHz
IN ALL BANDS

A(dB) = MIN [29 LOG(f^2/11), 50]
FOR 10 kHz < f ≤ 250% BW
IN 30-50 MHz AND 162-174 MHz BAND

A(dB) = MIN [116 LOG(f/6.1), 50 + 10 LOG P_W, 70]
FOR 10 kHz < f ≤ 250% BW
IN 406-420 MHz BAND

A(dB) = 50 + 10 LOG P_W FOR f > 250% BW
IF LAND, FIXED, OR MOBILE STATION

A(dB) = 43 + 10 LOG P_W FOR f > 250% BW
IF PORTABLE STATION

Figure 23. Transmitter Unwanted Emissions Standards.

APPENDIX A

INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE INCLUDING FOOTNOTES FOR THE 30-100 MHz BAND

TABLE A-1
INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE FOR THE 30-100 MHz BAND
(Page 1 of 6)

INTERNATIONAL			UNITED STATES				
Region 1 MHz	*Region 2 MHz*	*Region 3 MHz*	*Band MHz 1*	*National Provisions 2*	*Government Allocation 3*	*Non-Government Allocation 4*	*Remarks 5*
28-29.7	AMATEUR AMATEUR-SATELLITE		28.00-29.70			AMATEUR AMATEUR-SATELLITE	
29.7-30.005	FIXED MOBILE		29.70-29.80			LAND MOBILE	Industrial
			29.80-29.89			FIXED	29.81-29.88 Aeronautical fixed International fixed public
			29.89-29.91		FIXED MOBILE		See Section 4.3.6 of the NTIA Manual for Channeling Plan.
			29.91-30.00			FIXED	29.92-29.99 Aeronautical fixed International fixed public
30.005-30.01	SPACE OPERATION (satellite identification) FIXED MOBILE SPACE RESEARCH		30.00-30.56		MOBILE FIXED		See Section 4.3.6 of the NTIA Manual for Channeling Plan.
30.01-37.5	FIXED MOBILE		30.56-32.00			LAND MOBILE NG124	Industrial Land transportation Public safety
			32.00-33.00		FIXED MOBILE		See Section 4.3.6 of the NTIA Manual for Channeling Plan.

TABLE A-1
INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE FOR THE 30-100 MHz BAND

INTERNATIONAL			UNITED STATES				
Region 1 MHz	*Region 2 MHz*	*Region 3 MHz*	*Band MHz* 1	*National Provisions* 2	*Government Allocation* 3	*Non-Government Allocation* 4	*Remarks* 5
			33.00-34.00			LAND MOBILE NG124	33.00-33.01 Land transportation 33.01-33.11 Public safety 33.11-33.41 Industrial 33.41-34.00 Public safety
			34.00-35.00		FIXED MOBILE		See Section 4.3.6 of the NTIA Manual for Channeling Plan.
			35.00-36.00			LAND MOBILE NG124	35.00-35.19 Industrial 35.19-35.69 Domestic Public/Industrial/ Public safety 35.69-36.00 Industrial
			36.00-37.00	US220	FIXED MOBILE		See Section 4.3.6 of the NTIA Manual for Channeling Plan.
			37.00-37.5			LAND MOBILE NG124	37.00-37.01 Industrial 37.01-37.43 Public safety 37.43-37.5 Industrial
37.5-38.25	FIXED MOBILE Radio Astronomy 547		37.5-38.00	547	Radio Astronomy	LAND MOBILE Radio Astronomy NG59 NG124	37.50-37.89 Industrial 37.89-38.00 Public safety
			38.00-38.25	US81 547	FIXED MOBILE RADIO ASTRONOMY	RADIO ASTROMONY	See Section 4.3.6 of the NTIA Manual for Channeling Plan.
38.25-39.986	FIXED MOBILE		38.25-39.00		FIXED MOBILE		See Section 4.3.6 of the NTIA Manual for Channeling Plan.

TABLE A-1
INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE FOR THE 30-100 MHz BAND
(Page 3 of 6)

INTERNATIONAL

Region 1 MHz	*Region 2 MHz*	*Region 3 MHz*
39.986–40.02	FIXED MOBILE Space Research	
40.02–40.98	FIXED MOBILE 548	
40.98–41.015	FIXED MOBILE Space Research 549 550 551	
41.015–44	FIXED MOBILE 549 550 551	
44—47	FIXED MOBILE 551 552	

UNITED STATES

Band MHz 1	*National Provisions* 2	*Government Allocation* 3	*Non-Government Allocation* 4	*Remarks* 5
39.00–40.00			LAND MOBILE NG124	Public safety
40.00–42.00	US210 US220 548	FIXED MOBILE		See Section 4.3.6 of NTIA Manual for Channeling Plan. (ISM 40.68 ± 0.02 MHz)
42.00–46.60			LAND MOBILE NG124 NG141	42.00–42.95 Public safety 42.95–43.19 Industrial 43.19–43.69 Domestic public/Industrial/ Public safety 43.69–44.61 Land transportation 44.61–46.60 Public safety
46.60–47.00		FIXED MOBILE		See Section 4.3.6 of the NTIA Manual for Channeling Plan.

TABLE A-1
INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE FOR THE 30-100 MHz BAND
(Page 4 of 6)

INTERNATIONAL			UNITED STATES				
Region 1 *MHz*	*Region 2* *MHz*	*Region 3* *MHz*	*Band* *MHz* *1*	*National Provisions* *2*	*Government Allocation* *3*	*Non-Government Allocation* *4*	*Remarks* *5*
47–68 BROADCASTING	47–50 FIXED MOBILE	47–50 FIXED MOBILE BROADCASTING	47.00–49.60			LAND MOBILE NG124	47.00–47.43 Public safety 47.43–47.69 Public safety/Industrial 47.69–49.60 Industrial
			49.60–50.00		FIXED MOBILE		See Section 4.3.6. of the NTIA Manual for Channeling Plan.
	50–54 AMATEUR 556 557 558 560		50.00–54.00			AMATEUR	
553 554 555 559 561	54–68 BROADCASTING Fixed Mobile 562	54–68 FIXED MOBILE BROADCASTING	54.00—72.00			BROADCASTING	Television broadcasting
68–74.8 FIXED MOBILE except aeronautical mobile	68–72 BROADCASTING Fixed Mobile 563	68–74.8 FIXED MOBILE					
	72–73 FIXED MOBILE		72.00–73.00			FIXED MOBILE NG3 NG49 NG56	72.02–72.98 Operational fixed
	73–74.6 RADIO ASTRONOMY 570		73.00–74.60	US74	RADIO ASTRONOMY	RADIO ASTRONOMY	

TABLE A-1
INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE FOR THE 30-100 MHz BAND
(Page 5 of 6)

INTERNATIONAL			UNITED STATES				
Region 1 MHz	*Region 2 MHz*	*Region 3 MHz*	*Band MHz 1*	*National Provisions 2*	*Government Allocation 3*	*Non-Government Allocation 4*	*Remarks 5*
564 565 567 568 571 572	74.6–74.8 FIXED MOBILE 572	566 568 571 572	74.60–74.8	US273 572	FIXED MOBILE	FIXED MOBILE	
74.8–75.2 AERONAUTICAL RADIONAVIGATION 572			74.8–75.2	572	AERONAUTICAL RADIONAVIGATION	AERONAUTICAL RADIONAVIGATION	75 MHz Marker beacons.
75.2–87.5 FIXED MOBILE except aeronautical mobile	75.2–75.4 FIXED MOBILE 571 572		75.2–75.40	US273 572	FIXED MOBILE	FIXED MOBILE	
	75.4–76 FIXED MOBILE	75.4–87 FIXED MOBILE 573 574 577 579	75.40–76.00			FIXED MOBILE NG3 NG49 NG56	75.42–75.98 Operational fixed
565 571 572 575 578	76–88 BROADCASTING Fixed Mobile 576		76.00–88.00			BROADCASTING NG129	Television broadcasting
87.5–100 BROADCASTING 581 582	88–100 BROADCASTING	87–100 FIXED MOBILE BROADCASTING 580	88.00–108	US93		BROADCASTING	FM broadcasting

TABLE A-1
INTERNATIONAL AND NATIONAL RADIO FREQUENCY APPLICATION TABLE FOR THE 30-100 MHz BAND

INTERNATIONAL			UNITED STATES				
Region 1 MHz	*Region 2 MHz*	*Region 3 MHz*	*Band MHz 1*	*National Provisions 2*	*Government Allocation 3*	*Non-Government Allocation 4*	*Remarks 5*
100-108	BROADCASTING 582 583 584 585 586 587 588 589 590					NG2 NG128 NG129	
108-117.975	AERONAUTICAL RADIONAVIGATION		108-117.975	US93	AERONAUTICAL RADIONAVIGATION	AERONAUTICAL RADIONAVIGATION	

APPENDIX B

FOOTNOTES TO THE ALLOCATIONS

US74—In the bands 25.55–25.67, 73–74.6, 406.1–410, 608–614, 1400–1427, 1660.5–1670, 2690–2700, and 4990–5000 MHz and in the bands 10.68–10.7, 15.35–15.4, 23.6–24, 31.3–31.8, 86–92,105–116, and 217–231 GHz, the radio astronomy service shall be protected from extraband radiation only to the extent such radiation exceeds the level which would be present if the offending station were operating in compliance with the technical standards or criteria applicable to the service in which it operates.

