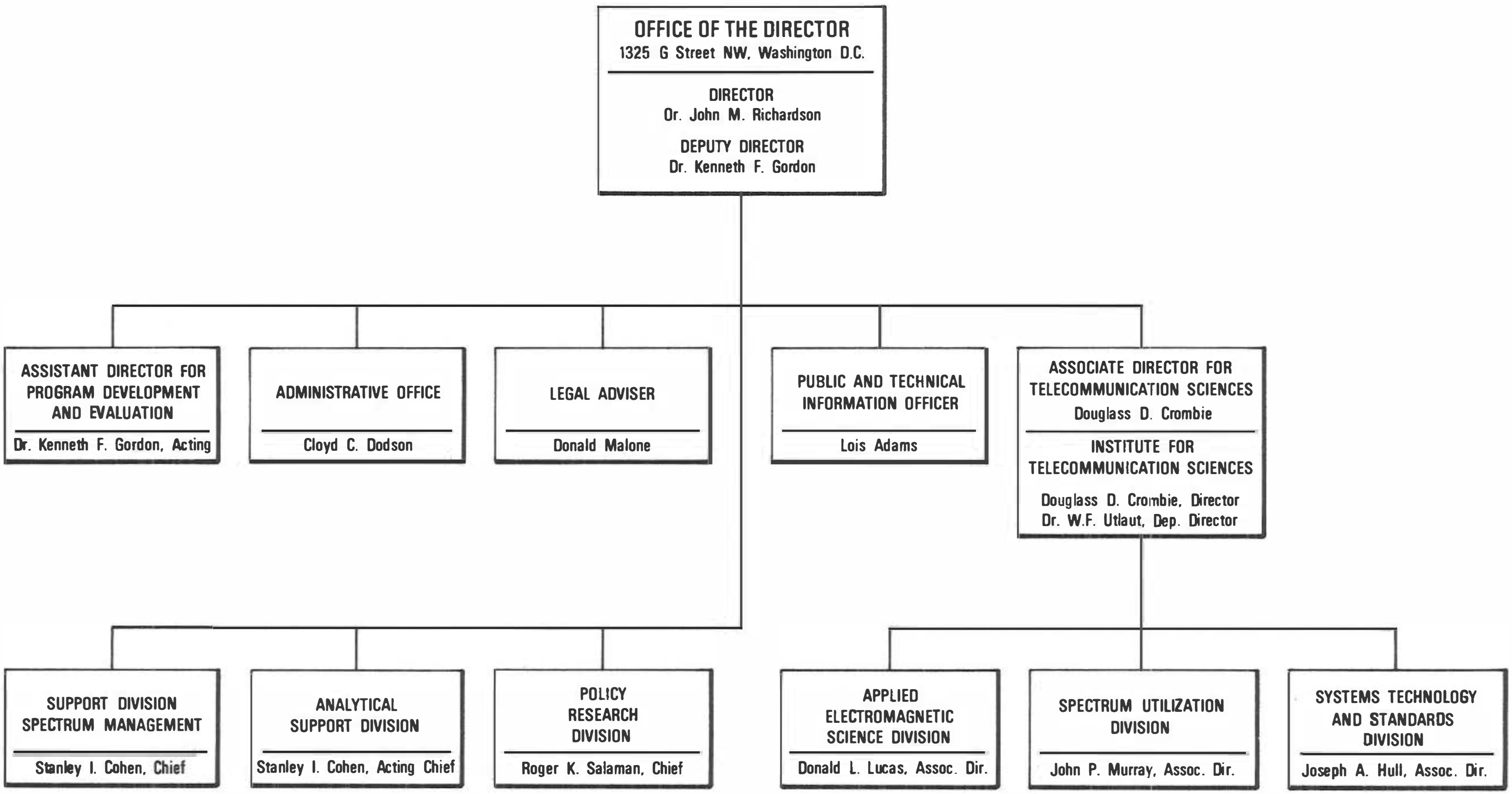
INSTITUTE FOR TELECOMMUNICATION SCIENCES
OF THE
OFFICE OF TELECOMMUNICATIONS

ANNUAL TECHNICAL PROGRESS REPORT 1977

For the period from July 1, 1976 through Sept. 30, 1977

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications



ITS
ANNUAL TECHNICAL PROGRESS REPORT 1977

For the period
July 1, 1976 through Sept. 30, 1977

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

Jordan J. Baruch, Assistant Secretary
for Science and Technology

OFFICE OF TELECOMMUNICATIONS
John M. Richardson, Director

FOREWORD

This annual report describes progress of the technical program of the Institute for Telecommunication Sciences (ITS) during FY77. ITS is the research and engineering arm of the Office of Telecommunications in the Department of Commerce.

The role of the Office of Telecommunications can be stated succinctly:

> To provide specialized research and analysis essential to successful application of telecommunications technology.

OT and ITS goals which form the focus of ITS activities are:

- Increase the availability of usable spectrum by engineering methods.
- Increase the likelihood of satisfactory telecommunication system performance, as affected by natural, engineering, and economic factors.

ITS' contribution to the achievement of these goals is provided through implementation of three major program elements:

- Efficient use of the spectrum,
- Engineering and evaluation of systems,
- Electromagnetic-wave transmission research and services.

These three program elements are not independent of each other, but have a high degree of interaction. For example, transmission phenomena play an important role in determining whether radio systems will work in the field, as do questions of mutual interference between systems or subsystems. Variability of transmission loss through the atmosphere determines the physical separation between systems sharing the same frequency and thus affects the efficiency of spectrum use. Engineering of systems to obtain the required performance demands adequate knowledge of transmission loss and distortion, as well as the effects of interference.

Efficient Use of the Spectrum

The objective of this program element is:

> To show how to substantially increase the permissible number of users in congested regions of the spectrum.

The spectrum is a limited natural resource being subjected to ever-increasing demands. Our role is to examine and understand the basic scientific and engineering factors which affect the efficiency of spectrum utilization, and to foster and encourage the use of techniques which maximize the number of spectrum users receiving satisfactory performance in a given geographical area, under interference-limited conditions.

Major opportunities for improving the efficiency with which the spectrum is used include the proper application of bandwidth expansion; reduction of radiation in unwanted directions from directive antennas; improving the predictability of the signal strength of both wanted and unwanted signals; understanding the interactions between systems which are closely-spaced geographically; recognizing that interference from co-channel signals may constitute a stronger and different performance limitation than natural or man-made noise; recognizing the desirability of maximizing the joint performance of many links rather than that of single links; and developing usable criteria for evaluating system performance versus spectrum requirements.

Most of the directly-funded portion of this program element is concerned with the basic issues mentioned above. In addition, work for other Federal agencies is concerned with electromagnetic compatibility analysis and radio coverage estimation. A major part of the effort is in support of the OT Spectrum Management Support Division in its role of assisting the Office of Telecommunications Policy (OTP), which manages the Government portion of the spectrum.

Highlights of FY 77 activities include:

- TV Drop-ins.
  Application by the FCC of planning techniques developed by ITS (under FCC sponsorship) for determining the consequences of allowing additional VHF TV transmitters. These techniques are applicable to many other situations in addition to the TV

drop-in problem and their application to land mobile radio is being actively pursued.

- CB Radio.
  Examination of the fundamental relations between performance and number of users per channel for CB operations. The effects of skywave (skip) interference were also investigated. This work is being used by the FCC Personal Radio Committee in its planning activities.

- Earth Terminal Antenna Pattern Measurement.
  Measurement of the full sidelobe pattern of a US Army 20-ft. diameter small earth station antenna. This measurement technique is inexpensive and could be readily used to obtain the sidelobe patterns of other civilian, as well as military antennas for use in satellite-small earth station systems.

- Interference Measurements.
  Measured interference at the NASA's Goldstone satellite earth station installation in the Mojave Desert. These measurements were made at the request of OTP/IRAC and will help resolve the problem of the growing incidence of interference at this important facility.

Details of this program are given in Chapter 1.

Engineering and Evaluation of Systems

The objective of this program element is:

- To provide user-oriented telecommunication system performance criteria and methods of performance measurement, and to relate these to more conventional engineering parameters.

ITS has recognized that there is a significant need for adequate means of specifying, evaluating, and measuring the performance, from a user's point of view, of telecommunication systems, and is attempting to fill this void. Criteria which are system independent, and which represent performance at the user's interface with the system, are badly needed for comparing alternative or competing services and for evaluating their benefits versus cost. In addition, improved techniques for the measurement of performance in the engineering sense of multiplexed, encrypted signals, in real time on message trunks, are badly needed to detect incipent failures. ITS is developing criteria and measurements for both voice and data transmission.

In addition, this program element is concerned with channel simulation and evaluation of modem techniques, and communications via fiber optics. Channel simulation is concerned with making available, in the laboratory, simulated channels which reflect accurately, in a statistical sense, the various multiplicative effects or distortions which occur on real channels, and which may cause a greater limitation to performance than additive noise. Such laboratory channel models are used to test and compare real hardware under controlled conditions much more economically than can be done in the field.

Communications by fiber optics promises to have significant impact on the transmission of very wideband signals, and may eventually replace terrestrial and submarine coaxial cables and mm waveguides for high data-rate transmission.

Significant achievements in FY77 include:

- Data Communications.
  Developed and published in the Federal Register (Tuesday, Feb. 22, 1977) Federal Standard 1033 which defines standard, universally applicable, user-oriented parameters for specifying data communication system performance. Industry reaction has been favorable.

- Satellite Communications.
  As an output of the DoC Science and Technology Task Force established in the Fall, 1975 (see OT Special Report 76-9, "Lowering Barriers to Telecommunications Growth"), OT established a new program in Direct Satellite communications. Barriers to use of small earth-terminal (0.5 to 5 meter diameter) satellite communications have been defined in three primary areas; namely: 1) Economic/Market, 2) Policy/Institutional/Regulatory, and 3) Technical/Informational. The program will examine these barriers and develop options for overcoming them.

- Fiber Optics Design Handbook.
  A design handbook entitled, "Design Procedures for an Optical Fiber Communications Transmission System" is nearing completion. The handbook discusses modulation techniques, multiplexing, and interface methods as well as the presentation of a sample design. It will soon be available to the

public, government, and industry.

- FKV Pilot Digital System Evaluation.
  A one-year evaluation of system performance and operational and maintenance procedures were carried out on the first multi-link digital system to be installed as part of the Defense Communications System in Europe. No failure of system performance was caused by any subsystem where a redundant element was available.

Details of this program are found in Chapter 2.

Electromagnetic Wave Transmission

The objective of this program element is:

- To provide complete, quantitative EM-wave transmission characteristics of communication channels for the many spectral regions of current interest.

ITS efforts in this area are aimed at improving the probability of successful deployment of radio systems designed to operate near the state-of-the-art, insofar as propagation is concerned. Deleterious propagation effects form a basic limitation to the performance of radio systems. Attenuation, scattering, ducting, and refraction affect both wanted and unwanted signals. Scattering and multipath may limit the available bandwidth.

ITS efforts in FY 77 continued to be directed mainly at the higher frequency end of the spectrum, about 10 GHz. Notable achievements include:

- 60 GHz Transmission.
  Measurements in the vicinity of 60 GHz indicate that the attenuation through heavy snow is much less than expected. The work suggests that use of mm wave links to replace short links operating at lower frequencies may be feasible. If so, valuable spectrum at lower frequencies could be made available for longer links, leading to better economic use of the spectrum.

- Laboratory mm Wave Studies.
  The report "Accurate Clear Air EHF Transfer Characteristics" was selected by the U.S. Army Research Office as one of three outstanding accomplishments out of seventy projects supported by ARO. (The work was also supported by OT.)

- HF Propagation.
  Completed 250 volumes of HF predictions for the Saudi Arabian Government. This work, supported by the U.S. Treasury contributed to the efforts of the joint U.S.-Saudi Arabian Economic Cooperation Commission.

- Protection of Nuclear Materials.
  Developed a communications management model for ERDA to assist them in developing improved communications with vehicles carrying nuclear material within the U.S.

- Data and Techniques Bank.
  In FY 77 a start was made to collect propagation data and propagation prediction models into a readily accessible library. Initial work concentrates on the higher frequency region.

Details of this program are found in Chapter 3.

ITU Support

ITS continued its support of U.S. participation in ITU matters. Mr. T. deHaas, U.S. Chairman of CCITT Study Group 7 led U.S. participation in the Study Group activities leading to the X.25 Standard for packet networks. This standard is already having substantial impact on equipment for international data transmission. In addition, Mr. deHaas served as International Chairman of CCIR Study Group 3 dealing with Fixed Services Below 30 MHz.

Dr. W.F. Utlaut, served as U.S. National Chairman of Study Group 1 (Spectrum Utilization and Monitoring), while Dr. H.T. Dougherty served as U.S. National Chairman of CCIR Study Group 5 (Propagation in Non-Ionized Media). These activities were mainly directed at establishing basic support for U.S. positions to be taken during the 1979 World Administrative Radio Conference.

Details of the program outputs are found in Chapters 2 and 3.

Support for Other Agencies

Much of the work described in this report is in support of other Federal Agencies and is funded by them. This work helps solve the immediate problems of the sponsoring agency. Such activities are mutually beneficial. They allow ITS to collect data which when combined with other data obtained under different sponsorship enables more comprehensive data bases to be maintained and developed inexspensively. By doing such work, we are kept in contact with "real world" problems and our staff competence is kept relevant and up to date. The work for various sponsors enables us to recognize key problem areas whose solution benefits all users of telecommunications technology as well as the individual agencies sponsoring various aspects of the work.

A further national benefit of our technical support for other Federal Agencies arises from "economy of scale." We provide technical resources to Agencies which require them temporarily as an adjunct to their mission responsibilities. Thus the need for Agencies to establish their own capabilities in these areas is avoided, with possible unnecessary duplication between Agencies.

In FY 77, our work for other Federal Agencies was oriented closely towards OT goals. OT's criteria for acceptance of work from Other Agencies can be summarized as follows:

1. The work falls within the authority of the Secretary of Commerce to undertake the work.

2. The work is relevant to national goals and commitments and has impact on these goals and commitments.

3. The work cannot be readily performed by the private sector (with certain exceptions such as unavoidable conflict of interest, intolerable delays, excessively higher costs, or unique facilities or capabilities within OT).

4. The work contributes to OT goals.

5. The work does not conflict with other ongoing work within OT.

All these criteria must be met.

The revised criteria will continue to ensure that the work we do for Federal Agencies will be a proper function of Government and consistent with the mission of OT and the Department of Commerce.

Acknowledgement

R.B. Stoner was responsible for the preparation of the report, from material provided by Associate Directors - J.P. Murray, J.A. Hull, and D.L. Lucas. He was ably assisted by other ITS staff.

D D Crombie

Douglass D. Crombie
Director, ITS

Cover: Winter scene shot on the grounds of the Boulder Laboratories, U. S. Department of Commerce, courtesy of Harry Covey, National Oceanic and Atmospheric Administration.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. EFFICIENT USE OF THE SPECTRUM

The radio, or electromagnetic, spectrum has seen dramatic growths in demand and use since the beginning of World War II. Since that time, a great range of new spectrum-dependent services has evolved. American industry, government, and private citizens have put the spectrum to work in such profusion that now saturation appears imminent and, in some cases, has already occurred. To provide for new and expanded use, two major alternatives exist. One is to exploit new regions of the spectrum at progressively higher frequencies. The second is to provide for a better understanding of the basic physical principles upon which spectrum use depends and, complementing this understanding, provide for more effective means of managing spectrum use.

Spectrum use by the U.S. Government alone is growing nine percent annually in those frequency regions where equipment is readily available. Embryonic efforts are being made to use the even higher frequencies above 10 GHz where equipment still remains to be developed for many applications.

The Office of Telecommunications, Institute for Telecommunication Sciences (OT/ITS) conducts a program of research and development which addresses both of these alternatives. Much of the work being done to extend the use of the spectrum to higher frequencies is discussed in the Electromagnetic Wave Transmission chapter of this report. That chapter also provides brief mention of some of the work being done to improve our understanding of propagation problems in these regions of the radio spectrum that are already extensively used.

In this chapter, some highlights of the OT/ITS program directly concerned with spectrum engineering are reviewed. Many of these spectrum engineering projects draw heavily on experience from other programs in ITS, including antenna design and measurement, channel characterization and system performance, and the many propagation related efforts.

SECTION 1.1. SPECTRUM ENGINEERING TECHNIQUES

Important methods and techniques for Spectrum Engineering are under development to meet a wide range of requirements. These methods address very specific situations as well as the broad questions of optimization to provide maximum benefit to the total user community.

For over a decade, government, academic, and industrial groups have advocated development of methods for improving the overall effectiveness of the utilization of the spectrum (as opposed to the optimization of the performance of individual systems). This concern paralleled and even predated similar realizations that ideal common use of environmental resources such as air and water may not coincide with economic maximization of an individual user's profits.

The developments reported here are discussed with current applications in mind. But their true value lies in their general character. In most cases, these methods can be readily adopted to meet many new requirements involving a broad range of telecommunications needs and services.

The presentation of summary results in graphic form (particularly as maps and map overlays), the development of demographic results, and the design of interactive computer programs that make it easy to ask "what if?" questions are symptomatic of our continuing effort to bridge the gap between technology and the planners and policy makers.

An Evaluation of VHF TV Drop-Ins was performed for the Federal Communications Commission. This was an engineering response to the controversial question as to whether it is possible or desirable to license new VHF television stations ("drop-ins") in market areas where such a station would be short-spaced to existing co-channel stations. The general question is "Will the disruption it will cause to the existing market structure be unacceptable?" Our own efforts were limited to predicting service areas and interference areas under a variety of assumptions concerning the design of the drop-in and the manner in which radio propagation should enter. We treated a generalized situation and then concentrated on specific proposals for stations near Knoxville, Tennessee, and near Johnstown and Altoona, Pennsylvania.

The analysis made use of a unique collection of computer oriented data bases--the FCC curves of radio propagation, topographic elevations for the United States, and population densities compiled from the 1970 census. This combination allowed us to unite propagation calculations, terrain shielding estimates, service and interference-free areas, and population counts.

Since the possibility of significant terrain shielding was an important question, we developed modifications to the FCC propagation calculations which take this into consideration. The City Grade, Grade A, and Grade B contours considering only average terrain effects are shown in Figure 1-1; curves using our modified computations for one of the proposed drop-ins are illustrated in Figure 1-2. The service ranges stop abruptly at the North Carolina state boundary because that is the top of the Great Smoky Mountains.

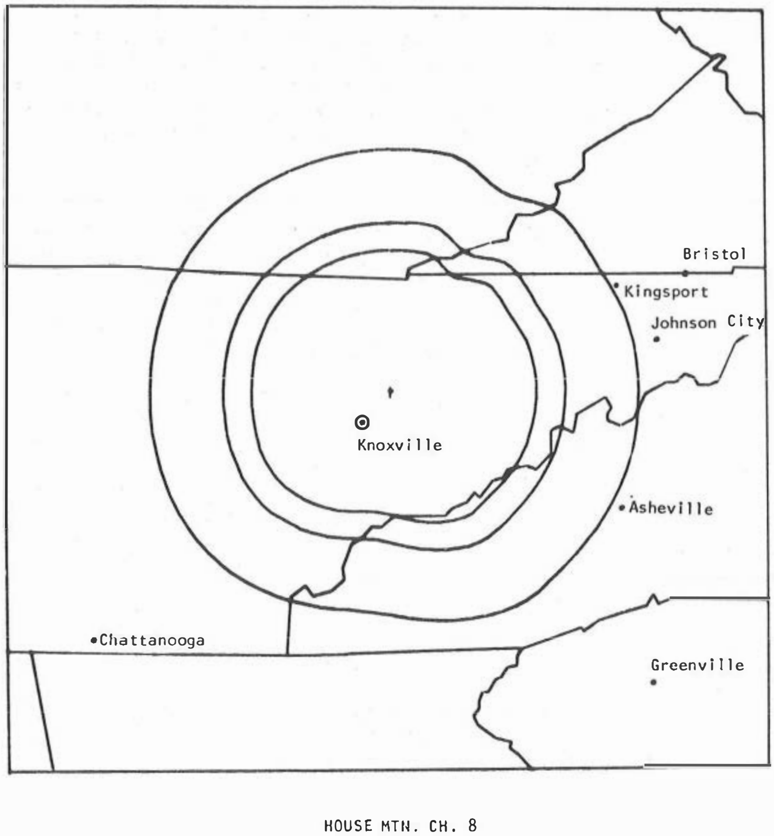


Figure 1-1. Service areas of the postulated drop-in. Shown here are the City Grade, Grade A, and Grade B contours computed using no terrain corrections.

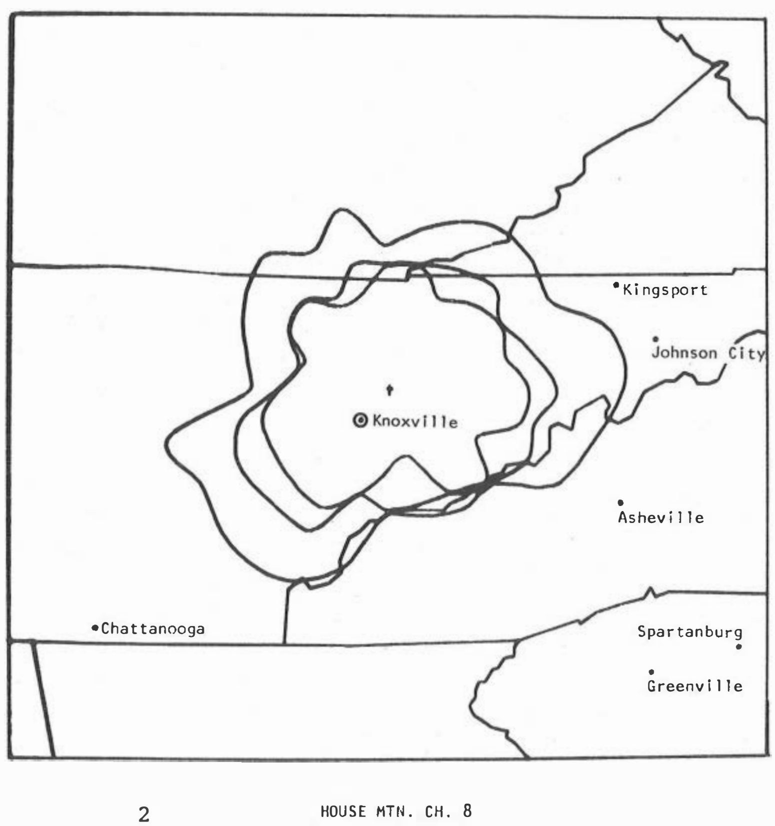


Figure 1-2. Service areas of the postulated drop-in. Shown here are the City Grade, Grade A, and Grade B contours computed using a modified terrain correction.

Most important, terrain shielding will reduce interference. Figure 1-3 shows the Grade B contour of the same drop-in and also the various "interference contours" that will be caused by existing co-channel and adjacent channel stations. Another most useful development in this project was a method to compute population coverage by modifying Census Bureau data and considering the statistical likelihood of signal reception. Using standard methods for computing field strengths, we found that this drop-in would serve 1,230,000 people--992,600 of them interference free. But using terrain shielding modifications, the same numbers became 873,200 and 817,200.

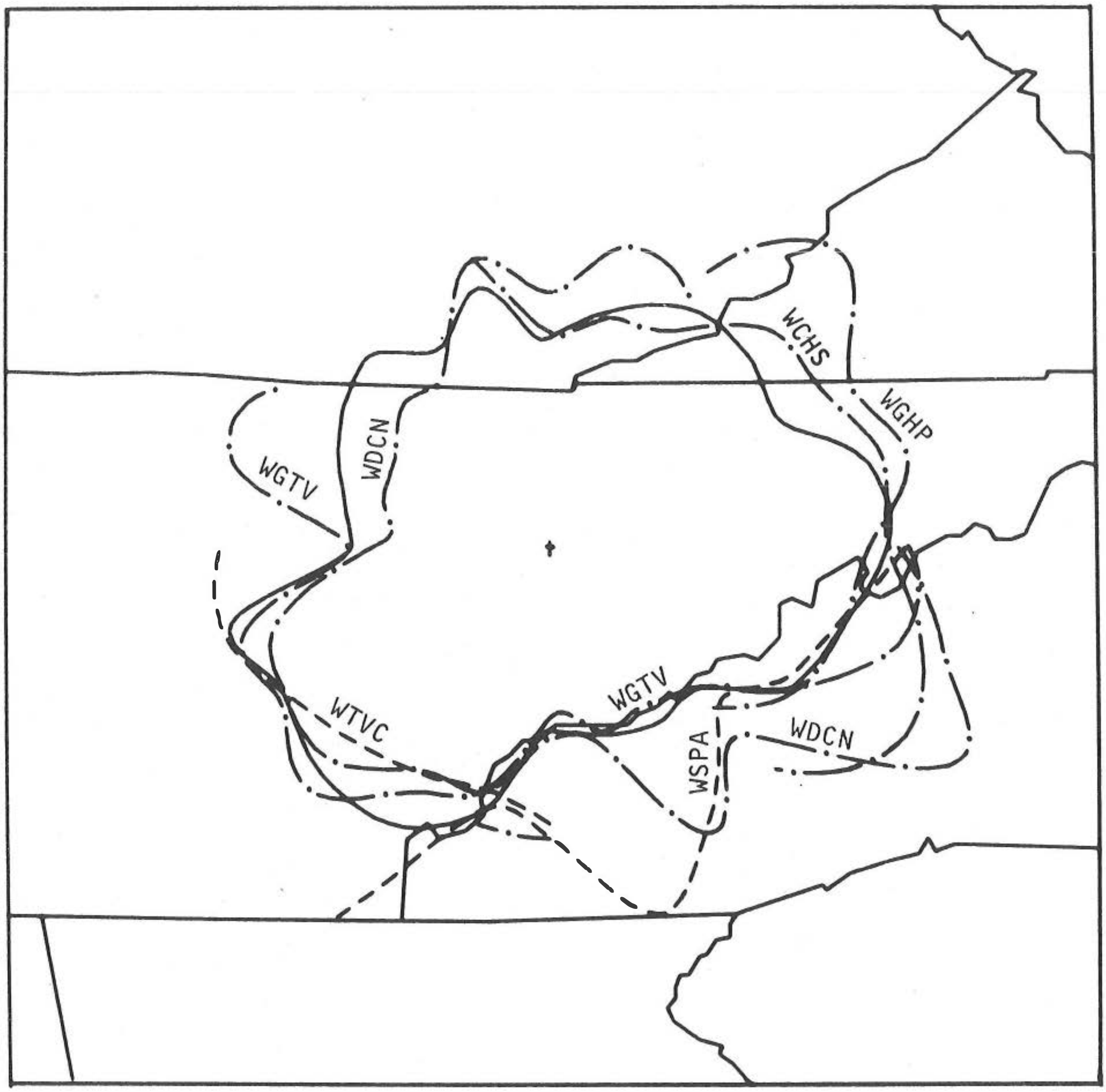
While these techniques have been developed for the television case, they also are broadly applicable to many radio coverage situations including land-mobile, translators, FM broadcast, and other services.

Another spectrum planning tool with a strong potential for applications to many kinds of spectrum planning problems is referred to as Network Service and Interference Predictions. The NOAA Weather Radio Program administered by the National Weather Service (NWS) broadcasts current weather conditions and forecasts on a 24-hours-a-day basis. Recently this broadcast network has also been designated as the primary element in the national disaster warning system. In order to effectively reach their goal of 95 percent of the population of the United States with these broadcasts, NWS expanded the network by adding new stations and a third channel. The planned location of Weather Radio Stations is shown in Figure 1-4. The network must be carefully designed in order to minimize the co-channel and adjacent channel self-interference that may result from operating closely spaced stations on only three channels. To assist NWS in siting new weather broadcast stations and selecting the optimum channels to meet their objectives, the Institute for Telecommunication Sciences has developed an interactive computer model called NETWORK.

NETWORK is designed to help NWS plan the expansion of the broadcast network by predicting the coverage that results when stations are added to or deleted from the network, or have their location or characteristics (i.e., frequency assignment, transmitter power, antenna height, etc.) changed. The NETWORK data base contains the required information about each station in the network to determine service areas, interference areas, and population coverage (see Figure 1-5). NETWORK's editing capability allows the user to easily modify any of this station data, and the resulting changes in service and interference areas are then calculated and added to the data bases used to display coverage. Thus the service and interference areas plotted on the interactive terminal and the population coverage statistics printed for any portion of the network will always reflect the current station parameters contained in the data base. This capability allows the user to select the combination of station location and technical characteristics that will maximize service and minimize interference for the network. By revising the station data and comparing the resulting coverage predictions, the user can effectively plan the expansion of the network to obtain the desired coverage at minimum spectrum usage.

NETWORK's predictions of how many people receive the weather broadcasts and which areas may experience self-interference are based on the values of field intensity calculated using the propagation loss data calculated by the Longley-Rice (L-R) area prediction model. The L-R model is used to calculate basic transmission loss for a path given a particular time availability, location variability, and prediction confidence. Basic transmission loss, denoted by L_b when measured in decibels, is the coupling loss between transmitting and receiving antennas. Because random changes occur in atmospheric conditions affecting the propagation of radio waves, and small variations in antenna siting and the shape of the terrain can cause other random changes in L_b, basic transmission loss is treated as a random function of both time and space. Time availability, q_T, is defined as the fraction of time during which the hourly median basic transmission loss does not exceed the predicted value L_b. For a desired signal, q_T is usually chosen to be large, and correspondingly, q_T is chosen to be small for undesired signals. The statistic location variability, q_L, must also be included since random changes in the antenna siting and propagation path cause changes in q_T. Thus the location variability is defined to be the fraction of similar paths for which there will be a fraction of time at least as large as q_T during which the hourly median basic transmission loss will not exceed L_b. The prediction confidence, Q, is a measure of how well the predicted value of L_b for a given q_T and q_L agrees with the measured data that the model is based on. NETWORK uses a prediction confidence of 50 percent; that is, the predicted L_b will be the median of the distribution of measured values for the desired q_T and q_L. This median value is sometimes referred to as the "best estimate" of the basic transmission loss for a particular case.

NETWORK calculates and displays on an interactive graphics computer terminal areas where the service, co-channel interference and adjacent channel self-interference are predicted to occur for a specified portion of the broadcast network. Service is defined using the "best estimate" of power density for 95 percent of the time and in 95 percent of the local area. Interference is defined using the "best estimate" of



HOUSE MTN. CH. 8

Figure 1-3. Interference areas of the postulated drop-in. Shown here are the Grade B contour of the drop-in and the interference contours due to existing stations, all computed using modified terrain corrections. The dot-dashed curves are the co-channel stations using precise offset. The short dashed curves are adjacent channel stations.

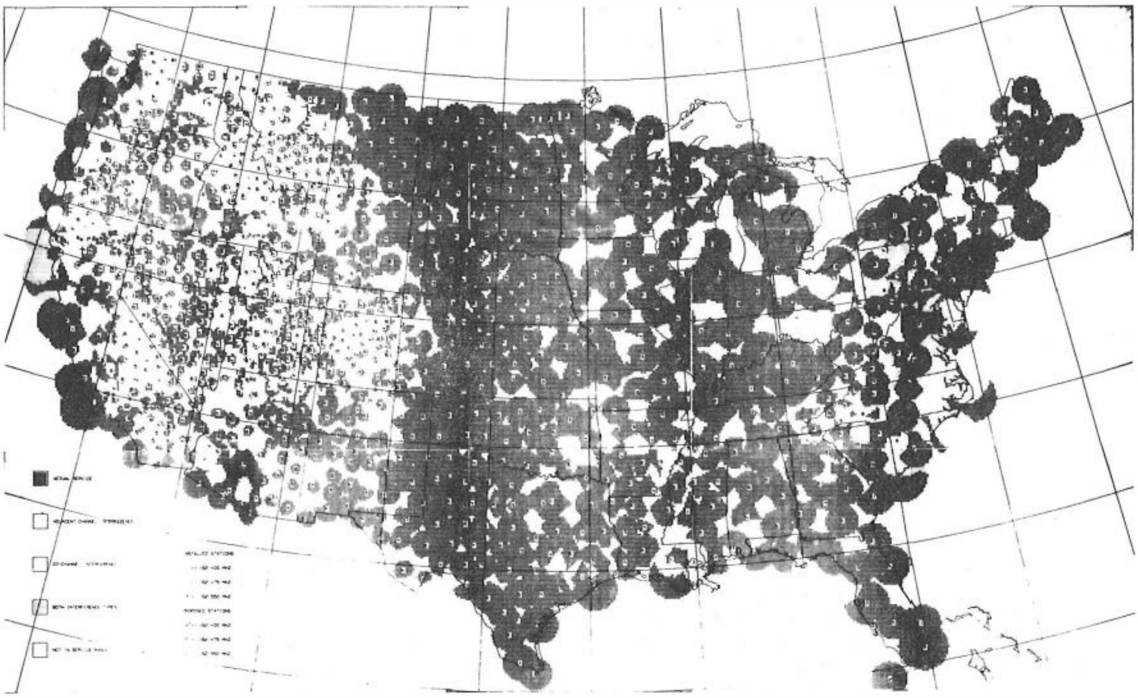


Figure 1-4. Locations of current and planned National Weather Service Stations.

```
  LOC     ID    FREQ LATITUDE LONGITUDE POWER  HT  ELEV   AZIM GAIN LOSS
                                        WATTS FEET FEET   DEG   DBI   DB
BALTMOR KEC83    1   39 11      76 40   1000   300   148  -1   11.0  2.0
NORFOLK KHB37    3   36 49      76 28    500   479    23  -1   11.0  3.0
SALISBR KEC92    1   38 18      75 40   1000   450    26  -1   11.0  5.0
MNASSAS KHB36    3   38 38      77 26   1000   510   400  -1   11.0  6.0
 WANT TO LIST MORE STATIONS? (Y OR N)
? N
 ENTER FUNCTION (ADD,CHANGE,DELETE,LIST,PRINT,PLOT,HELP,QUIT)
? PLOT
```

Figure 1-5. Typical data base information provided to the user on his display showing transmitter characteristics. Coverage provided by these stations is shown in Figure 1-6.

power density predicted to occur for 10 percent of the time in 50 percent of the local area. To store the data necessary for these predictions in a uniform manner, a 4-minute grid has been superimposed on the contiguous United States extending from the southwest corner at 24°N. 125°W. to the northeast corner at 49°N. 66°W. For every grid point, the median power density and its associated statistics for every station with 200 km of the grid point are stored. This information is automatically updated with the L-R whenever a station is added, deleted, moved, or the technical characteristics changed. Consequently, the service or interference coverage plotted always reflects the current station data.

Service or interference for the 4-minute area centered at a grid point is determined by comparing the service level power density from the desired (closest) station with the interference level power density from each of the other stations within 200 km. A grid point is considered to be served by its desired station if the service level power density from the closest station is greater than or equal to -127.7 dBW/m^2 (or 8 μV/m) and neither co-channel nor adjacent channel power levels are high enough to cause interference.

Co-channel interference is defined to occur when the power density from an undesired co-channel station is greater than or equal to 10 dB less than the service level power density from the desired station. For example, if the service level field strength at a grid point is 8 μV/m, co-channel interference is defined to occur when an undesired station on the same channel creates a signal that is greater than or equal to 2.5 μV/m.

Adjacent channel interference is defined to occur when the interference level power density at the grid point from an undesired adjacent channel station is at least 30 dB greater than the service level power density from the desired station. Co-channel and adjacent channel interference are only calculated for grid points that would otherwise have service from their desired station. If the point has a service level power density from its desired station of less than -127.7 dBW, it will be considered not served even though it may have signal levels high enough to be considered service from a more distant station.

Based on comparisons of the predicted service signal levels and interference signal levels from the desired and undesired station, a coverage code is assigned to each grid point and stored in the computer for plotting coverage areas and calculating population data. These codes are updated whenever the changes to the station data base require new signal predictions. The five types of coverage codes that are used are as follows:

- 0 - not served by desired station,
- 1 - served by desired station,
- 2 - co-channel interference present,
- 3 - adjacent channel interference present, and
- 4 - both co-channel and adjacent channel interference present.

These codes correspond to the selections available to the user for plotting coverage of any portion of the broadcast network.

In addition to predicting where service and interference areas will occur across the contiguous United States, NETWORK also estimates from the 1970 census data the number of people that are served by the broadcast network. These estimates, like the predictions of service and interference, are a function of the service level and interference level power density values at each grid point from the nearby stations. For population coverage estimates, people are considered to be served if they can receive <u>any</u> broadcast station with 50 percent confidence for 95 percent of the time and do not have either co-channel or adjacent channel interference.

Population estimates may be made either for an area or an individual station. To determine the number of people in a given area that have service from <u>any</u> nearby broadcast station, the number of people served by each station at each grid point is summed. This may result in more than 100 percent of the population in an area being listed as served, since some of the people are undoubtedly served by several stations. To calculate the number of people served by a particular station and the number of people not served by that station, it is necessary to look at the service or interference at each grid point within the 40 n mi service range of the station. The percentage of locations within the 4-minute square area around each grid point receiving a signal level of at least -127.7 dBW/m^2 with confidence 50 percent and for at least 95 percent of the time is determined. Then the percentage of the total population living in that 4-minute square area multiplied by the location variability are considered served by the desired station and the remainder are considered not served. If the grid point is listed as having co-channel or adjacent channel interference, no people living in the surrounding area will be counted as served. The total number of people served and not served by an individual station may be displayed using the PRINT option of NETWORK. The number of people served in a given area may be printed with the PRINT option and is automatically displayed along with the coverage plots for an area when the PLOT option is selected.

NETWORK may be run from either a CRT interactive-graphics terminal or a hard-copy printing terminal. If a CRT graphics terminal is used, the output options available include listing stations and their characteristics, printing population coverage data for an individual station or a given area, and plotting service and interference areas that may be superimposed on state or county boundaries for a selected area of the network. An example of type one coverage results is given in Figure 1-6. The plotting capability is, of course, not available when NETWORK is run from a non-graphic terminal.

Quantitative analysis of the tradeoffs between equipment specifications, operating procedures, and government regulations can show how to get maximum communications yield from the radio spectrum resource. The project Tradeoffs in Spectrum Use is developing a computerized model for such analysis. Emphasis is on strategic (rather than tactical) planning for interference-limited services and on results that are valid during fluctuations in customer demand and system environment.

The philosophy and structure of the model are described in OT Report 77-117, "Probabilistic Tradeoffs for Efficient Spectrum Use with a 'CB' Example." The report defines operational range as the largest distance at which satisfactory communications can be established on a stated percentage of the attempts and computes the effects of radio congestion, courteous operation, and equipment characteristics on this measure of service quality.

Some Citizen's Band users are courteous: they will not transmit on a channel if they hear a sufficiently strong signal on it. Because signal strength is an approximate function of distance, this means that courteous users will transmit only if they are greater than the "courtesy distance" from a transmitter that is on. Figure 1-7 shows operational range for typical CB radios as a function of the courtesy distance for different numbers of simultaneous transmissions (from outside the courtesy distance). As you might expect, operational range is larger for large courtesy distance, but the percentage increase is small except for very congested conditions (6 or 10 interfering transmitters).

Total capacity of the CB service can be estimated using the information in Figure 1-8, which shows the average operational range as a function of the number of interfering transmitters. For example, if the regulatory agency wants to ensure an average operational range of 3 km, even if users are not courteous (courtesy distance CD = 0), then there can be about three simultaneous interferers to a wanted signal in a metropolitan area. Combining this information with the data on the fraction of the population transmitting at a given time will show how many channels are required to provide the desired service.

OT Report 77-117 shows that receiver adjacent-channel rejection has little effect on operational range if the channels are uniformly used; co-channel interference is dominant then. But some channels are used more than others. Figure 1-9 shows operational range for a lightly used channel adjacent to a congested channel as a function of adjacent-channel rejection. The ratio of adjacent-channel users to co-channel interferers is N_2. For $N_2 = 20$, a receiver with good (50 dB) adjacent-channel rejection has a third more operational range than one with poor (30 dB) rejection.

The proliferation of CB radio has fortunately occurred during a minimum in the solar cycle. In a few years the solar cycle will return to a maximum and sky-wave or "skip" propagation of CB signals may increase interference and decrease operational range. A paper entitled "Effects of Local and Sky-Wave Interference on CB Radio Range" is now being prepared and will appear as an OT Report in the near future. This paper analyzes this possibility. Figure 1-10 shows the decrease of operational range as a function of ionospheric reflectivity (represented by the parameter "mean foF2"). It is assumed that the same fraction of the population is transmitting on this channel all over the United States, and that 20 percent of the stations are base stations, with the remainder mobile. Figure 1-10 shows that operational range in large cities does not decrease much for large foF2, because it is already small. The operational range in small cities and rural areas drops sharply, to almost the large city value if mean foF2 is 9 MHz or larger.

Table 1-1 contains the mean foF2 expected during the maximum year of an average solar cycle. Notice that foF2 is greater than 9 MHz for many time blocks near the center of the table. Using this information and known relationships between the solar cycle and foF2, the report concludes that if ionospheric reflectivity near the peak of the next solar cycle is similar to that for earlier cycles, and if CB radio use does not decrease, then operational range in small cities and rural areas will be significantly decreased for eight daylight hours per day for eight months of the three years near the peak of the cycle.

Some of the basic techniques commonly used by many radio planners and spectrum managers have been incorporated into a time-sharing computer program that is easy to use by the field personnel working on operational problems. These Telecommunications Analysis Services are used by a number of Federal and State government agencies.