US81—The band 38–38.25 MHz is used by both Government and non-Government radio astronomy observatories. No new fixed or mobile assignments are to be made and Government stations in the band 38–38.25 MHz will be moved to other bands on a case-by-case basis, as required, to protect radio astronomy observations from harmful interference. As an exception however, low powered military transportable and mobile stations used for tactical and training purposes will continue to use the band. To the extent practicable, the latter operations will be adjusted to relieve such interference as may be caused to radio astronomy observations. In the event of harmful interference from such local operations, radio astronomy observatories may contact local military commands directly, with a view to effecting relief. A list of military commands, areas of coordination, and points of contact for purposes of relieving interference may be obtained upon request from the Office of the Chief Scientist, Federal Communications Commission, Washington, D.C. 20554.

US93—In the conterminous United States, the frequency 108.0 MHz may be authorized for use by VOR test facilities, the operation of which is not essential for the safety of life or property, subject to the condition that no interference is caused to the reception of FM broadcasting stations operating in the band 88–108 MHz. In the event that such interference does occur, the licensee or other agency authorized to operate the facility shall discontinue operation on 108 MHz and shall not resume operation until the interference has been eliminated or the complaint otherwise satisfied. VOR test facilities operating on 108 MHz will not be protected against interference caused by FM broadcasting stations operating in the band 88–108 MHz nor shall the authorization of a VOR test facility on 108 MHz preclude the Commission from authorizing additional FM broadcasting stations.

US210—Use of frequencies in the bands 40.66–40.70 and 216–220 MHz may be authorized to Government and non-Government stations on a secondary basis for the tracking of, and telemetering of scientific data from, ocean buoys and wildlife. Air-borne wildlife telemetry in the 216–220 MHz band will be limited to the 216.000–216.100 MHz portion of the band. Operation in these two bands is subject to the technical standards specified in (a) Section 8.2.42 of the NTIA Manual for Government use, or (b) in Section 5.108 of the Commission's Rules for non-Government.

US220—The frequencies 36.25 and 41.71 MHz may be authorized to Government stations and non-Government stations in the Petroleum Radio Service, for oil spill containment and cleanup operations. The use of these frequencies for oil spill containment or cleanup operations is limited to the inland and coastal waterways regions.

US273—In the 74.6–74.8 MHz and 75.2–75.4 MHz bands, stations in the fixed and mobile services are limited to a maximum power of 1 watt from the transmitter into the antenna transmission line.

Non-Government (NG) Footnotes

NG2—Facsimile broadcasting stations may be authorized in the band 88–108 MHz.

NG3—Control stations in the domestic public radio services may be authorized frequencies in the band 72–73 and 75.4–76 MHz on the condition that harmful interference will not be caused to operational fixed stations.

NG49—The following frequencies may be authorized on a secondary basis for low-power (1 watt input) mobile operations in the Manufacturers Radio Service subject to the condition that no interference is caused to the reception of television stations operating on channels 4 and 5 and that their use is limited to a manufacturing facility:

MHz	*MHz*	*MHz*	*MHz*	*MHz*
72.02	72.10	72.18	72.26	72.34
72.04	72.12	72.20	72.28	72.36
72.06	72.14	72.22	72.30	72.38
72.08	72.16	72.24	72.32	72.40

Further, the following frequencies may be authorized on a primary basis for mobile operations in the Special Industrial Radio Service, Manufacturers Radio Service, and Railroad Radio Service subject to the condition that no interference is caused to the reception of television stations operating on channels 4 and 5; and that their use is limited to a railroad yard, manufacturing plant, or similar industrial facility.

MHz	*MHz*	*MHz*	*MHz*	*MHz*
72.44	72.52	72.60	75.48	75.56
72.48	72.56	75.44	75.52	75.60

NG56—In the bands 72.0–73.0 and 75.4–76.0 MHz, the use of mobile radio remote control of models is on a secondary basis to all other fixed and mobile operations. Such operations are subject to the condition that interference will not be caused to common carrier domestic public stations, to remote control of industrial equipment operating in the 72–76 MHz band, or to the reception of television signal on channels 4 (66–72 MHz) or 5 (76–82 MHz). Television interference shall be considered to occur whenever reception of regularly used television signals is impaired or destroyed, regardless of the strength of the television signal or the distance to the television station.

NG59—The frequencies 37.60 and 37.85 MHz may be authorized only for use by base, mobile, and operational fixed stations participating in an interconnected or coordinated power service utility system.

NG124—In the Public Safety Radio Service allocation within the bands 30–50 MHz, 150–174 MHz and 450–470 MHz, Police Radio Service licensees are authorized to operate low powered radio transmitters on a secondary non-interference basis in accordance with the provisions of Section 2.803 and 90.19 (f) (5) of the Rules.

NG128—In the band 535-1605 kHz, AM broadcast licensees or permittees may use their AM carrier on a secondary basis to transmit signals intended for both broadcast and non-broadcast purposes. In the band 88-108 MHz, FM broadcast licensees or permittees are permitted to use subcarriers on a secondary basis to transmit signals intended for both broadcast and non-broadcast purposes. In the bands 54–72, 76–88, 174–216 and 740–890 MHz, TV broadcast licensees or permittees are permitted to use subcarriers on a secondary basis for both broadcast and non-broadcast purposes.

NG129—In Alaska, the bands 76–88 MHz and 88–100 MHz are also allocated to the Fixed service on a secondary basis. Broadcast stations operating in these bands shall not cause interference to non-Government fixed operations authorized prior to January 1, 1982.

NG141—The frequencies 42.40 MHz and 44.10 MHz are authorized on a primary basis in the State of Alaska for meteor burst communications by fixed stations in the Rural Radio Service operating under the provisions of Part 22 of this Chapter. The frequencies 44.20 MHz and 45.90 MHz are authorized on a primary basis in Alaska for meteor burst communications by fixed private radio stations operating under the provisions of Part 90 of this Chapter. The private radio station frequencies may be used by Common Carrier stations on a secondary, noninterference basis and the Common Carrier frequencies may be used by private radio stations for meteor burst communications on a secondary, noninterference basis. Users shall cooperate to the extent practical to minimize potential interference. Stations utilizing meteor burst communications shall not cause harmful interference to stations of other radio services operating in accordance with the allocation table.

APPENDIX C

NATIONAL REGULATIONS CONCERNING TECHNICAL PARAMETERS AND OPERATIONS

5.1 TABLE OF FREQUENCY TOLERANCES AND UNWANTED EMISSIONS

Frequency Bands and Station Types	*Levels of Unwanted Emissions*	*Frequency Tolerance*
BAND: 29.7 to 100 MHz		
1. Fixed Stations		
1.1 10 W or less	D,E,B	20
1.2 above 10 W	D,E,C	5
2. Land Stations		
2.1 10 W or less	D,E	20
2.2 above 10 W	D,E	5
3. Mobile Stations		
3.1 10 W or less	D,E,C	20 (n)
3.2 above 10 W	D,E,C	5
4. Radionavigation Stations	D	50
5. Broadcasting Stations		
5.1 other than TV		
5.1.1 10 W or less	D	3000 Hz
5.1.2 above 10 W	D	2000 Hz
5.2 TV Sound and Vision	D	500 Hz (o)(p)(x)
6. Earth Stations	D	20
7. Space Stations	D	20
BAND: 100 to 470 MHz		
1. Fixed Stations		
1.1 band 100–406 MHz	D,E	5

5.1.1 Frequency Tolerances and Unwanted Emissions

The letters A thru N in Section 5.1.3 refer to the levels of unwanted emissions.

Units for frequency tolerance are (±) parts per million (ppm) unless otherwise stated.

The power shown for the various categories of stations is the peak envelope power for single-side-band transmitters and the mean power for all other transmitters, unless otherwise indicated. (RR)

5.1.2 Notes For Frequency Tolerance

(a) If the emergency transmitter is used as the reserve transmitter for the main transmitter, the tolerance for ship station transmitters applies.