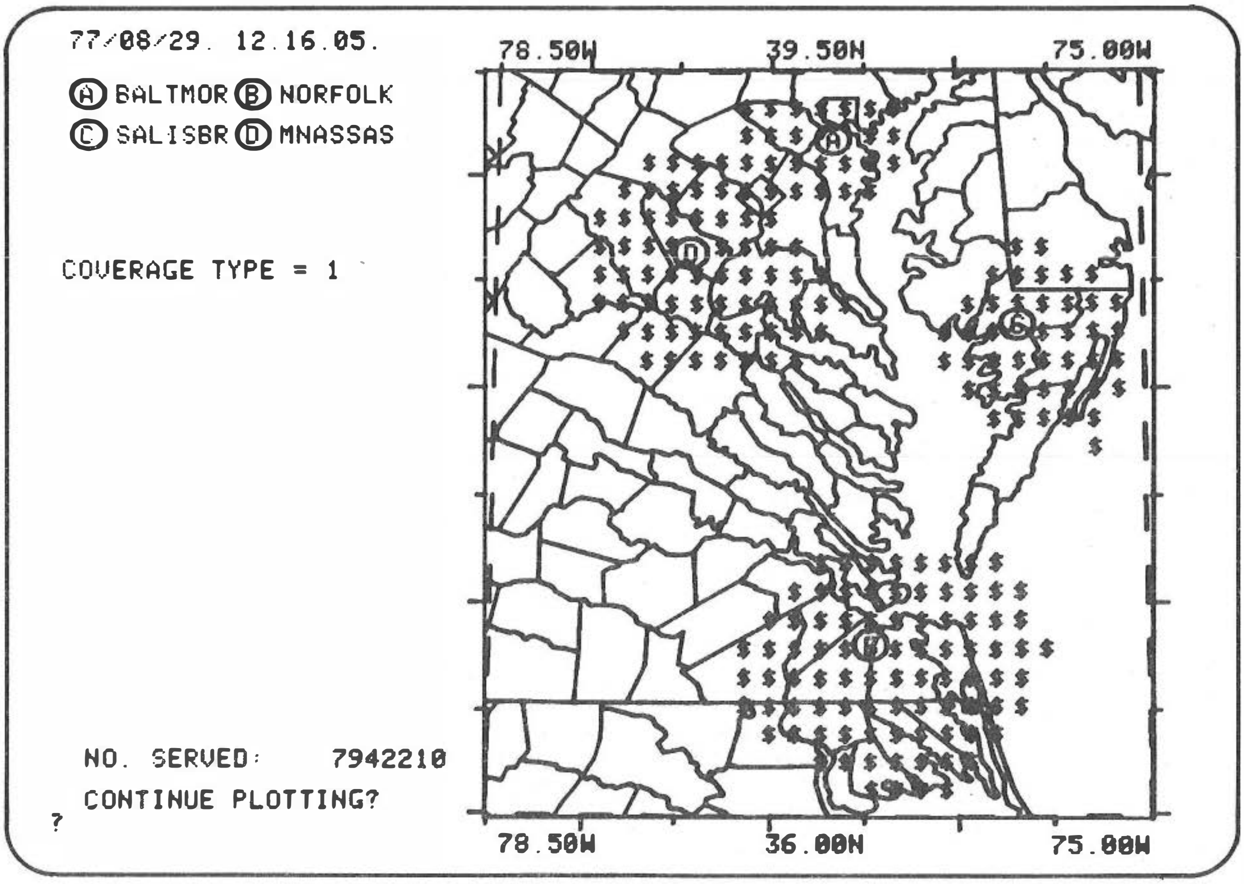


Figure 1-6. Coverage map considering six stations in the Chesapeake Bay area. The map is plotted on a display terminal in response to a direct question from the planner. The planner may also produce other versions of this map showing areas of no-service, co-channel interference, or adjacent channel interference. The display terminal may be located anywhere and use the OT/ITS computer.

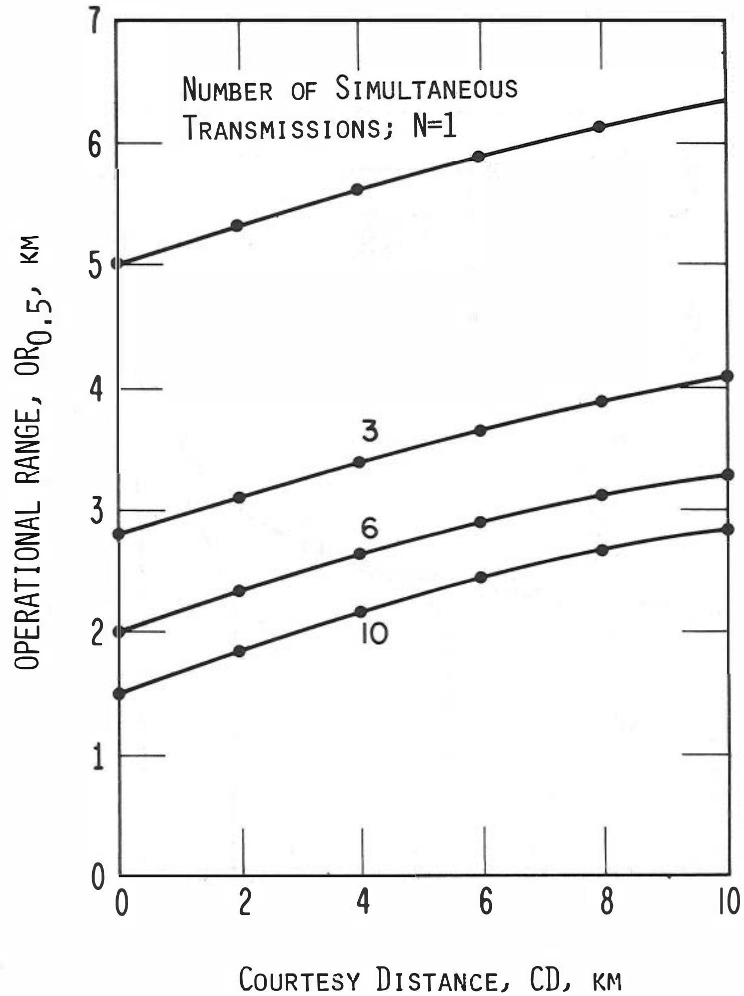


Figure 1-7. One result from the spectrum trade-off analysis technique: Citizen's Band operational range dependence on courtesy distance and number of simultaneous users.

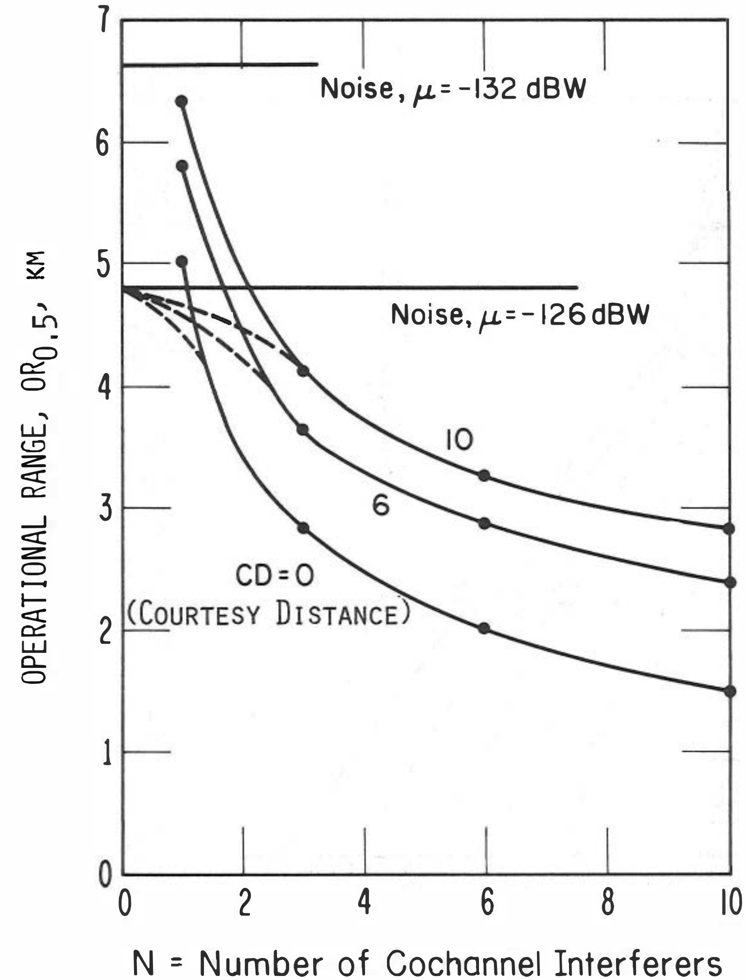


Figure 1-8. Spectrum trade-offs: Citizen's Band operational range dependence on number of interfering transmitters.

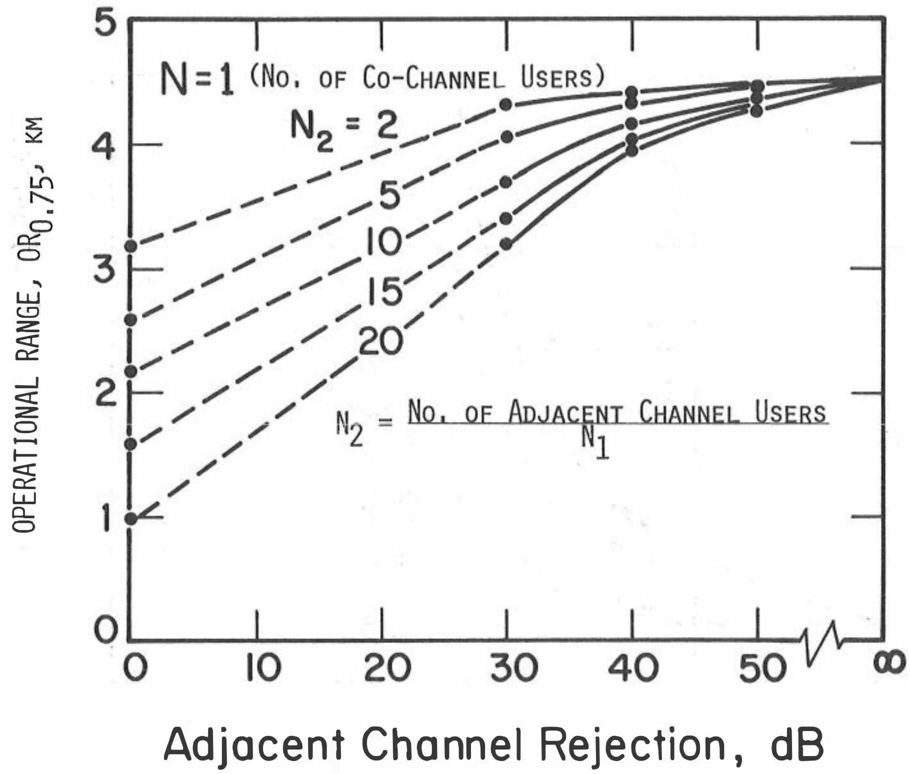


Figure 1-9. Spectrum trade-offs: Citizen's Band operational range dependence on adjacent channel rejection.

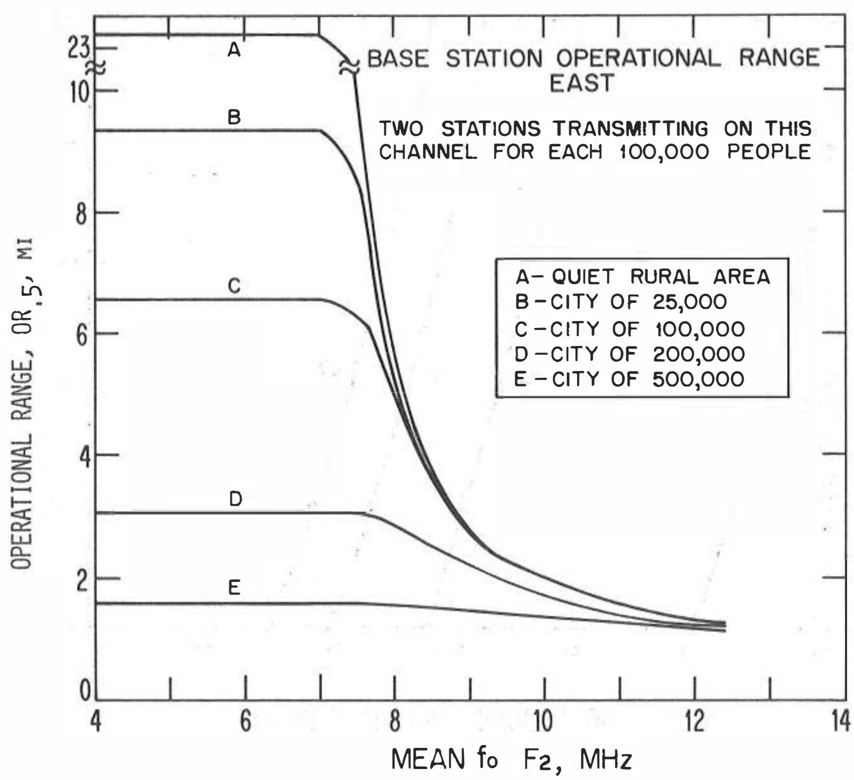


Figure 1-10. Citizen's Band operational range as affected by ionospheric activity.

Table 1-1. Mean foF2, MHz, for a Normal Year at Solar Cycle Maximum

(The average of monthly median foF2 for New York, St. Louis, and Los Angeles)

UT*	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
8	4.7	4.7	4.8	4.8	4.0	3.8	4.0	4.5	5.2	5.3	5.5	5.3
10	4.3	4.3	4.5	4.3	4.2	3.7	3.5	4.2	4.5	5.2	5.2	4.8
12	5.2	5.3	5.7	5.8	4.7	4.0	3.8	4.5	5.5	6.2	5.5	5.3
14	6.0	6.3	7.2	8.2	7.7	6.8	6.7	6.7	7.7	7.3	6.5	6.0
16	6.5	7.2	8.7	10.3	10.8	10.0	9.2	9.8	10.2	8.7	7.3	6.5
18	7.0	7.3	9.2	11.2	12.0	11.7	10.7	10.8	11.0	9.5	7.5	7.2
20	7.3	7.5	9.5	11.5	11.8	11.5	11.0	11.0	11.2	10.0	8.3	7.3
22	7.3	7.8	9.5	11.0	11.0	10.3	9.8	10.3	10.8	10.0	8.3	7.3
0	7.3	7.3	8.5	9.3	8.8	8.3	8.3	9.3	9.8	9.5	8.3	7.3
2	6.7	7.0	7.2	7.2	6.2	5.8	5.8	7.2	7.8	8.2	7.7	7.2
4	6.3	6.2	6.0	5.7	5.3	4.3	4.2	5.3	6.5	6.7	6.5	6.3
6	5.5	5.3	5.3	5.3	4.2	3.8	3.8	4.5	5.5	6.0	5.8	5.7

*UT is universal time which is sun time at Greenwich, U.K., EST = UT-5, CST = UT-6, MST = UT-7, PST = UT-8.

The service provides easy access to highly complex computer programs by users who are unable to maintain their own telecommunication expertise and programmers. The service is available to the agencies on a time-share computer; by dialing a Boulder Laboratories phone number, each user can gain access to the propagation programs at anytime and from anyplace. The programs will give the agencies terrain information about the locations within the U.S. where they propose to locate transmitters or receivers. Propagation programs are available for the frequency range of 20 MHz to 20 GHz covering both broadcast or mobile communications and point-to-point or relay communications. For propagation predictions below 50 MHz, see chapter 3, section 3.3.3.

Figure 1-11 shows partial input to the program. Figure 1-12 shows one of many types of propagation and coverage related results available immediately on the user's terminal. Figure 1-13 shows typical path profiles produced from topographic data bases. Note that the user has his choice of convenient units, as he does with most programs created as a part of this program. Figure 1-14 is a plot of the horizon at a prospective site for a satellite earth station, microwave link, broadcast facility, or any other facility where horizon obstructions are of concern. Figure 1-15 describes areas that are within radio line-of-sight of a transmitter located at "X."

Development, during the past year, of an automated model which predicts Communication System Performance has been sponsored by the U.S. Army Communications Electronics Engineering Installation Agency. The model has been designed for operation on CDC-6000 series systems and is suitable for analyzing communication systems operating at VHF and higher frequencies. In general terms, the model provides a capability for predicting communication system performance throughout a geographical area with analytical results provided as tabulated and/or plotted output as shown in Figure 1-16.

A scheme is employed for defining specific terrain-dependent paths on radials from the transmitter throughout the desired area, so that an approximate uniform grid coverage is calculated. Then the model computes the required propagation data for each path using a digitized terrain

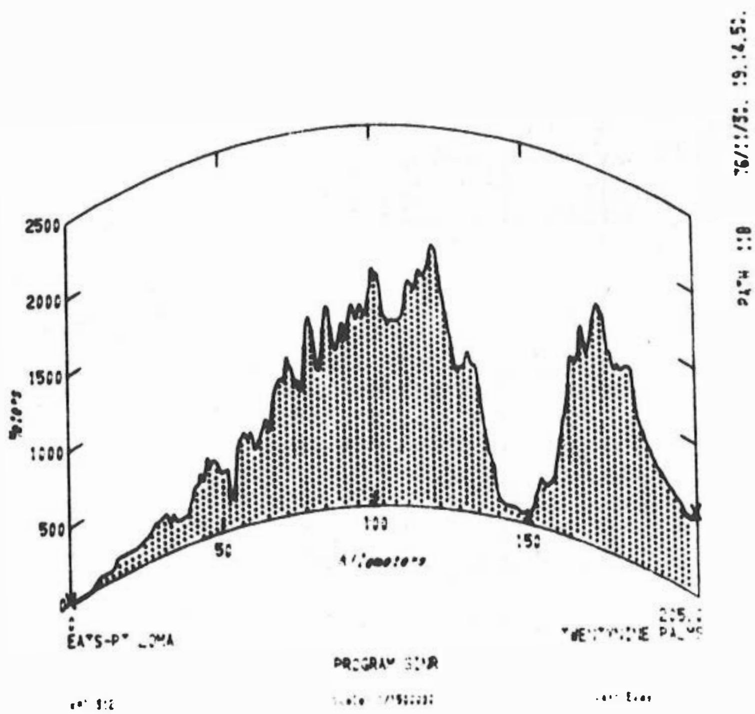
```
THE INSTITUTE FOR TELECOMMUNICATIONS SCIENCES
RADIO PROPAGATION OVER IRREGULAR TERRAIN
VERSION 4.20  6/21/77


 WHICH METHOD DO YOU WANT
    0 = AREA PREDICTION
    1 = POINT TO POINT PATH

10) PRO OP(0)=0

 TYPE OF OUTPUT
    1=BASIC TRANSMISSION LOSS
    2=FIELD INTENSITY
    3=POWER DENSITY
    4=AVAILABLE POWER
    5=AVAILABLE SIGNAL/NOISE
11) OUT OP(1)=1
 WHAT UNITS FOR HEIGHTS AND DISTANCES?
    1=METERS AND KILOMETERS
    2=FEET AND STATUTE MILES
    3=FEET AND NAUTICAL MILES
12) LN UNIT(1)=1
 LOCATION AVAILABILITY
14) LOC AVAIL(50.00 %)=50
```

Figure 1-11. Coverage and propagation program --partial input. (Part of the Telecommunications Analysis Services Program).

```
30) XMTR HT(10.0 M  )=15
 RCVR ANTENNA HEIGHT ABOVE GROUND
40) RCVR HT(10.0 M  )=10


PARAMETERS FOR BASIC TRANSMISSION LOSS FOR AREA PREDICTION


   XMTR          RCVR
   15.0 M        15.0 M    ANT HT ABOVE GND
  RANDOM        RANDOM     SITING
FREQ= 4000.000 MHZ   NS= 236. GND CONST   .001 S/M,  4.  HORIZ POLARZ
TERRAIN DELTA H= 494. M   CLIMATE=CONT TEMP
LOC AVAIL=50.00  %

CHANGE ANY PARAMETERS (0=NO, 1=YES)0
```

DISTANCE KM	FREE SPACE LOSS (DB)	BASIC TRANSMISSION LOSS (DB) NOT EXCEEDED WITH TIME AVAILABILITY 10.0	50.0	90.0	95.0	99.0
10.0	124.5	179.9	180.6	181.1	181.2	181.4
20.0	130.5	190.2	192.8	194.5	194.9	195.8
30.0	134.0	197.2	202.4	205.6	206.5	208.2
40.0	136.5	202.9	210.7	215.5	216.9	219.5
50.0	138.5	204.1	213.9	220.4	222.2	225.7
60.0	140.1	205.0	215.5	222.8	224.9	228.7

Figure 1-12. Coverage and propagation program--partial output. (Part of the Telecommunications Analysis Services Program).



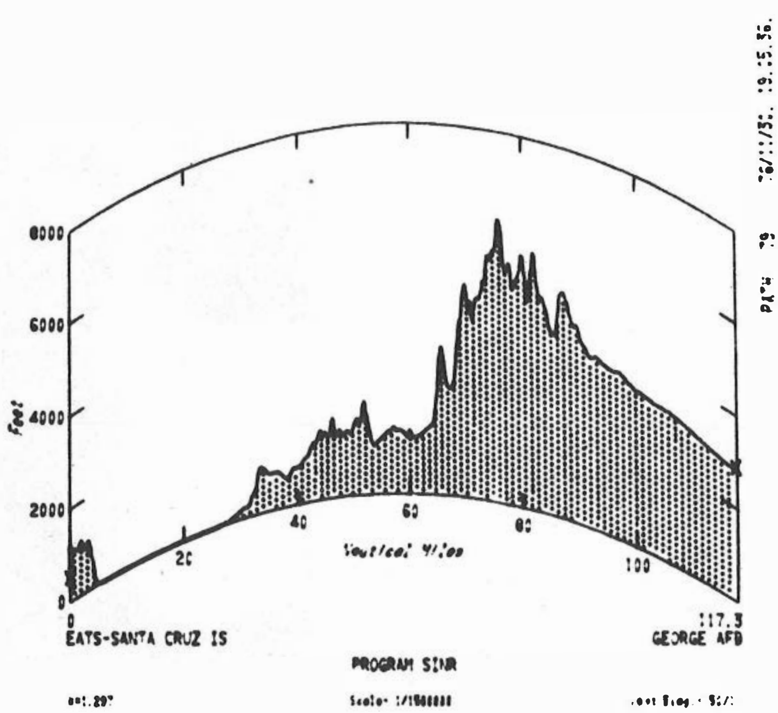


Figure 1-13. Terrain profiles extracted from a digitized terrain data base by the Telecommunications Analysis Services Program.

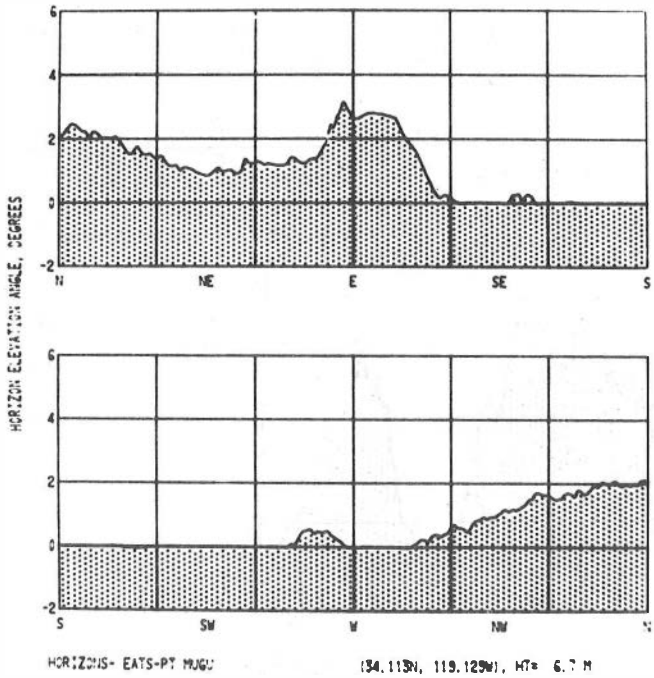
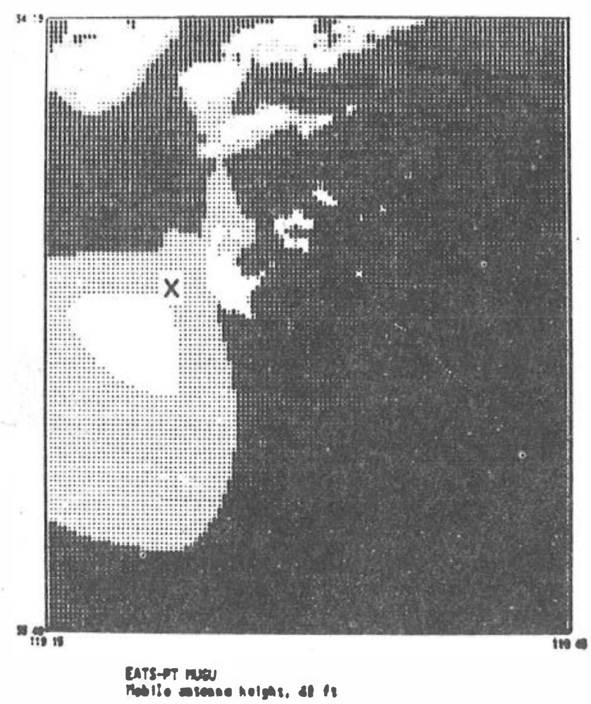


Figure 1-14. Plot of the angles to the radio horizon from the given location, 22 ft above the terrain, as provided by the Telecommunications Analysis Services Program.

Figure 1-15. Plot shows regions where an antenna 22 ft above the terrain located at the "X" is radio line-of-sight to the ground or ocean (white area), is radio line-of-sight to a mobile antenna 40 ft above the terrain (gray area), and is beyond line-of-sight to the antenna due to the terrain. (Output from the Telecommunications Analysis Services Program).



data base for selection of individual path profiles. The five types of output selections for the user are as follows: (1) single path profiles, (2) basic transmission loss, (3) power density, (4) received signal level, and (5) communication reliability throughout the geographical area. Communication reliability requires the user to specify satisfactory system performance in terms of a threshold for received signal level. Outputs of basic transmission loss, power density, received signal level, and communication reliability are plotted as equal-value contours of the selected output levels.

For communications at VHF and higher frequencies, the character of the terrain between the transmitting and receiving antennas and the heights of the antennas above surrounding terrain will affect significantly the attenuation of radio signals between the antennas. The model considers these terrain influences, along with other commonly considered influences, by automatically accessing digitized topographic data files (part of the model) to develop the path data needed to compute basic transmission loss. Basic transmission loss is computed using the Longley-Rice Propagation Loss Model formulation for point-to-point paths. The statistical character of the basic transmission loss resulting from long-term fading (time availability), path-to-path differences (location variability), and prediction confidence are used to develop the statistical outputs defined earlier. An output of predicted communication reliability portrays the probability that received signal level will exceed a received signal level threshold for specified conditions of time availability and location variability. For example, Figure 1-16 shows contours of communication reliability for values of 0.99, 0.90, 0.50, and 0.10 for time availability of 0.95 and location variability of 0.50.

Electromagnetic Cosite Analysis (EMCAN) Model Development. In the past, receivers and transmitters could be economically designed to minimize interference between services that shared either frequency bands or actual locations by properly designing the signal levels, tuned circuits, shielding, and filtering. Recently, however, communication needs have increased greatly, and communication sites have become crowded. The results are interference problems in a relatively dense electromagnetic environment. It is highly desirable, therefore, to be able to analyze the effects of an added piece of equipment to a crowded site before the actual installation or to assess the effects of changing an existing piece of equipment. To meet these needs, ITS is preparing a cosite analysis model for the U.S. Army Communications-Electronics Engineering and Installation Agency (USACEEIA).

The term "cosite" has been used in a number of ways in a number of contexts. One usage refers to the situation where antennas are termed "cosited" if either is within the near-field region of the other. Inasmuch as this definition requires too much information for a term that usually is used in a broad sense, a more practical definition is adopted for this work. Pieces of equipment (or more correctly, antennas) are termed "cosited" if they are located at the same site, regardless of whether one is in the other's near-field region. A site is defined to be a reasonably small region containing one or many pieces of communications equipment. For example, a site may be a hilltop near a city that may have microwave relays, broadcast equipment, mobile communications repeaters, etc. This capability, in a sense, is more than a cosite interference prediction model since several sites may be defined and intersite interference calculated. The actual limitation is a maximum separation of 5 statute miles ($\sim$8 km) between any two pieces of equipment.

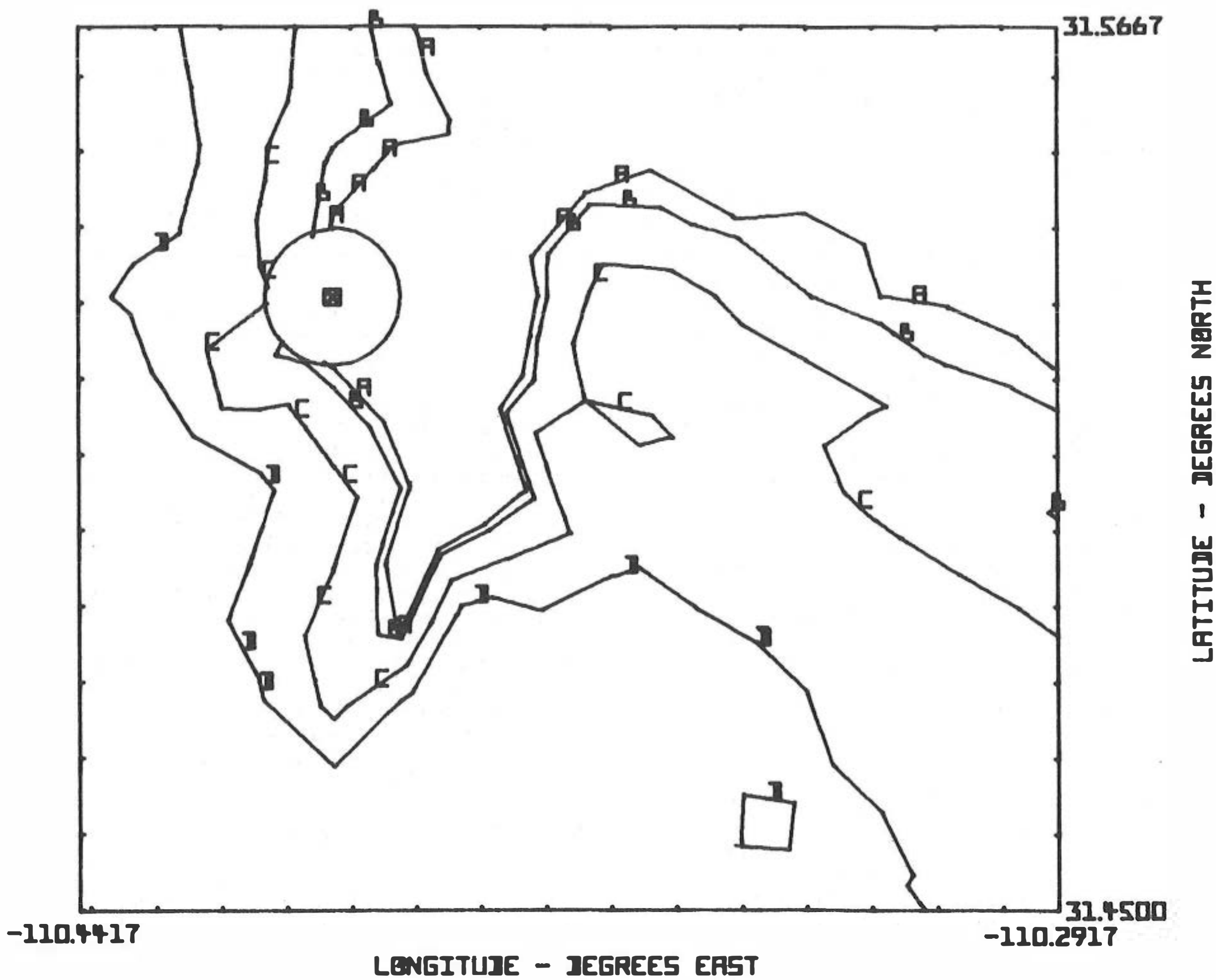
The EMCAN model, manifest as a computer program, is capable of predicting the interference level and, ultimately, a receiver performance score (e.g., articulation index or bit-error rate) for each receiver in the receiver list due to every or all transmitters in the transmitter list. All receivers and transmitters satisfying the range restriction and within the frequency limits of 30 MHz to 1 GHz are included in the analysis. The equipment lists are constructed in the first major component of the program, the input module, from two sources. The more significant of these two sources is the data base referred to as the Consolidated Frequency Environment File (CFEF), developed and maintained at the Electromagnetic Compatibility Analysis Center (ECAC) of the Department of Defense in Annapolis, Maryland. The other source of data is simply card input.

The reader is referred to Figure 1-17 for the remainder of this discussion. The input module is configured in two stages with a program stop between them. There are several reasons for this configuration. The most important reason is that stage I of the input module offers the opportunity to examine the CFEF data and to check for missing but needed information for pieces of equipment. The user also may enter information for additional pieces of equipment here. Stage II of the input module will require all the remaining data necessary for a run. Another reason for the two stage input is that the program may be run from the stage II input any number of times, with any of the input parameters changed or varied.

When all input functions have been performed, the first major step in the analysis is to determine all the potential interactions. The interaction information

COMMUNICATION RELIABILITY TEST 76/12/29.
14.39.21

COMMUNICATION RELIABILITY CONTOURS
BT=.950, BL=.500



CONTOUR LEVELS -
A= .990 D= .100
B= .900
C= .500

Figure 1-16. Area wide communications system performance output.

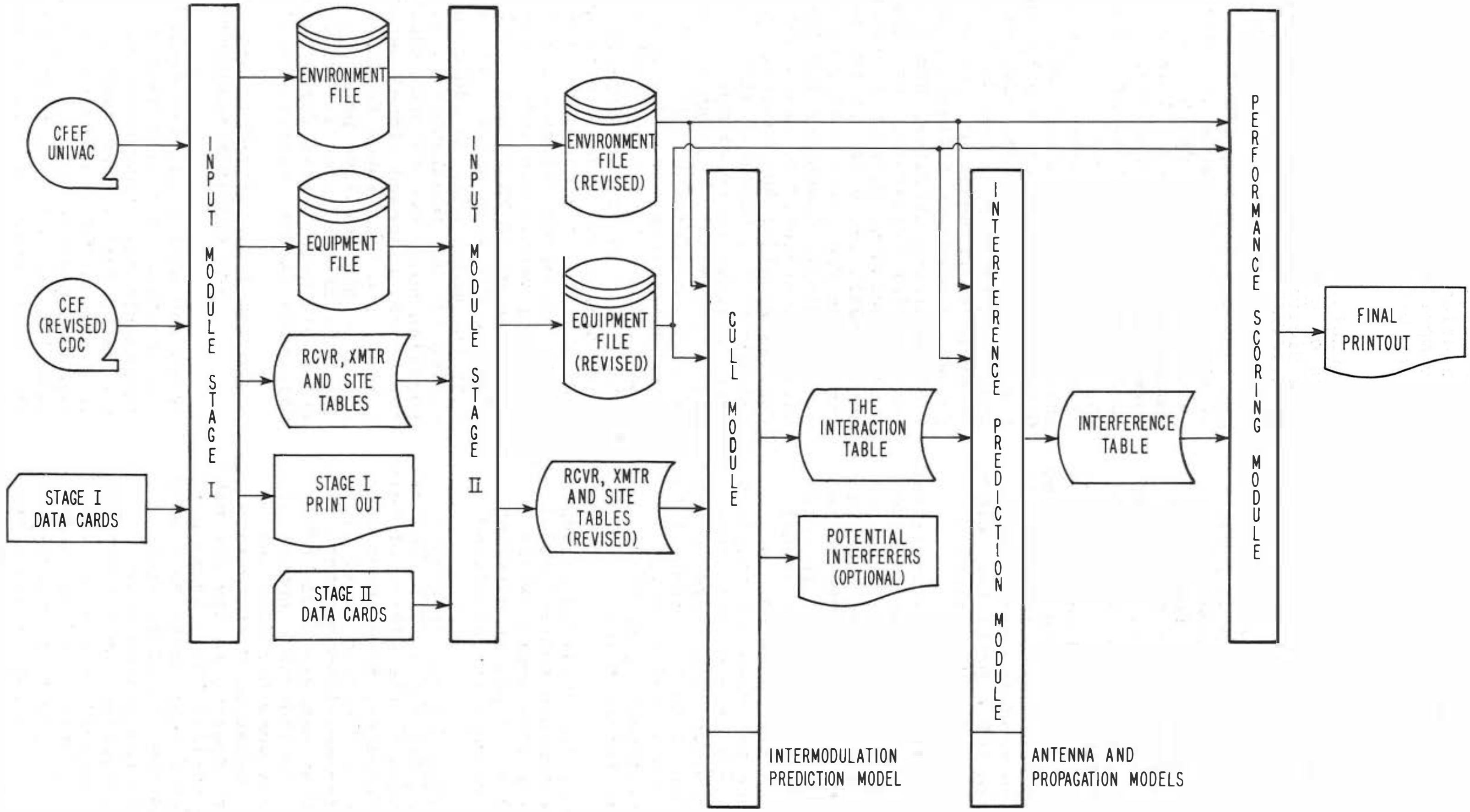


Figure 1-17. Basic structure of the Electromagnetic Cosite Analysis (EMCAN) model.

produced is in the form of a table called the interaction table, which lists all transmitter/receiver interactions in the categories of co-channel, adjacent channel, receiver intermodulation, transmitter intermodulation, and spurious emissions and responses. This cull process represents a major component of the program and is called the cull module.

A considerable amount of information about each piece of equipment is required to perform the detailed interference prediction analysis. For each receiver, for example, the local oscillator frequency, the intermediate frequency (or frequencies), tuning range, bandwidth, etc. are needed. These data are obtained from the Cosite Equipment File. This file currently lists characteristics for 123 receivers and 103 transmitters, which are indexed by system and/or component nomenclatures. It is also possible to read in, via cards, any or all the data for a particular piece of equipment for the current analysis.

The next major step in the analysis (after the cull module), which makes use of the above data, is the calculation of the total interference power levels at each receiver defined by the interactions listed in the interaction table. It is in this portion of the analysis that the actual relative geometries are taken into account. The antenna patterns and coupling or propagation submodels are used here. The results of this, the interference prediction module, form a major output of the entire program. The signal-to-noise (S/N) and signal-to-interference plus noise (S/I+N) ratios are formed here.

The last portion of the analysis is represented by the performance scoring module. The receiver performance score, which is a function of the desired and interfering inputs to each receiver, is calculated.

Special Computations for the Frequency Management Support Division. ITS provides technical assistance to the Office of Telecommunications' Frequency Management Support Division, whose function is to aid the Office of Telecommunications Policy on frequency management matters. One EMC study receiving a considerable amount of attention this past year has been the Joint Tactical Information Distribution System proposed to operate in the air navigation band of 960-1215 MHz. In support of the study, many flight tests have been made to determine the signal coverage around typical air navigation ground facilities and to determine the interference effects of JTIDS signals on the airborne air navigation receivers. ITS provided the ground-to-air propagation predictions, and a comparison of the measurements and predictions are shown in Figure 1-18. The region shown is of particular interest because it shows the behavior of the measured and predicted signal levels around the radio horizon. Considering the limited measurements that were made and the uncertainties in the antenna patterns, etc., the comparison between the measurements and the predictions is considered to be good.

A Simulation Model for Analyzing Performance of Some Simple Communication Systems on a Digital Computer. A digital-computer simulation model for analyzing the performance of some simple communication systems has been developed by ITS for the purpose of studying the effects of interfering signals, noise, and/or distortion on various communication systems. This work was performed under FAA sponsorship. The model consists of computer subprograms, each of which either simulates a basic component of communication systems or calculates characteristics of a component. The model presently consists of 19 subprograms; i.e., 5 modulators (AM, SSB, FM, FSK, and phase modulation), 5 demodulators, 2 signal generators (pulse signal and white Gaussian noise), 2 bandpass filters, 2 psophometers, 2 RF combining circuits, and 1 discrete fast Fourier transform. Details of the model, including Fortran listings and a user manual, are given in the report "A Simulation Model for Analyzing Performance of Some Simple Communication Systems on a Digital Computer," by Akima and Spaulding, Federal Aviation Administration Report No. FAA-RD-76-181, November 1976. This report also includes three examples demonstrating use of the model: (1) AM desired signal with AM interference; (2) FM distortion, which determines the effects of a Chebyshev-type bandpass filter on an FM signal by calculating the input suppression ratio, phase delay, and signal-to-distortion ratios (total and harmonic) for various filter parameter values and for various values of modulation index; and (3) the reception of an FM signal in the presence of white Gaussian noise. It is anticipated that the model will be added to by providing further modulators (e.g., PSK), non-Gaussian noise generators, additional filter types, baseband signal generators (e.g., voice), and techniques for specifying more specific and detailed performance measures (such as articulation serves for voice signals, bit error rates for digital signals, direction-finding errors, etc.).

SECTION 1.2. ADVANCED INSTRUMENTATION FOR SPECTRUM MEASUREMENTS

Needs for more realistic estimates of how the spectrum is really used generate requirements for instrumentation that is more accurate, faster, and more economical. In some cases, the requirement is for new types of measurement. In this section, we describe two basic kinds of instrumentation that share computer control and digital recording as common features. The first group of instruments provide powerful, computer-controlled capabilities mounted in vehicles for a variety of special uses.

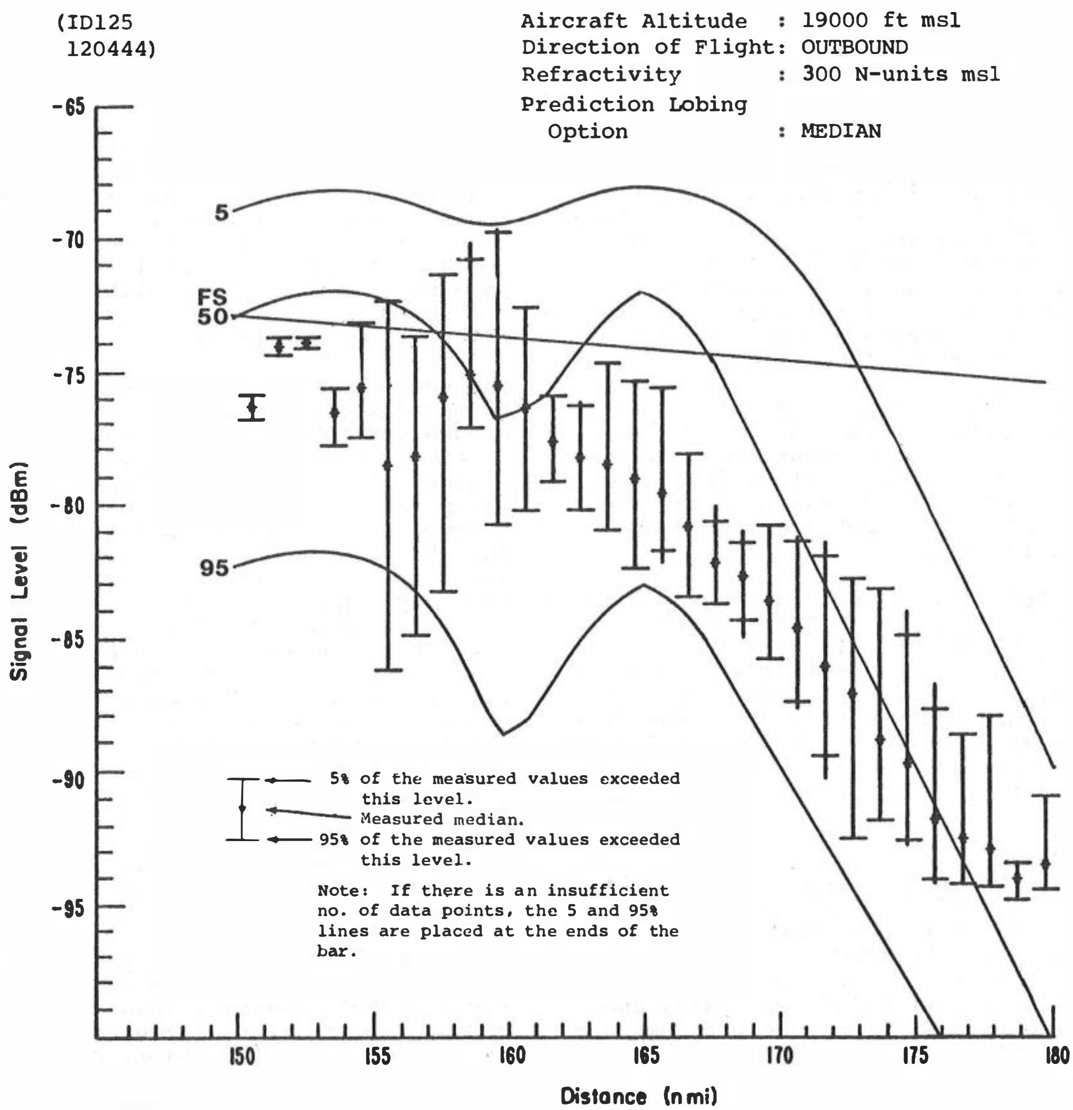


Figure 1-18. Comparison of measurements and predictions for the VORTAC at Gage, Oklahoma.

The second approach to instrumentation provides a small package that is very portable, operates with a wide range of existing equipment, and is relatively low cost.

The reader may also be interested in special instrumentation approaches developed for the measurement of full hemispheric antenna patterns reported in section 1.3 and measurement techniques for the measurement of spread spectrum interference effects reported in section 1.1.

Transportable Automated Electromagnetic Measurement System (TAEMS). A system has been developed for the Communications Electronics Engineering Installation Agency of the U.S. Army which will significantly enhance both the accuracy and amount of data recorded in an on-going effort to ensure operational electromagnetic compatibility among existing and planned U.S. Army communications facilities.

The TAEMS (Figure 1-19) is a self-contained, self-propelled, air/ground transportable, fully automated measurement and analysis facility, designed to perform frequency and time domain measurements of the electromagnetic environment over the range 10 Hz to 40 GHz.

As the TAEMS design evolved, it was established that standard or "off-the-shelf" equipment would not satisfy all requirements and that developmental work would be required. Consequently, down converters were designed and prototyped for the frequency region between 2 GHz and 40 GHz and a time compression analysis converter was developed to operate between 10 Hz and 10 kHz.

To expedite early deployment of the TAEMS, an EMC and TAEMS Training Course for Army personnel is underway at the Boulder Laboratory which stresses operational and maintenance of the TAEMS. In addition, basic topics of radio propagation, electromagnetic compatibility analysis, and radio frequency interference problems are being taught.

TAEMS Training. The second 12-week training course for Army personnel USACEEIA, Fort Huachuca, Arizona, was conducted on the Transportable Automated Electromagnetic Compatibility Measurement System (TAEMS). The course covered math review, spectrum analysis and signals, programming, interactive graphics, the system structure, computer operation, storage and display subsystem, rf front ends, antenna subsystem, vehicle configuration, system deployment, operating system generation, system calibration, the 8580 calls, manual operation, the ancillary equipment, vehicle operation, maintenance, automatic diagnostics, manual diagnostics, error reporting procedure, operative preventative maintenance, operator system maintenance, spectrum allocation and services, communication-electronics (C-E) systems, C-E operational standards, propagation, EMC fundamentals, and EMC measurements. The course prepared the operators to make the most effective use of the automated measuring equipment and system in analyzing electromagnetic compatibility problems.

Transportable Automated Electromagnetic Measurement System Software Applications. The three scenarios currently being developed under this project will permit the effective and efficient operational deployment of TAEMS system. The scenarios provide (a) the engineering basis for the measurements including premission requirements, measurement plans, and analysis methods; (b) suggested procedures for the operator to follow in applying the software programs; and (c) a library of specific software programs developed for each of the three scenarios.

The scenarios cover measurements of Electromagnetic Radiation Hazards, the EMC ground environment affecting Defense Satellite Communication Systems, and the evaluation of Airfield/Heliport Operational Equipment. The Hazard scenario describes a sequence of events and actions which must be undertaken to acquire, analyze, and characterize the electromagnetic radiation environment in the vicinity of ordinance and artillery sites worldwide in support of the U.S. Army Nuclear and Chemical Security Program. The Satellite scenario describes the on-site measurements and analyses which are necessary to evaluate the communication and interference environments for fixed and transportable satellite earth terminals. The Airfield scenario describes a sequence of necessary measurements and analyses for evaluating the performance on all operational communication systems and diagnose EMI problems in an airfield/heliport environment.

Air Force (AFSC) Multiple Receiver System (AN/MSR-T1). This program, under the Air Force Systems Command, involves the development, acquisition, integration, and testing of a preproduction, prototype multiple receiver system, designated the AN/MSR-T1. The design is based on user (SAC, TAC, PACAF, USAFE) command required operational capabilities (ROC's) for improved and updated USAF Operational Ranges and Strategic Training Range (STR) sites. The purpose of the AN/MSR-T1 is to provide a multiple signal intercept capability to monitor, measure, analyze, and characterize transmissions of airborne jammers and ground-based threats during the conduct of electronic warfare (EW) tests and exercises.

The prototype AN/MSR-T1 system design covering the frequency range 0.1-18 GHz has been completed. The system is configured in a self-propelled vehicle and employs directional and nondirectional antennas with a combination of a wideband receiver (500 MHz bandwidth), a series of three

Figure 1-19. Data acquisition vehicle of TAEMS system. This unit is designed to be air transportable and can be air lifted by helicopter.

narrowband tuners (20 MHz bandwidth), and a spectrum analyzer working with appropriate signal processing units (Instantaneous Fourier Transform optical processor, microprocessors, computers, special function hardwired units) and data/display/storage units. Figure 1-20 is an external view of the vehicle and antenna system. Figure 1-21 is a block diagram of the complete system.

The system is fully automated and will contain extensive software for command and control of all units and measurement/analysis routines for (a) spectrum surveillance, (b) ground-based threat and airborne electronic countermeasure (ECM) emission validation, and (c) EW evaluation. A spectrum surveillance capability is essential to effective range operations where multiple emitters of both participants and nonparticipants in EW training missions must be carefully scheduled and controlled to insure compatible operations. Ground-based threat/airborne ECM emission validation is an essential prerequisite to successful EW training missions. Incorrect or faulty threat/ECM emissions can cause costly mission reruns or produce serious interference problems to other participants or nonparticipants sharing the same or adjacent frequencies. Electronic warfare evaluation implies the reception and analysis of noise jamming and deceptive jamming techniques against various multiple threats to ascertain ECM effectiveness during tests and exercises. Electronic countermeasure effectiveness is evaluated by precise measurements of the time of response, frequency of response, and signal characteristics of airborne ECM reactions to threat emissions. These are the measurement objectives which were addressed in the design of the prototype AN/MSR-T1.

Extensive field tests will be conducted with the prototype AN/MSR-T1 over a period of 10 months at an Air Force operational EW training range (STR La Junta, Colorado) to verify conformance with design and measurement objectives before the production of additional systems is undertaken by the Air Force.

During this extended test period, special and regular B-52 and FB-111A SAC aircraft equipped with advanced ECM systems (ALQ-94, ALQ-117, ALQ-122) will be deployed against a wide variety of multiple ground-based threats. Each of these ECM systems are fully automated and generate multiple responses on a pulse-by-pulse basis to counter multiple detected threats by deception techniques. Programs are interleaved, depend upon the intercepted threat characteristics, and generate pulsed waveform patterns which produce range gate pull-off and velocity gate pull-off target deception at the threat radar receiver. Barrage noise and spot noise jamming techniques are also employed in manually operated airborne ECM systems (ALT-6B, ALT-28) to deny target tracking and/or generate multiple false targets at the receiver. Since the ground-based threats used for EW training exercises do not contain receivers for evaluating the airborne systems ECM response, the AN/MSR-T1 is being developed and deployed at each range for this purpose. Data will be output to SAC Bomb Wings for aircrew training proficiency ratings and identification of malfunctioning airborne ECM equipment. The AN/MSR-T1 will also be used for evaluating the performance of new automated airborne ECM systems as they become operational or are undergoing initial flight testing.

The program was started in February 1976 and has involved field tests of new technologies for receivers (wideband 0.5-18 GHz tuners with 500 MHz IF bandwidths) and signal processors (500 MHz bandwidth Bragg cell optical techniques with 1 MHz frequency resolution) which were considered essential requirements for the prototype AN/MSR-T1 design. The tests were undertaken to evaluate their practical application in the AN/MSR-T1 design, verify performance characteristics, and identify needed improvements. The initial tests were successful and detailed specifications were issued for procurement of preproduction prototypes for further testing and evaluation when integrated into the MSR-T1 system.

All hardware is under procurement, and delivery and integration is expected to be complete by December 1977. Air Force acceptance tests will begin in January 1978. Acceptance test plans are being prepared and tests will be conducted over a 6-month period followed by a 4-month user (SAC, TAC, AFEWC) command Operational Test and Evaluation (OT&E) period. User command OT&E will be conducted under simulated combat training conditions.

Air Force (TAC) Signal Analysis System. This project is an outgrowth of the Air Force (AFSC) Multiple Receiver System (AN/MSR-T1) and was initiated by the Tactical Air Command, Tactical Fighter Weapons Center Range Group (TFWCRG), Nellis AFB, Nev. The project involves providing the TFWCRG with an interim EW Signal Analysis System (SAS) based upon portions of the prototype AN/MSR-T1. Although the TAC/SAS concept and basic design are similar to the AN/MSR-T1, it will be deployed for different applications in EW test and exercise evaluation.

The TAC/SAS is to be used for (a) the evaluation of air-to-ground electromagnetic radiation patterns generated by wideband automated emitters on airborne fighter platforms, and (b) spectrum management to resolve and prevent RFI and EMC problems during the conduct of large scale EW

Figure 1-20. The signal analysis system.

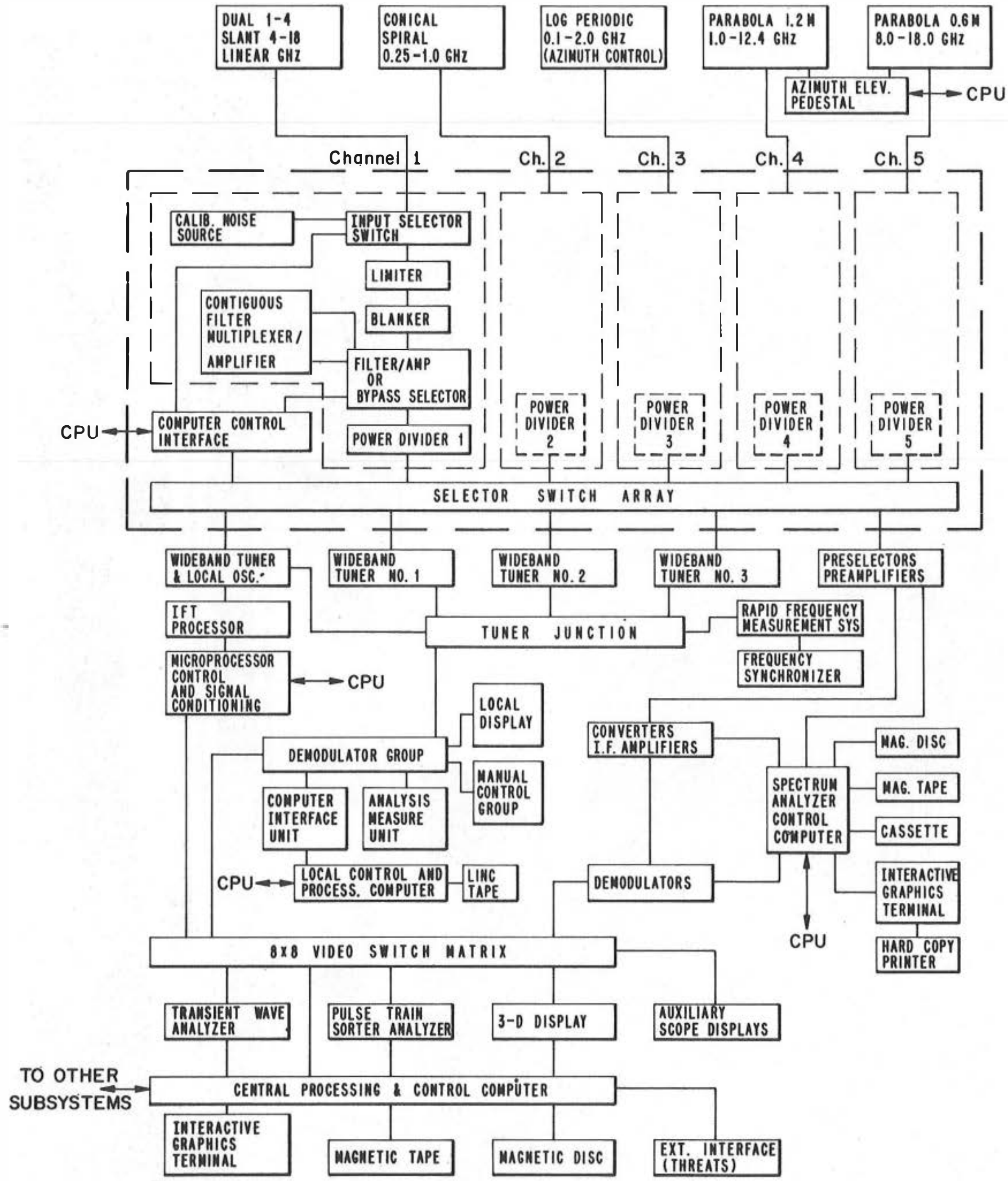


Figure 1-21. Signal analysis system block diagram.

training exercises. The TAC/SAS is to verify that specific in-flight EM radiation patterns are being generated to jam/deceive terminal threat ground-based acquisition and tracking radars. While these requirements are similar to those required for the AN/MSR-T1, the TAC/SAS must include a target tracking capability because multiple aircraft are involved and different flight tactics are employed. It is also required that the analysis of these air-ground signals includes effects of propagation attenuation and distortion (multipath) induced by atmospheric and terrain conditions between the airborne platform and the SAS. TAC fighter aircraft employ different ECM systems (ALQ-99, ALQ-119) with different repeater-noise-deception ECM techniques than SAC bomber aircraft and will require the development of different software analysis routines to evaluate ECM performance and EW effectiveness.

The project was initiated in May 1977, and detailed specifications for the design and configuration have been completed. Procurement of major hardware items is essentially complete. Signal analysis software routines have been started for the TAC/ECM systems with tests scheduled in the February-March 1978 time period.

Work was performed for the U.S. Army Communications Command (CEEIA) to improve the uses of the suitcase Automated Digital Recording of EMC Signals System (ADRES). The ADRES system, shown in Figure 1-22, is a small, lightweight system that allows collection of digital data from a wide range of receivers. In the photograph (see Figure 1-23), ADRES is shown with a spectrum analyzer, but numerous other receivers could also be used with it. The system can provide digital records during unattended operations of field intensity meters; instrumentation receivers; telemetry receivers; AM, FM, and TV receivers; land-mobile base and mobile receivers; and a wide range of other receiving systems. This year the work included expansion of the systems software, a demonstration measurement trip to Carson City, Nevada, and other hardware and software improvements so that the system could be also used to measure and field analyze propagation loss data.

The ADRES system software expansion includes routines such as autocalibration of the analog-to-digital (A-D) converters, calibration of the digital-to-analog converters (D-A), and automatic selection of the sampling rate corresponding to the spectrum analyzer scan time settings. Improvements in the tape recorder software drivers were also made.

An engineering group of CEEIA, assisted by an ITS engineer, conducted EMC measurements at Carson City, Nevada. The purpose was to find the cause of intolerable interference to the National Guard State communications net (which was also used as the Civil Defense communications net). The ADRES system was used on the trip to record and process the interference signals as an aid in determining the origin of the interference.

Hardware and software modifications were later made to the ADRES system to allow it to measure (and record) propagation loss data. The receiver used for these measurements was a field intensity meter, which was connected to the system instead of the spectrum analyzer. The software modifications allowed the propagation loss data to be recorded and analyzed to calculate maximum, minimum, and median signal levels over the measurement interval. Propagation loss measurements were then made in Germany by the engineers at CEEIA on a measurement mission in the spring of FY 77.

Work is ongoing to evaluate (and verify) new hardware and software techniques for EMC data recording and analysis which may result in evolving a second generation of the ADRES system. These new techniques include control of a 9-track digital tape recorder through DMA software and hardware, utilization of a high-level language (BASIC) on the system, and increasing the processing speed so more field analysis can be done in real time.

SECTION 1.3. SPECTRUM RELATED MEASUREMENTS

Some aspects of spectrum efficiency require measurements either to augment or validate analytical estimates or to provide a characterization of some particular factor that is analytically intractable.

In many cases we find that instrumentation development is an inherent part of the measurement process. Thus some part of what is reported here also should be considered as part of section 1.2.

Measurement Van Operations and Measurement Van Development. For the past several years this project has supported the OT and OTP frequency management operations with measurements of the general electromagnetic environment, as well as measurements on specific types of equipment. This sort of data is often needed to supplement data in the frequency manager's data banks, especially when the object of discussion is related to spurious emissions, interference between particular systems, or operational crowding in a band. These types of measurements are most often used to solve particular problems; they are also valuable to verify or improve existing models which are used in a wide range of spectrum planning functions.

The Radio Spectrum Measurement System (RSMS) was procured by ITS in 1973 to use

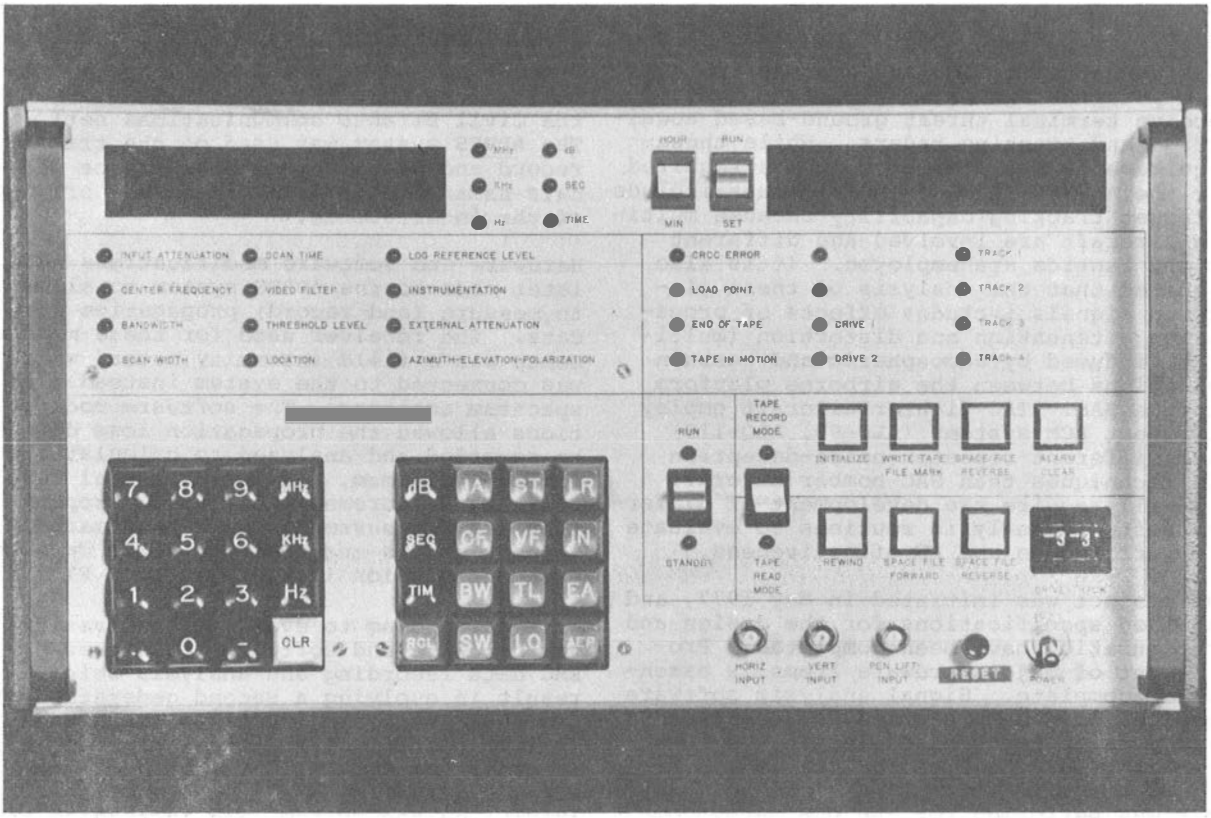


Figure 1-22. The ADRES data acquisition unit. This unit is easily field transportable and will operate with a wide range of standard receivers.

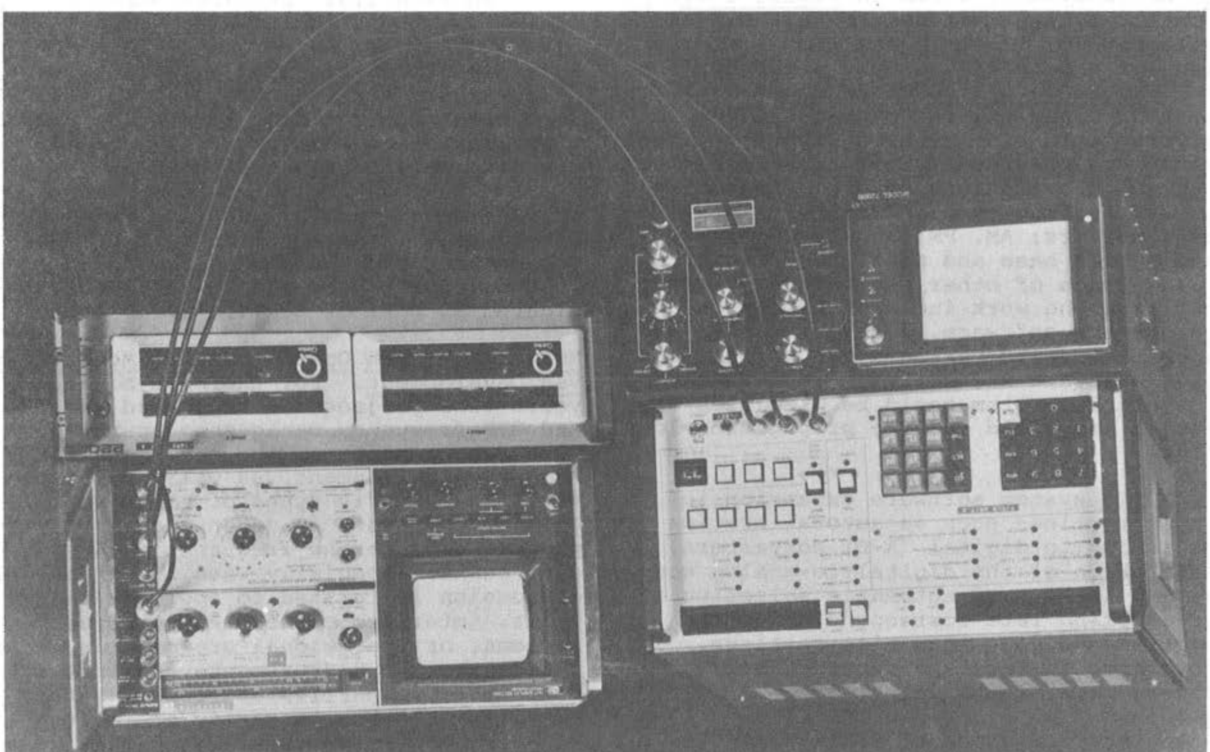


Figure 1-23. The ADRES unit with a spectrum analyzer (upper right), dual digital tape cassette drive, and an optional display unit.

in providing the necessary measurements of the electronic environment. This computer-controlled system has been used for a wide variety of measurements over the frequency range between 30 MHz and 12 GHz. The RSMS is integrated into a motorhome-type vehicle (Figure 1-24) containing an antenna system, electrical generators, a mobile phone, air-conditioners, etc., furnishing a laboratory environment for the measurement system which can be driven to the measurement site. The measurement system itself (Figure 1-25) is completely controllable via computer programs written in BASIC, which cause the measurements to be made rapidly, processed with proper calibration factors, analyzed, plotted, and recorded on magnetic tape. This capability has been used many times to measure and process literally billions of data points during a week of measurements, with the results of the entire set of measurements available in report-ready form a few hours after the last data point has been measured. Some representative examples of measurements which were made last year are included in the following paragraphs.

General studies of band usage were continued with a set of measurements in the El Paso, Texas, and White Sands Missile Range areas in many of the Federal Government communication and radar bands between 30 MHz and 10.5 GHz. The radar band measurements involved determining the operating characteristics and identity of operating radars seen by the RSMS. Operating frequency, emission spectra, pulse repetition frequency, pulse width, antenna pattern, and rotation period are usually measured. These characteristics are used to identify the radar and to determine whether it meets the nominal and regulatory specifications of the radar, and to see how closely the measured data match the data in the Government Master File (GMF).

Our continuing studies in the usage of Federal communication bands led to the development of an improved measurement capability for these bands. This capability was needed to eliminate spurious measurement system intermodulation responses, caused by the regular channelization plan in these bands (typically 25 kHz or 50 kHz) and the occasional presence of very strong local (mobile) transmitters. In addition, it was desired to eliminate an apparent response on channels adjacent to strong signals, caused by local oscillator noise sidebands in the measurement system.

A wide-dynamic-range measurement system was constructed to give excellent performance in selected communication bands. High-level components were used to obtain an instantaneous measurement range of about 110 dB (Figure 1-26), which tends to eliminate most intermodulation products. Deriving the local oscillator from a particularly quiet part of the frequency synthesizer and using rectangular bandpass crystal filters give an almost ideal measurement bandpass which is 18 kHz wide, but about 80 dB down only 25 kHz away (Figure 1-27).

Since the new measurement receiver generates very few spurious responses, it is possible to immediately process channel occupancy and amplitude statistics data while the measurements are being made. Typically, only a single file is recorded on magnetic tape containing the processed data from one hour of measurement in the selected band. These hourly files may be combined with other hourly files to get data from a larger time period, or they may be immediately graphed and listed on a hard-copy device. A typical plot is shown in Figure 1-28. The upper graph shows occupancy data for each channel, plotted on a logarithmic scale between 0.5 percent and 100 percent. The lower graph shows the peak (top of line) levels of signals received on that channel.

At the request of the National Weather Service, we measured the emission spectra of some WSR-74C weather radars operating at 5625 MHz. Previous to the RSMS measurements, there was some concern that large-scale deployment of these radars might cause interference to point-to-point microwave links operating in an adjacent band (5925-6425 MHz). Measurements on a few radars which had already been installed were sufficient to show that the earlier fears were unfounded and that the radar spectra were generally much better than the government criteria for allowable sidebands (dashed line in Figure 1-29).

A recent measurement problem for the RSMS concerned the NASA deep space receiving site at Goldstone, California, where a long-term interference problem occasionally caused loss of data from some deep space missions. Although the interference occurred sufficiently seldom that previous short-term monitoring efforts were unsuccessful, it was feared that the interference might recur during a particularly critical phase of an experiment.

A special surveillance program was developed to look for signals which might cause interference to Goldstone in the 2290-2300 MHz and 8400-8500 MHz bands. Figure 1-30 is an example of the output of this program.

This program continually scans across a frequency band, making peak and average measurements at each frequency, graphing the data at the end of each scan (every 2 seconds). If no signal appears above a preset threshold, the system throws the data away and makes another scan of that band.

Figure 1-24. The Radio Spectrum Monitoring System undergoing antenna calibration testing at an OT/ITS antenna range.

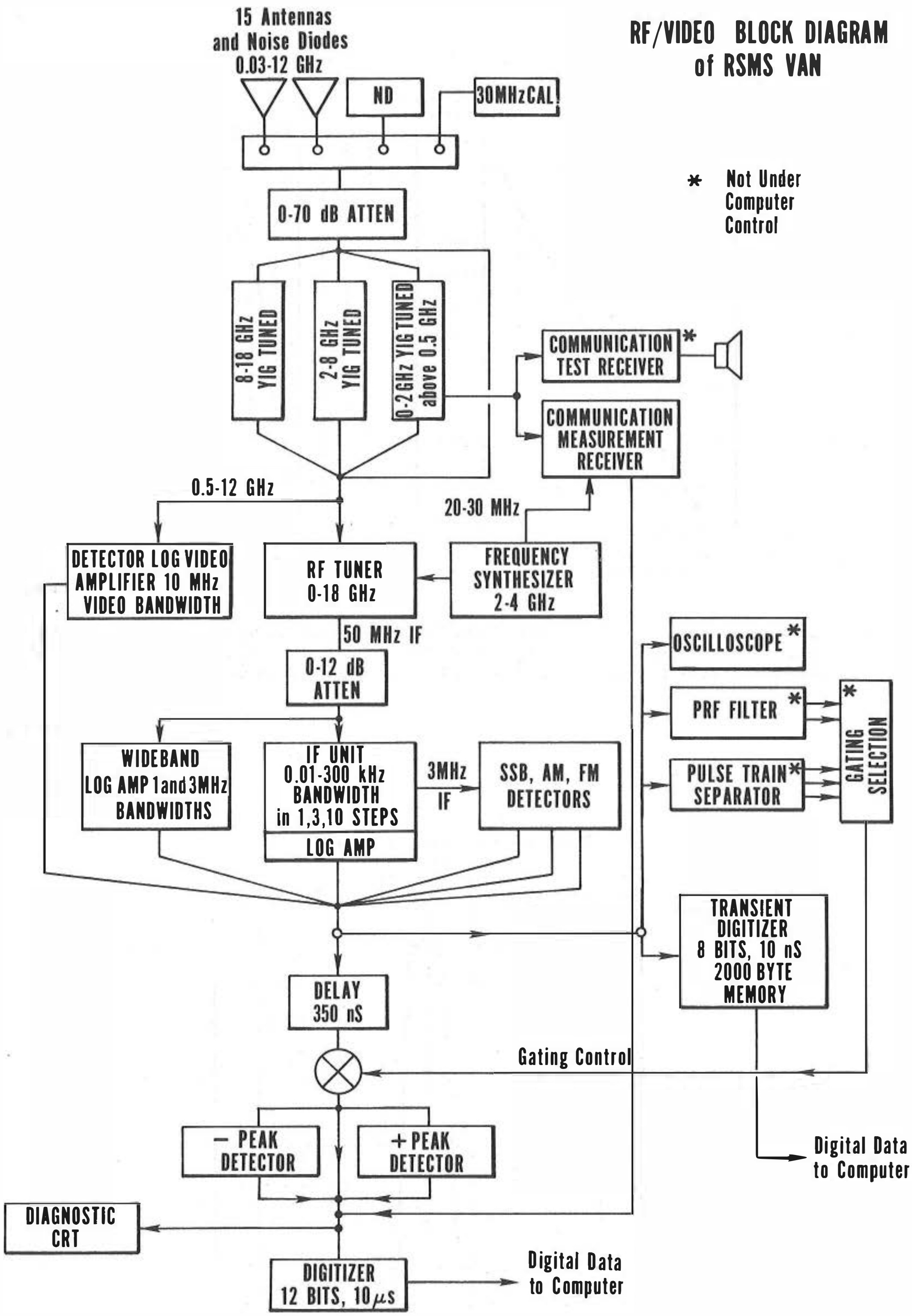


Figure 1-25. Block diagram of the RSMS showing some of the new capabilities (transient digitizer, pulse sorting, and communications measurement receiver).

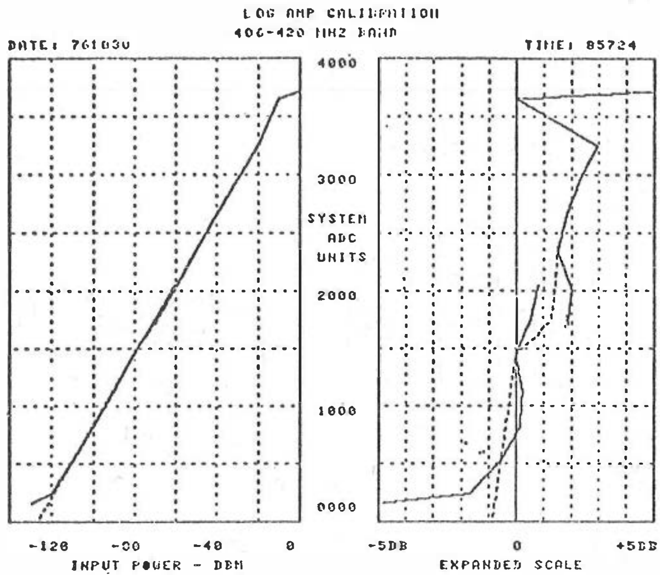


Figure 1-26. Dynamic range data of the OT/ITS developed Communications Band receiver. Note linear operation over 110 dB. This dynamic range has allowed greater speed and greater quality of measurements.

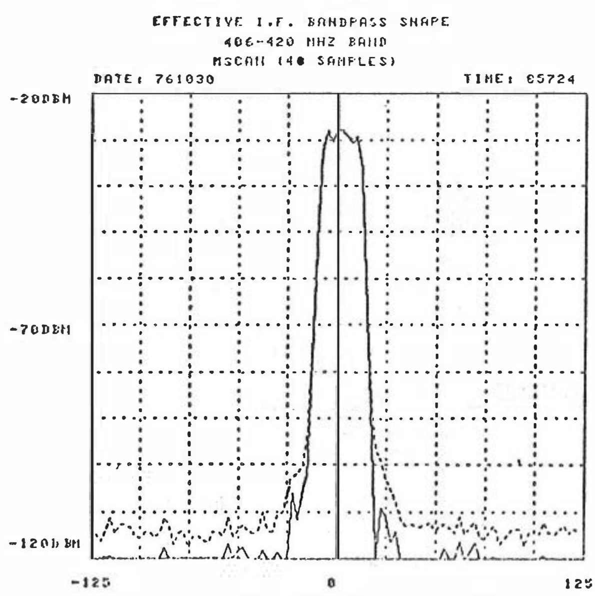


Figure 1-27. The extremely sharp selectivity of the RSMS receiver (80 dB down at 20 kHz) permits reliable measurements with much higher adjacent channel signals.

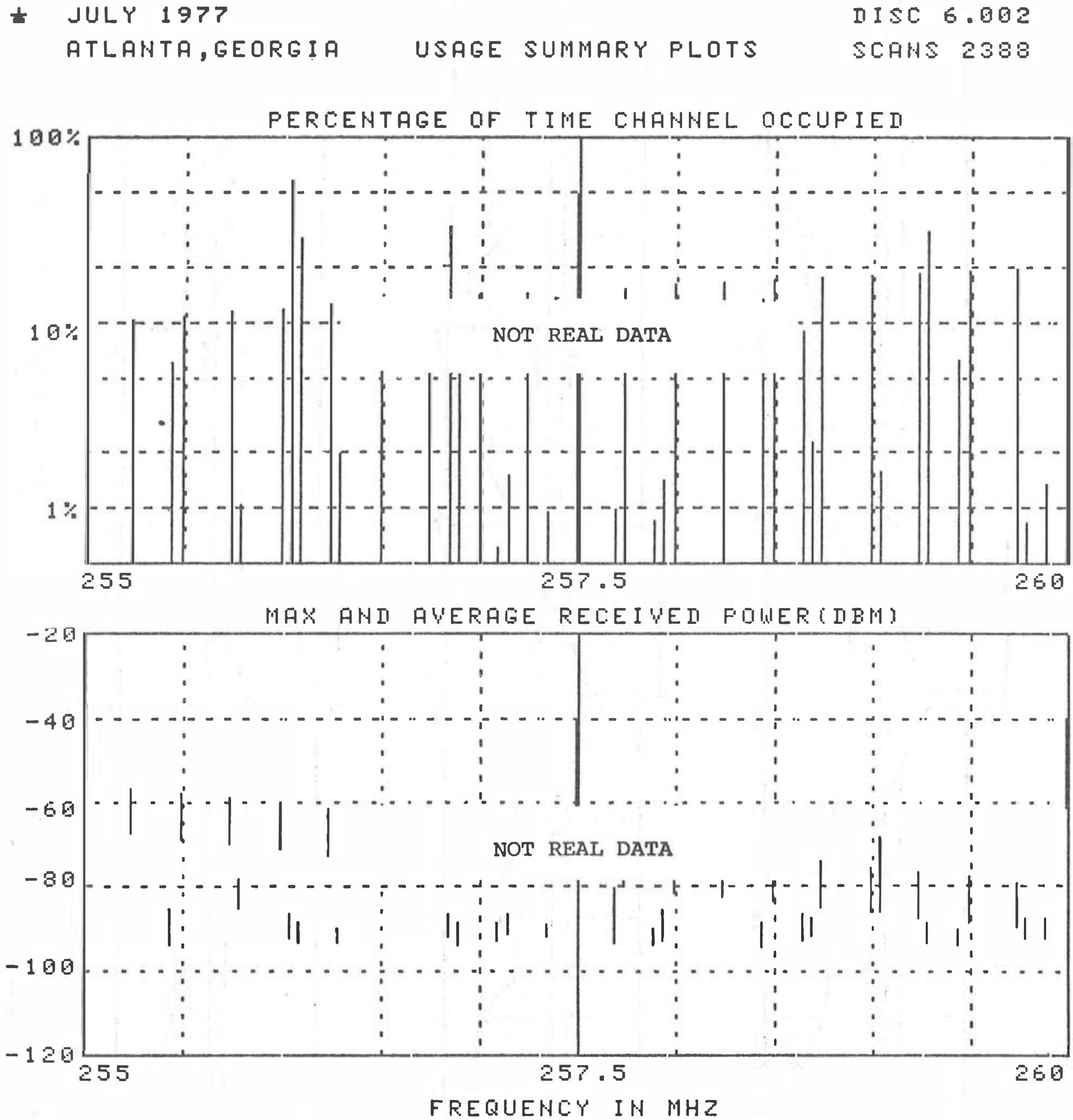


Figure 1-28. Plot of channel occupancy and amplitude statistics for the 255-260 MHz part of the 220-400 MHz band.

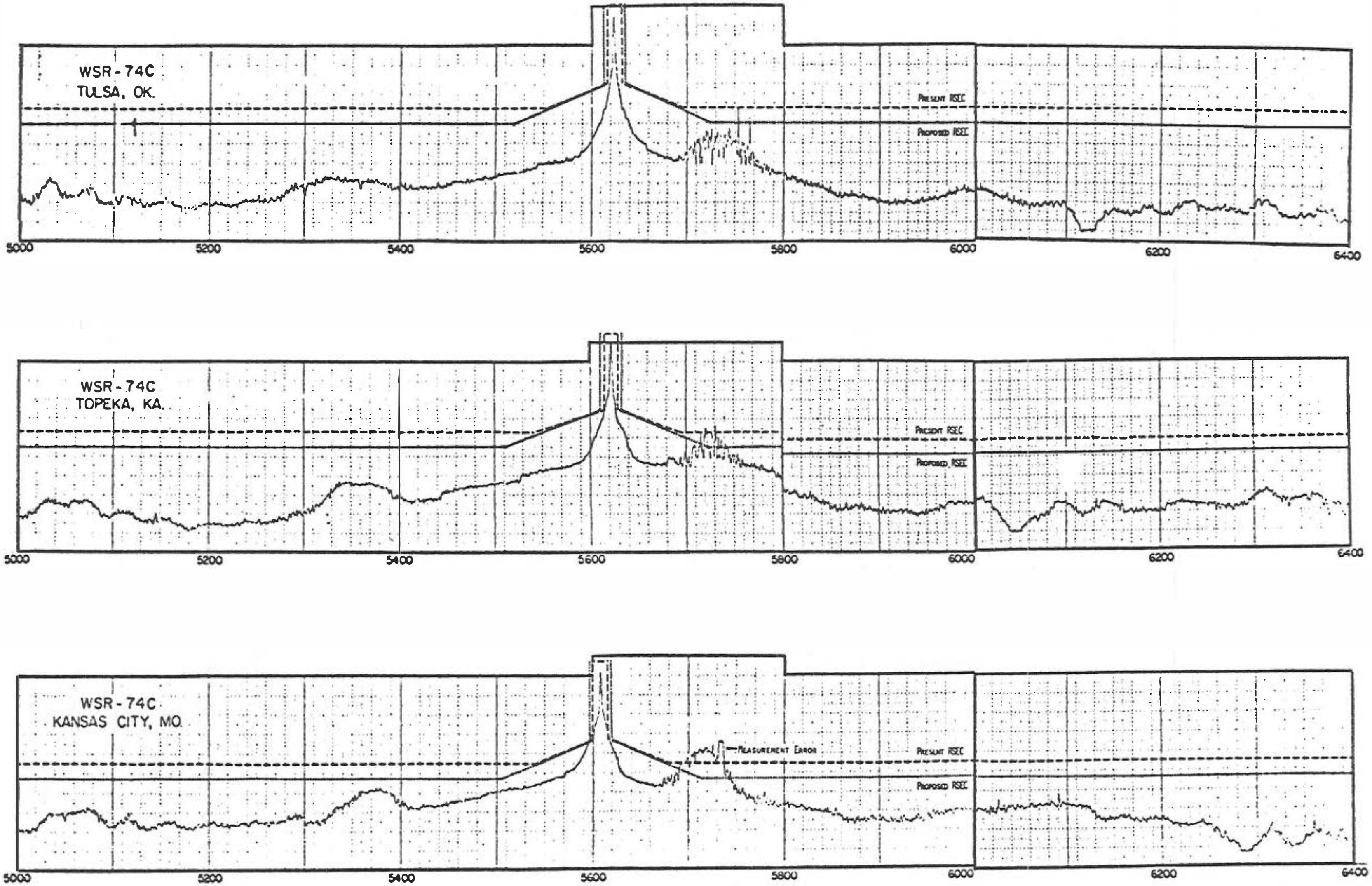


Figure 1-29. Radar spectra of the WSR-74C Weather Radar as measured by the RSMS. Note sideband measurements more than 700 MHz above the tuned frequency.