(b) In the area covered by the North American Regional Broadcasting Agreement (NARBA), the tolerance of 20 Hz may continue to be applied.

(c) 20 Hz is applicable to other than Aeronautical Mobile (R) frequencies.

(d) Travelers Information Stations (TIS) have a tolerance of 100 Hz.

(e) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 50 Hz applies to other equipment.

(f) For AIA emissions the tolerance is 50 ppm.

(g) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 50 ppm applies to other equipment.

(h) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 200 ppm applies to other equipment.

(i) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 300 ppm applies to other equipment.

(j) The tolerance for aeronautical stations in the Aeronautical Mobile (R) service is 10 Hz.

(k) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 30 ppm applies to other equipment.

(l) For AIA emissions the tolerance is 10 ppm.

(m) For ship station transmitters in the band 26.175–27.5 MHz, on board small craft, with a carrier power not exceeding 5W operating in or near coastal waters and utilizing A3E or F3E and G3E emissions, the frequency tolerance is 40 ppm.

(n) 50 ppm applies to wildlife telemetry with mean power output less than 0.5W.

(o) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 1000 Hz applies to other equipment.

(p) In the case of television stations of:

(1) 50W (vision peak envelope power) or less in the band 29.7–100 MHz;

(2) 100W (vision peak envelope power) or less in the bank 100–965 MHz;

and which receive their input from other television stations or which serve small isolated communities, it may not, for operational reasons, be possible to maintain this tolerance. For such stations, this tolerance is 1000 Hz.

(q) See Part 5.6.

(r) This tolerance is applicable to all transmitters, including survival craft stations, after Jan 1, 1983.

(s) Except for the RR Appendix 18 Maritime Mobile frequencies, where the tolerance is 20 ppm except for transmitters put in service after January 1, 1973, a tolerance of 10 ppm shall apply, and this tolerance shall be applicable to all transmitters after January 1, 1983.

(t) Outside band 156–174 MHz, for transmitters used by on-board communications stations, a tolerance of 5 ppm shall apply.

(u) For transmitters used by on-board communications stations, a tolerance of 5 ppm applies.

(v) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 20 ppm applies to other equipment.

(w) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 400 ppm applies to other equipment.

(x) For transmitters for system M(NTSC) the tolerance is 1000 Hz. However, for low power transmitters using this system note (p) applies.

(y) The indicated tolerance applies to new equipment after 1/1/87. A tolerance of 800 ppm applies to other equipment.

(z) For 10–10.5 GHz, the indicated tolerance applies to new equipment after 1/1/87. A tolerance of 2500 ppm applies to other equipment.

5.1.3 Levels of Unwanted Emissions

For purposes of this Manual, the term "authorized bandwidth" is defined as the necessary bandwidth (bandwidth required for the transmission and reception of intelligence) and does not include allowance for transmitter drift or doppler shift. See, in addition, Chapter 6 for the definitions of special terms including authorized bandwidth and mean power.

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

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

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

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

a. For transmitters of mean power of 50 kilowatts or greater and which operate over a frequency range approaching an octave or more, a minimum attenuation of 60 decibels shall be provided and every effort should be made to attain at least 80 decibels attenuation.

b. For hand-portable equipment of mean power less that 5 watts, the attenuation shall be at least 30 decibels, but every effort should be made to attain 43 plus 10 $\log_{10}$ (mean power of the fundamental in watts) decibels attenuation (i.e., 50 microwatts absolute level).

c. For mobile transmitters, any unwanted emissions shall be at least 40 decibels below the fundamental without exceeding the value of 200 milliwatts, but every effort should be made to attain 43 plus 10 $\log_{10}$ (mean power of the fundamental in watts) decibels attenuation (i.e., 50 microwatts absolute level).

d. When A1A, F1B, or similar types of narrowband emissions are generated in an SSB transmitter, the suppressed carrier may fall more than 300 percent of the authorized bandwidth from the assigned frequency. Under these conditions, the suppressed carrier shall be reduced as much as practicable and shall be at least 50 decibels below the power of the fundamental emission.

B. Unwanted emission standards for fixed SSB/ISB stations in the band 2–30 MHz are contained in Section 5.4.1.

C. Unwanted emission standards for mobile SSB stations in the band 2–30 MHz are contained in Section 5.5.1.

D. The mean power of any emission supplied to the antenna transmission line, as compared with the mean power of the fundamental, shall be in accordance with the following:

1. On any frequency removed from the assigned frequency by more than 75 percent, up to and including 150 percent, of the authorized bandwidth, at least 25 decibels attenuation;

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

3. On any frequency removed from the assigned frequency by more than 300 percent of the authorized bandwidth:

a. For transmitters with mean power of 5 kilowatts or greater, attenuation shall be at least 80 decibels.

b. For transmitters with mean power less than 5 kilowatts, spurious output shall not exceed 50 microwatts except for frequency modulated maritime mobile radiotelephone equipment above 30 MHz as follows:

(1) The mean power of modulation products falling in any other international maritime mobile channel shall not exceed 10 microwatts for mean transmitter power 20 watts or less.

(2) The mean power of any other unwanted emission on any discrete frequency within the international maritime mobile band shall not exceed 2.5 microwatts for transmitters with mean power of 20 watts or less.

(3) For maritime mobile transmitters of mean power above 20 watts, these 2.5 and 10 microwatt limits may be increased in proportion to the increase of the mean power of the transmitters above this 20 watts.

E. Unwanted emission standards for FM stations are contained in the following parts:

Frequency (MHz)	*Part of Manual*
29.89–50.00	5.6
150.8–162.0125	5.5
162.0125–174	5.6
406.1–420	5.6

F. Unwanted emission standards for radionavigation radars and radiolocation radars are found in Part 5.3.

5.6 FIXED AND MOBILE/LAND MOBILE, FM OPERATIONS (30–50, 162–174, and 406.1–420 MHz Bands) [22]

These standards do not apply to:

- Military equipment used for tactical and/or training operations.
- FM wireless microphone systems whose mean output power does not exceed 0.1 watt.
- Equipment operating on splinter channels. (See Section 5.2.1).
- Fixed stations equipment with multichannel emissions.

5.6.1 Standard: The following is for fixed and mobile/land mobile service employing fixed, land, mobile and portable stations using FM or PM emissions in the bands 30–50, 162–174, and 406.1–420 MHz with necessary bandwidth of 16 kHz.[23]

A. Transmitter

1. Frequency tolerance ppm

	Band (MHz)		
Station Class	*30–50*	*162–174*	*406–420*
Land, FX..........	5	5	2.5
Mobile...............	5	5	5
Portable............	20	5	5

2. Unwanted Emissions: The power of any unwanted emission on any frequency removed from the center of the authorized bandwidth (BW) by a displacement frequency (f_d) shall be attenuated below the unmodulated carrier power (PZ) in accordance with the following and Figure 5.6.1 A2.

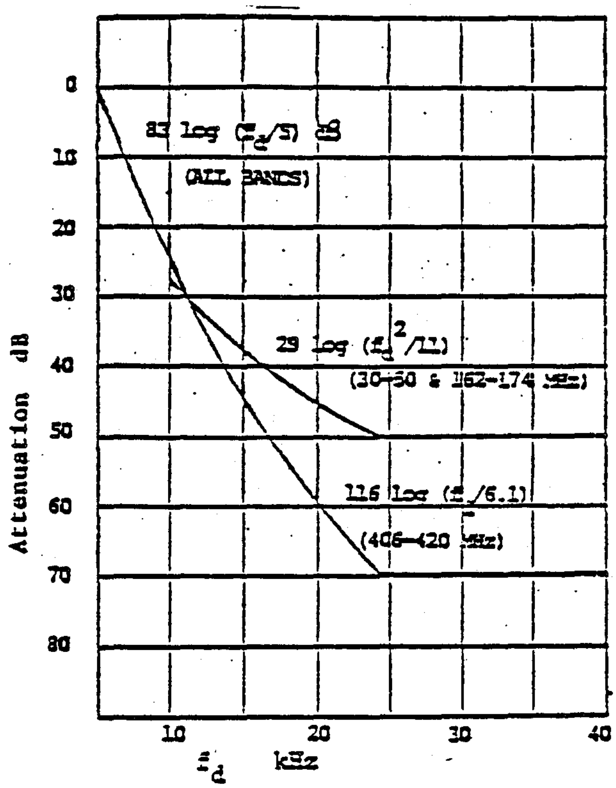


Figure 5.6.1 A 2

f_d	*Attenuation*
5 kHz < fd< 10 kHz	83 log (f_d/5) dB
10 kHz < fd< 250% BW	30–50 MHz & 162–174 MHz: 29 log (f_d^2/11) or 50 dB whichever is less
	406–420 MHz: 116 log (f_d/6.1) or 50 + 10 log (pZ) or 70 dB whichever is less
fd>250% BW	Land, Fixed, Mobile 50 + 10 log (pZ) dB (i.e. 10 microwatts absolute)
	Portable 43 + 10 log (pZ) dB (i.e. 50 microwatts absolute)