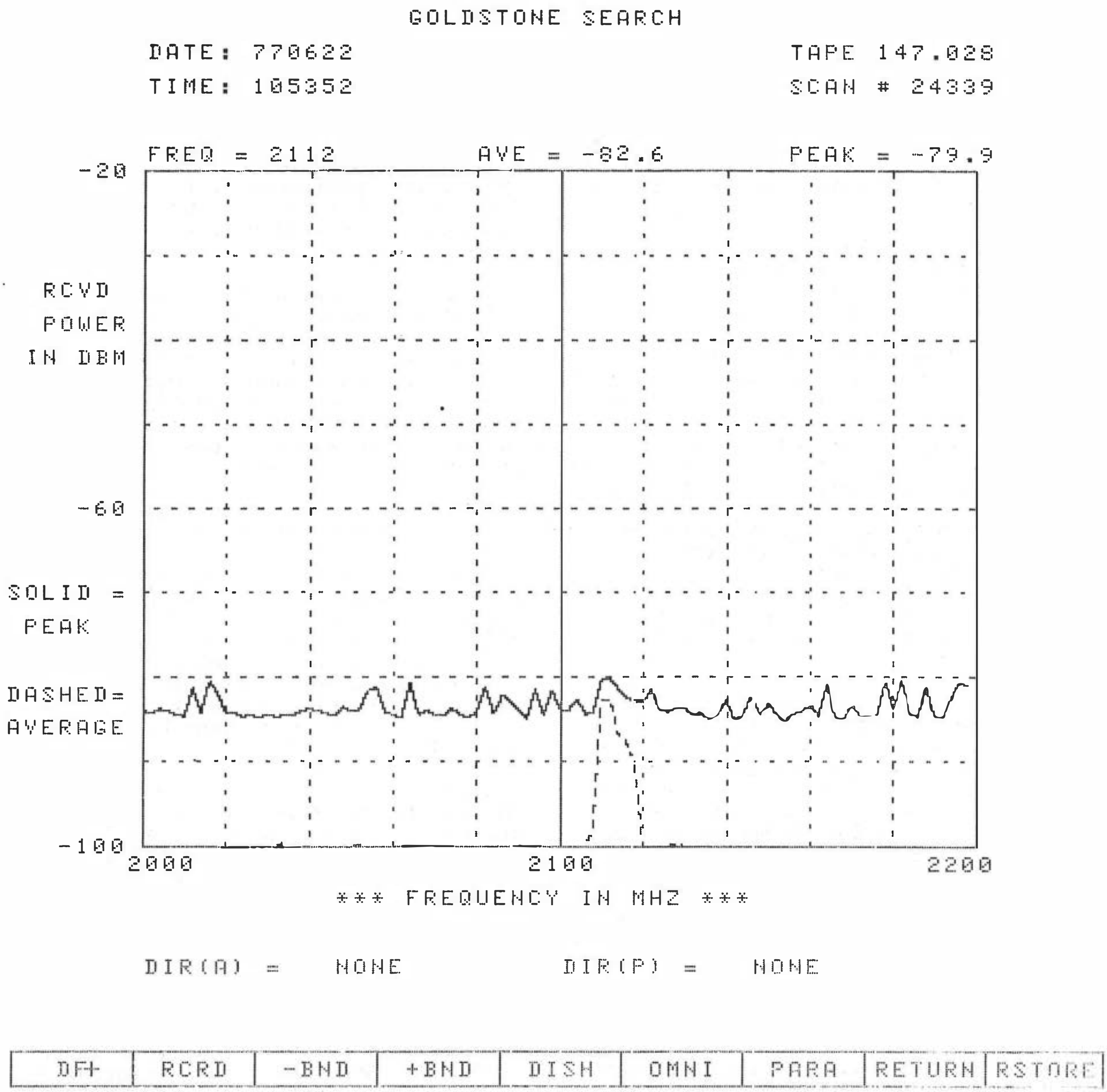


Figure 1-30. Output showing results from a special computer program written to automatically scan a band of interest and measure peak and average signal level and direction of arrival for detected signals.

If a signal does appear in the measurements, the system stops its scanning mode and tunes to the frequency of the signal. A high-speed PIN-diode switch measures the signal repeatedly for 10 ms on each of four cavity-backed spiral (CBS) antennas. A knowledge of the CBS antenna pattern is used with the relative signal strength measured on the four antennas to compute a direction of arrival. The data are recorded on magnetic tape; the graphed data are copied on an electrostatic copier; and the program returns to its scanning mode. Since the entire process operates without an operator, the program can be run on a 24-hour/day basis.

If the operator is present, the system may be stopped for a more detailed look at a signal, selected by setting a cursor on various options at the bottom of the graph. These options include switching to a higher or lower frequency band, selecting an omnidirectional or a dish antenna, choosing new operating parameters, etc. This program was used to make measurements for about five weeks at Goldstone on a 24-hour/day basis, furnishing a data base for a report which is currently being written.

Small Earth Terminal Antenna Measurements. The hemispherical power-gain pattern measurement technique, developed last year, was improved and used to measure the sidelobe patterns of a 6.1 m portable earth terminal antenna operating at 7.5 GHz (Figure 1-31).

Antenna power gain is measured utilizing airborne transmitting antennas as sources of test site illumination. The test antenna is centered on a heavy-duty turntable, which is also the roof of the below-ground receiving equipment room, capable of continuous rotation at speeds up to 4 rpm. During measurements, the test antenna rotates while the helicopter traverses a flight path designed to produce nearly uniform coverage of the hemisphere relative to the test antenna. The antenna test facility uses an optical tracker to track the helicopter and an automated data system to collect and display the data.

A relative gain method of measurement is employed with a single receiver switched rapidly between a reference gain antenna and the test antenna. Since the reference antenna is mounted on the optical tracking system used to obtain helicopter elevation and azimuth relative to the test site, it is always pointed at the test signal source. The gain of the test antenna relative to the gain of the reference antenna is equal to the difference in the received signal levels, expressed in decibels, plus a constant factor composed of the difference in cable losses and antenna mismatch losses. The maximum power gain of the reference antenna is known; therefore, these relative gain data are converted to absolute gain data by the addition of the reference gain value. Since circularly polarized reference antennas are not available, a linearly polarized standard gain horn is used as the reference antenna, and its gain is reduced 3 dB to account for the polarization loss in the measurement of circularly polarized test antennas.

Each separate measurement (the set of data covering the hemisphere for one range to the helicopter) results in 30,000 to 50,000 received signal amplitude data points stored on magnetic tape along with the angular positions of the turntable and optical tracker for each point. Data tapes are processed on the data system minicomputer.

Figure 1-32 shows an important result of this measurement project. This cumulative distribution plot of hemispherical power-gain data measured at four ranges indicates the measurements made at less than the far-field distance of 2.0 D^2/λ yield data that vary less than 2 dB from those data measured at greater ranges for about 90 percent of the pattern.

SECTION 1.4. SPECTRUM ENGINEERING FOR EFFECTIVE SPECTRUM USE

In addition to the development of new analytical and measurement techniques, ITS applies the results of such work to specific problems of concern to various agencies. One important factor in planning for new developments is our experience with such projects where the practical needs of operational agencies must be recognized.

Extended Area Test System EMC Analysis. The Pacific Missile Test Center (PMTC) operated by the Navy at Point Mugu, California, plans to extend the test area for the test and evaluation of developmental and operational Department of Defense weapon systems farther into the Pacific Ocean. The present PMTC test area is limited to radio/optical line-of-sight distances from land instrumentation at Point Mugu and San Nicholas Island.

The proposed Extended Area Test System (EATS) has been designed to provide tracking, control, communications, and data collection for airborne and seaborne elements participating in the tests and exercises. Operating in conjunction with existing and planned facilities of the Pacific Missile Range (PMR), the system extends the area in which tests can be conducted up to approximately 250 n mi (460 km) seaward from San Nicholas Island, and expands the volume of the test and the number of participants in the exercises. Fixed Ground Stations, Airborne Instrumentation Stations, and participant instrumentation packages are utilized by the EATS to obtain the real time positions of exercise participants, relay telemetry, and miss distance

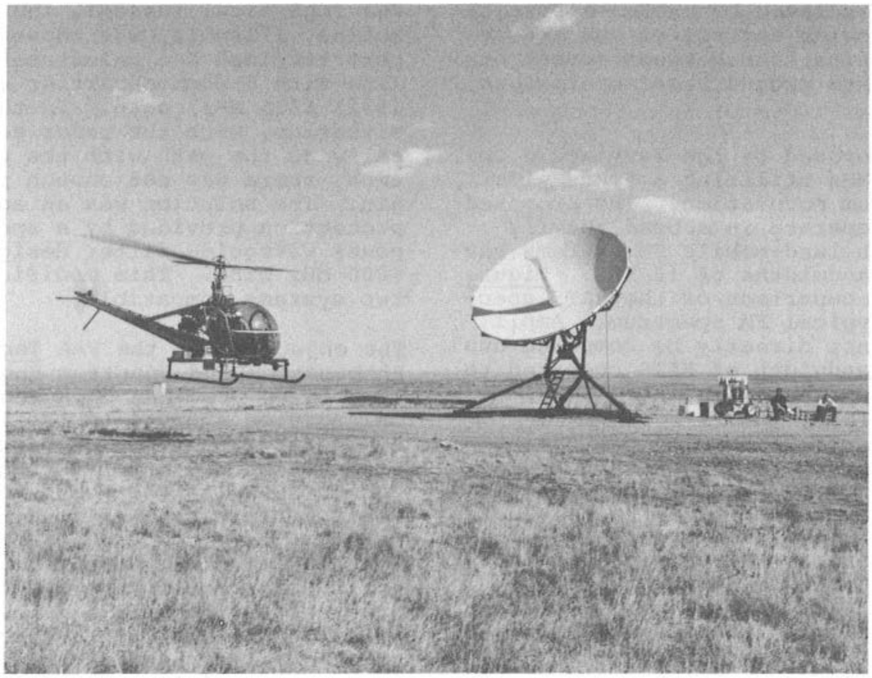


Figure 1-31. Light Terminal (LT) Antenna Group (G/T-26) at the ITS Table Mountain test range. The helicopter is the airborne platform for positioning the source of test site illumination. The optical tracking system is to the right of the test antenna with the standard gain horn, used as a reference antenna, at the horizon line pointing straight up.

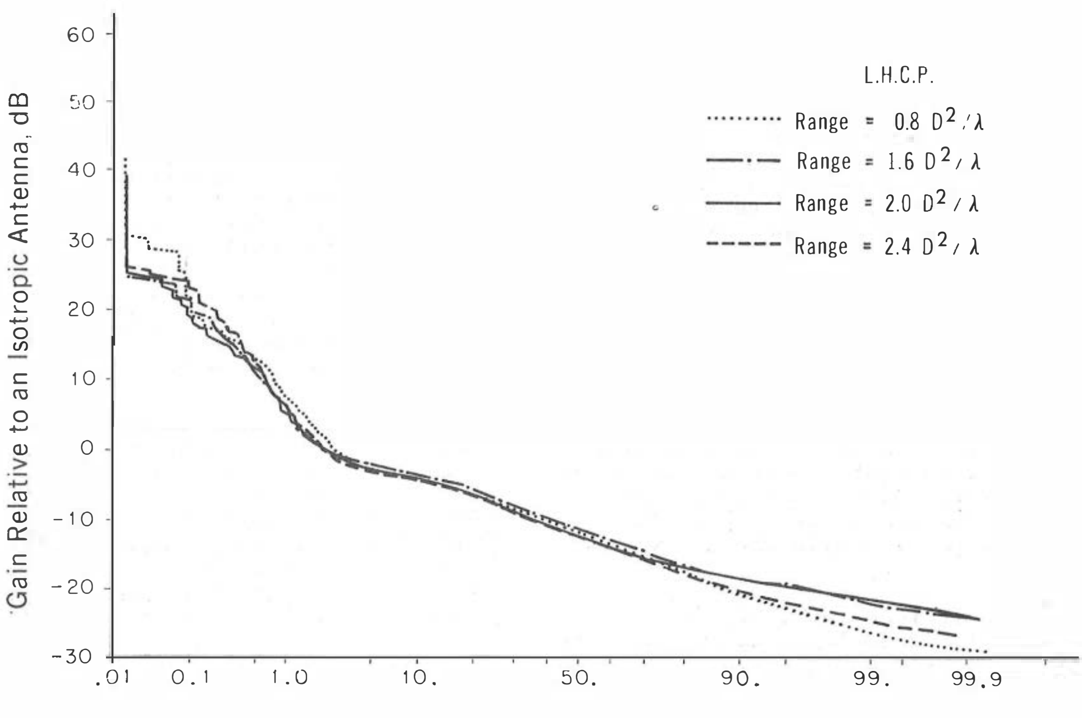


Figure 1-32. Overlay of cumulative distributions of antenna power gain.

measurements radiated by exercise participants, and provide control of and secure two-way communications between operational participants and ground based operations controllers.

The system proposed by the Navy would operate at 141 MHz utilizing a 4 MHz wide spread-spectrum modulation. The proposed system would operate in a band heavily populated with land-mobile FM systems having typical bandwidths of 16 kHz. Figure 1-33 shows a comparison of the EATS spectrum with a typical FM spectrum. Amplitude data cannot directly be compared due to the wide bandwidth of EATS compared to the spectrum analyzer.

ITS was tasked to perform an EMC analysis of the EATS operation in the land mobile band. The project was completed using the following approach:

(1) Identify the users of the 136-148 MHz frequency band.

(2) Determine their system characteristics.

(3) Establish signal-to-interference ratios which would cause problems to present users of the frequency band.

(4) Determine potential interference problems through computer simulation.

(5) Make an assessment of the potential problems.

Laboratory measurements were conducted to determine the effects of the spread-spectrum signal on the operation of typical land mobile FM receivers. Results similar to Figure 1-34 were obtained from the measurements. In summary, the EATS operation in the 136-148 MHz band is an example of a spread spectrum system which could be engineered into an already crowded band without causing harmful interference to the present band occupants.

Weather Radar RFI Survey. Efforts for the National Weather Service this year were twofold: obtain measurement of the actual emission spectra of the WSR-74C weather radar and offer consultative services to the users of the installation at Moline, Illinois.

There were questions raised about the actual emission from the weather radar in the common-carrier communication band (5925-6425 MHz) and its interference to these systems. The siting of these radar systems was based on an estimate of spurious emission being 80 dB down from the fundamental. Actual measurements by the OT/ITS monitoring van at Tulsa, Topeka, and Kansas City (see Figure 1-29) showed the levels to be well within specifications.

For logistical reasons, the radar site at Moline, Illinois, was chosen at the airport terminal and unfortunately was in line with a common-carrier communication (5925-6425 MHz) path. In the worst case situation, with the radar scanning vertically on the path with the communication link, there was not enough protection margin. The solution was an additional 50 dB protection provided by a special high-power waveguide filter designed for the 6000 MHz band. This modification made the two systems compatible.

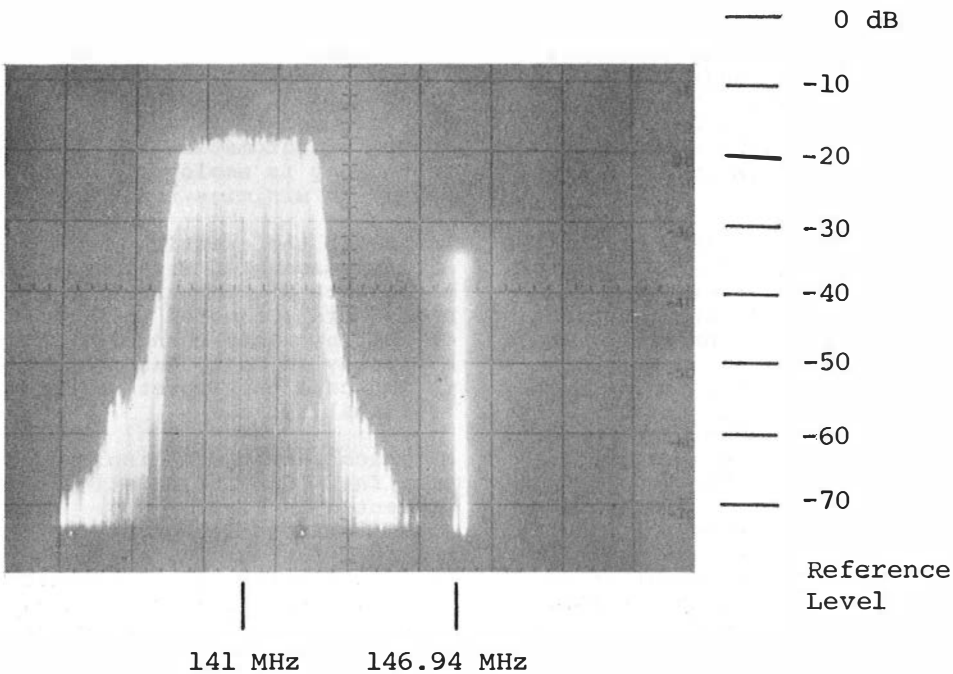
The objective of the FAA Technical Support/Propagation and Spectrum Engineering project is to provide, upon request, analytical service support to the Federal Aviation Administration (FAA) on electromagnetic propagation and spectrum negotiations in connection with the World Administrative Radio Conference (WARC).

Only one task was assigned in FY 77: preparing background material on which aeronautical radio bands are best suited for proposed Air Traffic Control (ATC) radio services. The bands to be included in the study are as follows: 960-1215 MHz, 1543.5-1558.5 MHz, 1595-1636.5 MHz, 1645-1660 MHz, 5000-5250 MHz, 15.4-15.7 GHz, 45-50 GHz, 66-71 GHz, 95-101 GHz, 142-150 GHz, 190-195 GHz, and 252-266 GHz.

This task is scheduled for completion in FY 78.

The Federal Railroad Administration (FRA) Railroad Communications Study. The railroad industry has evolved major operational and technology applications for radio communications since the end of World War II. These radio operations have generally supplanted the long-established wire telegraph and telephone systems and manual signal operations that have been so characteristic of the earlier railroad communications capabilities. Radio communication was recognized in the 1945-1950 period as affording a great deal of flexibility and reliability over the available signals or wire communications systems.

Generally, the radio communications systems utilized by United States and Canadian railroads can be categorized into system-wide microwave data and voice communications and VHF equipments directly associated with train and equipment control in the classification yards and enroute. The VHF radio systems afford direct voice communications between trains, train to dispatcher and wayside offices, train engineer/conductor to brakemen, equipment inspection and maintenance crews, and for various facility maintenance coordination activities. The VHF systems include large deployments of relay stations along railroad right-of-way, mobile equipments on locomotives and cabooses, fixed sites (wayside stations and control sites within classification yards), and pack-sets used by train assistance personnel.



Analyzer Bandwidth: 30 kHz
Analyzer Scan Width: 2 MHz/division

Figure 1-33. EATS emission and land-mobile FM emission.

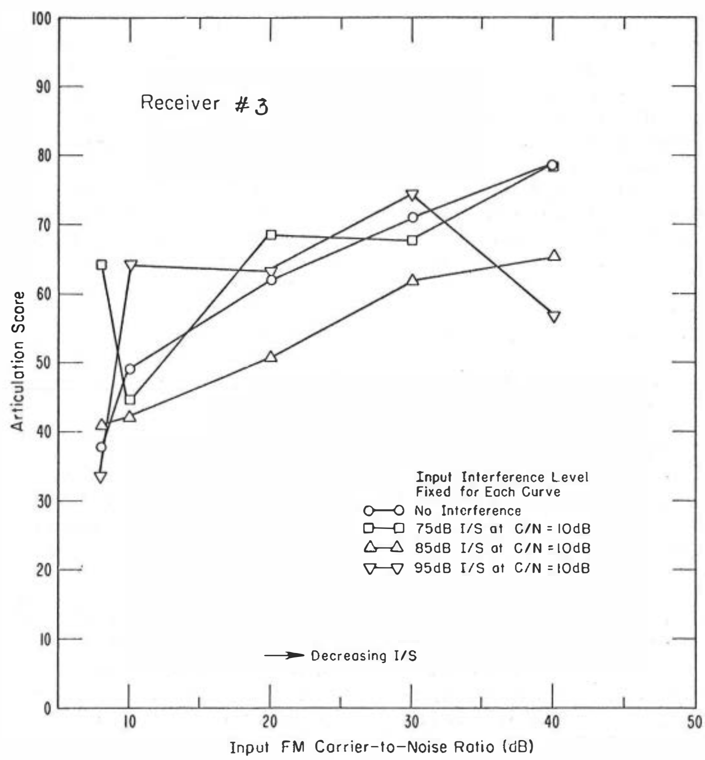


Figure 1-34. Articulation score results for receiver #3.

Since World War II, 92 channels have been allocated for this railroad usage. Of this total allocation, 58 are within the land mobile spectrum, and the remaining 33 are within the maritime bands--accommodated by special Footnote 287 to the International Allocations Table. This Footnote allows these channels to be utilized by railroads within the contiguous 48 States and Hawaii and Puerto Rico.

With the forthcoming 1979 WARC, a decision was necessary regarding the U.S. position on the continuation of this VHF railroad service allocation within maritime bands. International and maritime pressures would tend to remove these allocations for the U.S. railroads so as to standardize allocations. Also, the maritime industry has cited requirements for additional spectrum space for existing and future communications support services to the FCC, OTP, and Congressional agencies. These additional services include voice and wideband operations. Port area operations, therefore, required special consideration of the potential incompatibilities of railroad and maritime requirements. The FRA initiated this investigation to determine the utility of the VHF railroad communications and the economic and capability impact if any form of reallocation action was imposed. This program, therefore, includes all facets of the operational and functional analysis, communications technical capability and characteristics, the economics of reallocation and current investments, and technical and operational problems attendant with any reallocation into UHF spectral regions.

The primary thrust of this program was to evaluate the railroad VHF communications usage and the investment and reallocation penalties. The operational analysis phase was included to specifically identify the coupling between communications and operational support requirements--particularly relating to safety, command control, and efficiency.

The operations and analyses were divided into a series of event models that described enroute and yard train movement, maintenance, and administrative support events. A typical area event model is diagramed in Figure 1-35. This depicts the series of operations required for a train entering a classification yard, including track coordination, locomotive-engineer-brakeman movement coordination, equipment inspection assignment and execution, and removal of equipment having unsatisfactory mechanical status. This typical diagram was utilized in the construction of operations event models to which were coupled the specific communications functions, timeliness, and priority criteria identification. This series of models was exercised for typical yard and enroute operations to provide communications usage data and delay-availability characteristics for each frequency assignment. Two yards were represented: the Richmond, Fredericksburg, and Potomac Co. in Alexandria, Virginia; and the Atchison, Topeka, and Santa Fe operations at Barstow, California. The latter represents one of the more modern facilities in that a high degree of automation and systems control technology is employed to maximize facility usage and minimize train processing times.

To answer the question regarding the penalties associated with reduced allocations, three sets of communication event exercises were evaluated with functions combined on communication channels. This produced a display of delay and availability data to indicate the impact of reduced frequency availability.

A typical histogram display for the Barstow facility with existing assignments is presented in Figure 1-36. With restrained availability, histograms for the case of combined inspection, engine movement control, and maintenance operations are indicated in Figures 1-37 and 1-38. These data are typical of the decreased availability characteristics that occurred with the reassignment of functions into common channels for the two yards. Enroute tests indicated similar tendencies.

The reassignment process was implemented through a number of software components that were developed to manipulate FCC and American Association of Railroads (AAR) license files. Files and retrieval programs for all existing licenses and geographic locations were prepared with tags on those assignments within the bands covered by Footnote 287. Reassignment testing of these channels was based upon a separation distance of 60 miles and two channel frequency differences. An automatic examination routine tested proposed reassignments against these criteria. The 60-mile distance was based upon minimum detectable signal criteria for the pack-set and mobile receivers; the two channel separation was necessary because of intermodulation effects where equipments were in very close proximity. This latter consideration was of particular importance in yard operations where many pack-sets were close to mobile equipments on moving equipment.

With the exercise of this software for major U.S. railroad systems, the failure rate in the reassignment process exceeded 85 percent. This is not unexpected since these railroads extend over more than one-half of the continental United States which presents serious problems in geographical compatibility. This software was also exercised for eleven coastal and inland port areas. The port areas were emphasized because of the proximity with maritime operations.

In addition to the reassignment investigations, various networking modes were

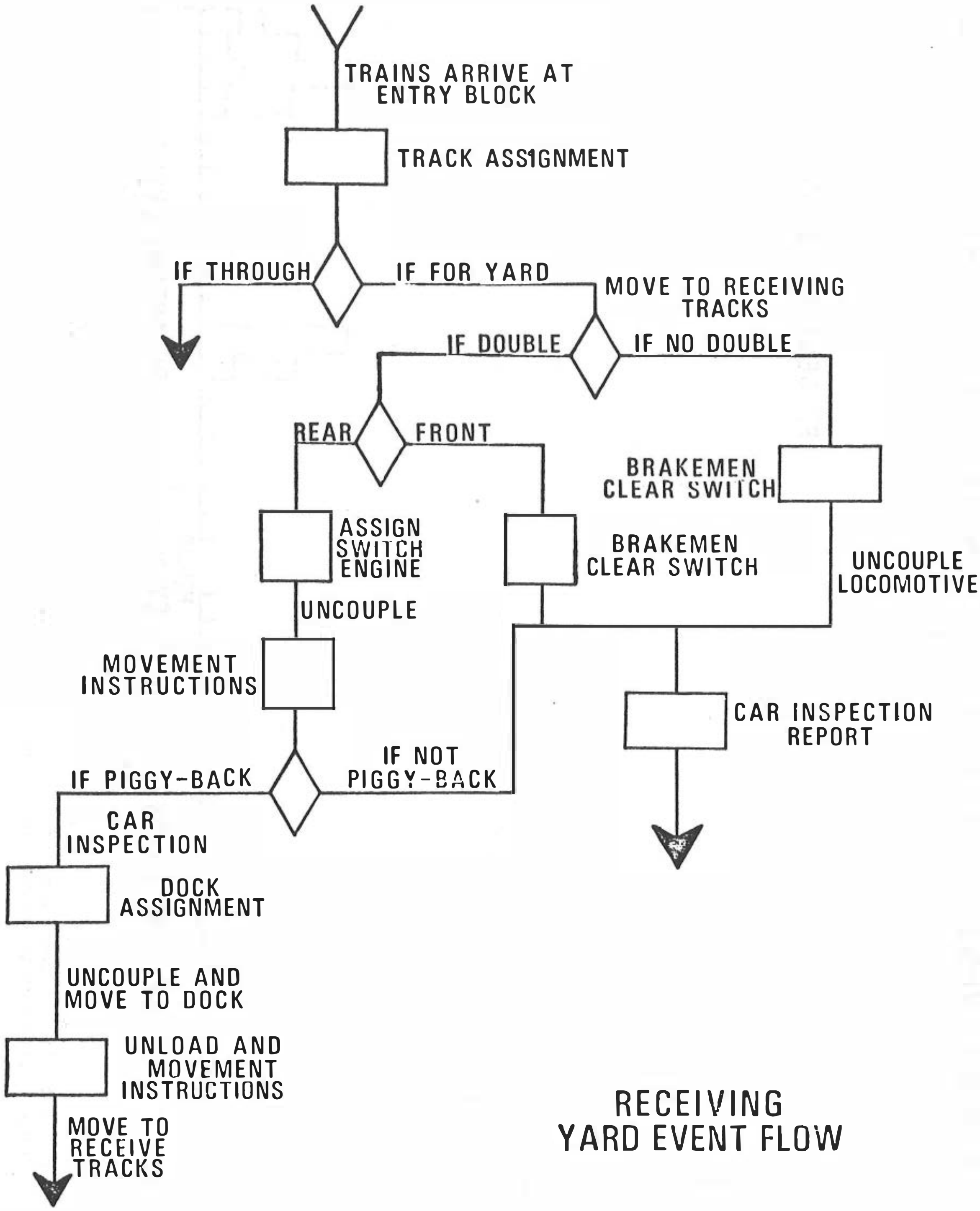


Figure 1-35. Receiving yard event diagram.

COMMUNICATIONS EVENTS – STATISTICAL SUMMARY YARD TRAIN MOVEMENT

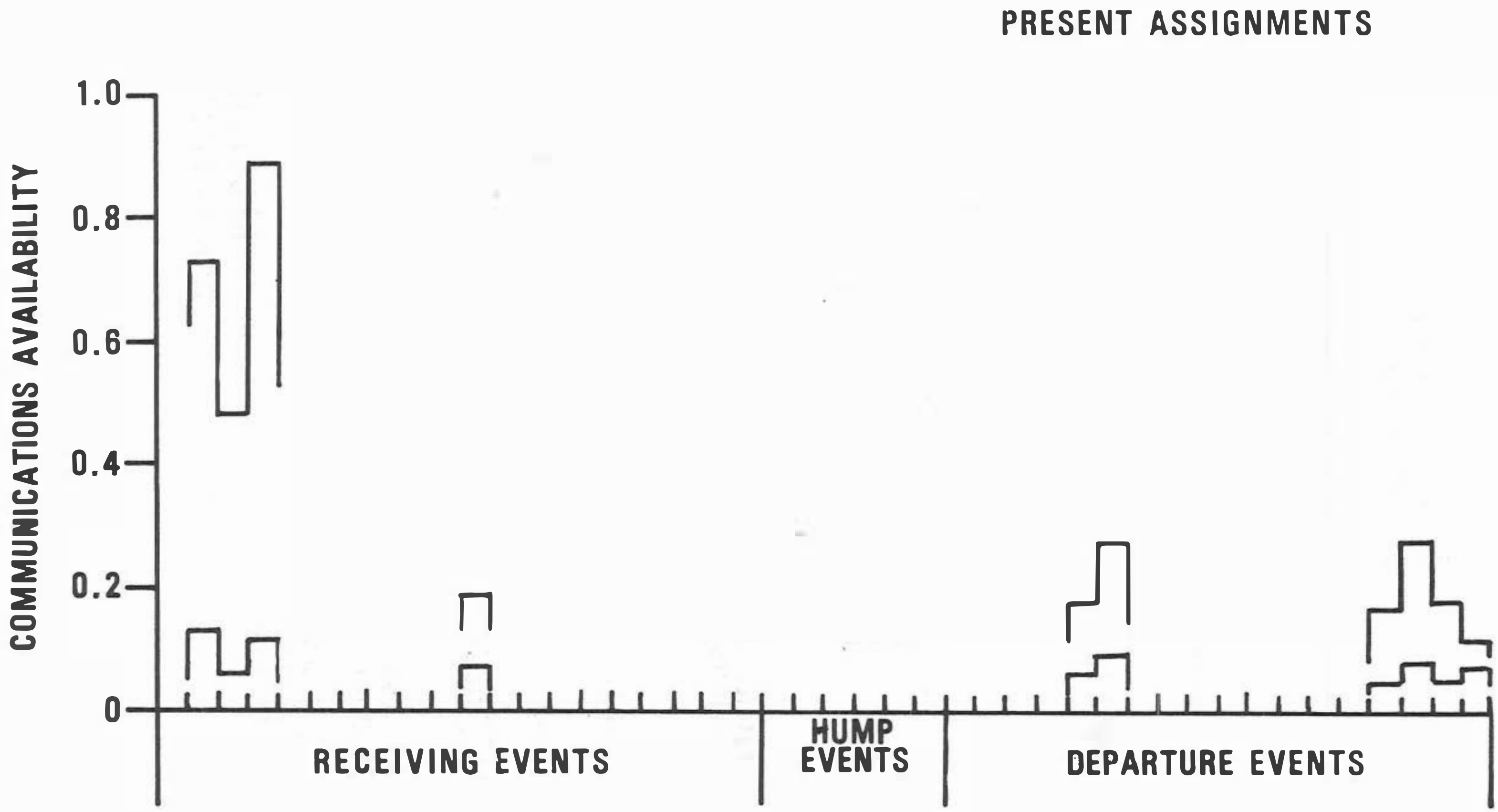


Figure 1-36. Availability of communications (waiting time in minutes) is shown for a major railway switching center using the presently assigned frequencies.

COMMUNICATIONS EVENTS - STATISTICAL SUMMARY YARD TRAIN MOVEMENT

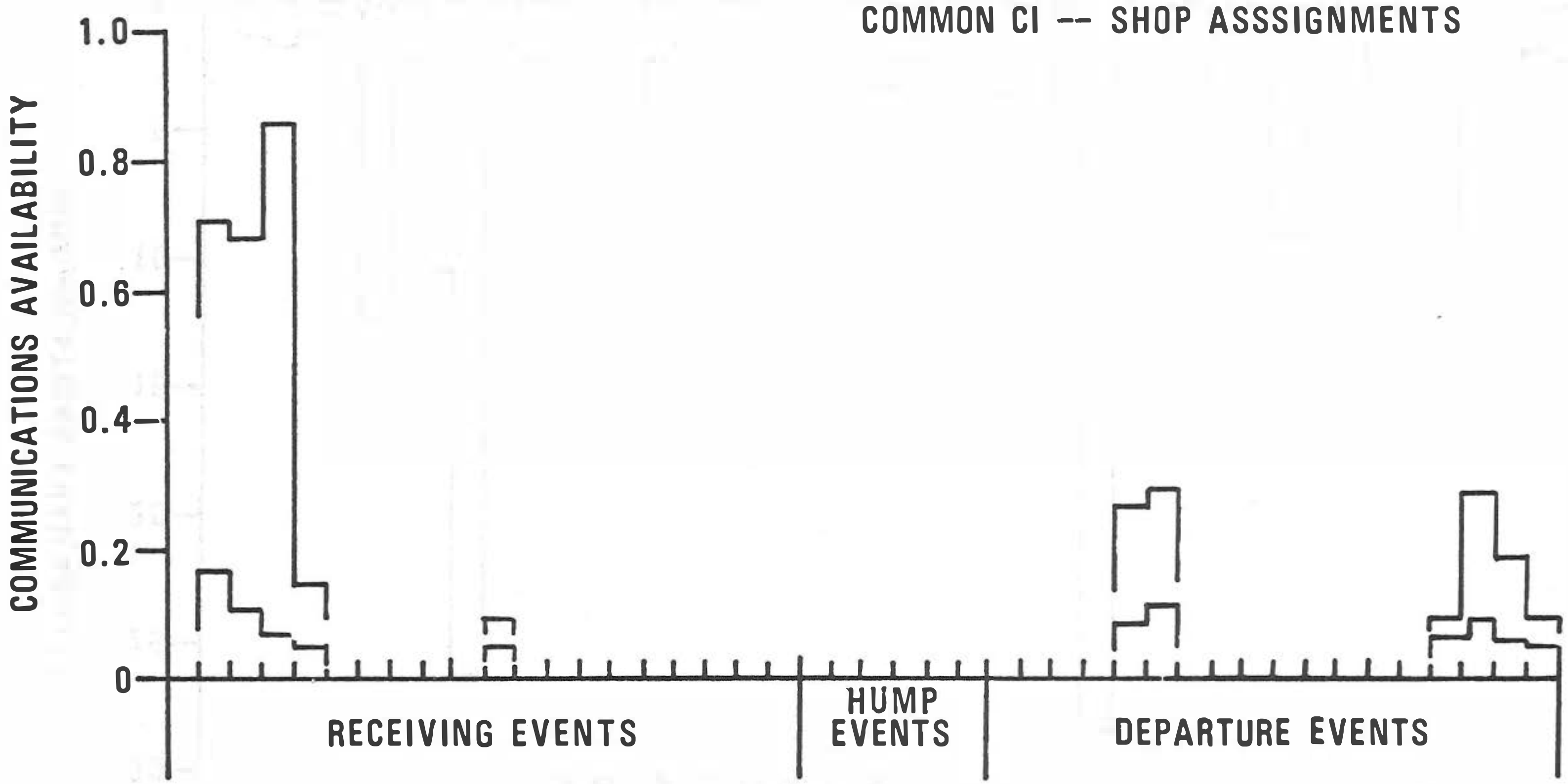


Figure 1-37. Eliminating frequencies assigned to certain activities so those activities share remaining frequencies results in increased waiting time.

COMMUNICATIONS EVENTS – STATISTICAL SUMMARY YARD TRAIN MOVEMENT

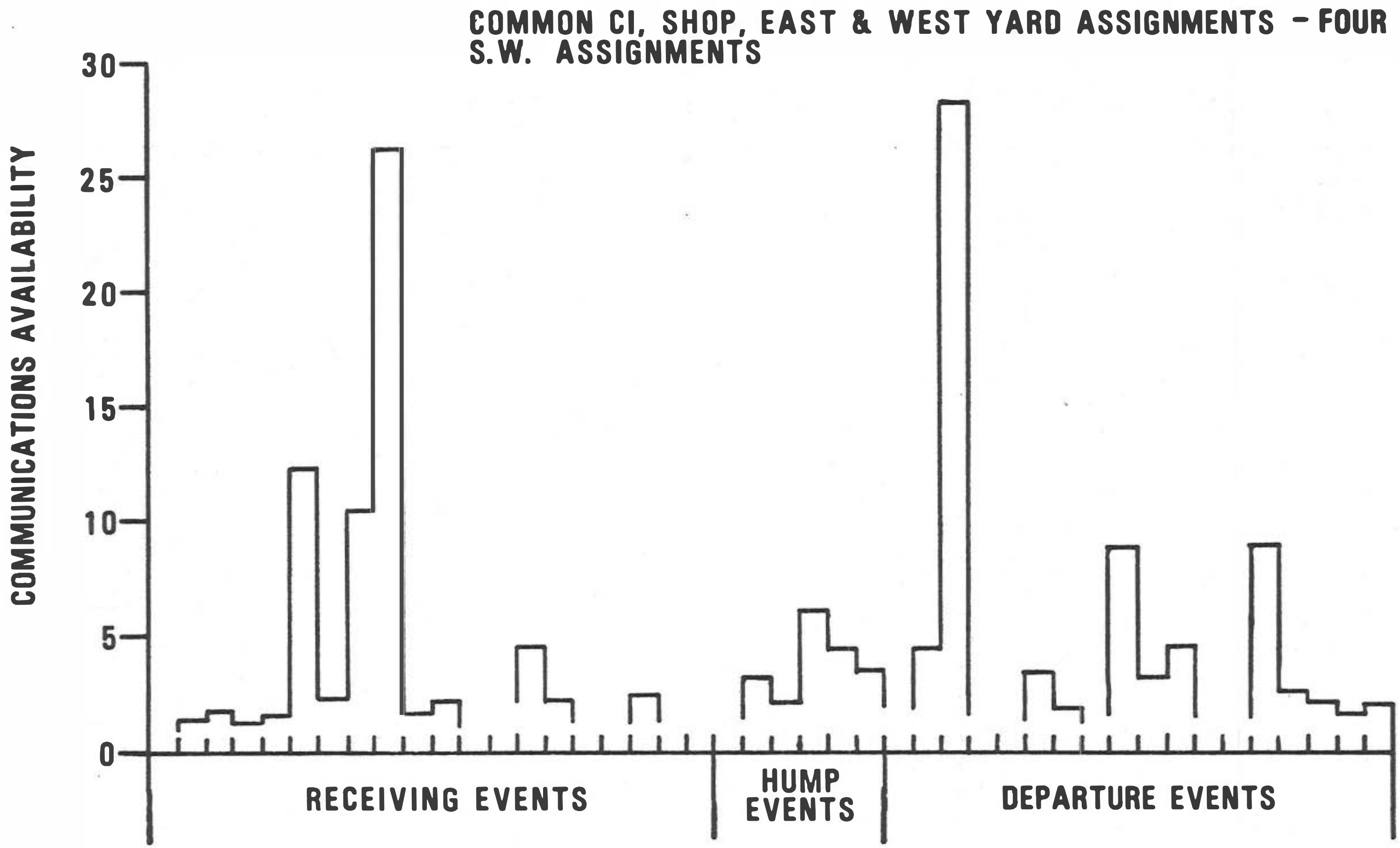


Figure 1-38. Removal of the frequencies assigned to the functions indicated in the histogram, with resulting increased channel sharing, shows a dramatic increase in waiting time for communication activities.

examined as to the potential for management of yard operations and port area operations where the frequency reassignments were reduced or shared. Star network configurations were tested and, generally, the interference potential and waiting time, particularly in emergency situations, were unsatisfactory. All protocol schemes provided minimal relief. The situation in port areas where maritime and railroad users share a common net is the more extreme because of the difficulties in operational coordination organizations.

Verification of the computer models was provided through a set of measurements of communications operations at the Barstow facility. The ITS instrumentation installed at Barstow included spectrum analyzer and recording equipment to collect data regarding the usage of all assigned channels. These data resulted in minor modifications to the model activity specifications, and some modification to the "message duration" statistical data.

This information and other records provided by industry organizations in the Chicago, Nashville, and Los Angeles areas indicated also that the railroad industry maintained a significant level of discipline in channel operations.

An assessment of railroad industry VHF radio communications investment was accomplished by collecting and correlating data from various industry and AAR sources. The current investment in equipment and support services exceeds $250 million.

An additional consideration of this program, as mentioned, concerns the possible reallocation of all or part of the existing VHF assignments into either 450 MHz or 900 MHz UHF regions. An examination of the capabilities of such a reassignment with direct replacement and the additional equipment and functions that would be required to achieve a support capability equal to the current VHF systems was also accomplished. As would be expected, propagation considerations in urban yards and mountainous enroute areas require the deployment of a significant number of relays to provide the necessary continuous service. Antenna control schemes and digital addressing were also evaluated relative to frequency requirements and operations support level. Serious technical disadvantages were evident unless the relay complement was extended by a factor of at least four in the urban yard areas and by a factor of more than two in the Appalachian and Rocky Mountain regions.

The conclusions and recommendations from this investigation detailed the operational support requirements in terms of safety and command control priorities for the VHF communications, the frequency usage statistics for the various assignments in yards and enroute areas, and operational and cost penalties imposed by reduced allocations or reallocations into the UHF spectral regions.

Based upon the analyses and data collected, the report recommended that the current VHF service be retained for the railroad industry. Reviews with FCC Maritime and Land Mobile Sections and the OTP Spectrum Management Group provided input to the WARC '79 Task Force communications pertaining particularly to Footnote 287 retention.

CHAPTER 2. SYSTEMS ENGINEERING AND EVALUATION

The objective of this program sub-element is to provide telecommunication system definition, designs, and consulting services to meet users' requrements through measurements, analyses, and evaluations and to develop and disseminate performance criteria. The resultant performance criteria and measurement methods are used by Federal agencies in planning, designing, specifying, procuring, leasing, and operating telecommunication systems. The project elements described below generally deal with existing or proposed telecommunication systems and/or subsystems. Section 2.1 addresses work relating to data communications. Section 2.2 presents several projects oriented toward satellite communications. Section 2.3 summarizes the terrestrial radio system performance efforts. Section 2.4 deals with radio channel simulation and radio system performance standards, and Section 2.5 presents related work in fiber optical communications.

SECTION 2.1. DATA COMMUNICATIONS

The rapid growth of digital communications arises from the need to: transfer data between computers; encrypt voice communications for security and privacy reasons; develop specialized networks for business, health care, electronic message services, and others; efficiently distribute digital communication services for a given customer or community; and recognize the extensive information content of the work output of our nation. Work in the data communications area described here is generally intended to develop system performance criteria and measurement methods that are system independent and user-oriented. Four projects are described, namely: Data Communications, Military Base Communications, High Speed Digital Cable Analyses, and USPS Electronic Message Service.

Data Communications. Millions of tax dollars could be saved each year through more efficient Federal procurement of data communications services. OT's Data Communications program aims to realize these cost savings and productivity increases by developing Federal Standards for specifying and measuring communication system performance. The Data Communications program was undertaken at the request of the Federal Telecommunications Standards Committee (FTSC), an interdepartmental standards group organized by the National Communication System under the auspices of the General Services Administration (GSA). The program is being coordinated with the Federal Information Processing Standards (FIPS) program of the National Bureau of Standards. Federal Standards developed under the program will ultimately be promulgated by GSA under Public Law 89-306.