3. Frequency Deviation for all station classes and frequency bands shall not exceed ± 5 kHz.

Measurement Methods. The prescribed measurement method to be used is given in the latest revision of Electronic Industries Association (EIA) Standard RS–152, "Minimum Standards for Land Mobile Communications FM or PM Transmitters, 25–470 MHz." [21]

B. Receiver

1. Frequency tolerance ppm: [24]

	Band (MHz)		
Station Class	*30–50*	*162–174*	*406–420*
Land, FX..........	5	5	2.5
Mobile...............	5	5	5
Portable............	20	25	5

2. Spurious Response Attenuation:

	Band (MHz)		
Station Class	*30–50*	*162–174*	*406–420*
Land, FX, Mobile...........	85 dB	85 dB	85 dB
Portable............	60 dB	60 dB	50 dB

3. Adjacent Channel Selectivity:

	Band (MHz)		
Station Class	*30–50*	*162–174*	*406–420*
Land, FX, Mobile...........	80 dB	80 dB	80 dB
Portable............	50 dB	70 dB	60 dB

4. Intermodulation Attenuation:

	Band (MHz)		
Station Class	*30–50*	*162–174*	*406–420*
Land, FX, Mobile...........	60 dB	70 dB	70 dB
Portable............	50 dB	50 dB	50 dB

5. Conducted Spurious Emissions:

All station classes and all bands −80 dBW

Measurement Method. The prescribed measurement method is given in the latest revision of Electronic Industries Association (EIA) Standard RS–204, "Minimum Standards for Land Mobile Communication FM or PM Receivers, 25–470 MHz." [21]

[21] Copies of these standards may be obtained from the Electronic Industries Association, 2001 Eye Street, N.W., Washington, D.C. 20006.

[22] In the band 406.1–410 MHz, power is limited to a maximum of 7 W/kHz of necessary bandwidth as specified in footnote US 117.

[23] The spacing of channels (adjacent channel spacing) is 20 kHz in the 30–50 MHz band and 25 kHz in the 162–174 and 406–420 MHz bands.

[24] Measurement Method—An unmodulated standard input signal source, adjusted to the standard input frequency as specified in EIA RS–204, shall be connected to the receiver under test and adjusted for an output of 20 dB above the receiver specified sensitivity. The center frequency of the IF passband shall be measured with equipment having a degree of accuracy of at least five times the minimum tolerance to be measured.

4.3.6 Channeling Plan for Assignments in the Band 29.89–50 MHz

This plan is a guide for identifying the center frequencies normally used for assignments with necessary bandwidths equal to or less than 16 kHz.

CONDITIONS AND LIMITATIONS

1. *Narrowband Operations.* Assignments with necessary bandwidths equal to or less than 16 kHz (narrowband assignments) may be authorized on the center frequencies shown in this plan and on qualified interstitial channels. A "qualified interstitial channel" is one which:

a. Has a center frequency which falls exactly halfway between two adjacent center frequencies shown in this plan,

b. does not overlap an all-government-agencies (AGA) channel,

c. will result in more efficient use of the spectrum, and

d. has been properly coordinated with all affected agencies.

2. *Wideband Operations.* Assignments with necessary bandwidths greater than 16 kHz (wideband assignments) may also be authorized in this band, provided such assignments:

a. Do not exceed 40 kHz of necessary bandwidth,

b. do not overlap an all-government-agencies (AGA) channel,

c. are positioned between the center frequencies shown in this plan when this will result in more efficient use of the spectrum,

d. have been properly coordinated with all affected agencies, and

e. are needed to satisfy requirements which cannot be accommodated with narrowband state-of-the-art equipment, or

f. are in direct support of military tactical and training operations which conform to the conditions and limitations of Section 7.15.4.

3. *Use of Coded Squelch.* Coded squelch (squelch control techniques) will be used whenever this technique will promote more efficient use of the spectrum; e.g. use of fewer frequencies, sharing of frequencies, reduction or elimination of interference, etc.

EXCEPTIONS

Exceptions to the above conditions and limitations will be considered by the FAS on a case-by-case basis.

29.90								
30.01	**32.01**	**34.01**	**36.01**		**40.01**	**41.01**		
.03	.03	.03	.03		.03	.03		
.05	.05	.05	.05		.05	.05		
.07	.07	.07	.07		.07	.07		
.09	.09	.09	.09		.09	.09		
.11	.11	.11	.11		.11	.11		
.13	.13	.13	.13		.13	.13		
.15	.15	.15	.15		.15	.15		
.17	.17	.17	.17		.17	.17		
.19	.19	.19	.19		.19	.19		
.21	.21	.21	.21		.21	.21		
.23	.23	.23	.23		.23	.23		
.25	.25	.25	.25		.25	.25		
.27	.27	.27	.27	**38.27**	.27	.27		
.29	.29	.29	.29	.29	.29	.29		
.31	.31	.31	.31	.31	.31	.31		
.33	.33	.33	.33	.33	.33	.33		
.35	.35	.35	.35	.35	.35	.35		
.37	.37	.37	.37	.37	.37	.37		
.39	.39	.39	.39	.39	.39	.39		
.41	.41	.41	.41	.41	.41	.41		
.43	.43	.43	.43	.43	.43	.43		
.45	.45	.45	.45	.45	.45	.45		
.47	.47	.47	.47	.47	.47	.47		
.49	.49	.49	.49	.49	.49	.49		
.51	.51	.51	.51	.51	.51	.51		
.53	.53	.53	.53	.53	.53	.53		
.55	.55	.55	.55	.55	.55	.55		
	.57	.57	.57	.57	.57	.57		
	.59	.59	.59	.59	.59	.59		
	.61	.61	.61	.61	.61	.61	**46.61**	**49.61**
	.63	.63	.63	.63	.63	.63	.63	.63
	.65	.65	.65	.65	.65	.65	.65	.65
	.67	.67	.67	.67	.67	.67	.67	.67
	.69	.69	.69	.69	.69	.69	.69	.69
	.71	.71	.71	.71	.71	.71	.71	.71
	.73	.73	.73	.73	.73	.73	.73	.73
	.75	.75	.75	.75	.75	.75	.75	.75
	.77	.77	.77	.77	.77	.77	.77	.77
	.79	.79	.79	.79	.79	.79	.79	.79
	.81	.81	.81	.81	.81	.81	.81	.81
	.83	.83	.83	.83	.83	.83	.83	.83
	.85	.85	.85	.85	.85	.85	.85	.85
	.87	.87	.87	.87	.87	.87	.87	.87
	.89	.89	.89	.89	.89	.89	.89	.89
	.91	.91	.91	.91	.91	.91	.91	.91
	.93	.93	.93	.93	.93	.93	.93	.93
	.95	.95	.95	.95	.95	.95	.95	.95
	.97	.97	.97	.97	.97	.97	.97	.97
	.99	.99	.99	.99	.99	.99	.99	.99

8.2.42 Wildlife and Ocean Buoy Tracking and Telemetering

Pursuant to footnote US210 to the National Table of Frequency Allocations, the use of frequencies in the bands 40.66–40.70 and 216–220 MHz may be authorized to U.S. Government radio stations on a secondary basis for the tracking of, and telemetering of scientific data from, ocean buoys and wildlife, subject to the following conditions:

1. Airborne wildlife telemetering in the band 216–220 MHz will be authorized in only the 216.0–216.1 MHz portion of the band.

2. All transmitters shall be FCC type accepted, or the equivalent, as specified in Section 5.109, FCC Rules and Regulations.

3. Classes of emission shall be limited to N0N, A1D, A2D, F1D, F2D, F9D.

4. Occupied bandwidth shall not exceed 1 kHz.

5. Maximum carrier power shall not exceed 1 milliwatt for airborne wildlife applications, 10 milliwatts for terrestrial wildlife applications, and 100 milliwatts for ocean buoys.

6. In the band 216–220 MHz, the carrier frequency shall be maintained within 0.005 percent of the assigned frequency.

7. In the band 40.66–40.70 MHz, the bandwidth required for frequency tolerance plus the occupied bandwidth of any emissions must be adjusted so as to be confined within this band, except as permitted by paragraph 8 below.