Outputs of the Data Communications program will consist of three related Federal Standards:

1) Federal Standard 1033 -- defines standard, universally applicable, user-oriented parameters for specifying data communication system performance.

2) Federal Standard "1033A" -- will define standard measurement methods to be used in conjunction with the standard parameters in assessing delivered performance.

3) Federal Standard "1033B" -- will define standard performance classes and requirements for interconnection of dissimilar networks.

The first standard will reduce Federal procurement administration expenditures by eliminating the need for requirements studies designed to select performance terms. Comparison of procurement practices among Federal departments and agencies reveals substantial duplication of effort in this area. The second standard will improve the performance of procured services by providing a basis for agreement between suppliers and users as to the validity of measured performance parameter values. Without such a basis, users have no way of determining whether delivered services are meeting stated requirements. Combined use of the first and second standards will vastly improve the ability of Federal agencies to evaluate alternative data communication services on a cost/performance basis. This improvement will reduce Federal communications costs and will encourage innovation and fair competition in industry. The third standard will promote efficiency and economy in Federal use of data communications by increasing interoperability between dissimilar networks. Increased network interconnection will enhance the operational capability and flexibility of the Federal telecommunications plant, and will make it possible for users to share, rather than duplicate, required services or facilities.

Past work on the Data Communications program has been directed towards two primary objectives:

1) Development and coordination of Federal Standard 1033.

2) Establishment of network measurement facilities and statistical tools required to support development of Federal Standard "1033A".

The FTSC published proposed Federal Standard 1033 in the Federal Register for public comment on February 22, 1977. This standard is unique in providing a method of describing system performance that is independent of network design characteristics. This enables straightforward comparison of systems that offer equivalent services by means of different facilities or procedures--in essence, a "truth in lending" approach applied to data communications. The standard is currently undergoing review and coordination within Government and industry.

Figure 2-1 summarizes the technical approach used in defining performance parameters for the proposed Federal Standard. Briefly, the communication process was characterized as a series of discrete performance attempts associated with three basic types of communications functions: access, user information transfer, and disengagement. With respect to each type of function, performance was evaluated in terms of three general criteria or concerns: efficiency (or "speed"), accuracy, and reliability. For each particular combination of function and criterion, two general classes of performance parameters were considered: proportion or probability parameters and time parameters. The parameters finally selected for inclusion in the standard are listed in figure 2-2.

In support of the measurement standard, OT/ITS procured and installed an ARPA network Host computer facility at ITS during FY 76 (see figure 2-3), and initiated an experimental measurements program using this resource during FY 77. Measurements of ARPA network access and disengagement performance have now been completed. OT/ITS has also conducted a series of statistical studies which have produced definitive new methods of determining the accuracy of performance parameter measurements.

OT has taken several steps to coordinate the Data Communications work with organizations not represented on FTSC. OT has contributed two formal docket submissions to the FCC's current inquiry into the quality and reliability of the specialized communication services (Docket 18920), and has reviewed FCC contractor reports on this issue at the Commission's request. OT has also contributed to the efforts of the American National Standards Institute (ANSI) to develop industry performance standards for particular network classes. ANSI has adopted an OT Report developed under the Data Communications program as a de facto standard for data accuracy measurement.

The real importance of the Data Communications program lies in its substantial cost savings potential. It is estimated that the Federal Government will be spending about $2 billion annually on data communications by 1980, and this expenditure will be increasing at an annual rate of 15-20%. Additional indirect costs associated with procurement administration are estimated at 6% of market price, or $120 million in 1980. Even assuming no reduction in the dollar value of procured services and only a 5% reduction in procurement administration expenses as a result of the proposed standards, the potential cost avoidance for 1980 alone is $6 million. Cost savings will accrue yearly (once the standards are put in service) and, in fact, will increase year by year with the dollar value of the procured services.

Military Base Communications. The U.S. Army Communications Systems Agency (USACSA) has sponsored an OT/ITS program in local digital communications for military base service areas. In 1976, ITS conducted a parametric study of the projected, 1980 to 1985, digital service requirements for the Local Digital Distribution System (LDDS). The study included a definition of a rather broad range of services, scenarios, and parametric scaling of system features. As the ITS program progressed, the importance of the parametric approach increased and the system cost emerged as the most prominent of all parameters considered. In the OT Report 76-95, it is shown how the cost of each LDDS installation is a system concept-dependent variable. To optimize the total cost, the concepts must be properly chosen.

In 1977 the program was modified to include Access Area Digital Switching (AADS). First ITS undertook to describe and document seven selected hub-oriented PABX alternatives. The objective of this effort was to establish a basis and assessment criteria for future system designs, and eventually to recommend a lesser number (about two) of alternatives for further in-depth study. The actual selection of several preferred PABX candidates was made jointly by USACSA and OT/ITS in May 1977. A report covering this 1977 effort has been drafted. It is scheduled to appear in 1977 under the tentative title, "Access Area Digital Switch Program: Hub Alternative Evaluation for Local Military Communications."

A more recent AADS Task, initiated in June 1977, deals with brief introductions to digital and electronic PABX's culminating in examples of PABX system design. A draft entitled, "Example Digital PABX for Access Area," has been prepared and is currently under review. In this Task, the example systems (see figure 2-4) are required to provide integrated interferences and digital switching to DCS access areas. A prototype PABX that employs data busses and time-division switching (see figure 2-5) is shown to be amenable to both gradual and abrupt line and trunk transitions from analog to digital. Key PABX system functions, service features, and cost considerations are included.

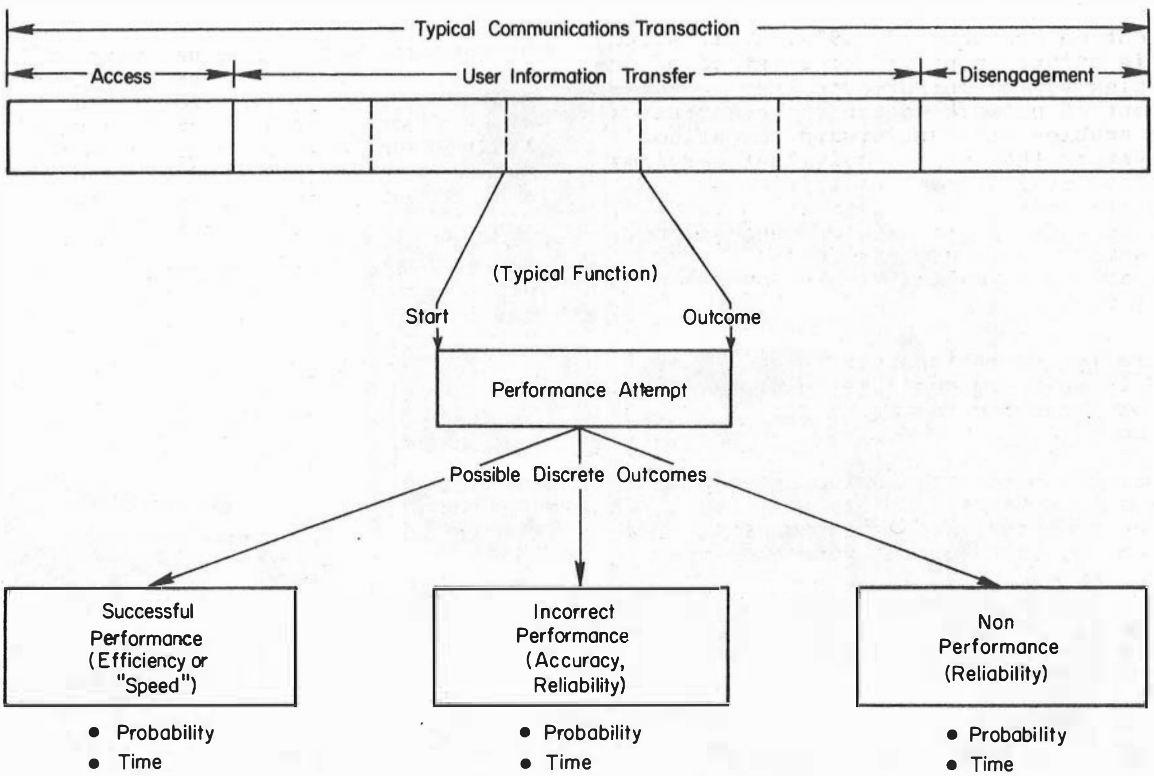


Figure 2-1. Performance assessment approach used in defining performance parameters for the proposed Federal Standard 1033.

CRITERION	FUNCTIONAL PHASE		
	ACCESS	USER INFORMATION TRANSFER*	DISENGAGEMENT
EFFICIENCY	ACCESS TIME	BLOCK TRANSFER RATE END-TO-END BLOCK TRANSFER DELAY BLOCK EFFICIENCY BLOCK RATE EFFICIENCY	DISENGAGEMENT TIME
ACCURACY	INCORRECT ACCESS PROBABILITY	BLOCK LOSS PROBABILITY BLOCK MISDELIVERY PROBABILITY ADDED BLOCK PROBABILITY BLOCK ERROR PROBABILITY	————
RELIABILITY	ACCESS DENIAL PROBABILITY ACCESS DENIAL TIME	SERVICE TIME BETWEEN OUTAGES OUTAGE DURATION (DOWNTIME)	DISENGAGEMENT FAILURE PROBABILITY

*ALL BLOCK-ORIENTED PARAMETERS ARE TO BE SPECIFIED BOTH ON A BLOCK BASIS <u>AND</u> ON A BIT BASIS. THE BLOCK LENGTH USED SHALL BE AN OPERATOR-DEFINED AVERAGE BLOCK LENGTH.

Figure 2-2. Performance table from the proposed Federal Standard 1033.

Figure 2-3. OT/ITS ARPA network Host computer facility.

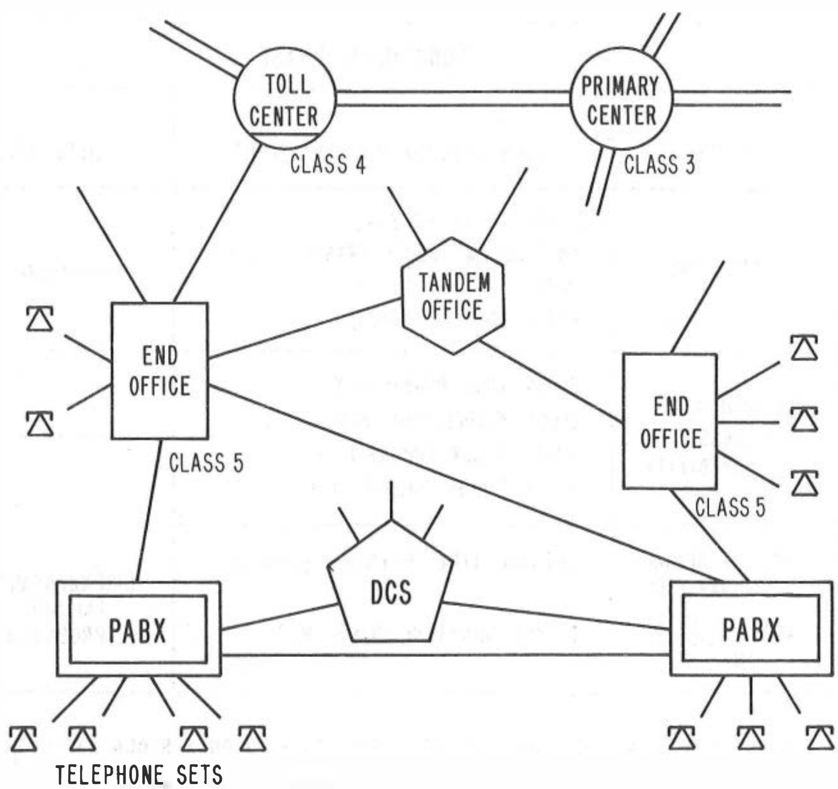


Figure 2-4. Basic deployment concept of PABX's with DCS and common carrier networks.

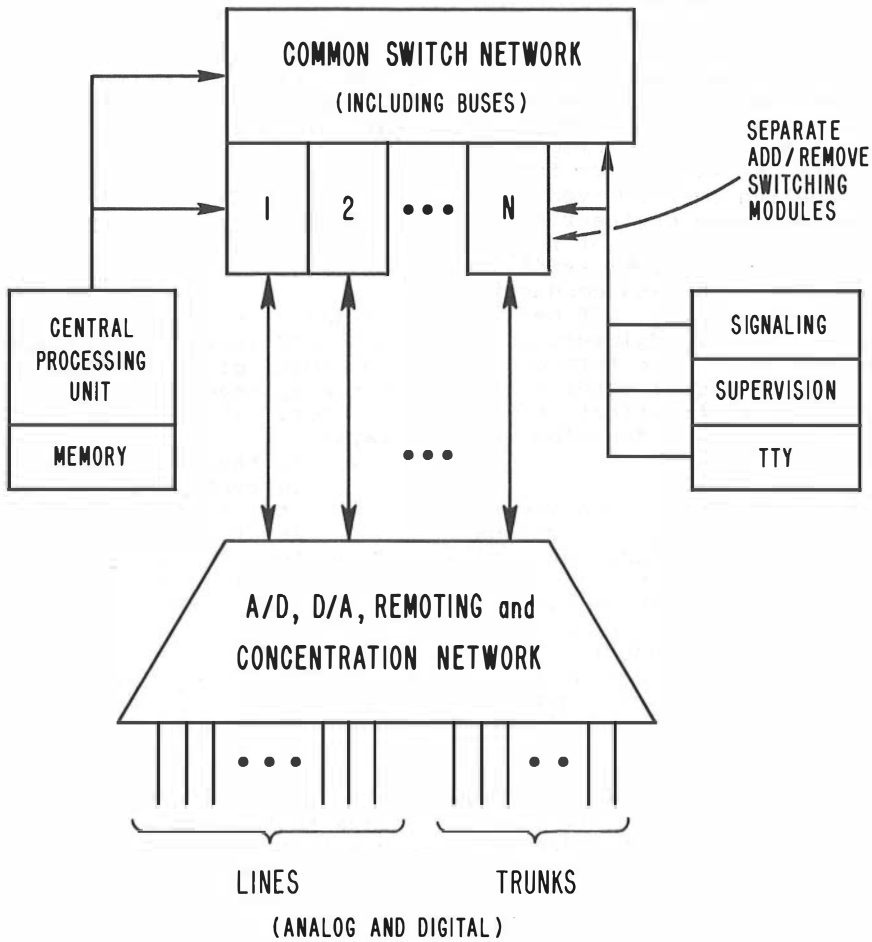


Figure 2-5. Prototype PABX with stored program control and TDM circuit switching.

High Speed Digital Cable Analyses. A review of the performance characteristics of shielded cable such as coaxial and twin-axial types was made to determine the adequacy of such cables to transmit high-speed digital signals. Comparisons were made with fiber optic transmission lines to provide a basis for selection of alternative cable types. OT Report 77-111, "Pulse Distortion in Coaxial Cable," by Allen Q. Howard, Jr. discusses the limitation of conductivity-induced distortion in coaxial cable. Appropriate theoretical formulations were applied to various pulse shapes and pulse trains (rectangular, gaussian, raised cosine) to determine distortions introduced by various cable parameters. A computer-graphics program plots out the distortion of wave forms for various signals traveling over a given distance through a cable of known engineering parameters. The effect on a train of rectangular pulses of a coaxial transmission line for normalized geometries and conductivities is shown in figure 2-6. Of particular concern to communication engineers is the distortion of the pulse wave form and the necessity to provide signal conditioning equipment to minimize the effects of such distortion on the receiver decision making capabilities.

A second report, OTR 77-114, analyzes pulse distortion in metallic cable, describes the effectiveness of shielding in a noisy environment, and discusses fiber optical transmission alternatives to metallic cable. A figure of merit is developed for cables in which the product of pulse rate and distance between terminals is related for a maximum allowable bit-error rate. The figure of merit is deduced from the characteristics of the transmission cable--specifically, geometries, dielectric fill, and attenuation. This gives a designer a quick tool for gauging the usefulness of a given transmission line. Table 2-1 shows representative figures of merit for various cables. This illustrates the relationship of geometries and attenuation to the figure of merit.

A third and final report entitled, "Digital Transmission via Coaxial, Twinaxial, and Fiber Optical Cables," is now in review. It presents a discussion of problem areas in the transmission of high-speed digital information over various forms of coaxial or other shielded cable. A data base of existing cables and their designated characteristics is assembled. Figures of merit were calculated for representative types of cables to determine their transmission capabilities for digital rates up to 50 Mb/s. This report discusses cable testing procedures and interface signalling hardware and specifications to meet telecommunications requirements.

USPS Electronic Message Service. This project represents Phase V of the OT/ITS continuing support program of technical studies for the U.S. Postal Service. The overall effort is focused to provide technical support, analysis, and review of the Electronic Message Service System (EMSS) Definition and Evaluation (D&E) program. The intent is to develop and analyze system requirements and alternatives, and to evaluate criteria, values, and data.

ITS is involved in developing system requirements and alternatives, performance and evaluation criteria, and data as needed by the USPS in providing direction, guidance, progress, approvals to contractors, and technical consultation to the USPS on an as-needed basis. ITS is called upon to assist the USPS in monitoring contractor performance by supporting the USPS in responding to all contractor-generated efforts.

In addition to the above monitoring responses, ITS services are provided in the development of various types of data and criteria as needed for guidance of the contractor. ITS assisted here in four major ways:

a) Further development of EMS Systems Concept Matrix,
b) Continuation of the Mail Composition Input Percentages Study,
c) EMS Accuracy or Error Trade-Off Studies, and
d) Development of System Evaluation Criteria.

In detail, these four areas can be described as follows:

a) Development of EMS Systems Concepts Matrix.

This task, having been initiated under the previous ITS/USPS Agreement, is a continuation. This task required ITS to develop and analyze system alternatives using the system planning factors, service variations, and standard performance requirements specified under the previous agreement. The objective of this task was to develop system concepts using a matrix generator approach. The matrix generator approach is serving as an alternate to the contractor's "seed bed" approach for generating systems concepts. More than 100 concepts were identified and described by this matrix. This matrix serves as another source of concepts from which 56 alternatives were selected, and then were reduced to 28 alternatives. Then, in cooperation with the USPS and the contractor, who has selected his own alternatives, a final three candidates will be chosen for the EMS system.

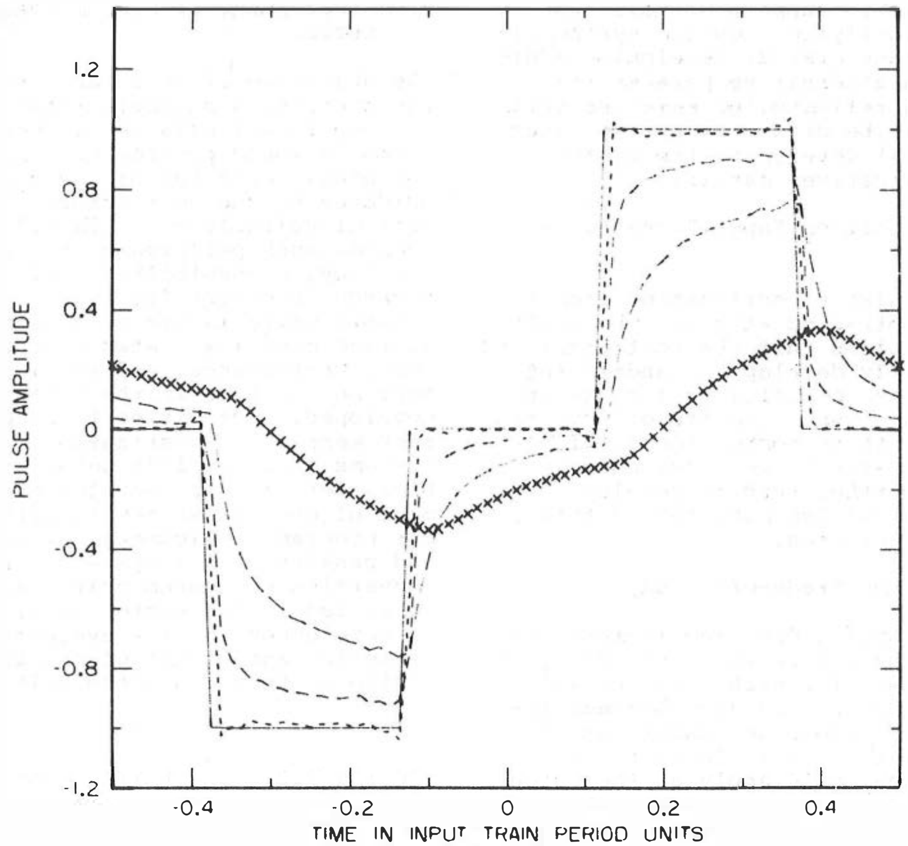


Figure 2-6. Conductivity distortion of a periodic pulse train.

Table 2.1. Figures of Merit for Various Cables

Cable	Largest Dimension (cm)	$\hat{\alpha}$ (dB/km) (at f MHz)	F_{mc} (Mp/s•km^2)	Req'd F_{mc} 50 Mb/s•(0.3 km)^2
CX-11230/G	0.43	14.81* (2)	1.0	4.5
RG8A/U	0.7	66 (100)	2.50	
RG220/U	2.3	23 (100)	20.6	
RG11A/U	0.7	75 (100)	1.94	
RG318/U	2.2	13 (100)	64.5	
RG319/U	4.1	7.2 (100)	210	
RG59/U Triaxial	0.8	85 (100)	1.51	
Twinaxial	0.8	134 (100)	0.61	

*Military specified value of α is 22 dB/km at 2 MHz.

ITS activities in support of this task were: 1) identifying required system alternative parameters; 2) developing additional system alternative parameters; 3) analyzing and refining the selected parameters to describe different system alternatives; and 4) developing the system concepts/alternatives matrix.

b) Mail Composition Input Percentages Study

This task is also a continuation from a previously contracted effort. The earlier agreement requires that the contractor and the USPS jointly develop a standard set of 10 different compositions for use in the EMS study. The objective of this task was to review those compositions which are specified in terms of percentages only--to define them further--and to develop six more compositions (to make the 10 total) for guidance purposes.

c) EMS Accuracy Trade-Off Study

This study supports USPS requirements to investigate and define the range of system accuracy values, for each service, which strikes a reasonable balance between the extremes of unacceptable quality and unacceptable system cost. These accuracy or error values would apply at the output of the electronic message system where customers normally would be involved. The accuracy values to be considered in this study must begin at the customer input interface, so that the complete system end-to-end error sources, including network, storage, and conversion subsystem, can be identified. Message copy includes direct digital data, character reader, graphics, microfilm, and microfiche. Both telecommunications input and output as well as paper and film input and output have been included in the study.

To the extent possible, previous experimental results in the literature and contractor's reports were obtained and evaluated and the properties of the human visual system as an image evaluator were taken into account.

Specific ITS activities in support of this task were: 1) establishing error limits parametrically for typical services; 2) developing an end-to-end block diagram model and identifying critical blocks and parameters; 3) performing literature reviews on network links, conversion subsystems, storage, and error sources; 4) developing a statistical model; 5) developing experimental data requirements; and 6) developing acceptable level-of-error results.

d) Development of System Evaluation Criteria.

The objective of this task is to develop and exercise a suitable-alternative model for use in criteria development. These criteria would provide the USPS with the technical basis for providing the required guidance to the contractor. The development of suitable criteria will have to include such performance factors as speed, accuracy, accessibility, reliability, transparency, and security as well as system and network criteria for efficiency, throughput, storage capacity, network capacity, etc. Cost, performance, and service profiles must be included in the criteria to be developed. Activities included in this task were 1) investigation of EMS systems in sufficient detail to serve as a basis for criteria development; 2) development of one EMS system to serve as a model for program development; 3) identification and ranking of all systems, network, and conversion subsystem criteria that must be satisfied in the system development program; 4) development of the evaluation and ranking criteria; and 5) use of the investigated system(s) to explain the criteria.

SECTION 2.2. SATELLITE COMMUNICATIONS

A new directly funded project was initiated in FY77 to determine the need for a public service satellite pilot program and to evaluate the technical, economic, and regulatory barriers to the implementation of such a pilot program. Work has continued in the support of other Federal agencies to provide technical consultation on operational satellite systems. Five tasks will be described, namely, Direct Satellite Communication, Alternative Reception Techniques for Direct Satellite Communication, Improvement of the GOES Interrogation Link, Certification of GOES Data Collection Platform Radios, and GOES and TIROS-N Equipment Certification.

Direct Satellite Communications. A direct satellite communication (DSC) system is characterized by the use of small, inexpensive earth station terminals; "small," as used here, is intended to mean terminals whose antenna diameter might vary from 0.5 to 5 meters. The terminals would be located on, or close to, the user's premises. DSC systems also may have satellites with high-powered transmitters and antennas with narrow, multiple beams.

The objective of the Direct Satellite Communications Program is to accelerate growth in the use of direct satellite communications by 1) lowering the barriers to the use of small earth station terminals and 2) identifying and consolidating the telecommunications needs of the public service sector.

This program is an outgrowth of the Dept. of Commerce, Science and Technology Task Force. The Task Force identified satellite communications as one of the telecommunications technologies which was well developed, but whose new products and services were not rapidly appearing in the marketplace (see OT Special Report 76-9).

Early in the program, barriers to the accelerated implementation of DSC systems were identified. These barriers fall into three primary groups:

1) Economic/Market Barriers,
2) Policy/Institutional/Regulatory Barriers, and
3) Technical/Informational Barriers.

Within these general categories, many specific barriers were identified, far more than could be specifically addressed during this program period. Some of the specific accomplishments of this program are addressed in the following paragraphs.

During the year, ITS was requested to comment on materials which had been filed with the FCC relative to Rule Making proceedings, RM-2614 and RM-2725. These proceedings were relative to establishment of policies on the design of domestic communication satellite services and the authorization of receive-only small earth station antennas. The outcome of these rule-making proceedings was to authorize the use of receive-only antennas as small as 4.5 meters for CATV systems and to establish the technical licensing policies for use on these antennas.

A study was conducted of the public service sector need for an in-orbit communication satellite after the ATS-6 and CTS experiments are completed. Numerous organizations have studied possible demonstration programs in advanced satellite technology for public service sector telecommunications. The ITS study concluded that a pilot program, rather than a demonstration program, would be more appropriate, if it was decided to develop another communication satellite. The major features of a demonstration program and a pilot program are summarized in Table 2.2, which also highlights the differences between the two types of programs.

A study has been conducted of satellite earth-station requirements for antenna size and diameter as a function of application, modulation, multiple access method, and existing as well as proposed CCIR and FCC rules and regulations. This study has been based on existing and planned communication satellites in the 4/6 GHz and 12/14 GHz frequency allocations. Earth-station antenna diameters in the 0.5 to 9 meter range are under consideration. Results of operations with existing domestic satellites, INTELSAT satellites, and CTS as well as ATS-6 have been incorporated. A report will be published in early FY78 giving the initial results of this study.

The other major study of this program concerns estimates of digital and analog communication network costs using costs for satellite transponder lease, earth stations, and leased private line channels for comparison. As an example, satellite based communication networks with leased 4/6 GHz or 12/14 GHz satellite transponders and leased or owned earth stations can yield cost advantages of as much as 40% to 80% relative to leased private line networks based on analog or digital terrestrial network tariffs, or leased private line channels based on existing common carrier domestic satellite communication tariffs. These percentage reductions apply to national networks of 25 or more stations with network total traffic loads which require 100 megabits/second or more.

Alternative Reception Techniques for Direct Satellite Communication. As part of the study to assess the feasibility of a direct communication of a natural disaster, severe storm warning system, the ITS conducted a measurement program to determine the attenuation of UHF radio signals by typical single-family dwellings. These attenuation measurements were made using an unmodulated signal transmitted from the ATS-6 satellite. The results of these measurements were reported in OT Report 76-98,

These measurements show that while the average penetration loss into a typical house is quite low (less than about 7 dB), there is a significant proportion of houses which have an excessively high penetration loss. One specific class of house which has a high penetration loss is the mobile home. Trees were found to cause significant attenuation where a house is surrounded by large trees.

The objective of the current project is to evaluate novel, low-cost alternative methods and techniques for receiving radio signals in a variety of houses including mobile homes (where attenuation is high).

This study was divided into two principal parts: (1) the study of reception techniques and alternative methods of coupling the radio signal into a bouse, and (2) an analysis of the use of frequency modulation for narrow-band voice communication via satellite.

Table 2.2

PILOT VERSUS DEMONSTRATION PROGRAM

MAJOR FEATURES - DIFFERENCES

	PILOT PROGRAM	DEMONSTRATION PROGRAM
DURATION	- 10 YEARS OF OPERATIONAL SATELLITES	2-3 YEARS OF OPERATIONAL SATELLITES
ORIENTATION	- DELIVERY OF ACTUAL SERVICES	TECHNOLOGY DEMONSTRATION; SERVICES SECONDARY
INDUSTRY ROLE	- MAJOR PARTICIPANT FROM BEGINNING AS SYSTEM PRIME DEVELOPER AND OPERATOR	MAJOR SUPPLIER OF TECHNOLOGY PARTS OF THE SYSTEM
GOVERNMENT	- PRIMARY BUYER WITH OVERALL SYSTEM REQUIREMENTS: GOVERNMENT GUARANTEES 10 YEAR PROGRAM FUNDING	SYSTEM PRIME DEVELOPER, AND OPERATOR, AND PRINCIPAL USER
TRANSITION	- PLANNED TRANSITION TO COMMERCIAL SERVICE INCLUDED FROM START	AFTER DEMONSTRATION, PUBLIC SERVICE SECTOR AGENCIES LEFT WITHOUT SERVICE. EACH AGENCY MUST BEGIN AGAIN.
OLD PLANT INTEGRATION	- ECONOMIC/SERVICE INTEGRATION OF PRESENT/PLANNED SATELLITE AND TERRESTRIAL PLANT AND SERVICES	NONE
TRAFFIC MARKET	- NEW TRAFFIC NOT ECONOMICALLY FEASIBLE WITH OLD PLANT	TENDS TO BE TRANSFER TRAFFIC WITH TECHNOLOGY INCOMPATIBLE WITH PLANNED COMMERCIAL PLANT

The first portion of this study was reported to the sponsor in a letter report, Reception Techniques for Direct Satellite Communication. This study was restricted to the UHF band, and at about 1 GHz within that band. General conclusions from the study are:

(1) At frequencies of about 1 GHz, antennas for outside mounting could be manufactured at reasonable cost (less than $15.00).
(2) The signal available by coupling the ac power line to the houses was about 20 dB lower than that available using an omnidirectional antenna inside the house.
(3) With currently available technology, the cost of a receiver operating at 1 GHz would be too high for public acceptance in a disaster warning system (probably more than $300). The primary cost driving factors are the rf front end and the needed frequency stability.

The second part of this study was reported in OT Report 76-108. The general conclusions from this study are:

(1) The minimum recommended signal-to-noise ratio (SNR) for satisfactory operation of a disaster warning system is about 21 dB, where

$$SNR = \frac{\text{voice signal peak envelope power}}{\text{average noise power in a 3 kHz band}}.$$

(2) This minimum recommended SNR will occur at about the threshold knee of the input-output curve for an ideal fm receiver with an fm modulation index of two. A higher modulation index would not be appropriate for a minimum-signal design criterion.

(3) Due to the wide IF bandwidth of the FM receiver and the resultant high pass-band noise level, the use of a frequency down-converter was not a viable alternative.

This project was completed in FY 77 and no additional work is anticipated.

Improvement of the GOES Interrogation Link. Assessment and testing of the Geostationary Operational Environmental Satellite (GOES) Data Collection Platform Interrogation (DCPI) link using the Synchronous Meteorological Satellite (SMS-2) began in response to a request from the NOAA Data Buoy Office (NDBO), Bay St. Louis, Mississippi. That office reported they had experienced difficulty with those signals at 468.825 MHz.

Bit-error-rate tests and radio-set interrogations were made from the Command and Data Acquisition Station, Wallops Island, Virginia, to Boulder, Colorado, via the SMS-2 to measure performance. It was determined that (1) the received signal level was too low for reliable operation of the Data Collection Buoy Radio Set using a low-gain omnidirectional data buoy antenna and (2) the interrogation channel was subject to severe co-channel interference from non-government land-mobile transmitters which have primary frequency allocations at 468.825 MHz.

Improved performance was demonstrated through the use of a higher-gain antenna and the insertion of a low-noise amplifier in separate tests. The latter was recommended as an immediate solution to provide improved performance. Use of a 12.5 kHz offset to the interrogation frequency was recommended to minimize land-mobile interference.

This project, started during FY 76, was concluded in FY 77 with the issuance of OT Report 76-106.

Certification of GOES Data Collection Platform Radios. The GOES Satellites are in an earth-synchronous orbit. The purpose of the satellites is to give a nearly continuous view of the earth's surface from the Pacific, across the Americas, to the Atlantic.

The emphasis is on an environmental, rather than a meteorological view, and on use of satellite technology to help describe man's physical world--the interacting composite of earth, sun, atmosphere, oceans, and oceanic life.

The GOES satellite carries a 16-inch telescope for visible and infra-red scanning. This telescope permits day-and-night scanning, objective determinations of cloud types, temperature monitoring, height measurements, and wind field location. Another mission of the GOES satellite is to collect and disseminate data collected by remotely located environmental observing platforms. These data collecting platforms (DCP) measure river levels, ocean temperatures and current drift, snow and rain depths, wind velocities, temperature, and soil moisture content. These platforms are capable of monitoring almost any phenomenon that can be sampled by an external sensor and expressed electronically. These data are transmitted through the satellite to a central command and data acquisition station, and are then sent to Suitland, MD, from where the data are disseminated to field service stations and to weather service forecast offices. This national system is operated and managed by the National Environmental Satellite Service (NESS) of NOAA.

Within the next few years, the GOES system is to be integrated into an international satellite network. Japan, the European Space Agency, and Russia are to launch satellites compatible with the GOES. When this is completed, there will be an intergovernmental research and observation effort under the auspices of the World Meteorological Organization and the International Council of Scientific Unions.

OT/ITS has responsibility for certification of the data collection platforms (DCP). The purpose of the certification standards is set forth by NOAA/NESS. These standards are necessary to maintain operational integrity within the complex GOES satellite system. Before a DCP can be put into the GOES satellite system, a certification officer, appointed by NOAA/NESS must first witness the certification tests as performed by the manufacturer on each model of DCP that is intended for field service stations.

A DCP may be deployed in a variety of environments such as in the ocean on an ocean buoy, in a remote section of the Rocky Mountains, or in the deserts of California. The DCP is placed in an environmental test chamber where it is cycled from ambient temperature to +50° C, and to -20° C. It is then tested for long-term frequency stability, carrier phase jitter, spurious outputs, modulation, power output, and transmission format. These tests are performed at each of the three temperatures. If these tests, as performed by the manufacturer and witnessed by the ITS certification officer, meet all of the prerequisites as set forth by NOAA/NESS, then a certification is issued to the manufacturer by NOAA/NESS. This allows that model of DCP to be used in the GOES system.

GOES and TIROS-N Equipment Certification. During the past year ITS has witnessed certification tests performed by three contracting GOES manufacturers. They had contracts with the United States Geological Survey (USGS) and the National Data Buoy Office (NDBO).

A system modulation question was raised by the National Weather Service (NWS) and the NOAA/NESS asked ITS to review the questions and make a technical assessment of the modulation of the DCP radio set. It was ascertained that the DCP radio sets would not violate the integrity of the GOES satellite.

A meeting was held with representatives from ITS, NOAA/NESS, NASA, representatives from six radio-set manufacturing firms, the French C.N.E.S. (National Center for Space Studies), and from EMD, a French radio-set manufacturer on certification of Tiros-N data collection radio sets.

The TIROS-N satellite is one of the series of satellites which gather environmental data. The ARGOS data collection subsystem on the TIROS-N satellite is being developed, and will be operated by the French as a joint U.S.-France venture. The data will be transmitted to C.N.E.S. and will be processed for users. TIROS-N will have the capability of reporting the positions of floating or drifting data collection platforms (balloons, buoys, etc.). A preliminary set of certification requirements (frequency stability, spurious response, etc.) were discussed in detail.

Certification is necessary to provide system integrity and some quality assurance of data collected.

Final requirements for certification tests of TIROS-N radio sets will be made at future meetings.

SECTION 2.3 TERRESTRIAL RADIO SYSTEM PERFORMANCE

This activity is the continuation of a long-term contribution to the acceptance, evaluation, operation, and upgrade of existing communication systems operated by the Federal government. The projects generally result in recommendations for system design and/or upgrading as requested by the other Federal agencies. Nine tasks are reported, namely: MarAd Assistance, Digital European Backbone Path Tests, FKV Pilot Digital System Evaluation, Dau-Cabuyo Link Measurements, Optimum Combiner Parameter Evaluation Program, Automated Measurement System Upgrade, U.S. Coast Guard Consulting, and Wire Mesh Studies.

MarAd Assistance. Since 1973, ITS has provided a range of services to the U.S. Maritime Administration (MarAd), including test facilities and assitance, CCIR documentation, and technical representation in connection with various advanced communications projects. Some of the specific efforts in FY 77 are described in the following paragraphs.

1) Digital Selective Calling (SELCALL) for the Mobile Maritime Service. ITS provided the technical input to and participated in CCIR Interim Working Party 8/3. At its last meeting in June 1977, the Working Party unanimously adopted a complete Draft Recommendation on the techni-

cal and operational characteristics for the digital selective calling system. This Draft Recommendation will be submitted for final approval at the January 1978 meeting of CCIR Study Group and the subsequent CCIR XIVth Plenary Assembly in June 1978. The agreement in all details of the system marks the culmination of many years of effort in the CCIR and in several countries; its importance can hardly be overstated, as demonstrated by the fact that several countries will make the installation of SELCALL equipment mandatory for their merchant marine.

2) Direct Printing System for the Maritime Mobile Service in accordance with CCIR Recommendation 476 has only recently become of increasing interest in the U.S. maritime community. ITS acted as technical representative for a MarAd demonstration project involving the installation of Rec. 476 equipment on U.S. vessels and at the RCA coast station KPH near San Francisco.

3) In addition, ITS acted as MarAd technical representatives for a contract with GTE/Sylvania to demonstrate the feasability and practicability of using microprocessor techniques in a new generation of Rec. 476 equipment.

4) Based on experience encountered in this effort and on comments received from other U.S. manufacturers, ITS prepared a Draft Revision of CCIR Recommendation 476 which will facilitate the understanding and interpretation of this Recommendation for other manufacturers wishing to build such equipment.

Digital European Backbone (DEB) Path Tests. This project was a continuation of the path-test program conducted in FY 76. The DEB program is conducted under the auspices of the U.S. Air Force, Electronics Systems Division, Hanscom AFB, MA. The ITS project was conducted in support of the microwave-links engineering design study which was performed for the Air Force Communication Services (AFCS) at Richards-Gebaur AFB, MO.

The project during FY 77 was conducted in two phases. In the first phase, path tests were performed over three LOS links in northern Italy. Two of these proposed links for the DEB system formed an alternate routing for a link that was tested and determined to be unsuitable during the 1975 program. The alternate links were found to be satisfactory, and the terminal configurations were specified for each in order to meet DCA design criteria. The third link tested was a LOS path 64 km long from an elevation of approximately 2.2 km to a sea-level terminal near the west coast. The link was tested previously in 1975, and found to have a significant obstruction (mountain ridge) about 10 km from the high terminal. The 1975 measurements were performed under adverse weather and propagation conditions, and a definite determination of the obstruction terrain elevation was not possible. Measurements were repeated in October 1976, which provided a comprehensive evaluation of the link. A report of this phase of the work was prepared and published as OTM 77-234.

The second phase of the project was in support of the Air Defense Weapons Center (ADWC) at Tyndall AFB, FL. A series of four microwave LOS links form a data transmission and communication system along the Gulf Coast of the Florida panhandle, serving the Multiple Airborne Target Trajectory System (MATTS) test range. These links traverse low, wooded terrain and stretches of water. They range in length from approximately 12 km to 38 km. Problems on these links have been experienced by the users for some time. It was suspected that periodic, deep signal fading was being caused by insufficient path clearance and surface reflections; the latter was suspected particularly on the over-water paths.

The ITS pseudo-noise (PN) channel probe was first used to measure the impulse response of the transmission channel over each link. These measurements were performed by multiplexing the probe test signal with the normal information signal, and using the existing MATTS antennas. No significant surface reflections were detected during these tests, but several periods of anomalous propagation were observed. An analysis of these periods was performed in conjunction with meteorological data obtained from the National Weather Service in the region. The fading phenomena were attributed to surface-based layers and ducts with severe refractive gradients. A few periods of measurement were found to be very tractable with the calculated radio refractive index profiles.

Systematic path tests were later performed with test antennas mounted to permanent and temporary towers on all four links. Recommendations for engineering upgrade of each link were made, based on the system tests. This phase of the work culminated in a report to the U.S. Air Force entitled, "Link Performance Measurements on the MATTS Microwave System," OTM 77-236.

A complete description of the PN channel probe was presented in OT Report 76-96.

FKV Pilot Digital System Evaluation. The purpose of this project was to develop, install, and operate automated monitoring instrumentation to evaluate the performance of a five-link pilot, digital, communications system. The system was procured and operated by the U.S. Army Communications Command in West Germany between Heidelberg and Stuttgart-Vaihingen. Also, an evaluation of operations and maintenance procedures was made and recommendations for improvement and changes consistent with the improved design of the digital radio equipments were developed. This field measurement and assessment was carried out for a period of one year and was terminated on December 31, 1976.

The data collected by the automated monitoring system on magnetic tape were processed by computer following the one-year measurement period to produce histograms of received signal levels, outage times of radio receivers and transmitters (where monitored), plots of time availability, format violations of 3-level partial response baseband signals, and several alarm indicator signals within the system. A significant conclusion was that no failure of system performance was caused by any subsystem where a redundant element was available. There were two links in the system that experienced an outage of approximately 12 minutes due to rain attenuation. There was a total of 68 hours of outage time, much of it due to primary power failures which were not adequately covered by standby power sources. A summary of the system outages is shown in the table below. Care should be used in interpreting human error in that it encompasses such areas as regulations and administrative error.

A primary conclusion reached regarding operations was that routine testing and checking of the radio system should be terminated. Sites should be maintained by mobile test teams with necessary expertise and equipments rather than by on-site maintenance personnel. This both reduces manpower requirements and inventory of test equipment.

A five-volume final report, OTM 77-238, is in publication covering:

I: System Summary
II: Operation and Maintenance Analysis
III: Engineering Analysis
IV: Data Acquisition System Hardware
V: Data Acquisition System Software.

TABLE OF AVAILABILITY

	Predicted by Contractor	Predicted by DCEC	Measured on FKV
Unavailability	0.0000234	0.0001	0.0039
Availability	0.9999766	0.9999	0.9961
Outage min/yr	12.3	52.6	2040

OUTAGE TIME BREAKDOWN

Cause		Cumulative Min. Outage
Prime Power Failure		520
Propagation		12
Key Changes		50
Other Causes		1458
Equipment Failures	180	
Human Error	1278	

Optimum Combiner Evaluation. This project involved the testing of a digital line-of-sight microwave communication link near Heidelberg, Germany. The tests were designed to determine if momentary outages which had been observed on this link were caused by phenomena associated with the rf signal such as rf noise bursts, distortion of the rf signal, or fading of the rf signal at rates on the order of 100 dB/second. A photograph of the test instrumentation used is shown in Figure 2. 7. If such outages were associated with such phenomena, modification of the combiner design would be considered.

Empirical results from the FKV (Frankfurt, Koenigstuhl, Vaihingen) communications system evaluation indicated the possible presence of deep and rapid fades which adversely affect bit-error rate and link availability. To obtain sufficient quantitative information about these short-term outages and their causes so that they might be reduced or eliminated on this and other systems, OT/ITS was tasked by USACEEIA to monitor the parts of the FKV system which would provide such information. ITS had previously instrumented this system (see the task immediately above) to monitor many parameters which

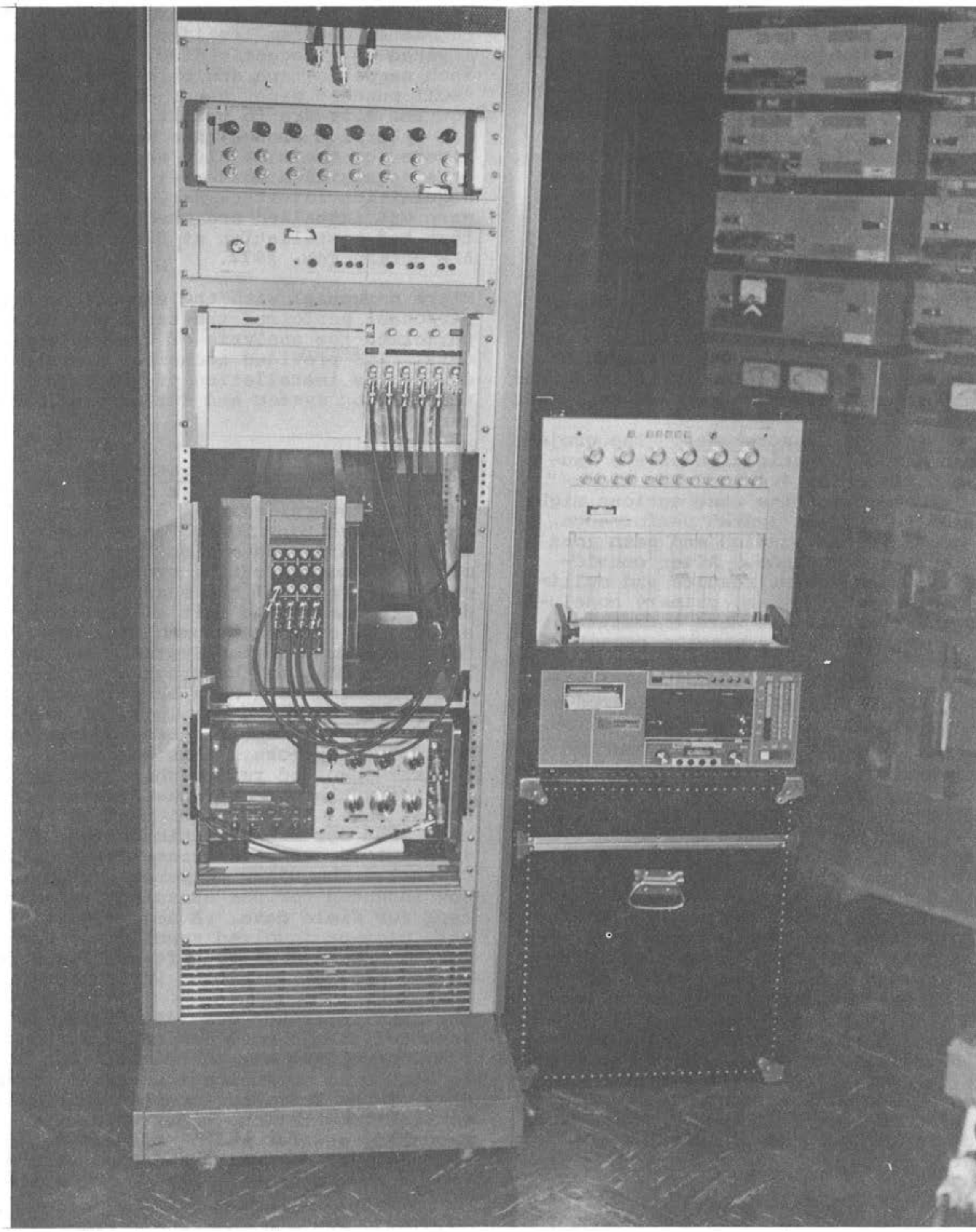


Figure 2-7. Electronic equipment used for monitoring rapid rf events.

indicate causes and extent of other system malfunctions. This previously installed equipment was used in conjunction with additional fast-response equipment to monitor the short-term outages and determine to what extent they are caused by low rf signal levels, noise, or rf signal distortion. A histogram of the short-term outages observed for the test period March through June is shown in Figure 2.8.

The outages were found to be caused by phenomena not associated with the rf signal. The actual causes could not be isolated with absolute assurance, but the major probable cause was isolated. Ordinary multipath fading was observed on the link, and the operation of the receiver switch combiner was observed and analyzed.

Dau-Cabuyo Link Measurements. The project concerned the investigation of the Dau-Cabuyo diffraction 4.4-to-5 GHz microwave link to determine what actions might be taken to upgrade system performance. Path geometry was studied and path loss measurements were made. After considering the measurement results and multipath fading predictions, primary conclusions and observations were enumerated. Several options (e.g., passive repeaters) for improving the link performance were listed with technical advantages and disadvantages. Figure 2.9 shows a portion of the diffraction path on the Dau-Cabuyo link.

Parameter Evaluation Program (PEP) Phase I. This program was a joint effort of ESD, Mitre Corporation, AFCS, and ITS. The program was primarily a test bed evaluation (essentially laboratory configuration) to determine and validate the utility of specific performance indicators in the Defense Communication System Time Division Multiplexing supported systems. Equipment of the type applied in the Digital European Backbone Stage I Program was to be used and had been previously installed in a test bed at Richards-Gebaur AFB. The equipment consisted of AN/FRC-162 radios, T1-4000 multiplexers, and CY-104 encryption units. A data acquisition system consisting of a 2100 minicomputer, two platter disc systems, one-half inch 9-track magnetic tape drive, and a high-speed plotter/printer was available.

ITS supplied interface hardware and interconnecting cables to interface the monitored equipment to the minicomputer. This type of system would insure recording responses and indicators which were transient in nature and would also provide the capability of determining the time sequence of indicators.

ITS supplied one set of data acquisition software as required to permit the interface hardware to communicate with the minicomputer. The software consisted of commented program listings and was delivered on a magnetic disc, one-half inch magnetic tape, and on eight-level ASCII punched paper tape. A set of test routine software to permit checkout of all interface connections was also delivered on the same disc and tapes as the data acquisition software. The data acquisition interface hardware and software was installed and checked out at the test bed installation at Richards-Gebaur AFB during Feb. 1977.

Mitre personnel with the support of AFCS personnel performed the tests, and Mitre performed the analysis of the collected data. ITS provided technical assistance during the installation of the data acquisition system and during preliminary testing.

Automatic Measurement System Upgrade. This project is part of a larger effort, spanning several years, to provide new and improved techniques for measuring engineering parameters on long-line microwave communication systems. The primary purpose of the measurement and data program is the initial test and acceptance of the equipment for the Defense Communication System. Another important goal in the program is the establishment of a data base to use as the system baseline for later comparison after the equipment has been operating for a year or more. This specific project involved refurbishing and repackaging the computer-based Received Signal Level (RSL-2) equipment which had been used for measurements on the DCS 4-GHz microwave path across the English Channel. The RSL-2 computer system is now intended for use as an analysis tool for field data. A second part of this project involved specifying, procuring and developing software for a new set of programmable test instruments.

The IEEE interface bus (488-1975) was selected as the most desirable method for controlling all instrumentation used in Air Force communication system testing. Some of the Test and Acceptance Calculator Instrumentation (TACI) which was procured, and for which software was developed, was delivered and demonstrated to the Air Force to complete the project.

Automatic Measurement System Upgrade: II. This project is a continuation of the above project using automatic test equipment to upgrade the communication equipment and system testing. A major effort involved setting up concepts and procedures to be used by the Air Force in the initial testing of DEB Phase I using the TACI equipment. In this role, ITS personnel served as consultants to develop software at Richards-Gebaur Air Force

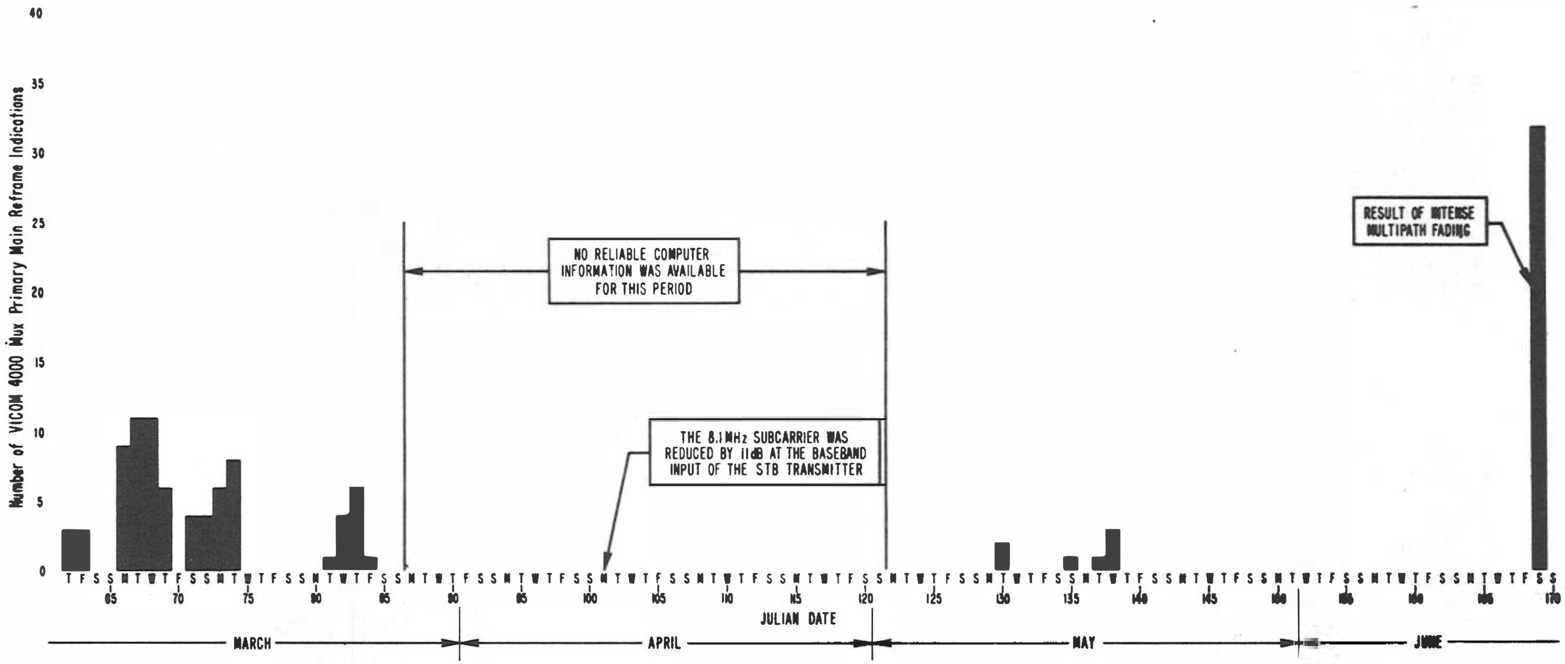


Figure 2-8. Momentary link degradation histogram for the total test period based on framing format violations.

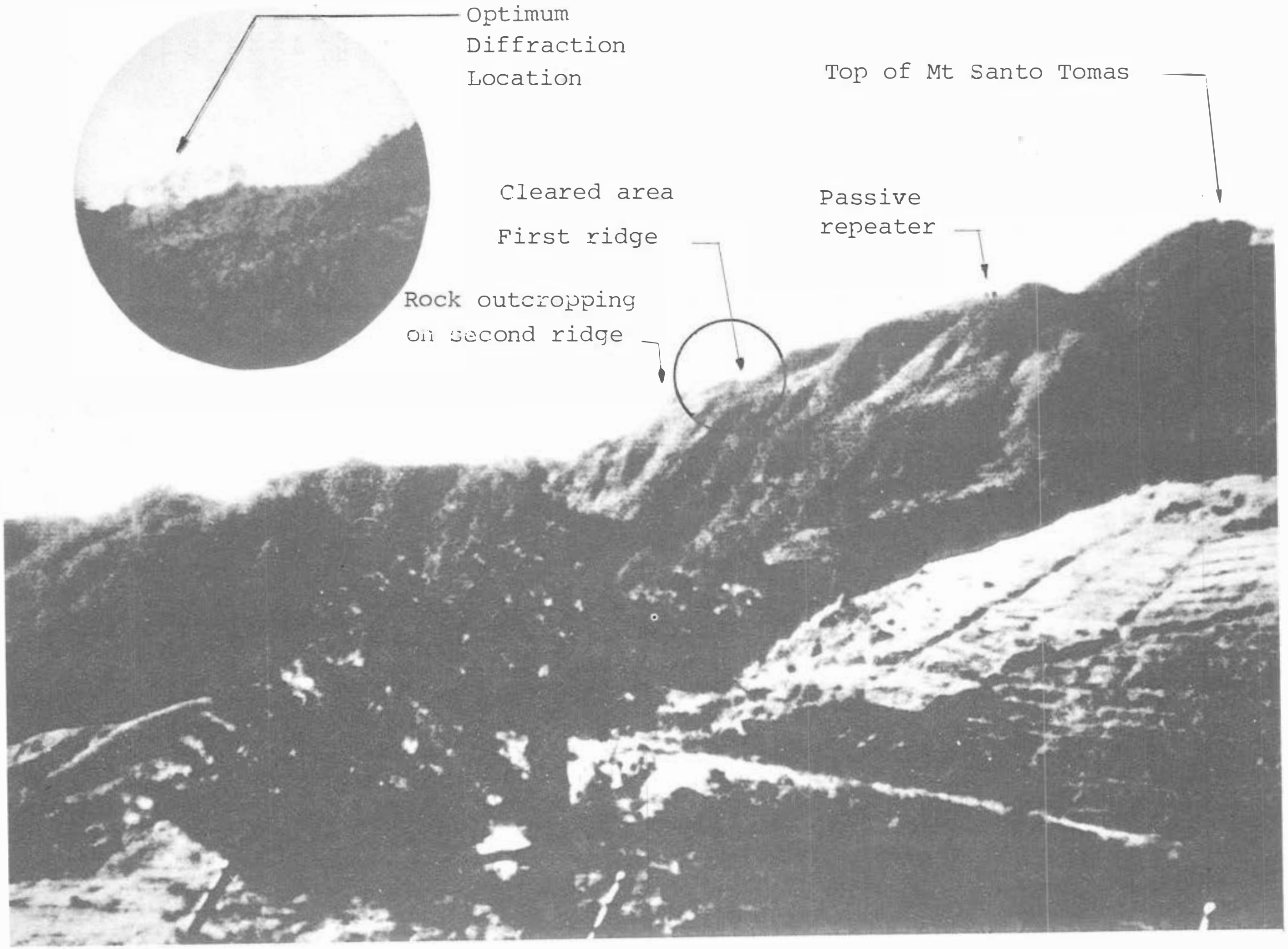


Figure 2-9. Diffracting ridge profile normal to the great circle path as seen from Cabuyo.

Base, MO. A second part of this project involves specifying and acquiring equipment to be used in the development of specialized instrumentation controlled by a microprocessor and interfaced to the TACI controller with the IEEE 488-1975 bus.

U.S. Coast Guard Consulting. The work done for the Coast Guard by ITS is generally in support of their HF communication system needs. The variety of analyses performed vary from simple, routine ionospheric predictions to large network coverage and trade-off studies.

Some of the routine ionospheric predictions done this fiscal year were supplied to the San Francisco and the Boston communication stations. The former station needed tables of the maximum usable frequency (MUF) and the frequency of optimum traffic (FOT) for the circuits between the San Francisco and the Honolulu stations and Coast Guard vessels in McMurdo Sound, Antarctica. The Boston station needed similar predictions for the circuits between the station and several selected regions in the North Atlantic.

Wire Mesh Studies. Wire mesh screens are often used in shielding of electromagnetic waves because they are lighter and less expensive than solid metal sheets. Although a single planar array of wires is sometimes adequate, two planar arrays of perpendicular wires are required when the incident electric field has arbitrary polarization. In the general case the wire spacings in the two planar arrays are not equal, and the mesh cell is rectangular. The electromagnetic properties of such rectangular meshes are not well known, particularly when the incident electromagnetic field has arbitrary polarization and angle of arrival.

A major difference between wire meshes and solid metal sheets is that the mesh will support a surface wave. This surface wave is particularly important when the source and observer are both located near the mesh. A rigorous formulation for the interacting wire currents has been extended from the case of plane-wave incidence to the source-free problem of surface-wave propagation. A computer program has been used to solve for the surface wave propagation constant numerically. The propagation constant is closely related to the shielding effectiveness of the mesh for grazing propagation. When the mesh is square, it has nearly isotropic behavior and the surface wave properties are nearly independent of the propagation direction (isotropic behavior). However, a rectangular mesh is highly anisotropic.

An approximate method of "averaged boundary conditions" is available for analyzing rectangular meshes which have electrically small wire spacings. This method has been used to solve for the previously mentioned surface wave propagation constant, and the agreement with the numerical method is good when the wire spacings are sufficiently small. This approximate method has also been used to derive a surface transfer impedance for rectangular meshes. This transfer impedance is anisotropic for rectangular meshes, but is isotropic for square meshes. For practical mesh configurations which are not infinite or nonplanar, the approximate impedance sheet representation provides a useful means in analyzing such structures. One example is the braided shield of a coaxial cable which has been characterized by a surface transfer impedance which is inductive.

The general goal of this work is to understand thoroughly the electromagnetic properties of wire meshes so that mesh screens can be designed to be effective without using a large amount of metal. Further work is continuing on the problem of propagation between a pair of mesh plates because such parallel plate waveguides are used in electromagnetic pulse (EMP) simulators. Also planned is further analysis of propagation along a mesh located over a lossy half-space where the application is design of antenna ground screens.

SECTION 2.4 SIMULATION AND STANDARDS

Simulation and standards (including handbooks and glossaries) are combined here. Simulation provides a realistic and repeatable method for evaluating and comparing the performance of different subsystem elements (e.g., modems) on an objective basis. In section 2.1, standards development for data communications was discussed. The tasks mentioned below are standards activities on which OT is making contributions, but which have not reached the level of public attention as that of the data standards. Four tasks are described; namely: MEECN simulation, Objective Measurement of Voice Intelligibility, LESL Standard, and Federal Standards Glossary.

Minimum Essential Emergency Communication Network (MEECN) Simulation. The objectives of this project are:

(1) To obtain comprehensive performance measurements simultaneously on the US Air Force 616A and US Navy Verdin VLF-LF digital communication system under a variety of channel conditions

using the ITS Ionospheric Channel Simulator.

(2) To perform synchronization tests between the 616A and Verdin systems.

(3) To develop and evaluate an experimental interference suppressor that can be used with such systems.

The 616A and Verdin are sophisticated systems that incorporate several modulation techniques with a number of compatible modes of operation that are used in the Department of Defense's Minimum Essential Emergency Communication Network (MEECN). A first set of channel-simulator measurements was made in one mode of operation in FY 75. A classified report on the results of these measurements was completed and published in FY 76.

During FY 76, a similar second set of channel-simulator measurements was made simultaneously on the 616A and Verdin systems in six modes of operation common to the two systems. The system performances were determined with respect to a variety of channel distortions: gaussian noise, atmospheric noise, cw interference, multipath, doppler, fading, and repeat jamming. In around-the-clock measurements over a six-month period, 47 channel-simulator experiments were performed, each of which yielded a pair of performance curves (one for each system) of character error probability as a function of the magnitude of the channel distortion.

During FY 77, the results of the second set of channel-simulator measurements were analyzed, and a comprehensive classified report was prepared, "Comparative evaluation of 616A and Verdin Modems, Phase II, Part 2," (U), OT Tech. Memo. 77-239C, 1-222 (Secret). The report includes theoretical analyses of system performance with respect to gaussian-noise, cw-interference, doppler, and multipath channel distortions, including the improvements provided by error-correcting coding. The analyses were used to prepare theoretical error-probability performance curves for comparison with the measured error-probability performance curves.

During FY 77, synchronization tests were also performed on the 616A and Verdin systems under ideal channel conditions (no channel distortions). A report on these tests, as well as some earlier synchronization tests, will be prepared early in FY 78.

In FY 76, an experimental interference suppressor, suitable for use in the 616A and Verdin systems, was designed and built, and partially bench tested. During FY 77, work on the interference suppressor was postponed because of the effort required on the other tasks. Early in FY 78, bench testing of the experimental interference suppressor will be resumed and completed. The suppressor will then be temporarily incorporated as part of the 616A receiving system, and channel-simulator measurements will be made to determine the improvement in the 616A performance provided by the suppressor under a variety of channel interference conditions. A report will then be prepared describing the design of the suppressor and the results of the channel-simulator experiments.

Objective Measurement of Voice Intelligibility. This project is jointly funded by the Federal Aviation Administration and the US Army (CEEIA). The objectives of the study were to develop synchronization techniques, normalization methods, an extended data base as identified in a previous feasibility report (Federal Aviation Report FAA-RD 75-189); and to provide a software package for calculating the resultant objective scoring technique. The work was influenced by the desire for an eventual hardware implementation.

Specifically, eight 50-word phonetically balanced word groups, recorded by five speakers (three male, two female), were played through 12 different systems. The systems included both analog and digital voice systems and different types of noise and interference. An objective scoring using standardized trained listener panels was obtained. A comparison of the objective and subjective scores for each word group is shown in Figure 2.10.

A final report, "An objective evaluation of voice communication channels," to be published as a Department of Transportation Report, is in final stages of review.

Law Enforcement Standards Laboratory (LESL) Standards. Following a Congressional mandate to develop new and improved techniques, systems, and equipment to strengthen law enforcement and criminal justice, the National Institute of Law Enforcement and Criminal Justice (NILECJ) has established the Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards.

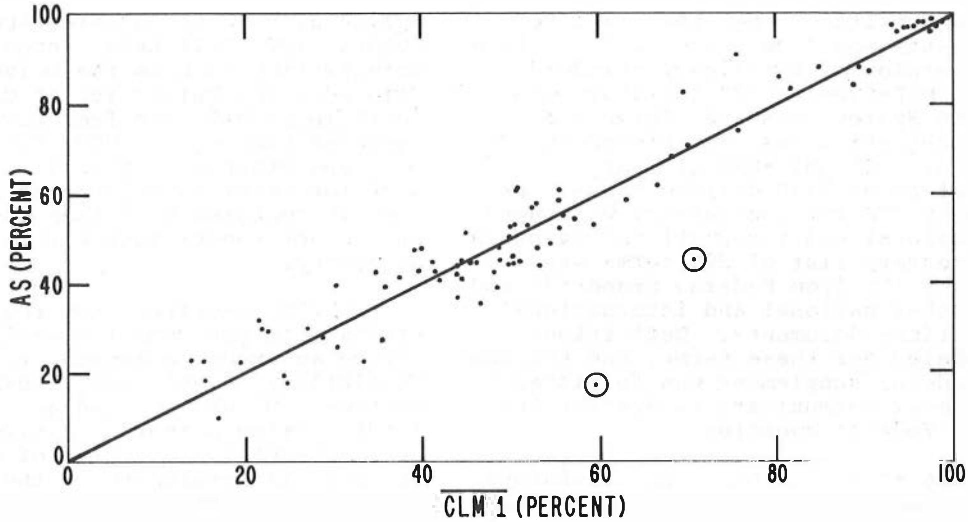


Figure 2.10. The objective measure $\overline{CLMI}$ versus the subjective measure AS. Each point represents the average scores for one 50-word phonetically balanced word group.

The function of LESL is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment. Outputs from this work are usually in the form of performance standards, user guidelines, and state-of-the-art reports.

During FY 77, ITS completed performance standards on selective calling and tone-coded squelch systems for police communications equipment. A variety of standards have been prepared by LESL in previous years for base station, mobile, and personal/portable communications equipment. Since a majority of existing law enforcement communications systems use some form of selective signaling or tone controlled squelch to minimize annoying interference and provide a variety of alerting systems, a standard for selective signaling is needed to augment the existing LESL standards.

Two standards were developed:

(1) tone pulse selective signaling systems using tones between 300 and 3000 Hz (in-band tones), and

(2) continuous tone-controlled squelch systems using tones below 300 Hz (out-of-band tones).

These standards are based on:

(a) needs for efficient law enforcement operations;

(b) detailed tests on commercial systems;

(c) present and proposed industry standards;

(d) equipment compatibility requirements;

(e) state-of-the-art in equipment development.

Standardized measurement techniques were developed and are incorporated to ensure uniform performance and compatibility for equipment from different manufacturers. These standards will be significant in enhancing the cost-effectiveness of law enforcement procurements and ensuring acceptable communications performance.

Telecommunications Glossary. Communications among federal telecommunications personnel, and between federal telecommunications organizations are improved if a mutually understood language is employed. Federal communications standards, specifications, contracts, operating manuals, etc., need a common terminology for correct interpretation. Similarly, a common reference list of communications terms and definitions is needed to aid the design, development, operation, and maintenance of Federal communications systems. This Federal glossary must be consistent with international, national, departmental, industrial, and technical society standards.

The immediate objective of this project is to prepare a draft Federal Standard on Telecommunications Terms and Definitions. To reduce the cost of this effort, and to avoid duplication of effort, it was decided by the FTSC (Federal Telecommunications

Standards Committee) that the draft Federal Glossary would be based upon the final revised version of a military standard glossary, MIL-STD-188-120 (Military Communication System Standards Terms and Definitions), which has been stored by ITS on computer. The MIL-STD glossary, consisting of about 1300 defined terms, was reviewed by ITS for consistency with pertinent national and international standards. A supplementary list of 200 terms was selected by ITS from Federal Standards and various other national and international communications documents. Definitions were prepared for these terms, and the completed Federal supplement was furnished to NCS (National Communications System) for review by Federal agencies.

During FY 77, comments and revisions from the Federal community were collected and these 200 terms, with 450 others, were collected to be reviewed later by the resolution committee. ITS will host these committee meetings and will collect comments and incorporate suggestions and corrections into the final glossary. The availability of the computer-stored text of the military standard will make possible an enlarged Federal Glossary at a relatively low cost.

SECTION 2.5. FIBER OPTIC COMMUNICATIONS.

OT's mission statement states that its role is to "assist the Department of Commerce in fostering, serving, and promoting the nation's economic development and technological advancement by improving man's comprehension of telecommunication science and by assuring effective use and growth of the nation's telecommunication resources." OT is specifically charged with acquiring, analyzing, synthesizing, and disseminating information for the efficient use of the nation's telecommunication resources and with assisting other Federal agencies in the use of telecommunications.

OT has assumed a role as a catalyst in assisting industry and other government agencies more rapidly to develop and apply the emerging fiber optics communication technology. Four task areas are described; namely: Fiber Optic Communications, Fiber Optics Design Handbook, Interbuilding Networks, and Fiber Optic Communications System Consultation.

Fiber Optics Communications. In FY 1975, OT/ITS established an Ad Hoc Optical Communications Task Force to provide a forum for government and industry technical workers, potential users, and policy makers to explore the applications, advantages and potential problems in adopting and using optical communication technologies. The Task Force work has been well received and the meetings well attended by representatives from industries such as GTE Sylvania, Hewlett-Packard, Spectronics, Hughes, ITT, Bell Labs, Xerox, and from universities such as the University of Colorado, the University of California (Berkeley), MIT, and from government agencies such as OT, OTP, HEW, USPS, NBS, DoD, and others. Currently, the mailing list for meeting notices and summary records contains more than 200 names with only minor repetitions within any company or agency.

OT/ITS receives many requests and visits from government agencies seeking advice and recommendations regarding the feasibility of utilizing fiber optic systems. OT has pursued an active role in discussing potential applications with several civilian agencies of government. Interest is developing in the selection of a pilot intra-building networking application.

A study was made of the telecommunications requirements for a large hospital (1000 beds) with needs extrapolated over the next 3 to 10 years. Communications requirements developed for a variety of data terminals, monitoring equipment, high and low data rates, and interconnects for closed circuit TV networks. A hospital wing was chosen to have 50 beds. Typical wing telecommunications data and video requirements for the present and for the 1980 time frame are tabulated in the accompanying Table 2.3.

Several alternative bussing configurations as well as the particular advantages of fiber optic networks are described in a report entitled "Telecommunications for a Large Modern Hospital" to be published. In addition to the large information carrying capacity of the fiber optic network(s), there are significant other attributes of importance to the hospital environment. For example, the electrical isolation eliminates shock hazards for both patients and medical personnel. Also, the immunity from electromagnetic interference and noise increases the reliability of the recorded information.

As an extension of activities by the Task Force, a Standards and Definitions Working Group will be initiated by OT/ITS among Task Force members as an Ad Hoc Committee to determine component standards, measurement procedures, and performance standards, which should be developed for submission to national standards committees.

Table 2.3. Telecommunication Requirements for a 1000-Bed Hospital

Service	Users	Today's Requirements	Per Wing Bandwidth* Required to Enter/Exit	Projected 1980 Requirements	Per Wing Bandwidth* Required to Enter/Exit
a) Telephone	Patients, Staff	1500 lines (handsets) (30 per wing)	120 kHz	3000 lines (1500 handsets)	240 kHz
b) Audio Intercom	Patient-Nurse Station	30 sets of intercoms with 30 stations each	N/A	Same	N/A
c) Paging Intercom	Administration Staff	1 zoned system with about 250 speakers	10 kHz	Same	10 kHz
d) Portable Pager	Administration Staff	Key Personnel and physicians	Radio	Same	Radio
e) Pneumatic Tube	Staff	1 Terminal Wing	N/A	Might be replaced by electronic terminals and supply distribution	See item "i" below
f) Low-Speed Data Logging From		Low speed (100-300 b/s) per function			
-Patients	Patient to Nurse/computer	Internal to equipment	N/A	Remoted via bus or 'phone line	120 kHz (could be a subset of item "a" above)
-Plant Alarms	Monitors to Administrative Staff	10 to 50 functions (1-300 b/s)	4 kHz	Five-fold increase in alarms	10 kHz
-Lab Tests	Local data from instruments to controller/computer	Depends on laboratory and instruments: 300 to 9600 b/s	N/A	Some data sent to central computer as an item "g" below	See "g" below
-ICU, CCU etc.	Intensive monitoring locally in special patient wing	10 sets of 4 function monitors into 1 or 2 consoles & computer	N/A	Double number of functions, remote a few readouts	20 kHz
g) Data exchange (Med-Hi speed)	Computer to computer	Short runs of twisted pair (9600 b/s) & Coax links (1 Mb/s)	20 kHz - 2 MHz*	More short runs; 5 to 10 times more hi-speed links - coax, fiber optics	20 kHz - 10 MHz*
h) Television					
CATV (12 ch)	Patients, Staff (Entertainment, Educational)	Coax system throughout hospital	100 MHz	Same, except fiber optic cable could be substituted	100 MHz
CCTV (2 way)	Staff to staff; Staff to Patients	If any, 1 dedicated system	12 MHz, if applicable	5 to 10 terminals connected by coax or fiber optics	12 MHz
CCTV (1 way)	Plant security, Administration	5 channels	5 MHz, if applicable	10 channels	5 MHz, if applicable
i) Alphanumeric orders	Staff: laundry, dietetic, pharmacy, admission, etc., nurses	5 to 10 scattered throughout the hospital (300 - 1200 b/s)	3 kHz*	1 or 2 terminals per wing on a hospital-wide data bus (9600 b/s)	20 kHz/unit on a 2 MHz bus*

Fiber Optics Design Handbook. This project is in two phases: The first phase (not previously reported) dealt with component development and recent optical waveguide device trends; that phase was completed on October 1, 1976. The second phase, scheduled for completion in September 1977, is addressed to the preparation of a design handbook.

The purpose of Phase 1 was to investigate the possible use of fiber waveguides to replace radio and conventional cable communication techniques in the interconnect facility (ICF), between a technical control facility and a satellite earth terminal, in the Defense Satellite Communication Systems (DSCS) for phase II, stage 1-C upgrade and beyond. The study considered the various components required to meet the needs of operational telecommunications for the US Army. In particular, of immediate concern was a fiber waveguide link which could be incorporated directly into the DSCS stage 1-C program. Expected operational requirements are from 1.54 to 50 Mb/s over distances of one to three kilometers.

The data base presented in the Phase I report was based on efforts by other Government Agencies, particularly the military, as well as civilian agencies.

A design handbook, entitled "Design Procedures for an Optical Fiber Communications Transmission System" is currently in preparation. This document will provide a communications engineer with a systematic guideline and approach for both the design and evaluation of an optical-fiber communications/transmission system. Special emphasis will be on methods and alternatives for replacing an existing cable or microwave channel with an optical fiber link. The interface criteria for this transmission medium to couple effectively to existing terminal equipment are developed. The handbook discusses modulation techniques, multiplexing for multichannel systems, and interface methods. It goes through an actual design from the expressed requirements of the user to the decision points of the engineer based on real-world tradeoffs. The report also discusses performance and evaluation and appropriately describes measurements that are common to conventional communication systems.

Interbuilding Networks. An analysis has been made of alternative cable specifications, to provide comparative operational and economic models for fiber optical systems when compared to coaxial cable. A report, "Cost and Operational Considerations in the Use of Optical Waveguides in an Army Base Information Transfer System," is in preparation. The report discusses the potential use of optical waveguides in an information exchange system consisting of many terminals distributed uniformly over the area of a circle of a given radius. Cost comparisons are made between coaxial cable and glass fiber systems. The results show definite advantages for fiber waveguide systems when data rates are high due to the wide bandwidth capabilities of fibers. Since any bussing system, whether loop, stem, or Tee, requires power or optical splitters, branching points, and combiners for multiterminal networks, a section of this report has been devoted to the properties of star couplers, Tees, and mixers. Their inherent losses and the basis for choices are discussed. The Steiner-Street model developed in an earlier OT Report is offered as a partial solution for minimizing overall cable length in interconnecting a large number of terminals in party-line configurations.

Fiber Optic Communication System Consultation. This project is a consultative project with tasks defined as the need arises. Two tasks were considered during the year and brief unpublished reports were written:

Task 1: Examine the possible investment recovery for the development of components at $\lambda = 1.2$ μm.

This task was concerned with the sponsor's investing several million dollars in the development of detectors and sources which operate well at $\lambda = 1.2$ μm. Because of the improved operational characteristics of the fiber at this longer wavelength, fewer repeaters would be required for a long-haul system. The study showed that, in the interest of reducing repeater spacing, it would be prudent to invest development funds in the search for operational components at the longer wavelength. Using the model developed in the study, the report showed that the funds would likely be recovered through a savings in repeater cost.

Task 2: Examine the tradeoffs between multimode graded index fibers and single mode fibers.

This task was concerned with the return to single mode waveguides as a viable transmission line for long-haul systems. Recent trends show that graded index multimode fibers have substantial potential but the tolerances on the profile are very demanding. The biggest problem with single mode waveguides is in coupling because of the small core radius. If the coupling problem can be managed, as seems likely, the single mode waveguide emerges as a very strong candidate for use in long-haul systems. The advantages that it offers are substantial, including relaxed tolerances on mechanical dimensions.

CCIR

In FY 77, two documents were prepared for Study Group 3 which deals with Fixed Service at Frequencies Below About 30 MHz.

As part of the work performed for the Maritime Administration (MarAd) of the US Department of Commerce, contributions were prepared and presented to Study Group 8 and to the Interim Working party 8/3 (see also Sec. 2.3). ITS work for the CCIR Interim Working Party (IWP 8/3) dealt with the subject of Digital Selective Calling.

CCITT

The CCITT U. S. Study Group on Data Transmission corresponds to two international Study Groups: Study Group VII, New Data Networks, and Study Group XVII (formerly Special A), Data Transmission. The ITS chairman of the U.S. preparatory group also heads the delegations to the international CCITT Study Groups VII and XVII meetings. Some key recommendations to which the USSG heavily contributed are X.25 (packet switched nteworks), V.27 ter (4800 bps modems for use on the switched telephone network), and V.29 (9600 bps modems for use on leased lines).

CHAPTER 3. EM WAVE TRANSMISSION

The ground, the atmosphere, and the ionosphere degrade radio waves in varying degrees, depending on circumstances. It is the purpose of the EM Wave Transmission Program to study these effects and provide models to the system designer that will aid him in providing more cost effective and spectrum efficient designs. The phenomena which cause these detrimental effects on radio and optical systems are, in general, frequency dependent; therefore, specific studies and tests are required for specific frequency ranges and applications.

Some of the phenomena which effect radio signals and are studied in this program are:

1. Attenuation by atmospheric gases, hydrometeors (rain, snow, hail, clouds, etc.), or ionization.

2. Scattering by hydrometeors or irregularities in the refractive index of the lower atmosphere or ionosphere.

3. Refraction, ducting, and multipath, resulting from atmospheric or ionospheric layers.

4. Dispersion, resulting from frequency dependent properties of the atmosphere, ionosphere, and earth.

5. Scintillation of amplitude, phase, polarization, and angle of arrival, resulting from turbulence and irregular structure in the atmosphere and ionosphere.

6. Reflection, scattering, multipath, and lower atmosphere perturbations resulting from terrain and man-made structures.

The effect upon any specific system of the above phenomena is not only highly frequency dependent, but is also dependent upon the type of service required for the specific application.

One driving force behind the EM wave transmission program is the need for more spectrum space. Therefore, this program provides models, techniques, and information to aid the system designer and frequency manager in their decisions for better spectrum use.

Experimental or theoretical determinations of radio wave transmission characteristics, or the channel transfer function, are reported in section 3.1. Measurements of transmission media properties and analyses of collections of such data are included in section 3.2. Section 3.3 describes the development and testing of models which incorporate the transmission information in engineering tools. Predictions of transmission characteristics and system performance are discussed in section 3.4. Section 3.5 reports on applications of the knowledge and tools to specific problems of other government agencies, such as mine and forest service communications.

SECTION 3.1. WAVE TRANSMISSION CHARACTERISTICS

Experimental determinations of the effect of the transmission media on electromagnetic wave transmissions are reported in this section; in particular, those effects produced by the atmosphere.

Broadband Transmission in the 10-100 GHz Range. In the 10 to 100 GHz measurements program, the multifrequency (9.6, 28.8, and 59.1 GHz) links were extended to 740 meters length, and the 1 Gigabit per second digital modem was used to measure bit-error rates on the 59.1 GHz link. Except during heavy rain storms, the error rates were below 1 in 10^7, only slightly higher than that observed in back-to-back tests on the modem.

Through the loan of a 60 GHz hybrid power amplifier from USAF Avionics Lab, the 59.1 GHz transmitter power was raised from 1 mw to 40 mw.

The technique of cross-correlating a PN-code with 2 nanosecond bit length has been applied to the 59.1 GHz link. Analysis of these data should permit description of the transfer function of the atmospheric transmission channel. Figure 3-1 shows an example of the signal obtained from the correlation detector.

SECTION 3.2. CHARACTERISTICS OF THE TRANSMISSION MEDIA

This section is concerned with the study of transmission media to help those who design, construct, or use telecommunication systems to better understand the characteristics of the media and their effects on radio signals. We first discuss the non-ionized atmosphere and then the ionosphere.