8. The mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the following schedule:

a. On any frequency removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: at least 25 decibels;

b. On any frequency removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: at least 35 decibels;

c. On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth; at least 43 plus 10 Log_{10} (mean output power in watts) decibels or 80 decibels, whichever is the lesser attenuation.

7.15.3 Military Communications in non-Government Bands Above 25 MHz for Tactical and Training Operations

The military services may employ frequencies in certain non-Government bands above 25 MHz, after coordination between FCC field personnel and military field personnel, for tactical and training operations in the U. S. and Possessions in accordance with the arrangement between the FCC and the Military entitled "Field Coordination of Military Tactical and Training Assignments 25–2400 MHz." The military use of non-Government frequencies under the procedures stipulated will not be a bar to the present or future assignment, through the normal IRAC/FCC process, of non-Government frequencies to non-military Government agencies, and, in such military use of non-Government frequencies, protection shall be afforded to Government operations authorized on specific frequencies within the non-Government frequency bands concerned. The text of the arrangement between the FCC and the Military follows.

1. In order to provide for military tactical and training assignments in the United States and Possessions, FCC field personnel and military field personnel are authorized to coordinate such assignments without referring these matters to Washington headquarters.

2. Military agencies have agreed that prior to coordinating tactical and training frequency assignments with FCC field offices, military field representatives will first establish that proposed assignments have a good chance of being compatible with non-Government assignments. Consequently, FCC Field Engineers in Charge (EIC) are not expected to "engineer" such assignments for the Military.

3. The following procedures will apply to the use of the non-Government bands between 25 and 2400 MHz specified herein:

a. The Military will not request the use of frequencies allocated to non-Government services whenever the tactical and training requirements can be met through the use of Government bands.

b. Military tactical and training assignments shall cause no harmful interference to non-Government assignments and military operations shall be terminated immediately upon notification that harmful interference has occurred.

c. Military tactical and training assignments must accept such interference as may be caused by non-Government assignments.

d. Tactical and training assignments shall be temporary for a period of no longer than one year and the military representatives shall recoordinate if continued use is desired. The military field representatives shall maintain a current list of such assignments and furnish the EIC with three copies thereof annually.

4. The following shall be used as a guide for the coordination of military tactical and training assignments when it has been determined that the use of non-Government bands is necessary:

a. Bands allocated to the Broadcasting Service for domestic use.

(1) The following are the bands between 25 and 2400 MHz that are allocated for this purpose:

MHz	*MHz*
54–72	174–216
76–100 (ex. Alaska)	470–608
100–108	614–890

(2) FCC field engineers are acquainted with the areas being served by broadcasting stations and these engineers will not permit military tactical and training assignments on TV or FM channels in the areas where the public is receiving service. In many instances such service is received far beyond the normal service ranges of broadcasting stations. However, reception in such areas shall be protected regardless of the *quality* of such reception.

b. Bands used for auxiliary broadcast purposes.

(1) The following are the bands between 25 and 2400 MHz that are allocated for this use:

MHz	*Use*
25.85–26.48	Remote Pickup
152.86–153.35	Remote Pickup
160.86–161.40 (Puerto Rico and Virgin Islands only)	Remote Pickup
161.625–161.775 (except in Puerto Rico and Virgin Islands)	Remote Pickup
450–451	Remote Pickup
455–456	Remote Pickup
942–952	STL
1990–2110	TV Pickup, TV-STL

(2) Frequencies in bands used by remote pickup, studio transmitter links and other broadcast auxiliaries may be used for military tactical and training purposes providing FCC field engineers coordinate such use with the appropriate broadcast station licensees. For example, there is no objection to a military tactical and training assignment co-channel to a remote pickup assignment in the same area provided the broadcast licensee is cognizant of such arrangements and can be assured that in the event a remote broadcast pickup is necessary, any military operations that may be on the air will shut down immediately upon notification.

As an additional example, frequencies which are assigned to studio transmitter links may be utilized by military tactical and training assignments, providing these assignments are coordinated by the FCC Field Representative with the broadcast licensees involved and the tactical and training assignments so arranged as to cause no harmful interference to an STL. In all cases where a tactical and training assignment is made on an auxiliary broadcast service frequency within interference range of a co-channel FCC licensee, the licensee should be given the name of the military representative to contact in the event interference is caused.

c. Public Safety, Citizens Radio, Industrial, Land Transportation and Maritime Mobile Bands.

(1) The following bands between 25 and 2400 MHz are allocated for this purpose:

MHz	*MHz*	*MHz*
25.01–25.33	39.00–40.00	156.675–156.725
26.96–27.54	42.00–43.20	156.875–157.025
29.70–29.80	43.68–46.60	157.45–157.74
30.56–32.00	47.00–49.60	158.10–158.46
33.00–34.00	150.80–152.00	158.70–161.775
35.00–35.20	152.24–152.48	173.20–173.40
35.68–36.00	152.84–156.25	451.00–454.00
37.00–38.00	156.325–156.625	456.00–459.00
		460.00–470.00

(2) Frequencies in bands allocated to these services for land mobile use may be authorized for military tactical and training assignments provided the assignments are coordinated between FCC field engineers and military field representatives. The set of curves attached hereto should be used as a guide in these matters. These curves are a combination of propagation theory backed up by considerable measurement data and they do not necessarily represent finite values upon which engineering determinations may be made. Consequently, personnel in the field will need to take into consideration such factors as local terrain. For example, an obstruction such as a hill or a mountain range might lower considerably the distance between a non-Government and a military tactical and training assignment. On the other hand, there are certain locations where better than average radio propagation conditions exist, and it will be necessary for FCC field engineers and military representatives to take this into account. If doubt exists as to the practicability of a proposed tactical and training assignment, tests should be conducted.

d. Bands allocated to non-Government fixed service (excluding common carriers).

(1) The following are the bands between 25 and 2400 MHz that are allocated for this purpose:

MHz	*MHz*
72.0–73.0	1850–1990
75.4–76.0	2130–2160
76.0–100 (In Alaska)	2180–2200
952–960	

(2) In bands allocated to the non-Government fixed service (excluding common carrier), military tactical and training assignments may be authorized after coordination with appropriate FCC field offices. It is not possible to develop typical standards for the coordination of such assignments in fixed bands due to the fact that, in general, highly directive antenna are used and problems of interference protection will vary greatly. Since many military tactical and training operations involve the use of highly directive antennas, it may sometimes be possible to coordinate such assignments, although they may be in the same area as non-Government assignments, by taking into account directive antenna features of the installations involved. In coordinating such assignments FCC field engineers are urged to coordinate proposed military tactical and training assignments with FCC licensees whenever there is a doubt as to the compatibility of the proposed military assignments. Tests should be conducted if necessary.

e. Bands allocated to non-Government aeronautical fixed and international fixed public services.

(1) The following bands between 25 and 2400 MHz are allocated for this purpose:

MHz
26.95–26.96
29.80–29.89
29.91–30.00

(2) In the above bands, military tactical and training assignments may be authorized after coordination with appropriate FCC Field Offices provided that the military use is limited to those periods when propagation conditions would not normally support long distance communication, and therefore could be expected to confine to the local area the potential of interference to non-Government services.

f. Amateur Bands

(1) The following are the bands between 25 and 2400 MHz that are allocated for this purpose:

MHz	*MHz*
28–29.7	420–450
50–54	1215–1300
144–148	2300–2400
220–225	(This band extends to 2450 MHz.)

(2) The following provisions are applicable in the use of the above bands for communication purposes (i.e. for other than radiolocation purposes).

(a) Subject to the provisions of the rules adopted by the Federal Communications Commission, amateur stations generally are operated freely on any frequency within the established amateur bands. Therefore, great care needs to be taken in the coordination and in the use of such frequencies by the Military.

(b) The following conditions shall be observed in the military use of amateur frequency bands between 25 and 2400 MHz for routine day to day tactical and training purposes:

1 Operations on such frequencies will be confined normally to the hours of 0600–1800 local civil time.

2 Prior to transmission on specific frequencies, military personnel should ascertain that such frequencies are not in actual use by amateur stations within the local area in a manner which is likely to suffer harmful interference if the frequencies were used for military operation.

3[4] In recognition of the primary status of amateur stations as against the secondary status of military frequency use in such bands in peacetime, military personnel have responsibility in the event of, evidence of, or actual complaints of interference, to take effective remedial action without undue delay.

4 Insofar as practical, consideration should be given in planning the use of such frequencies to their employment in a manner or at transmitter locations well removed from areas of civilian population where amateur use is likely. Appropriate measures should be adopted to minimize interference as by the use of minimum radiated power and intermittent transmissions of short duration.