3.2.1. Atmospheric Characteristics

Millimeter Wave Transmission Spectroscopy, 40 to 140 GHz. The microwave spectrum of oxygen (O_2-MS) dominates transfer characteristics of air over the 40 to 140 GHz frequency range. Laboratory studies of the atmospheric O_2-MS continued under various simulated conditions. Interesting new results (see Figure 3-2) were obtained from a systematic study of the influence of collisions by various air molecules (N_2, Ar, CO_2, H_2O, etc.) upon oxygen lines in the 60 GHz complex. These results add to a reliable quantitative formulation of the atmospheric

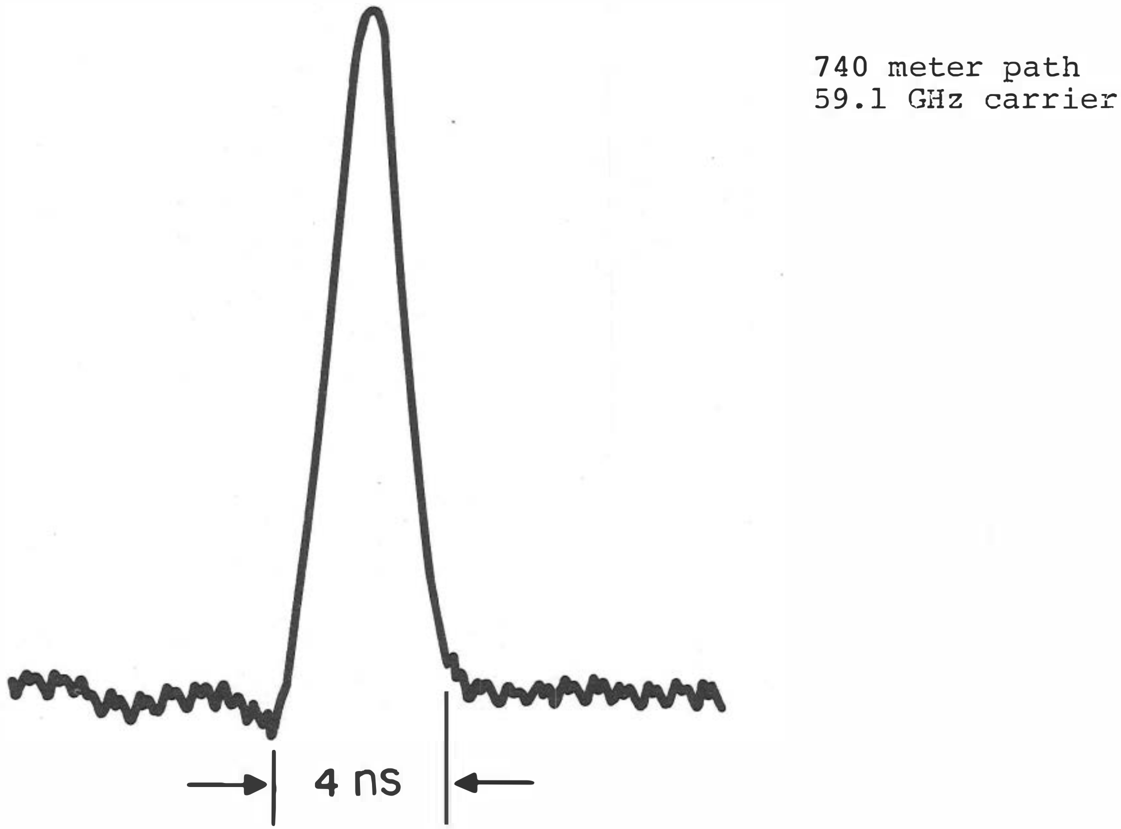
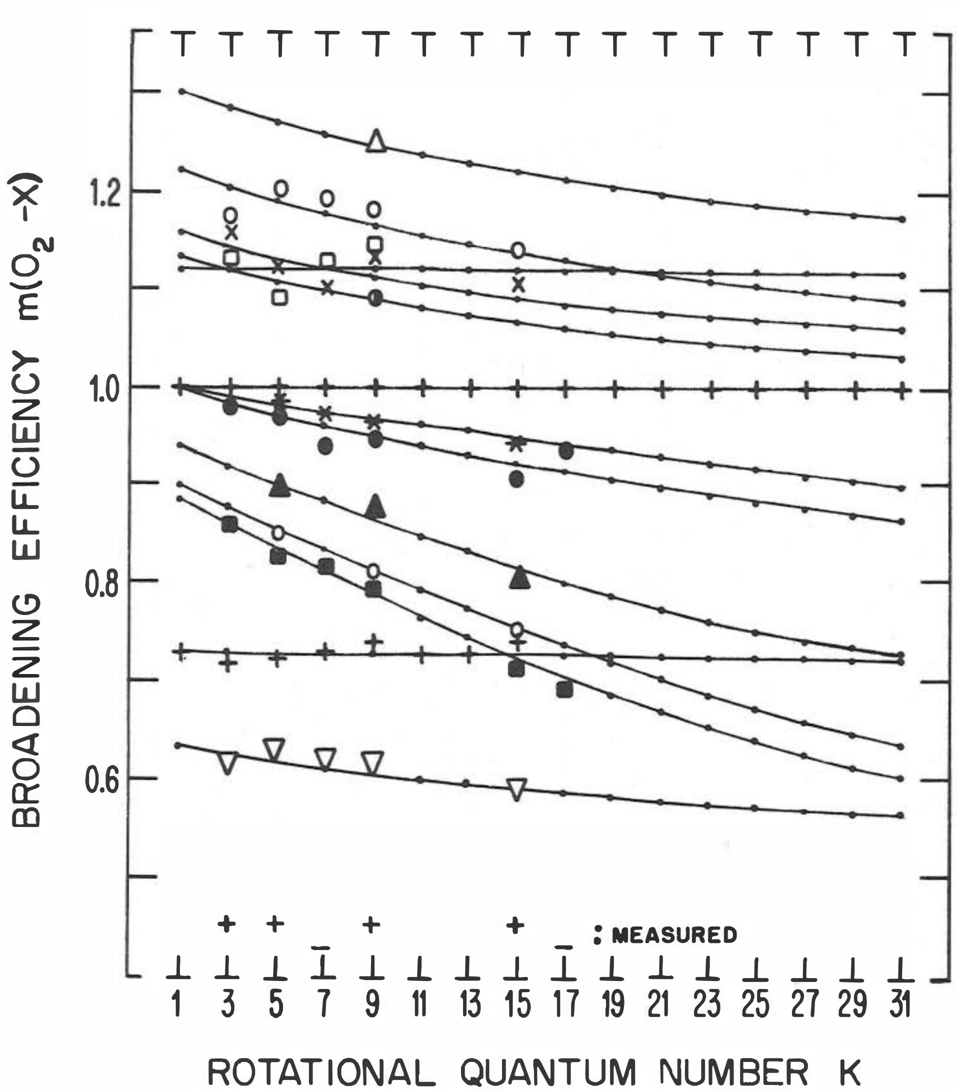


Figure 3-1. Lag cross-correlation between a transmitted and received 500 mb/s pseudo-random binary word.



PERTURB. X	SYMBOL	MASS M	REFRAC. R ppm/torr	AIR(c) COMPOS. ppm/vol
H_2O	△	18	5.87	VARIABLE
H_2	□	2	0.163	0.5
CH_4	o	16	0.531	2
CO_2	x	44	0.593	314
N_2O	◐	44	0.669	0.5
O_2 (a)	+	32	0.318	209476
N_2	●	28	0.352	780840
Xe	▲	131	0.809	0.087
He	+	4	0.0422	5.24
Kr	o	84	0.508	1.14
Ar	■	40	0.332	9340
Ne	▽	20	0.0811	18.18
AIR (b)	*	28.9	0.345	10^6

(a) m = 1 by definition

(b) Data from $\Delta N_0(\mathrm{AIR})/\Delta N_0(O_2)$

(c) U.S. Standard Atmosphere 1976

Experimental Conditions:

$(\nu - \nu_0)$ = ±5 MHz, H ≈ 0 gauss, $p(O_2)$ = 2 to 3, p(X) = 0 to 5 torr, 300° K

Figure 3-2. Broadening efficiencies for 12 atmospheric gases upon the 32 lines of the O_2 microwave spectrum (experimental results and predicted trends).

O_2-MS, and they contribute to a better understanding of molecular structure and interaction.

The treatment of millimeter wavelength spectra of the clear atmosphere, (i.e., transfer and emmission functions) was reduced to an engineering calculation scheme void of referrals to complicated quantum - mechanical descriptions. The EHF properties of air are calculated from easy-to-measure meteorological variables, most directly based upon ITS laboratory truth data and state-of-the-art theory.

Orbital Standards Platform (OSP) Preliminaries and Analysis. The frequency managers or regulators adopt in their frequency-allocation regulations, the equivalents of performance specifications for antenna patterns, spurious emissions, polarization characteristics, etc. The formulation of such specifications are often seriously impeded by the lack of sufficiently precise measurement facilities and procedures. For example, the testing of antenna characteristics (side-lobe gains and off-axis polarization, depolarization, etc.) are restricted by the equipment investments and operational costs of anechoic chambers, statistical sampling on outdoor ranges, or approximations by scaled-frequency models. For the manufacturer and the operator of satellite systems, much of the complexity, uncertainty, and expense of such measurements would be avoidable by the nation-wide availability of an Orbiting Satellite Platform (OSP) radiating to the surface a standards-quality emission of calibrated frequency, polarization, and power characteristics. See Figure 3-3.

In a cooperative program involving the Communications Satellite Corporation (COMSAT), NASA's Goddard Space Flight Center (NASA/-GSFC), the National Bureau of Standards (NBS), and OT's Institute for Telecommunication Sciences (OT/ITS), an initial candidate OSP has been determined. Further, a selected list of potential OSP users -- entities having either a direct concern with satellite systems (operators, manufacturers, regulators) or with atmospheric and other natural processes (researchers) -- has been compiled as a sample of the telecommunications community. Comments on the initial OSP candidate received from potential OSP users have been included in further specification of the OSP candidate system.

Satellite Propagation Observations at 19 and 28 GHz. Future domestic satellite communication systems carrying high density traffic will use frequencies up to 30 GHz because of the presently greater bandwidth available and because these frequencies are not currently being heavily used.

Beacons at 19 and 28 GHz on several domestic geostationary satellites have been launched. The objectives of this ITS program are to monitor these beacons and collect attenuation and phase information. The data will help to determine minimum power and other performance margins needed for future satellite communication systems operating up to 30 GHz.

Colorado is an excellent location for data collection from the 19 and 28 GHz satellite signals since currently there is no other site planned west of the Mississipi, and the Colorado site should provide optimum reliability from elevation angle considerations.

The satellite beacon transmissions will originate from three satellites, each with a 19 and 28 GHz beacon. The 19.04 GHz beacon signal will be switched between two orthogonal linearly polarized (i.e., vertical and horizontal) antennas at a 1 kHz rate. The 28.56 GHz signal will be transmitted continuously from a linearly polarized antenna (vertical only). The 19 and 28 GHz signals will be coherent since they are derived from the same fundamental source.

The current status of the project is that the 28 GHz receiver has been completed and the 19 GHz receiver will be completed and tested by September 1, 1977.

A 10-foot antenna and positioning mount has been installed on the south end of Wing 3 of the Radio Building.

Preliminary attenuation and phase data will be recorded on analog strip chart recorders. Eventually, an automated data acquisition system will be incorporated to collect and analyze the data.

Kwajalein N-Meter. A microwave refractometer was developed for use at the Kwajalein Missile Range. The instrument (Figure 3-4) can be used with up to 4 sensing cavities for fixed installations on the ground or for use in aircraft. It will be used to measure refractivity structure on the range. These data will provide corrections for atmospheric effects to improve the accuracy of radars used for tracking incoming vehicles to impact. The instrument is described in a report entitled "Operating Manual for Model 7 Microwave Refractometer" being prepared as an OT Technical Memorandum.

Experimental and Theoretical Assessment of Multipath Effects on QPSK. Recently there has been increasing interest in the use of many forms of phase modulation for transmission of digital information over high-data-rate links. One of the more important measures of performance of a high-data-rate digital system is the bit-error probability. A mathematical model has been developed for computing the bit-error probability for a channel where the received

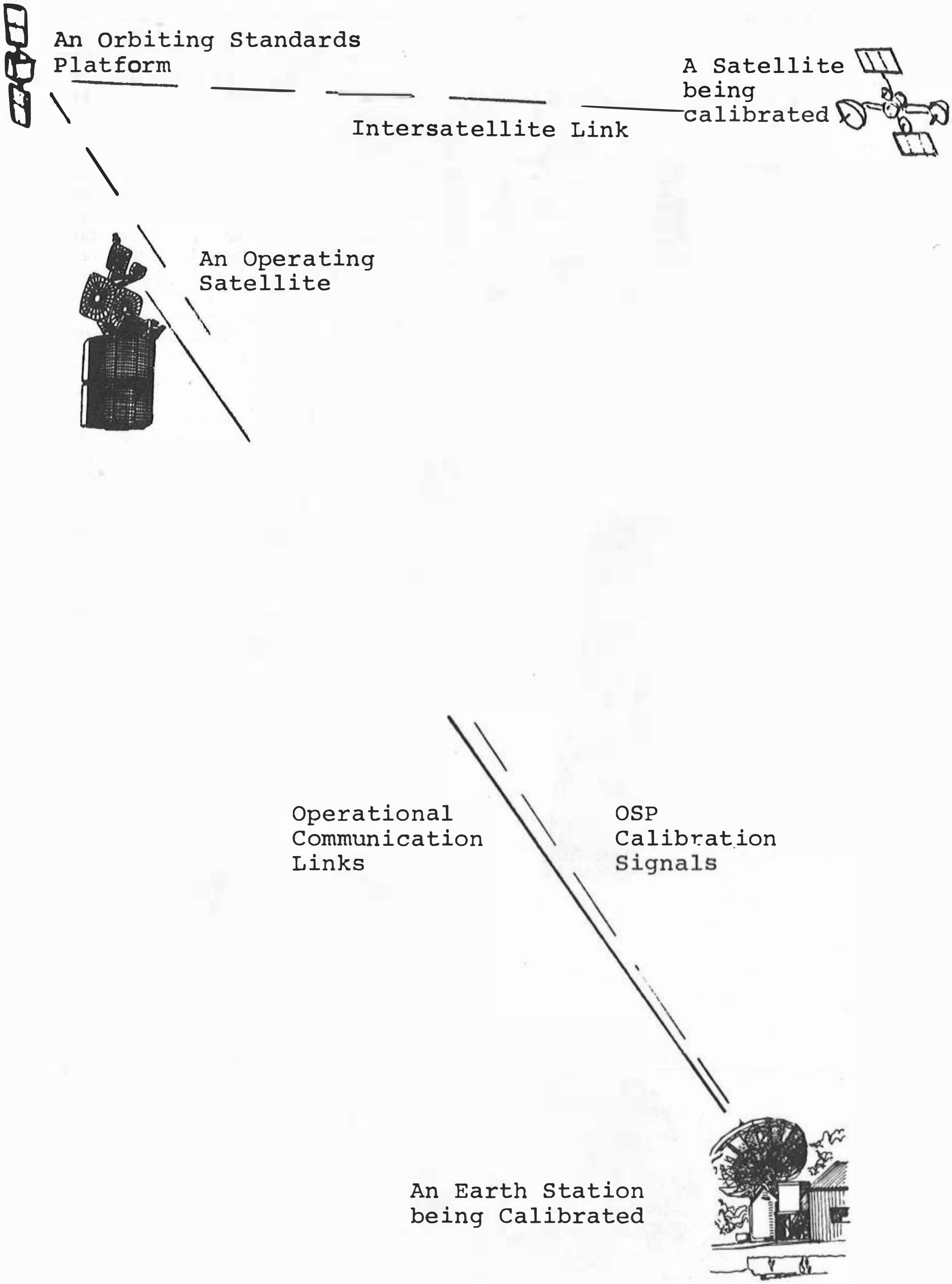


Figure 3-3. An orbiting standards platform for satellite/satellite and satellite/earth calibrations.

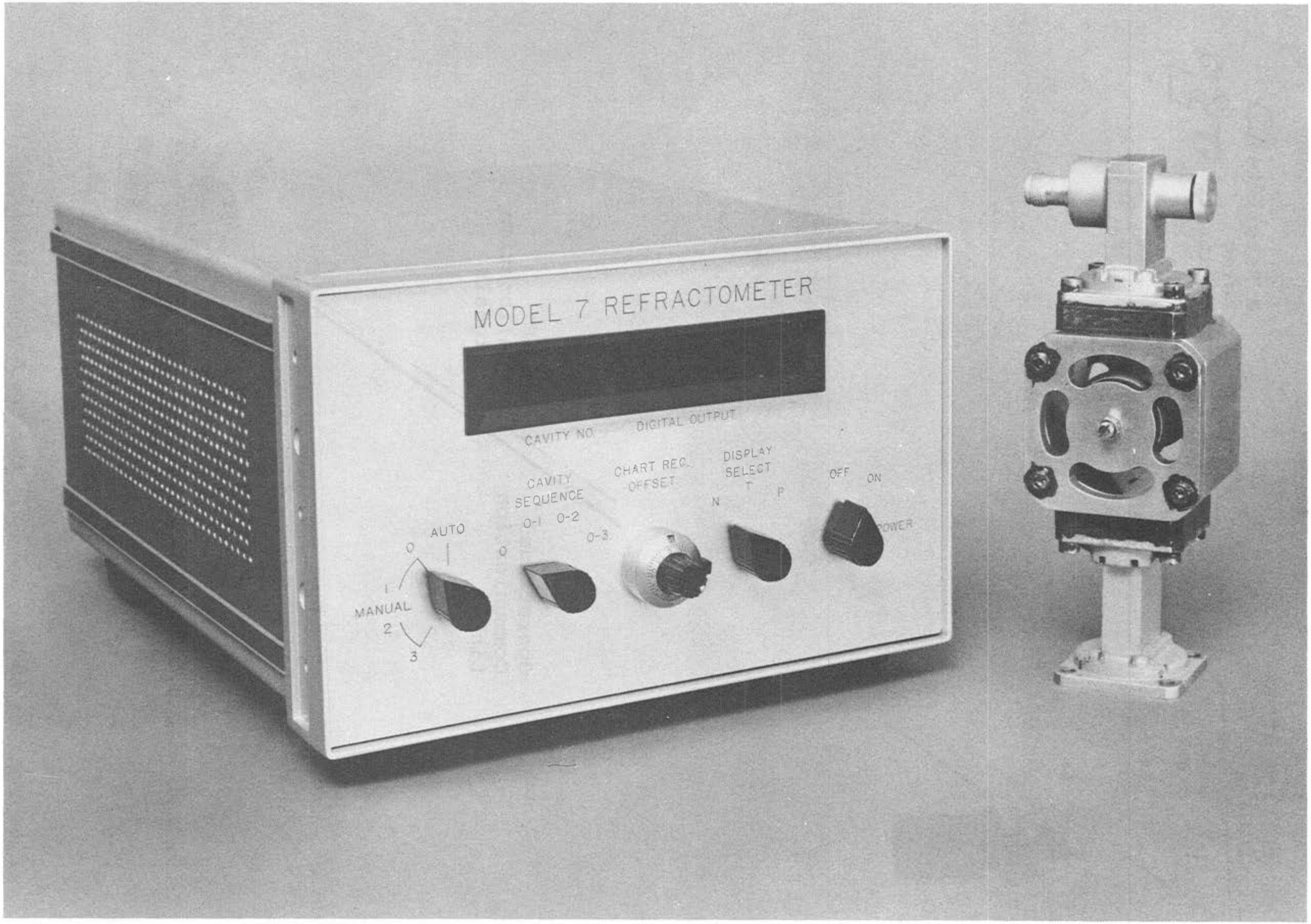


Figure 3-4. The ITS Model 7 microwave refractometer can sequentially sample up to 4 sensing cavities. It was designed for use at the Kwajalein Missile Range to improve the accuracy of tracking radars.

signal consists of the undistorted transmitted signal; a reflected, attenuated; and delayed replica of the transmitted signal and white Gaussian noise. The reflected ray overlaps in time with the direct ray (undistorted signal) and produces intersymbol interference.

The computed bit-error probabilities are compared with observed values from (1) a laboratory experiment in which the transmission is through coaxial cables using a carrier frequency of 1.5 GHz and the delay and attenuation are introduced with an adjustable delay line (line stretcher) and fixed attenuators, and (2) an outdoor 100 meter folded link using a carrier frequency of 30.3 GHz where the multipath is introduced with a second reflector in close proximity to the main reflector for folding the path. The data rate for each experiment was 1 Gb/s, QPSK modulation; however, after demodulation, these data are divided into two 500 mb/s streams and the errors are measured on each stream separately.

The experimental apparatus for the 1.5 GHz indoor multipath experiment used a line stretcher to give about a 50 cm range of continuously variable delay for the multipath signal. Additional 50 cm sections of co-ax cable were inserted in the reference branch to obtain a total range of delays out to 200 cm. The fixed attenuation in the interference branch was 7 dB greater than that in the primary or direct ray path. Wideband noise was added to the resultant signal to degrade it, so some nonzero (i.e., about 10^{-6}) errors occur when the interference branch was removed.

In Figure 3-5 we plot the observed and predicted bit-error probabilities versus normalized round-trip delay, 2d/cT, for two bit durations for the 1.5 GHz experiment. One interesting feature of Figure 3-5 is the relatively high P_e's during the entire 2nd bit interval, and the other noteworthy feature is the oscillatory behavior during the first bit interval. This quasi-periodic variation in P_e versus 2d/cT in the first bit interval is a consequence of the periodic variation in the effective signal-to-noise variation during the same period.

In Figure 3-6 we plot the observed and predicted bit-error probability versus normalized round-trip delay, 2d/cT, for the 30.3 GHz experiment. The experimental setup for the 30.3 GHz experiment consisted of a 200 m folded (100 m from transmitting and receiving antenna to reflector) path with a second corner reflector added to create the multipath. The echo area of the corner reflector was down about 7 dB from the echo area of the flat plate used to fold the path. This was the same ratio of direct ray to reflected ray as used in the 1.5 GHz experiment. The delay was varied by placing the corner reflector on an optical bench and moving it along the line of the path. In contrast to the 1.5 GHz experiment, the main source of errors in the 30.3 GHz experiment originated as phase noise at the rf mixer as a result of frequency multiplication. In Figure 3-6 we show the bit-error probability for a variance of phase noise of 0.15 rad^2 (rms phase variation of $\pm$ 22). Only the observed maxima in bit error probability in Figure 3-6 are presented for reasons of clarity; i.e., the rf variation shown for the calculated data also was present in the observed data.

In conclusion, it was encouraging to find how well the mathematical model predicted the bit-error probability both qualitatively and quantatively.

3.2.2. Ionospheric Characteristics and Effects

Reliable, computerized methods for predicting the communications coverage of low-frequency radio transmitters are being developed by the LF Coverage Prediction project. Standard engineering descriptors of the transmitter, antenna, and geographic area (or specific path) are required input. The output is the signal-to-noise ratio available a chosen percentage of the time.

There are two critical stages to the calculation. The first is the estimation of the antenna efficiency, given the antenna configuration. This is not a trivial problem because LF antennas are usually electrically short and located very near (in wavelengths) an imperfectly conducting medium--the ground. The product of the transmitter power and the antenna efficiency is the radiated power.

The second important stage of the calculation is the propagation or transmission loss computation. A full-wave theory which includes the proper combination of surface wave, sky wave, and diffraction is used in combination with with empirical sky-wave reflection coefficients.

Finally, standard numerical maps of the atmosphere noise competing with the signal are used to compute the signal-to-noise ratio.

Sophisticated computer programs used to predict the time availability of LF and VLF radio systems require a model of the lower ionosphere as input. This model should vary realistically with time and geographic location for accurate link evaluation. The project MEECN Transmission Models is developing such a model using individual measured profiles of electron density retrieved from the literature. The parameters of an exponential model of the ionosphere are derived from the data using multi-parameter statistical analysis. Propagation experience is used to constrain and validate the model.

Table 3-1 shows the final analytic form derived for a time-varying model of the lower

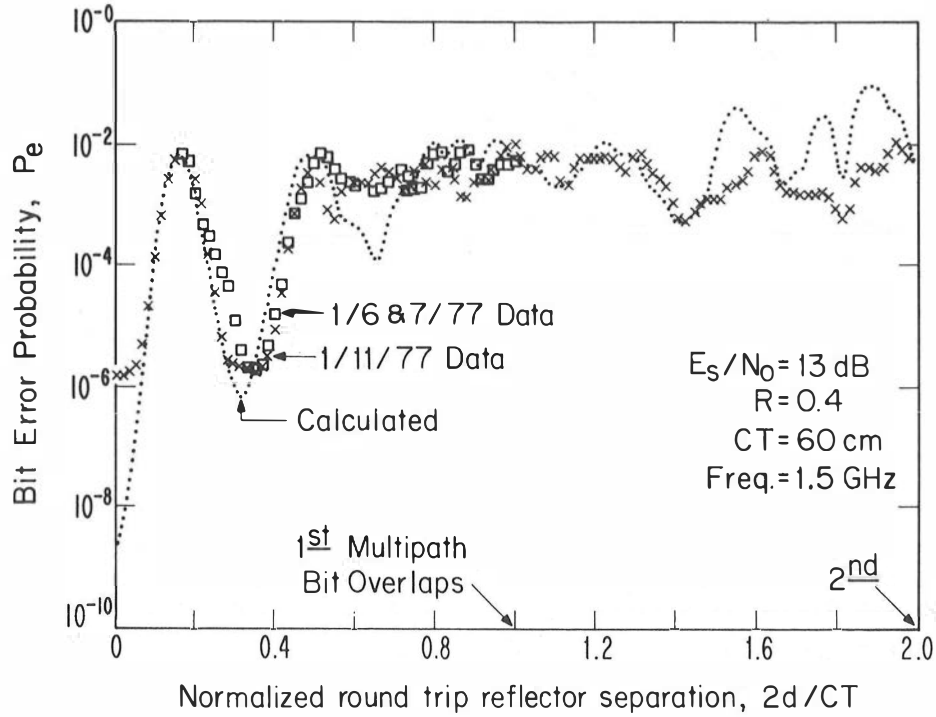


Figure 3-5. Observed and predicted bit-error probability versus round trip delay for 1.5 GHz indoor multipath experiment.

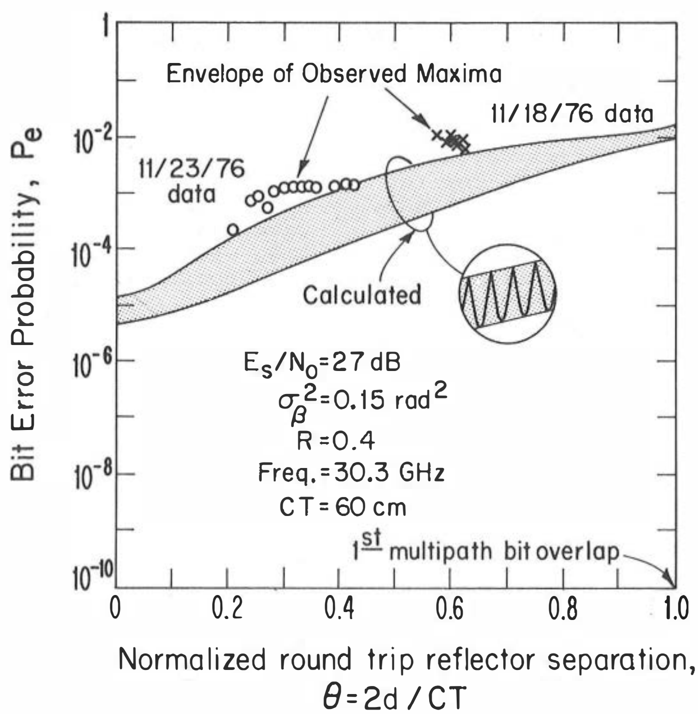


Figure 3-6. Observed and predicted bit-error probability versus round trip delay for 30.3 GHz outdoor multipath experiment.

Table 3-1. Ionospheric Model for Use with MEECN 20-6- kHz Circuits

$N(h) = N_o \exp(\alpha(h-h_w));$

where: $N(h)$ is the D-region electron density at height h(km);

$N_o = 1.43(10^7) \exp(-0.15\ h_w);$

$h_w = 74.4 - 8.1\ x_1 + 5.8\ x_2 - 1.2\ x_3 - 0.044\ x_4 - 6.0\ x_5;$

and

$\alpha = 0.385 - 0.166\ x_1 - 0.086\ x_3 + 0.13\ x_5;$

and

$x_1 = \cos(\chi)$, where χ is the sun's zenith angle;

$x_2 = \cos(\theta)$, where θ is the latitude;

$x_3 = \cos\phi$, where $\phi = \frac{m-0.5}{12}(2\pi)$, and m is the month number;

x_4 = the Zurich smoothed relative sunspot number;

$x_5 = 0$ for quiet conditions; $x_5 = 1$ for disturbed conditions.

Model is for all hours and all latitudes. Disturbed in χ_5 is defined as $K_p > 4$, riometer absorption > 0.5 db, or SID condition.

ionosphere for use in propagation calculation.

SECTION 3.3 DEVELOPMENT AND IMPLEMENTATION OF EM WAVE TRANSMISSION MODELS

Information about EM Wave Transmission Characteristics and the characteristics of the transmission media are incorporated into engineering models. These models are being developed for users within and outside government. As in section 3.2, we first discuss the non-ionized media cases, and then those primarily influenced by the ionosphere.

Propagation Models and Data Bases. Over the years, OT has developed many propagation models for a variety of telecommunication problems. This year, a project was initiated to provide the beginnings of a unified data base for propagation models to support a wide range of anticipated communication concept, design, and evaluation situations based on current and previous works. This will be the beginning of a data and techniques bank which will consolidate the results of telecommunication research into an overall data base, including both atmospheric structure from models and measurements, and algorithms for translating these into performance predictions for specific system applications.

The FY 77 beginning concentrated on the frequencies between 10 and 100 GHz. The various models and algorithms are intended to be upgraded as new and/or better information becomes available. In succeeding fiscal years, it is anticipated that a comprehensive library of information will exist which will cover frequencies from VLF through optical.

An example of what is presently available in the beginning catalogue is shown in Figure 3-7.

This information will be made available to other government agencies and the private sector upon their request. Over 30 computer programs and data bases under the following four categories now exist in the beginning catalog.

Category 1. Computations of Transmission Loss and Radar Returned Power.

Category 2. Computations of Desired/Undesired Signal.

Category 3. Computations of Atmospheric and Precipitation Parameters.

Category 4. Data Bases and Associated Programs.

3.3.1. Atmospheric Transmission Models

Atmospheric Characteristics and Digital Systems. Another significant impact of the atmosphere is the anomalous microwave propagation that can accompany strong stratification (layering), both aloft and near the surface. The potential for interference is then rather serious, but relatively straight forward formulas have been deduced to assess this potential (OT Report 76-107).

The year-to-year variability of rainfall has been determined for Europe. Figure 3-8 shows the contours of one-minute rainfall rate (in mm/hr) expected for 0.01% of an average year, $R_1(0.01\%)$. Figure 3-9 shows the contours of the expected year-to-year standard deviation of that rain rate, $S_1(0.01\%)$. Note, that there are locations for which $S_1(0.01\%)$ approaches 1/3 of the $R_1(0.01\%)$ value.

U. S. Rainfall Data on Terrestrial Links. Application of rainfall predictions to both terrestrial point-to-point and earth/satellite systems continued as a priority consideration (OT Report 77-123). In a climatological study for the United States, this project developed a procedure for delineating rainfall zones by means of parameters that have telecommunications impact but are derivable from historical climatological data. Figure 3-10 shows a zonal map of the United States that was developed on this basis.

Progress in determining the year-to-year variability of rainfall has finally achieved the circumstances whereby a comparison of observed and predicted rainfall (or its attenuation of microwaves) is meaningful. Figure 3-11 shows a comparison of predicted 30 GHz attenuation due to rain (via the Dutton-Dougherty Model for an earth terminal at Asheville, North Carolina) with observations of ATS-6 satellite data (reported by NASA at Rosman, North Carolina). Asheville is approximately 35 miles from Rosman.

In the Propagation Development project, an important couple of steps were taken. These were the writing of two computer programs which are designed to help the frequency manager or the systems designer in computing the effects of radio propagation. The first is an "area prediction" model which is useful in treating broadcast and mobile systems and in general discussions of the interaction between different types of systems. It embodies the latest version (the so-called Version 1.2) of the Longley-Rice model of radio propagation and provides complete statistical analyses.

The second program is a "pointwise" model and assumes that the two terminals and the terrain between them are known to the user or that enough information is supplied to allow reconstruction of the terrain profile from files of topographic data. At present the program is really only a skeleton, which will soon be fleshed out. When it is, it should be useful for frequencies from 20 MHz to 200 GHz and for antenna

Title: DEGP 76

Computes: Distribution of annual attenuation due to rain, clouds, atmospheric gases.

PHIRAP = partial phase delay due to rain only to height H, in radians

REVTAUP = partial atmospheric attenuation to height H, in decibels

ETADB = reflectivity in DB relative to 1 KM(-1) at height H

PHIRA = total link phase delay due to rain, oxygen and water vapor dispersion, in radians.

REVTAU = total atmospheric attenuation on link, in decibels.

Input:

NS = number of data stations.

NF = number of frequencies desired.

IF NCLD = O, the program performs computations with a built-in nonprecipitating cloud distribution (subroutine cldbank). If NCLD not = O, a cloud attenuation distribution must be provided as subroutine CLDDIS.

NA = number of elevation angles desired.

NH = number of heights desired. If it is not = 2, get attenuation coefficient at surface only. Otherwise, do the whole program as usual.

F = frequency in GHz.

STAT = station identification, not to exceed 40 letters and numbers in length.

P = station average annual pressure in millibars.

T = station average annual temperature in degrees centigrade.

RH = station average annual relative humidity as a decimal fraction.

BETA = ratio of thunderstorm rain to non thunderstorm rain, see RICE, P.L. and N.R. Holmberg (1973), cumulative time statistics of surface point-rainfall rates, trans. IEEE com. soc, 10, Oct.

R = rainfall rate in MM/HR, corresponding to a give percent of an average year (RELI).

HTOP = cloud top height in kilometers corresponding to a given percent of an average year (RELI).

RELI (CURRENTLY IN DATA STATEMENT) = percent of an average year of interest (time availability per year).

THETA = elevation angle of earth station antenna, in degrees

H = height above surface in kilometers.

Limitations: Not valid for satellite/earth trojectaries where the elevation angle to the satellite is less than 5°

Current Status: Does not yield smooth output; i.e, the output distribution is not smooth, and should also be graphically displayed, to be of maximum usability.

References: Dutton, E. J., Earth-Space Attenuation Prediction Procedures at 4 to 16 GHz (soon to be OTR)

For more information contact: E. J. Dutton

Figure 3-7. Sample information page from catalogue.

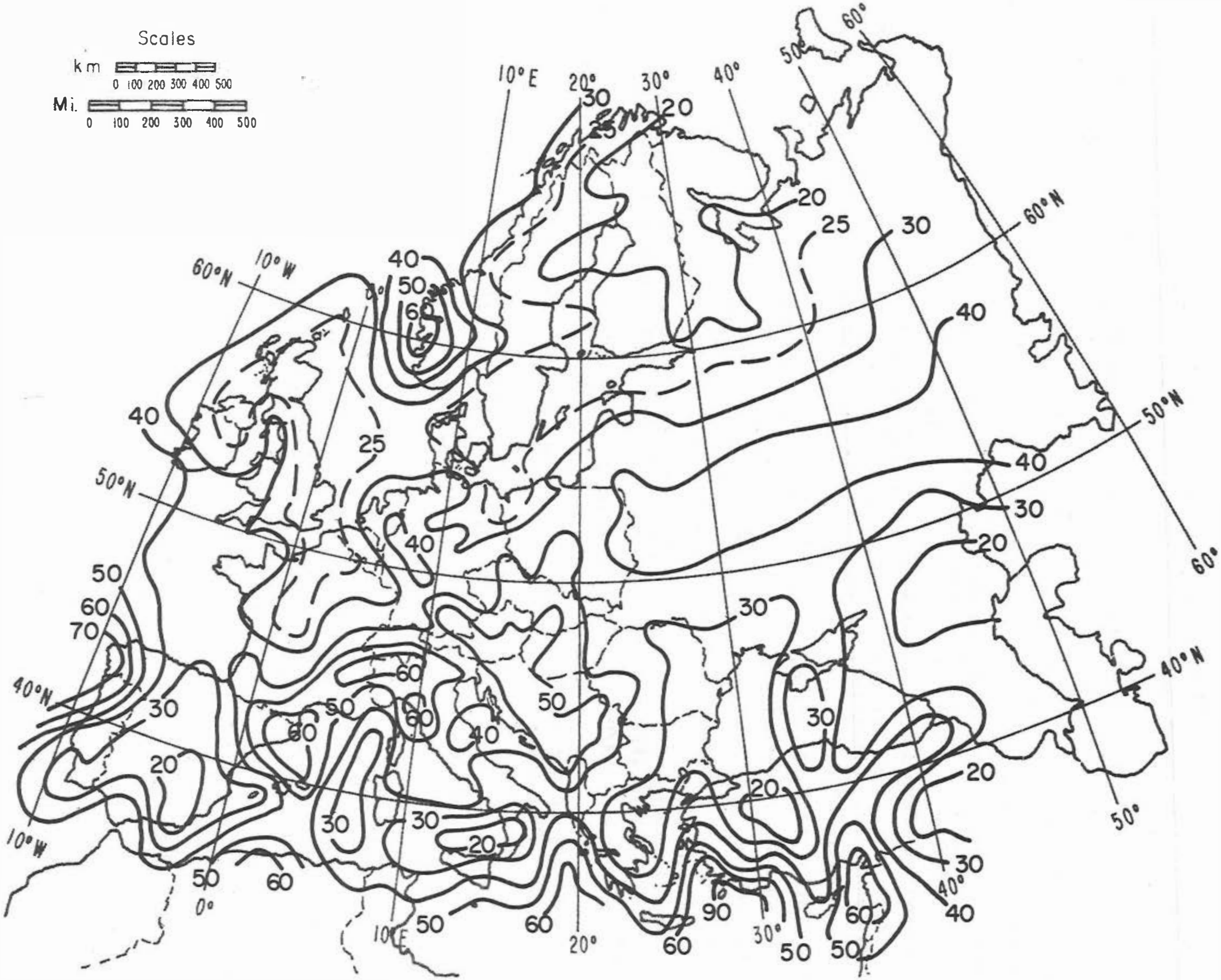


Figure 3-8. Rainfall rate in mm/hr. expected for 0.01% of an average year in Europe.

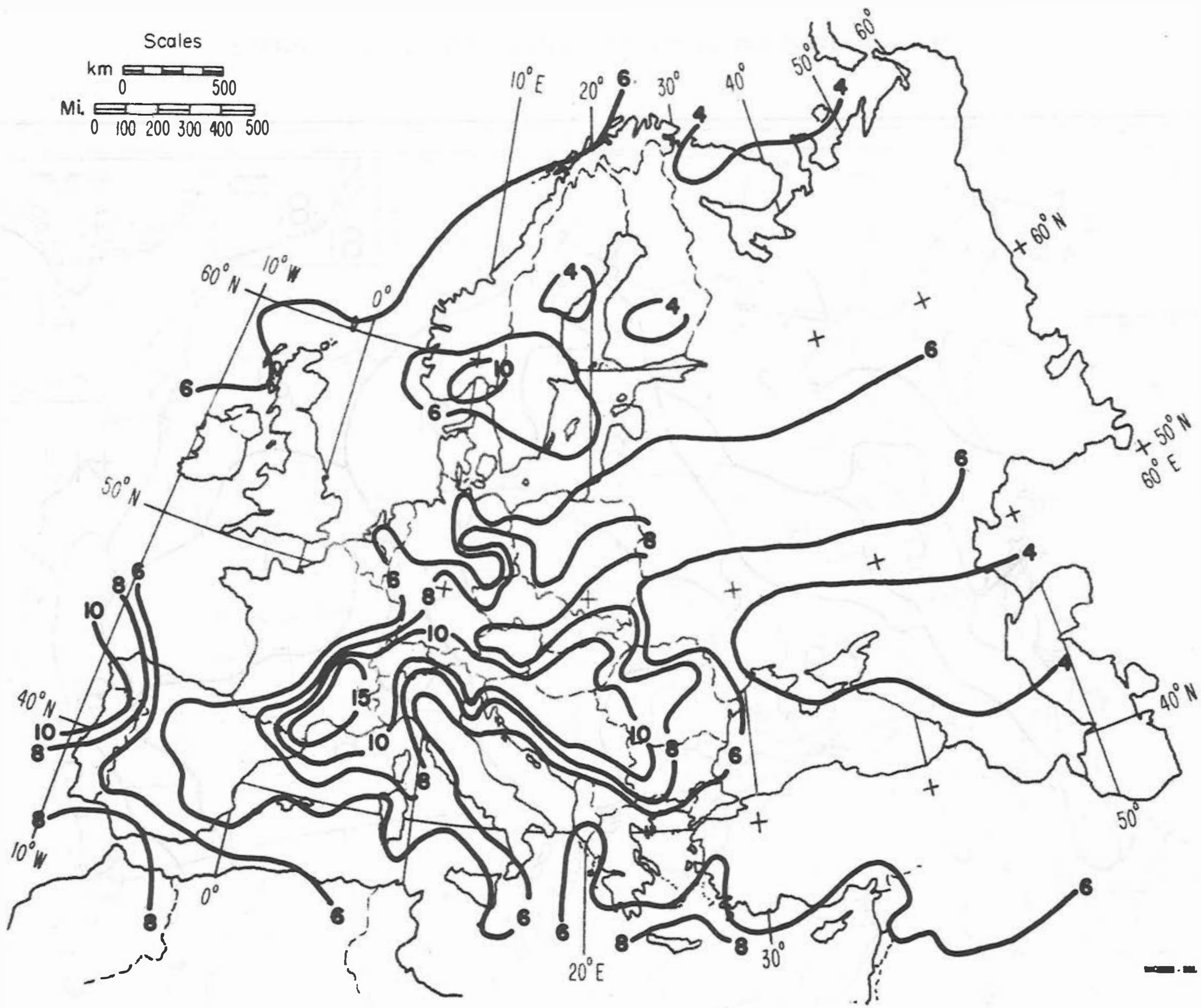


Figure 3-9. Standard deviation of the year-to-year variation in rainfall, in mm/hr., for Europe.

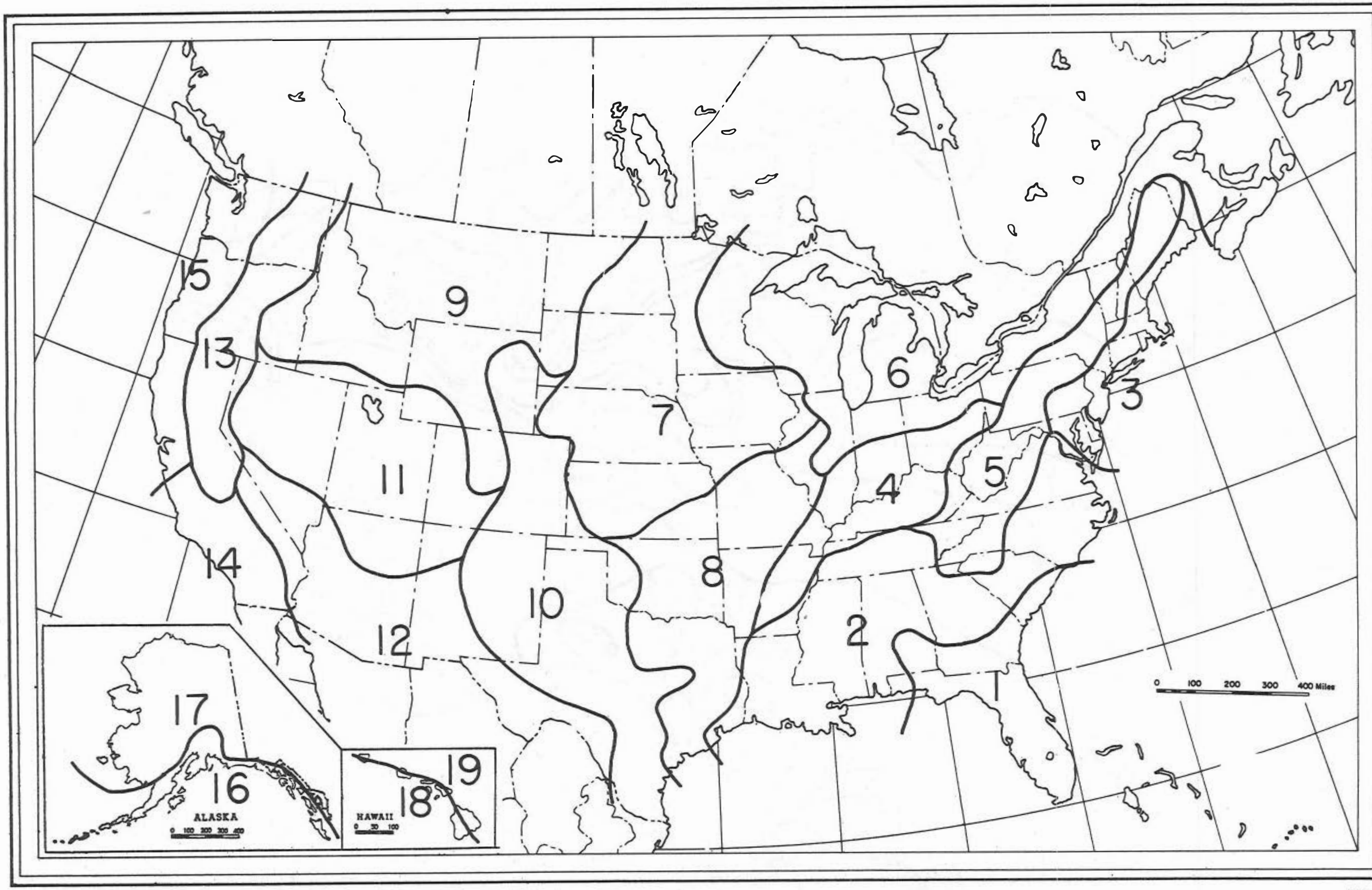


Figure 3-10. Rainfall climatic zones of the United States.