5 It should be recognized that long distance propagation characteristics of the 28 MHz and 50 MHz bands, especially in the case of the former, require that good judgment be exercised in military use of these bands. Only when sky-wave propagation is not present is it practicable to use these bands for anything except extremely low power.

7.15.4 Military Communications in the Government Bands Between 30 and 50 MHz for Tactical and Training Operations

To meet local military peacetime tactical and training requirements within the United States and Possessions, the military services may employ frequencies in the bands 30.00 to 30.56, 32.00 to 33.00, 34.00 to 35.00, 36.00 to 37.00, 38.00 to 39.00, 40.00 to 42.00, 46.60 to 47.00, and 49.60 to 50.00 MHz on a secondary basis to the services of other Government stations authorized on frequencies within these bands provided that:

1. Operations shall be with field-type portable and mobile equipment.

2. Minimum antenna power shall be used commensurate with the actual communication requirement but not in excess of 50 watts.

3. The bandwidth of emission shall not exceed 6 kHz with type A3E emission or 36 kHz with type F3E emission.

4. Prior to transmission, responsible military personnel shall ascertain that services being performed by other Government agencies in the local area will not be disrupted or suffer harmful interference as a result of such military use of frequencies within the local area.

5. The use of any frequency authorized herein shall be terminated immediately upon notification that harmful interference is being caused.

[4] This refers to military use for communication purposes and not to military radio location uses which have priority status in the amateur bands above 220 MHz.

APPENDIX D

DESCRIPTION OF THE PRODSIR MODEL

The PRODSIR (PRObability Distribution Signal to Interference Ratio) is a computer simulation model used to predict the probability of successful communication in an electromagnetic environment. The technical parameters in the model are statistical and each is described by a probability density function (pdf). Numerical integration rather than a Monte Carlo simulation is used to combine the effects of the parameters in the random process. The PRODSIR model, developed by Berry (see Reference 21) is appropriate to simulate the communication performance of radio equipments which are randomly distributed spatially. The model can predict, for an electromagnetic environment, the pdf and cumulative probability distribution of signal (S), interference (I), and S/I. The computer program works to the solution

$$Pa = P(S-I \geq R) = \int_{R}^{\infty} f_{S-I}(X)\,dX$$

where

S is the received signal strength in dBW
I is the received interference in dBW
R is the required S/I in dBW
$f_{S-I}(X)$ is the pdf of X=S-I.

The inputs to the PRODSIR model are:

(1) for the wanted signal
a) the pdf of radiated power of the wanted transmitters
b) the conditional pdf of transmission loss, given wanted path length
c) the pdf of wanted path length

(2) for each category of interferer

a) the pdf of radiated power

b) the conditional pdf of transmission loss, given interfering path length

c) the pdf of path lengths

d) the traffic intensity, U, of interferer in this category

e) the receiver transfer function, if any

(3) the pdf of ambient noise, and

(4) the required signal-to-noise ratio.

In this meteor burst study, the PRODSIR model has been used to find separation distances which yield

For land mobile receiver:

$P(S/I \geq 17 \text{ DB} = 90\%)$ in the coverage area

For meteor burst receivers:

Mean I = -126 dBm.

A block diagram of the PRODSIR model is shown in Figure D-1.

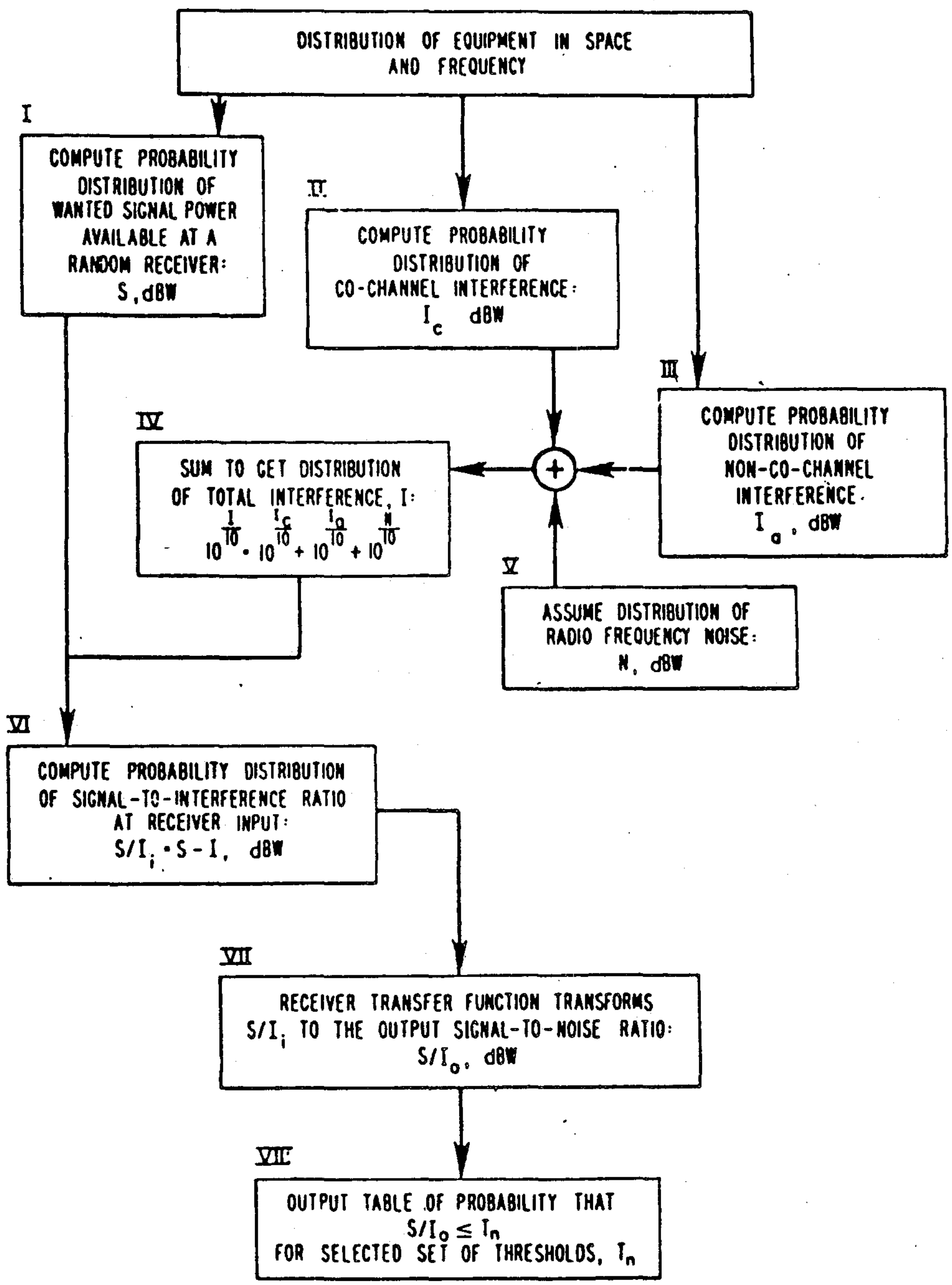


Figure D-1. Block diagram of major steps in computing probability distribution of signal-to-(interference plus noise).

Source: Berry (see Reference 20).

APPENDIX E

GROUND WAVE PROPAGATION MODEL

The propagation model included in the PRODSIR model is statistical within the PRODSIR simulation. At a given distance, D, the basic transmission loss in the PRODSIR model is Gaussian distributed (in dB) with a σ (standard deviation) and mean value $M = A + B \log D$ (dB).

The σ and the constants A and B must be supplied as inputs to the simulation.

A specific version of the area Longley Rice model was used to find the constants, σ, A, and B. The propagation model was run for a relatively smooth terrain with Δh = 60 meters, conductivity = .005/m and dielectric constant of 15. It was found that the transmission loss varied little over the range 30-50 MHz. The specific frequency of 45 MHz was used to find the final σ, A, and B data, but any frequency in 30-50 MHz would have similar propagation losses. Thus, the results in Section 7 apply to all interference situations for frequencies in the range 30-50 MHz. The σ was computed from the 16 and 84% confidence values with

$$\alpha = |16\% \text{ confidence value} - 50\% \text{ confidence value}|$$

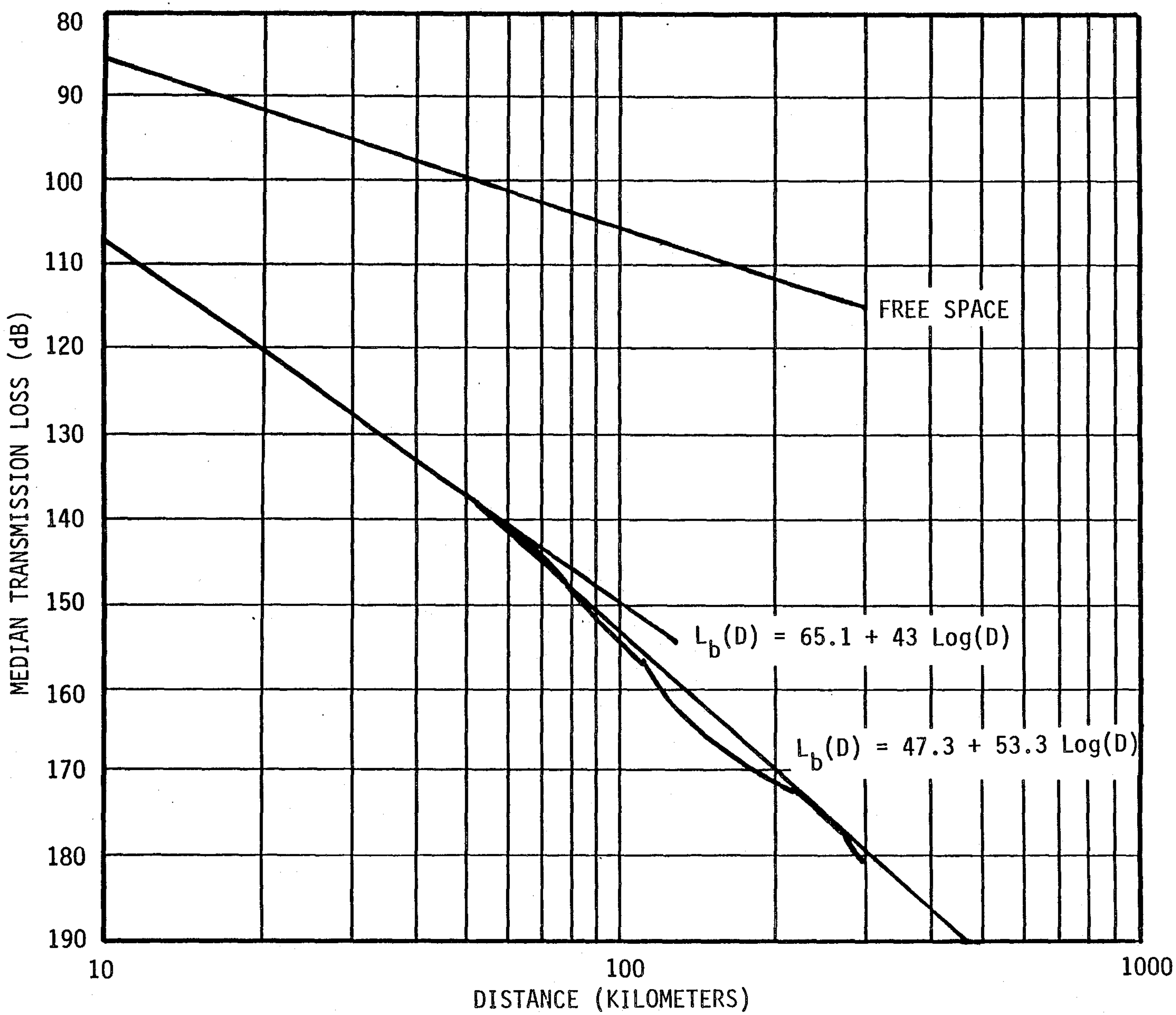
$$\beta = |84\% \text{ confidence value} - 50\% \text{ confidence value}|$$

$$\sigma = (\alpha + \beta)/2$$

Multiple runs for the Longley Rice model for Δh = 60 m and f between 40-50 MHz yielded a representative value of σ = 7 dB.

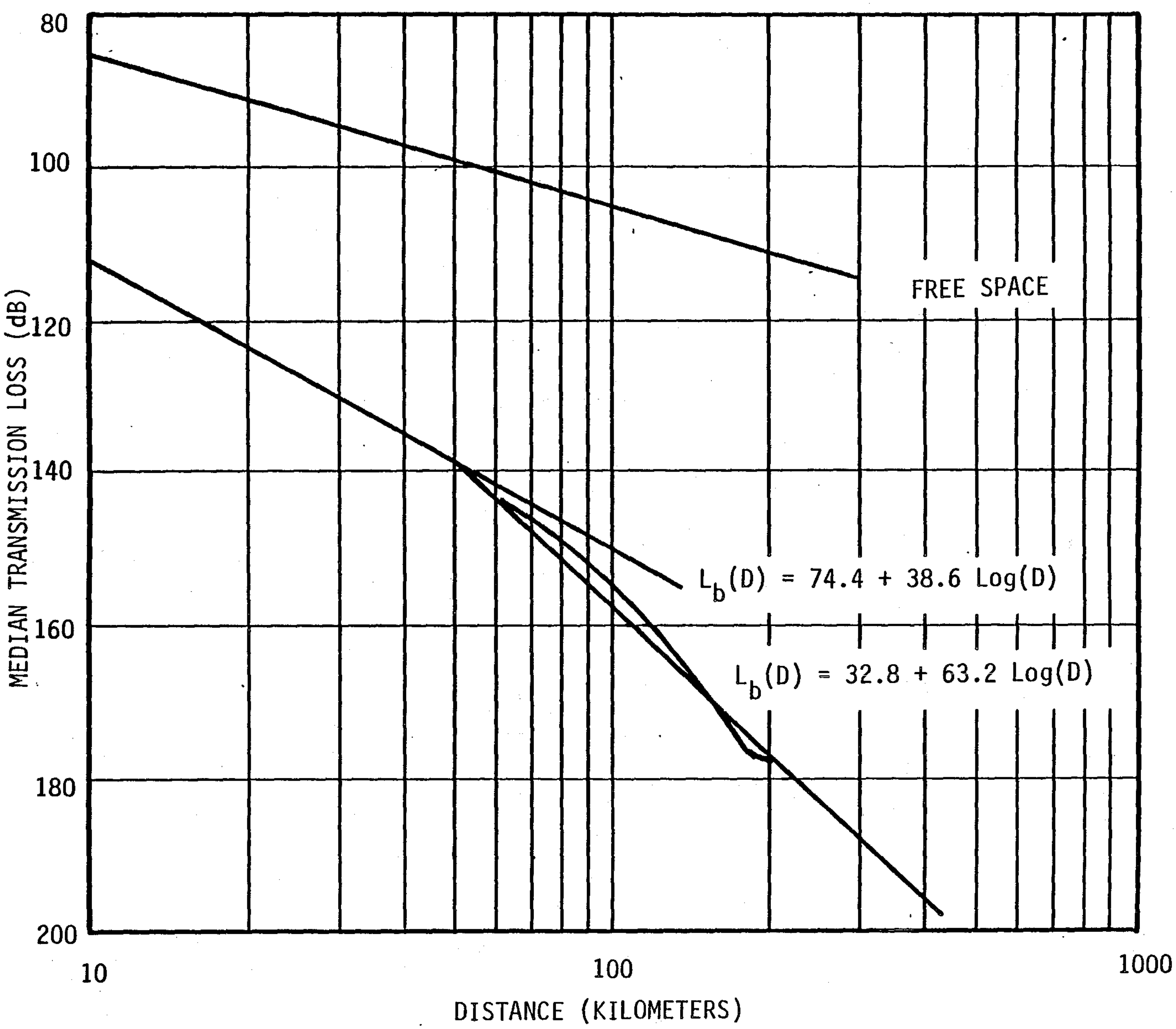
Figures E-1 through E-4 show the Longley Rice basic transmission loss, L_b, versus distance for antenna heights for meteor burst equipment scenarios.

In several instances, it can be seen that a single A and B do not fit the propagation loss over the full distance range. In this case, the curves were fit by a two segment fit. The caption in the figures describes for which interference situation the propagation model was used (e.g., land mobile base station interference to a meteor burst receiver).



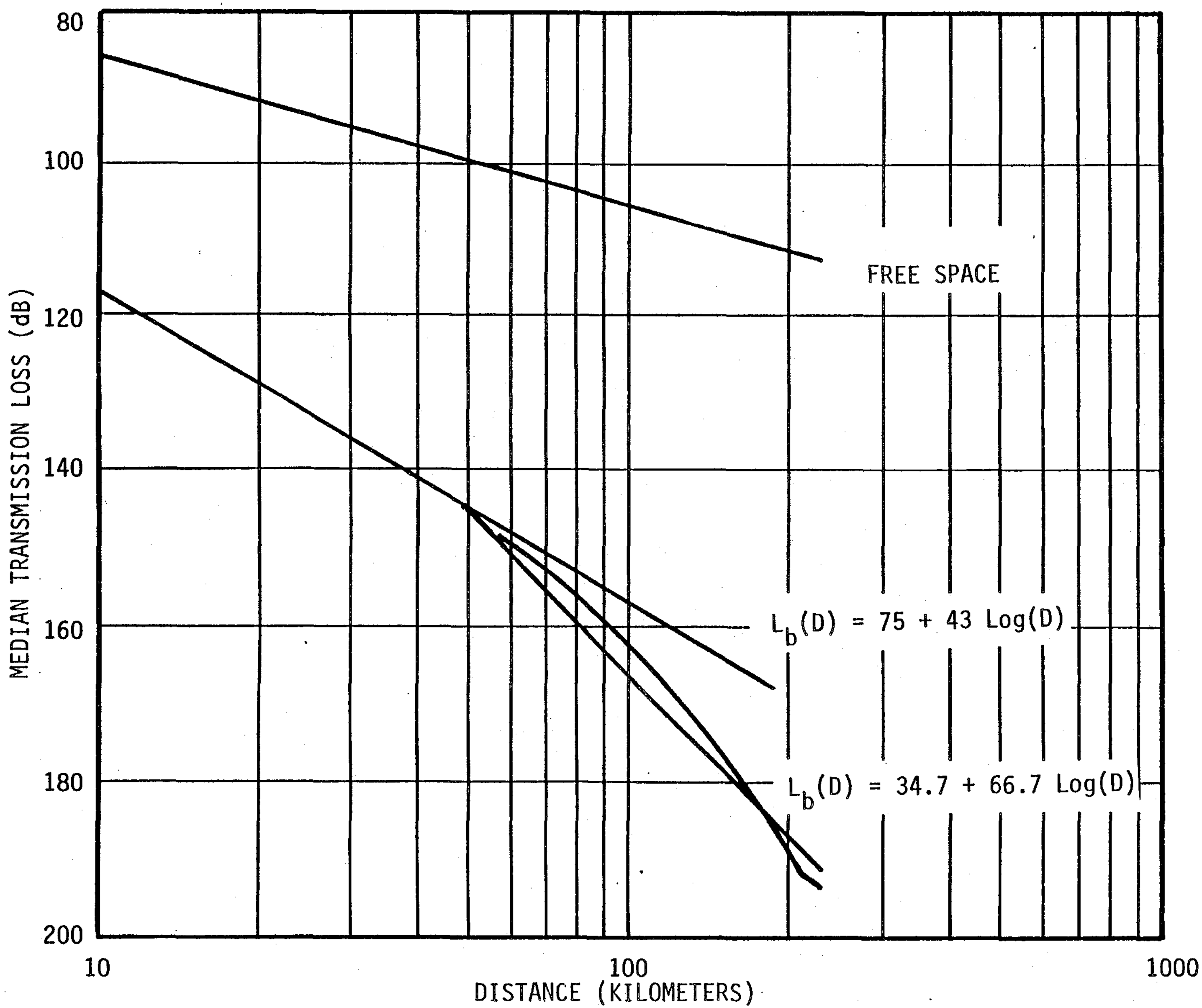
45 MHz Tx Ht = 15 M Rx Ht = 10 M

Figure E-1. Propagation Model for (a) Land Mobile Base Station Interference to a Meteor Burst Receiver (b) Meteor Burst Interference to a Meteor Burst Receiver.



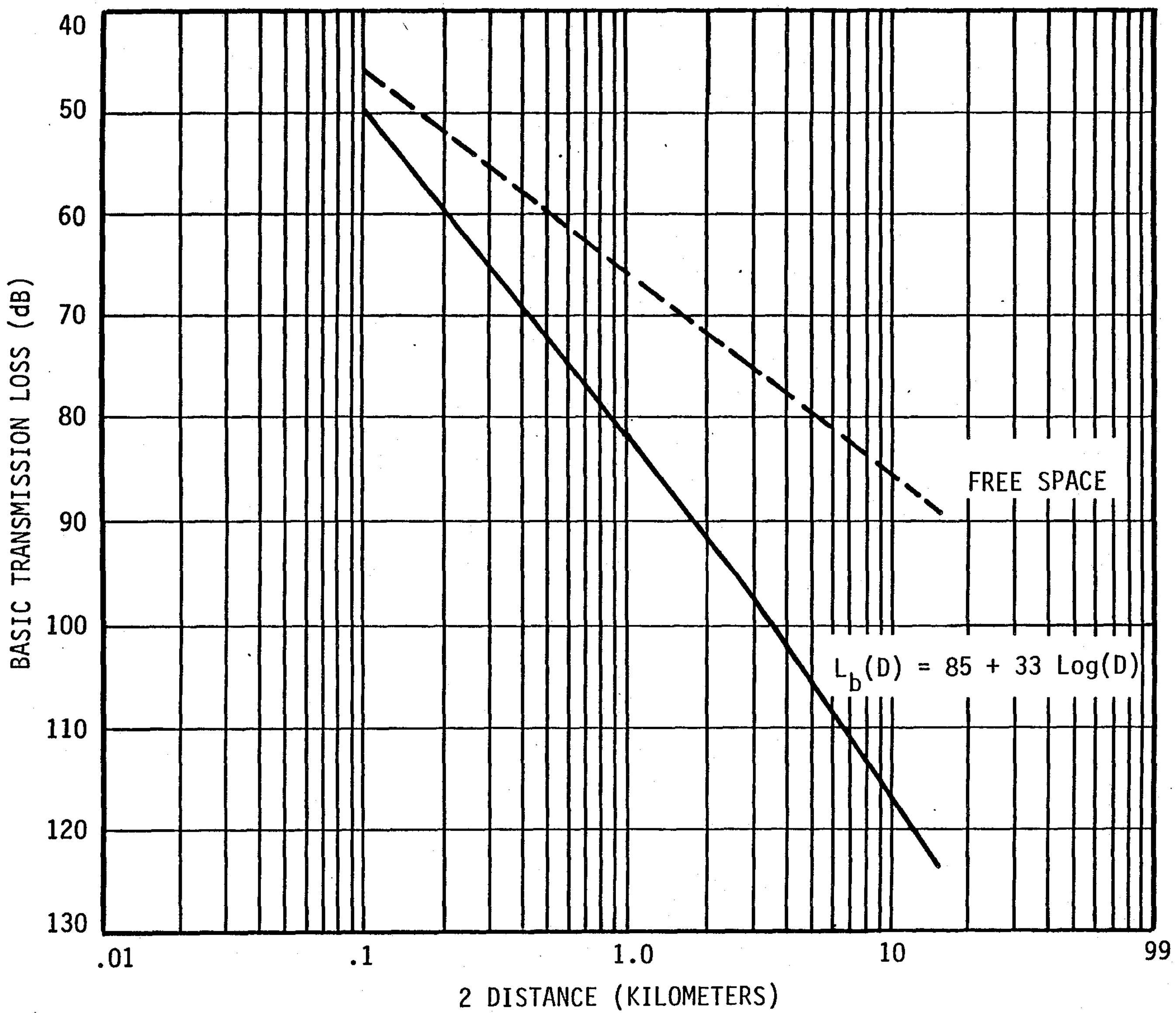
45 MHz Tx Ht = 15 M Rx Ht = 1.5 M

Figure E-2. Propagation Model for (a) Meteor Burst Transmitter Interference to a Land Mobile Base Station Receiver (b) Meteor Burst Transmitter Interference to a Mobile Station Receiver.



45 MHz Tx Ht = 15 M Rx Ht = 1.5 M

Figure E-3. Propagation Model for (a) Mobile Interference to a Meteor Burst Receiver, (b) Meteor Burst Transmitted Signal Received by a Cordless Telephone.



45.0 MHz 15.0 M Tx (Good) 1.5 M Rx (Random)

Figure E-4. Propagation Model for a Cordless Telephone Signal Interference to a Meteor Burst Receiver.

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14. SUPPLEMENTARY NOTES

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

The technical and operating characteristics of meteor burst systems of importance for spectrum management applications are identified. A technical assessment is included which identifies the most appropriate frequency subbands within the VHF spectrum to support meteor burst systems. The electromagnetic compatibility of meteor burst systems with other equipments in the VHF spectrum is determined using computerized analysis methods for both ionospheric and groundwave propagation modes. It is shown that meteor burst equipments can cause and are susceptible to groundwave interference from other VHF equipments. The report includes tables of geographical distance separations between meteor burst and other VHF equipments which satisfy interference threshold criteria.

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

Compatibility; Interference; Meteor Burst; Spectrum Management

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