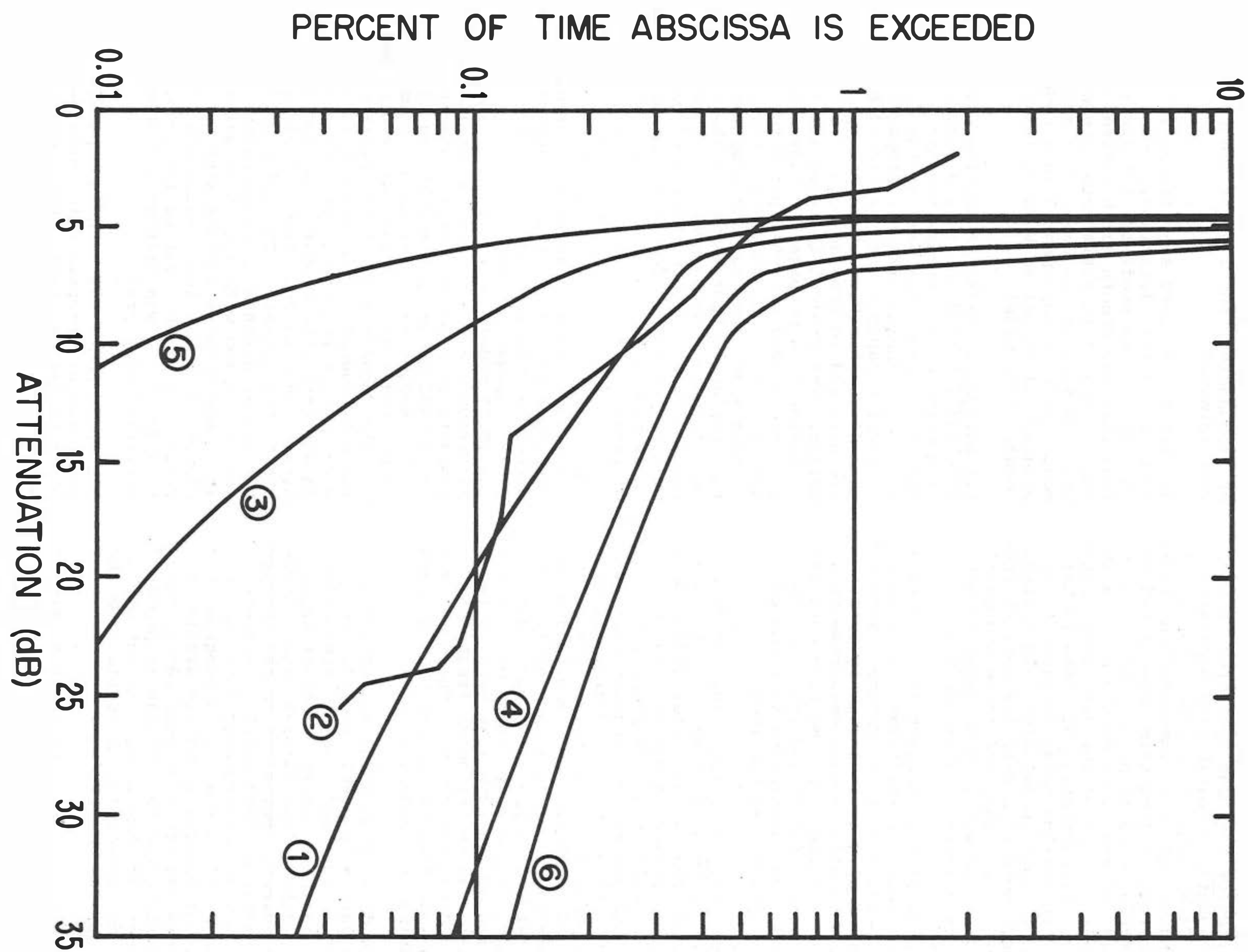


Figure 3-11. Comparison of attenuation due to rainfall predictions and observations. Curve 1 is the slant-path attenuation prediction for an average year. Curve 2 is observed attenuation. Curves 3 and 4 and curves 5 and 6 are the expected year-to-year variation for respectively 90% and 95% of the years.

heights from 1 m above ground to about the orbit of the moon.

The first phase of a study of Power Fading Statistics has been sponsored by the Electromagnetic Compatibility Analysis Center, Department of Defense. In the engineering design of a communications link, the magnitude of long-term (power) fading is estimated using techniques that are ten years old and that were developed from an empirical analysis of the data then available. The extrapolation of these techniques to the systems being designed today is often of dubious validity. In particular, there were then very few data at frequencies above 1 GHz, and those who must design links or worry about interference at SHF are working on shaky ground.

The purpose of this project is to rectify the situation. In the first phase, this year, we have made a literature search and have turned up what is certainly an adequate sample of long-term measurements at the higher frequencies. We have outlined an approach to filing and analyzing those data, and have recommended that the project be continued as outlined.

Path Loss Model Revision. This project, sponsored by the U.S. Army Security Agency Test and Evaluation Center (USASATEC), revised and updated a USASATEC computer model for radio frequency propagation loss at VHF and higher frequencies. Development of the original model, called Program LOSS, also was done at OT/ITS and documented in OT Technical Memorandum 104, September 1972. Program LOSS applied the Longley-Rice area prediction propagation loss model in the computation of estimated statistics of the path loss between two radio antennas operating at frequencies between 20 MHz and 20 GHz. The model was written specifically for the CDC 3000 and 6000 series of computers.

Revision of Program LOSS, accomplished under the current project, provides the propagation loss model as an interactive program featuring question/answer input dialog, editing capabilities, and CALCOMP plotted output. Revisions to the Longley-Rice propagation loss model subsequent to 1972 also were incorporated into the revised LOSS model, now called Program RLOSS. Versions of Program RLOSS are available for PDP-10 and CDC 6000 computer systems. Documentation for the program is provided in a report to the sponsor, as yet unpublished, but informally available from the sponsor or the OT/ITS.

One project, sponsored by the U.S. Army Electronics Command, led to an Improved Longley-Rice Model. The Longley-Rice model of radio propagation is the "area prediction" model used in several of the spectrum engineering tasks of Chapter 1, when it is necessary to analyze broadcast and mobile systems in the range 20 MHz to 20 GHz. It was originally developed and tested for rather low antennas in irregular terrain. Later tests against data showed poor agreement when higher antennas, higher frequencies, and line-of-sight conditions were involved.

We have now devised specific modifications to overcome this deficiency. They affect only the values predicted for distances less than the smooth earth horizon and seem to result in satisfactory agreement with the data we now have. The modified model has been implemented in a computer program and is called Version 1.2 of the Longley-Rice model.

Air Navigation Aids. A knowledge of service and interference ranges associated with existing and future air navigation aids is an important part of the FAA's spectrum planning effort. Propagation prediction capabilities developed by OT as part of the Air Navigation Aids project are utilized to provide much of this information. The project includes the (1) development of a propagation model applicable to systems used or anticipated for VHF/UHF/-SHF air navigation aids, (2) incorporation of this model into various computer programs that produce output useful in the development frequency management procedures, (3) production of computer generated propagation or interference predictions for the FAA on an as-requested basis, and (4) comparison of predictions with experimental data.

During 1971-1973, an air/ground propagation model applicable to irregular terrain was developed by ITS for the FAA and was documented in detail. This IF-73 (ITS-FAA-1973) propagation model has evolved into the IF-77 model, which is applicable to air/ground, air/air, ground/satellite, and air/satellite paths. It can also be used for ground/ground paths that are line-of-sight, smooth earth, or have a common horizon. Model applications are restricted to telecommunication links operating at radio frequencies from about 0.1 to 20 GHz with antenna heights greater than 0.5 m. In addition, the elevation of the radio horizon must be less than the elevation of the higher antenna. The radio horizon for the higher antenna is taken either as a common horizon with the lower antenna or as a smooth earth horizon with the same elevation as the lower antenna's effective reflecting plane. During 1977, documentation for IF-77 was written and should be published next year.

The IF-77 model has been incorporated into ten computer programs which provide 28 plotting capabilities. Each program causes the computer to produce (1) listings of parameters associated with particular runs and (2) microfilm plots. A guide to the plotting capabilities of these programs is provided in Table 3-2. An "Applications Guide" covering these capabilities was written during 1977 and should be published

Table 3-2. Plotting Capability Guide for IF-77 Programs

Capability	Remarks*
Lobing**	Transmission loss versus path distance.
Reflection coefficient**	Effective specular reflection coefficient versus path distance.
Path length difference**	Difference in direct and reflected ray lengths versus path distance.
Time lag**	Same as above with path length difference expressed as time delay.
Lobing frequency-D**	Normalized distance lobing frequency versus path distance.
Lobing frequency-H**	Normalized height lobing frequency versus path distance.
Reflection point**	Distance to reflection point versus path distance.
Elevation angle**	Direct ray elevation angle versus path distance.
Elevation angle difference**	Angle by which the direct ray exceeds the reflected ray versus path distance.
Spectral plot**	Amplitude versus frequency response curves for various path distances.
Power available	Power available at receiving antenna versus path distance or central angle for time availabilities 5, 50, & 95%.
Power density	Similar to above, but with power density ordinate.
Transmission loss	Similar to above, but with transmission loss ordinate.
Power available curves	Several power available curves versus distance for a selected time availability and a fixed lower antenna height.
Power density curves	Similar to above, but with power density as ordinate.
Transmission loss curves	Similar to above, but with transmission loss as ordinate.
Power available volume	Fixed power available contours in the altitude versus distance plane for time availabilities of 5, 50, & 95%.
Power density volume	Similar to above, but with fixed power density contours.
Transmission loss volume	Similar to above, but with fixed transmission loss contours.
EIRP contours	Contours for several EIRP levels needed to meet a particular power density requirement are shown in the altitude versus distance plane for a single time availability.
Power available contours	Similar to above, but with power available contours for a single EIRPG.
Power density contours	Similar to above, but with power density contours.
Transmission loss contours	Similar to above, but with transmission loss contours.
Signal ratio-S	Desired-to-undesired, D/U, signal ratio versus station separation for a fixed desired facility-to-receiver distance, and time availabilities of 5, 50, & 95%.
Signal ratio-DD	Similar to above, but abscissa is desired facility-to-receiver distance and the station separation is fixed.
Orientation	Undesired station antenna orientation with respect to the desired-to-undesired station line versus required facility separation curves are plotted for several desired station antenna orientations.
Service volume	Fixed D/U contours are shown in the altitude versus distance plane for a fixed station separation and time availabilities of 5, 50, and 95%.
Signal ratio contours	Contours for several D/U values are shown in the altitude versus distance plane for a fixed station separation and time availability.

* Additional discussion, by capability, will be provided in the "Applications Guide," which should be published in 1978.

** Applicable only to the line-of-sight region for spherical earth geometry. Variability with time and horizon effects are neglected.

next year. It contains (1) information on input parameter requirements, (2) sample output graphs for each capability, (3) sample application problems to illustrate graph usage, and (4) information needed by potential users to request program runs from OT/ITS.

Radio Channel Capacity Limitation. There is considerable interest and an increasing need for digital data transmission over military tactical networks. As the demand for higher and higher data rates increases and communications technology advances, the factors which limit this rate tend to shift from technological areas to the fundamental physical limitations inherent in the transmission medium itself.

During FY 77, ITS prepared a report describing the constraints and, where data were available, the limits imposed on channel capacity by unpredictable signal distortion in the propagation channel. To compile the report, ITS conducted a literature search, compiled pertiment data, and consulted with telecommunications engineers. The factors limiting the capacity of radio channels are summarized in Table 3-3, taken from an OT report in the process of being published.

Emphasis in the report is on physical limitations pertinent to digital systems operating in the microwave region of the spectrum. Particular emphasis is placed on links between land-mobile units and base station terminals operating in urban and suburban environments.

The objective of the report is to determine the maximum data rates that can be achieved with practical systems utilizing their radio channel and to present these in a convenient form. (See Figure 3-12.)

The ultimate goal of the report is to relate radio channel characteristics to the maximum data rate achievable in that channel and to compare these results with an idealized system operating over an undistorted channel against additive noise.

This evaluation and comparison is accomplished by presenting the idealized case first. Then the channel characteristics are defined in terms of the channel's effect on the signal, the propagation mechanisms involved in specific links and their response, the response relationship to coherent bandwidth, the coherent bandwidth's effect on signaling rate, the signal power requirements as a function of signaling rate, and the maximum data rates achieved with undistorted signaling rates. Estimates of the maximum rates which can be obtained over various types of links are illustrated and compared with some wideband tactical networks using FM carriers.

3.3.2. Ionospheric Transmission Models

Computer programs developed by ITS for predicting ionospheric transmission and the performance of HF radio systems are used by government agencies and commercial firms in the U.S. and other nations. A continuous program is carried on to upgrade and expand predictions services to fit users needs.

Normal day-to-day and hour-to-hour departures of critical frequencies (foF2) and other ionospheric characteristics from observed median values have a significant effect upon the range of useful frequencies on HF communication circuits. Even greater effects result from disturbances in the earth's magnetic field and from certain forms of activity on the sun. During this fiscal year, a survey of papers and other work addressed to this problem has been carried on through the CEEIA Short Term MUF Predictions Project. Emphasis has been placed on studies into and methods developed for predicting these short term variations, in an effort to produce near real-time corrections in long term predictions of ionospheric communication circuit parameters, specifically usable frequencies.

Three systems developed for the purpose of providing near real time evaluation and predictions have been studied in some detail. The systems were developed, respectively, by ITS, the U.S. Air Force Global Weather Central (AFGWC), and the Naval Ocean Systems Center (NOSC), formerly the Naval Electronics Laboratory Center. Of these systems, only the AFGWC system is operational at the present time; the ITS system has been, for the most part, deactivated because of lack of requirement; the NOSC system has undergone operational testing and is being evaluated -- however, in its present form (due to equipment limitation) it is not readily accessible by other users.

The project goal is to present to USA/CEEIA this fiscal year an evaluation of various systems, describing advantages and disadvantages of each, and to suggest a system to be adapted to CEEIAs requirements. Such a system is likely to be one of these three, or a combination of certain parts of all three systems.

Development and Improvement of Prediction Formats. The USIA/VOA in maintaining and improving its worldwide broadcast schedules on high frequencies, requires predictions of its expected broadcast coverage well in advance to prepare for its broadcast schedules.

To assist in the preparation of schedules, and expecially to assist in the coordination of these schedules with other high-frequency broadcast operations, a special

Table 3-3. Factors Limiting Capacity of Radio Channels

- Technological Constraints
  - Hardware
    - Instabilities
    - Non-Linearities
    - Availability
  - Economic
    - Complexity
    - Siting
    - User's Requirements
  - Regulatory
    - Power Emissions
    - Bandwidth Allocations
    - Frequency Assignments
- Physical Limitations
  - Bandwidth
  - Noise
    - Additive
    - Multiplicative

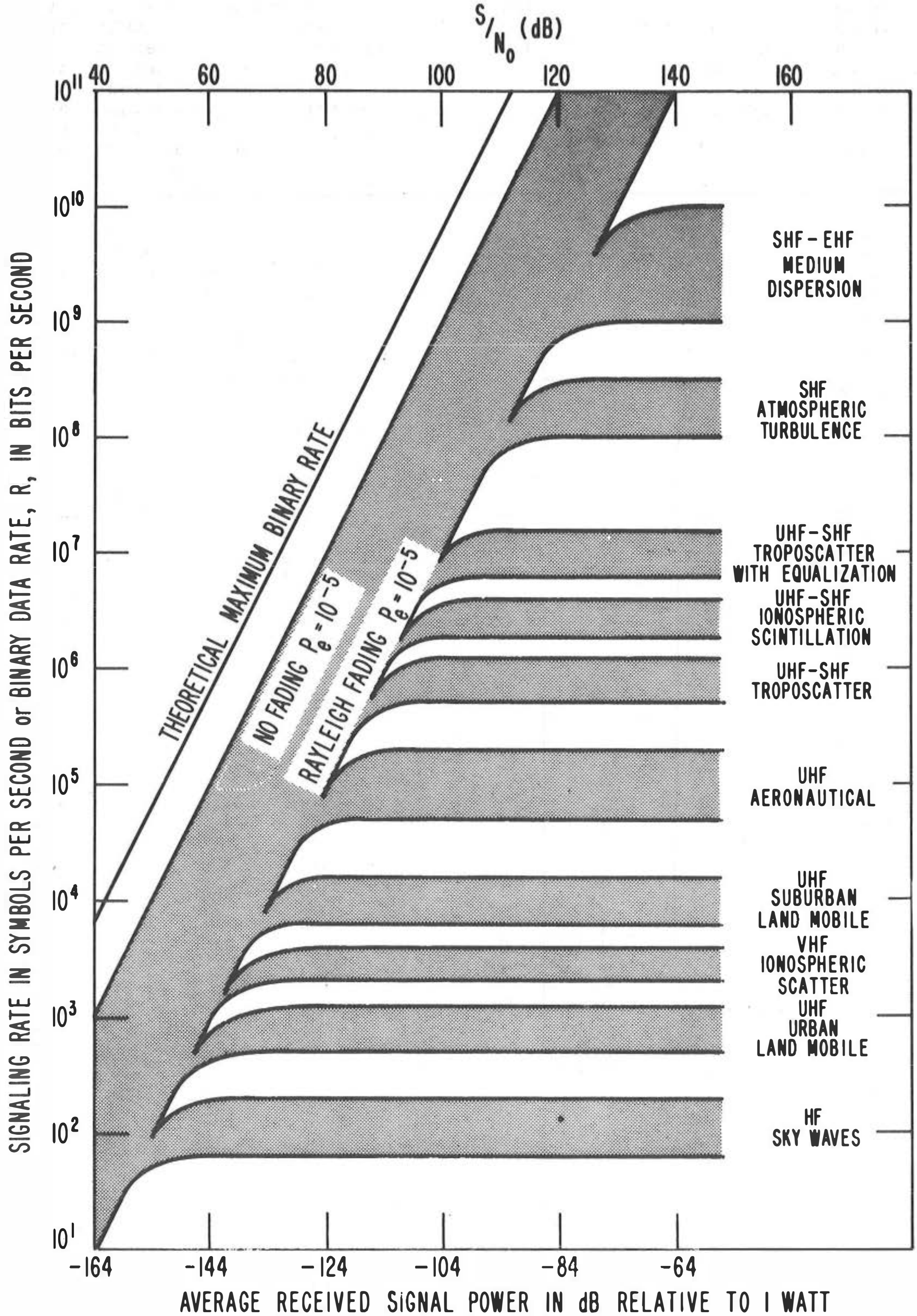


Figure 3-12. Rate limits on some binary links and channels.

effort was made in FY 1977 to consolidate the normal circuit predictions so schedule preparation would be simplified. Figure 3-13 is an example of a consolidation of regular prediction material to illustrate the variation of broadcast coverage as a function of time-of-day and distance from the transmitter.

Selection of Signal-to-Interference Ratio. For the coordination process, the required signal relative to interference plus noise was considered in an effort to improve the prediction of times, frequencies, locations, etc., which would theoretically permit compatible high-frequency broadcast operations. It is tentatively concluded that the required signal relative to the combined noise and interference is a function of the available signal relative to the noise. Table 3-4 shows this relationship.

3.3.3. Terrain Models

Propagation Over Irregular Terrain. A computer algorithm was written which maps irregular terrain from input elevations versus distance and uses this data to compute basic transmission loss for radio frequencies less than about 50 MHz. For path loss predictions at higher frequencies in the VHF band up to 20 GHz see Chapter 1, Section 1.1. The input elevations versus distance can be obtained from U.S. Geological Survey Maps. The signal at the receiver shown in Figure 3-14 is affected by the mean curvature of the earth, height profile along the path, change in ground constants along the path, height of the transmitter and receiver above ground, and transmitter frequency and polarization. Earlier versions of the algorithm have been used to evaluate possible transmitter antenna sites by commercial companies (e.g., Boeing, General Electric, Collins Radio, GTE Sylvania), research laboratories (e.g., Lawrence Livermore Labs, University of Arizona), DoD (e.g., SAMSO, ECAC, NRL, ONR, Ft.Huachua), and foreign laboratories (e.g., Royal Radar Establishment). The algorithm is to be delivered by U.S. Study Group 5 of C.C.I.R. in September 1977, Geneva, Switzerland for international use in path loss predictions. In FY 77 and FY 78, predicted results for basic transmission loss will be compared with measurements of transmission loss for VHF TV stations transmitting horizontal polarization and "proof of performance" curves from HF AM radio stations transmitting vertical polarizations.

The aim of the Automated Digital Topographic Data Techniques project is to design an improved digital terrain elevation data base and related software to be used by USACEEIA in carrying out its worldwide responsibility for planning and installing Army line-of-sight and troposcatter communication systems. Computer models for predicting the performance of such systems require information derived from terrain profiles along a large number of potential propagation paths between transmitter and receiver locations. There consequently exists a need for rapid and accurate means of automatically generating these profiles, utilizing digital elevation data stored on magnetic tapes or disks. To better satisfy this need, ITS is developing a digital terrain data base that:

(1) provides significantly greater detail than can be obtained from the one currently being used by the sponsor;

(2) can expand toward global coverage as additional data become available;

(3) can be generated in a reasonably efficient way from existing and projected sources of raw data;

(4) can be utilized in an acceptably fast and efficient manner for terrain profile generation and other telecommunications applications; and

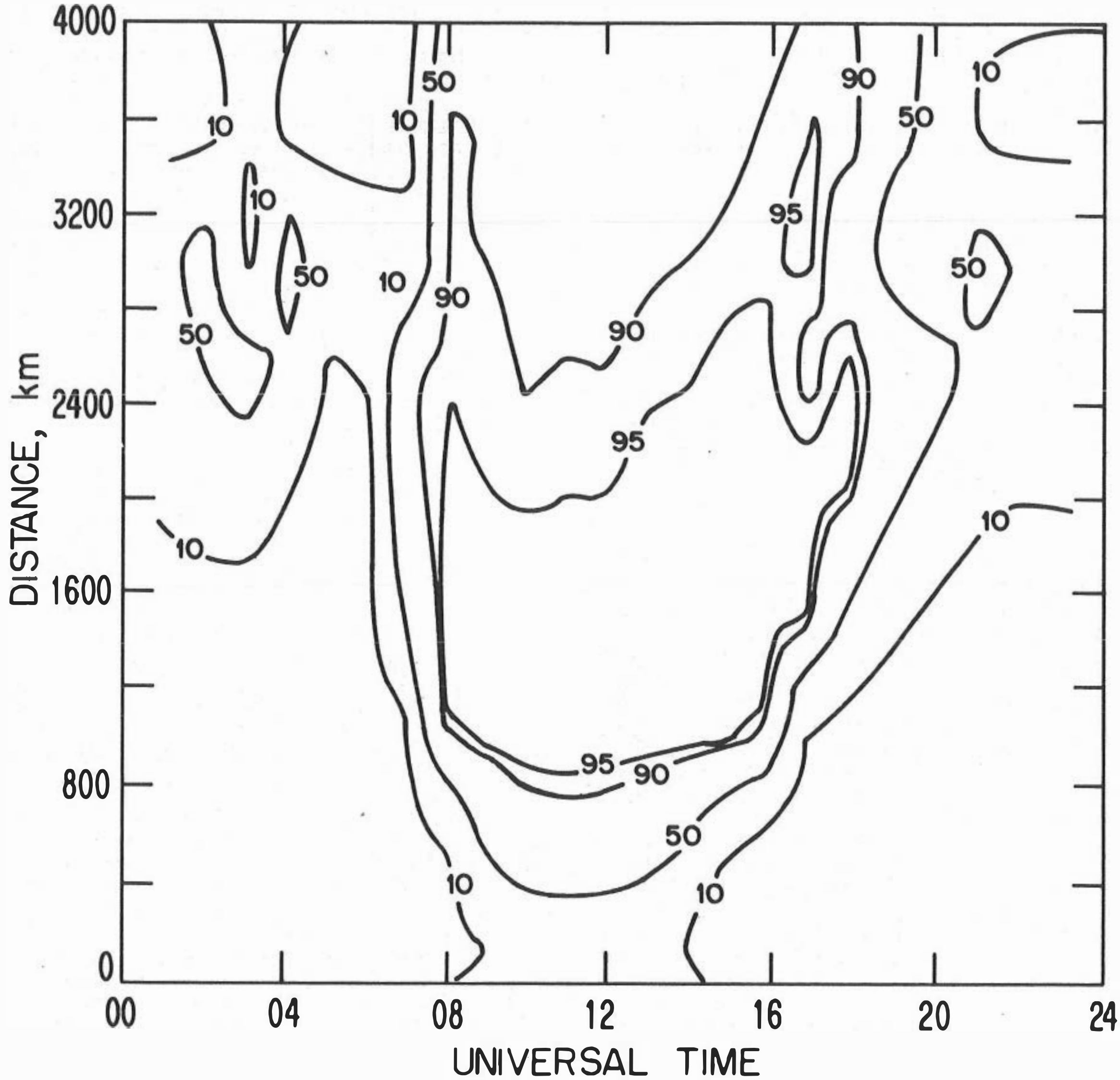
(5) minimizes storage space requirements (subject to the constraints imposed by conditions (1) and (4) above).

After a preliminary study of several alterative types of data bases, it was concluded that the conditions listed above are best satisfied by one consisting of elevations at a regular latitude-longitude grid whose basic interval is 3 seconds. The primary source of raw data for the present and near-term will be the so-called Standard Digital Terrain Elevation Data File being produced by the Defense Mapping Agency (DMA).

The detailed structure of the various (logical) records that will comprise the data base (TOPOG), and the manner in which these records will be organized into a hierarchy of data structures, has been worked out. Effort is now being concentrated on (1) developing computer software for generating TOPOG records and files from DMA Standard Files and (2) devising a basic retrieval subprogram which, when given the latitude and longitude of an arbitrary point on the earth's surface, utilizes TOPOG files to return either the elevation of that point or a message indicating that the requisite data is not contained in TOPOG. These tasks will extend into FY 78.

SECTION 3.4. PREDICTION OF TRANSMISSION PARAMETERS AND SYSTEM PERFORMANCE

Completed enginnering models for EM wave transmission calculations are delivered to sponsoring and requesting agencies for their use. Following are representative uses of these services.



PERCENT OF RELIABILITY

DECEMBER 1977, SSN = 49 FREQUENCY = 9.00 MHz
MUNICH, GERMANY 48.10N 11.60E AZIMUTH 270 DEGREES

Figure 3-13. Sample chart showing the variation of high-frequency broadcast coverage as a function of distance and time.

Table 3-4. An Estimate of the Required Hourly Median Signal Levels Relative to Noise Plus Interference as a Function of Available Signal-to-Noise Ratios in the High-Frequency Broadcast Service

S/N*	S/I*	S/(N+I)*	S/(N+I)**	$S/(N+I)^{**}_{o}$
18 dB	30.0	18.0	28.0	67.0
20	11.0	10.0	20.0	59.0
22	8.0	7.5	17.5	56.5
24	7.0	7.0	17.0	56.0
26	6.5	6.5	16.5	55.5
28	6.0	6.0	15.5	54.5
30	5.5	5.5	15.0	54.0
32	5.0	5.0	15.0	54.0
34	5.0	5.0	15.0	54.0
36	5.0	5.0	15.0	54.0

*Steady state signals

**Rayleigh fading signals

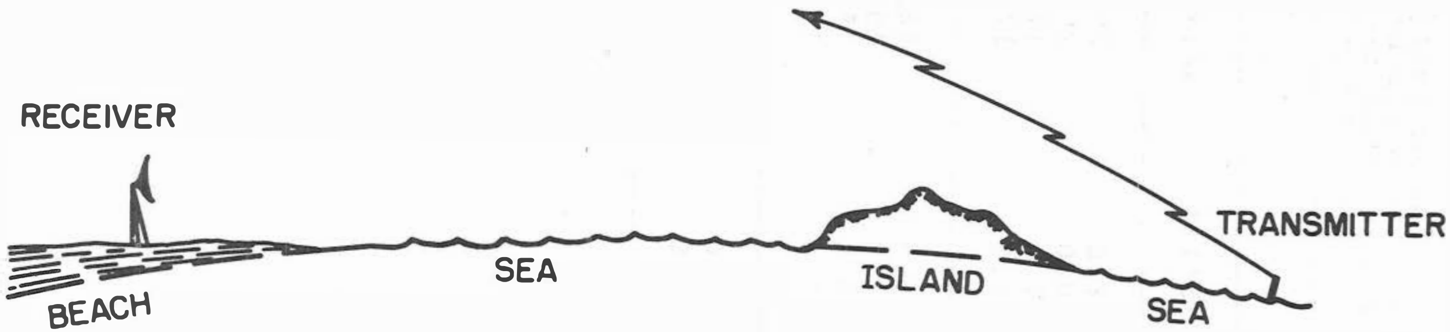


Figure 3-14. A possible propagation path.

3.4.1 Long-Term Ionospheric Predictions

The USIA/VOA requires regular predictions of "circuit" performance as an aid in planning appropriately for the continuation of its world-wide HF broadcasts.

The Radio Propagation Predictions project was established to provide the VOA with the following HF performance predictions: (1) for about 150 broadcast circuits at least eight months in advance for alternate months; (2) for 30 selected VOA circuits, one month in advance, for each month; and (3) for the same months as in (1), above, for circuits from Tinang, Kavala, Greenville, and Wooferton that make a selection of the optimum antenna.

Files have been maintained for local batch processing and for use by means of a remote Telex terminal.

Predictions have been delivered on schedule, and VOA continues to make occasional use of the remote access feature.

For the next fiscal year, changes in the predictions are to be made so that some of the circuits covered by (1) above, specifically, those for Monrovia, Munich, and Tangier, will be treated as in (3) so that the optimum antenna will be chosen. The programming required for making this conversion has been done under this project, in part, and under the Consultative and Advisory Services project.

In addition to the VOA, there are other government agencies and industrial organizations requiring Numerical Prediction Services. This project provides numerical coefficients, HF radio propagation predictions, computer programs, and other materials (e.g., maps and reports) as requested on a cost reimbursable basis.

ITS provided monthly prediction numerical coefficients for foF2 and M(3000)F2 to approximately 12 yearly subscribers. HF radio propagation predictions were provided routinely to ITT World Communications, Associated Press, Voice of the Gospel, NOAA/-SEL, and the American Radio Relay League (for publication in QST). In addition, predictions were made for EXXON Corporation; FAA (Anchorage); Fairchild Space and Defense Systems; Hy-Gain Electronics Corporation; Marcom Systems; McPhee Consulting Engineers; NOAA/NOS; ITS, Divison 1 (for the Coast Guard); Radio Nederlands; Page Communications Engineers; Singer Products; Sunair Electronics; Techno Gener, Ltd. (Iran); and TRW. A listing of the atmospheric noise coefficients was prepared for Dr. Picquenard of Brazil. The HFMUFES 4 program was sent to General Electric; RADC (Hanscom Field); Arens Applied Electromagnetics; Strategic Communications Command (Ft. Huachuca); CIA; Copus, Inc.; E-Systems, Inc.; Imperial Government of Iran; ITT Avionics Division; Mission Research Corporation; Sylvania, Inc.; U.S. ERDA; University of Texas; and D. J. Fang (for the Republic of China).

Predicting Techniques for Marginal HF Communication Systems, Operation Skywave, Transmission Loss Predictions Above 30 MHz. Radio communications within the HF band at intermediate to long distances depends on the ability of the ionosphere to return significantly strong radio signals to the earth. For any given distance at a given time, some combination of frequency, antenna radiation angle, and transmitter power exists which will give satisfactory performance. Unfortunately, in order to share the HF spectrum, the available frequency(ies) is fixed, while the ionosphere is changing. Thus, some method must be available both in the design phase and in the operational phase of a communications system to predict and to analysis the performance of the system. The modeling effort reported here is the result of the experience gained in the last decade since the last modeling effort, and reflects more the changing needs of the newer communication systems than the acquisition of new data describing the ionosphere. During this year, the modeling effort was completed and incorporated into an operational program. The resulting analysis tool was used for four different tasks involving HF communication systems.

The ionospheric communication analysis program (IONCAP) is a complete recoding of the predictions program with emphasis on modular construction, table look-up methods, and simple FORTRAN conforming to ANS (American National Standards). No subsection is considered permanent, so the modular form allows replacement of submodels without distrupting the rest of the program. However, no changes were made to the models unless measurements indicated the necessity or new requirements called for an extension of the program. The extensions were largely in the frequency domain, downward to 2 MHz and upward to 55 MHz, and in the distance domain for longer distances. The extension down in frequency was necessary since an explicit complete electron density profile which may give heights within the absorbing region is now used. The extension upward in frequency was at the request of users interested in the occurance of relatively low values of field strength. Previously, the programs ended when the probability of the operating frequency being lower than the predicted monthly median MUF (maximum usable frequency) became sufficiently small. Now that models of over-the-MUF losses, scatter losses, and revised distribution of the losses have been added, prediction may extend upwards to 55 MHz. The extension in distance was necessiated by the inadequacy of using ray theory methods at the longer distances. This inadequacy occurs for two basic reasons; first, the long-term prediction data base does not provide sufficient accuracy to allow the determination of the possible modes, and second, the propagation mechanisms for long distance are not accurately protrayed by ray theory methods. The long-path model basically determines the most effective take-off angle and reception angle using local ionospheric conditions and then obtaining the complete path loss using a loss per kilometer model. This loss mechanism allows part of the path to support propagation which does not pass through the absorbing region (i.e., an implicit assumption of M-modes, choradal modes or scatter modes). Specific new modeling efforts include:

1. A complete explicit electron density profile. While this function is not measurable, the integration of the profile to give an ionogram is. These prediction ionograms have been checked against measurements.

2. For oblique ray paths, Martyn's theorem has been corrected for a curved ionosphere. The correction was derived to assure agreement with full ray tracing using the same electron density profile.

3. Explicit sporadic E modes have been added to the program. The model is composed of subparts which have been derived from and tested against measurements over the past 30 years.

4. A revised median loss model has been created. The same basic equation is used, but an additional term is added for E modes, and a revision of the collision frequency term for modes with reflection heights within the absorbing region added. Also, a deviative loss term is added to high angle modes (these are also an addition to the program). The revision as well as the total loss equation was compared to field strength measurements.

5. An MUF model has been added which directly calculates the values rather than searching for the correct value. The complete electron density profile is used. The distribution of the MUF over a specified month for each possible layer is now included.

6. The distribution of transmission loss has been extended to vary with each operating frequency and with each type of mode. This allows the extension of statistical system performance upward in frequency.

7. Some modifications to the antenna models have been made, the most significant being for vertical antennas which are electrically short.

8. The complete set of models for long paths, as described above, have been added.

The revised prediction and analysis progr-am has been used in conjunction with other methods for four specific tasks. An air-transportable, mobile, HF, communications system, already deployed, which experienced only marginal communications performance especially at the longer distances, was studied. The expected performance of the system over the desired distance range (50 to 1000 km) and over the solar cycle was predicted and compared to the performance of the system. Specific hardware modifications recommended included antennas and signal processing equipment. Possible implementations of these recommendations are now available from industrial sources.

The U.S. Army, in its tactical operations, makes extensive use of high-frequency communication. To assure this communication, it is desirable to be able to select the proper operating frequency at any time in many geographic locations for the specific equipment involved. This selection process has been assured by "Intermediate and Short Distance Sky-Wave Propagation Charts." Improvements in the performance of sky-wave systems as a result of recent operational experience with over-the-horizon radars, permits a revision of these propagation charts to reflect these propagation prediction improvements. A revision of the "Intermediate and Short Distance Sky-Wave Propagation Charts" has been undertaken for the U.S. Army. The revised charts involve 32 different geographic areas covering most land masses.

In addition to the tactical operations, sky-wave propagation information is required to assure the proper frequency selection for communications between aircraft and the base stations. This sky-wave propagation information has been provided as "Air/-Ground Sky-Wave Propagation Charts for Selected Worldwide Stations." The preparation of these charts has been undertaken for 55 air-base stations to essentially provide worldwide coverage.

The fourth specific application of the program was to ERDAs mobile convoys, which are required to be in constant communication with the base station.

Ionospheric Propagation Models. Consultation concerning the use and proper interpretation of long-term ionospheric predictions is provided on a routine basis to many government agencies, and, especially, to the U.S. security agencies.

HF Circuit Predictions for Ministry of Information Saudi Arabia. Saudi Arabia operates HF transmitters at Riyadh with the view of putting a signal (and the Saudi

Arabian message) out to the rest of the Arab world. Near the start of the fiscal year, ITS was asked to provide the Saudi Arabian government with predictions for their HF broadcast operation. The predictions were made for high and low sunspot numbers, for each month of the year, and for 11 broadcast "circuits" -- from Riyadh to the capital cities of each of 11 Arab countries. Consideration was given the specific antennas to be used, most of which are slewable curtains. The ITS effort resulted in a 265 volume set containing the predictions and (in Volume 1) instructions and plots of the antenna patterns. An engineer for the Saudi Arabian Ministry of Information visited ITS for a week's study and discussion of the use of these volumes.

3.4.2. Ionospheric Warning Service and Short-Term Predictions

In addition to advance predictions of HF circuit performance characteristics on a "batch" basis, it is often necessary that the VOA Frequency Division have a capability for acquiring circuit predictions for certain circuits on a rapid basis. It is therefore desirable that they have quick access to a system through which they may obtain such predictions.

During this fiscal year the VOA Time Share Service provided that capability by maintaining programs in, and methods of acess to, the XDS 940 time share computer at the Boulder Laboratories. Solar and geophysical data files were maintained and certain special data-base modifications were made upon demand. Occassionaly VOA personnel were given instructions on procedures to establish and use special programs/files in the time share system.

SECTION 3.5. APPLICATIONS

The constant study of EM wave transmission characteristics, the development of up-to-date theoretical and empirical models, and the study of real-world telecommunication problems lead to state-of-the-art applications for telecommunication uses. This section deals with a variety of programs which show the broad spectrum of applied electromagnetic sciences.

3.5.1. Remote Sensing with Over-the-Horizon Radar

NOAA Sea Scatter and Project NONESUCH. A joint effort involving sea-scatter radar between the Office of Telecommunications, National Oceanic and Atmospheric Administration, and the Naval Research Laboratory has continued at San Clemente Island off the coast of California. Some years ago it was recognized that a need existed in the area of environmental sensing and monitoring for a technique and system for monitoring the principal wave height, period, and direction of the sea waves over a wide area at a given time. The design and construction of the San Clemente Sea Echo Radar has enabled the development and testing of various technicques to perform these tasks. The two principal sponsor this year were NOAA and NRL.

Activity on the project during the last year has been at a low level. The transmitter units at San Clemente Island have been modified with a different receiver preamplifier arrangement to provide better shielding to the units and to solve the problem of a chain breakdown of the components in the units. A unit was also designed and built to level the output of the transmitter units as a function of frequency.

An additional phasing unit was installed at the San Clemente Island facitilty to enable the beam to be scanned over an additional 40 degrees, which resulted in a beam coverage total of 80 degrees centered at 320 degrees from true north. This large sector was utilized in a number of measurements of the surface wave scatter from the vicinity around San Clemente Island. A number of different other measurements by other investigators were also made in the same area to provide a basis for establishing ground truth for the state of the sea in the area for comparison with sea state deductions made from the sea scatter measurements. There was also some activity in support of OHD studies.

Radar Reliability Studies. A study was completed and a report written for the Naval Research Laboratory, Washington, D. C., on Airborne Radar Reliability. The rapid advance and application of high level technology and complex electronic systems have emphasized the need for finding new ways of ensuring reliability and availability of airborne radar systems. Some of the means of achieving these goals are: more use of solid-state components; use of more built-in test features; designing the system so that it can be automatically tested and checked; designing redundance into the system; the use of a computer to monitor, control, and increase the overall performance of the radar system; and the use of few components.

3.5.2. Antennas and Radiation

Buried Antenna Studies continues this year with a new problem--feasibility of using vehicular antennas inside the tunnel of the proposed MX buried trench weapons system. The impetus for this work is an estimated $0.75 billion cost saving over the current base-line antenna concept.

Full-scale and model antenna measurements are currently in progress at the ITS Table Mountain test range.

Figure 3-15 is a photograph of a prototype model antenna array designed to operate in contact with the tunnel roof.

BOM Analytic EM Waves. Various subsurface guided wave mechanisms have been analyzed for the Bureau of Mines. The primary applications have been in mine communications, but some attention has also been given to EM remote sensing of the rock structure surrounding tunnels. The following specific areas have been studied during the past year.

The input impedance of antennas in tunnel environments is an important factor in the efficiency of an underground communications system. An idealized model has been utilized to determine the effect of both tunnel walls and longitudinal conductors (pipes, rails, cables, etc.) on the input impedance of either dipole or loop antennas. A computer program has been written which is valid for arbitrary antenna location and orientation over a wide frequency range. The tunnel influence is most important for frequencies below about 20 MHz where the loss resistance due to the tunnel walls greatly exceeds the free-space radiation resistance of the antenna. The results are useful in computing path loss between a pair of antennas in a long tunnel and also have application to remote sensing of the electrical properties of the surrounding rock.

Trolley wire communication in mine tunnels utilizes a quasi-TEM mode of propagation with forward current in the trolley wire and return current in the trolley rails. In practice, losses due to eddy currents in the rock walls and shunt loading of the trolley wire can limit the range of transmission significantly. To extend the transmission range, a smaller "dedicated" wire can be utilized to allow the propagation of a low-attenuation mode which is relatively insensitive to either continuous or discrete loading of the trolley wire. The typical frequency of operation is about 100 kHz, and the configuration has been analyzed by both full-wave theory and an approximate transmission line approach. A related problem involves the potential hazard of coupling from the trolley wire fields to a blasting cap circuit. This hazard has been evaluated by extending the above analysis to the appropriate blasting cap geometry.

In some situations, it is useful to transmit information to the surface along a drill stem in conducting rock. Consequently, the excitation of currents on a metal rod in a conducting medium has been analyzed by both numerical and asymptotic methods with good agreement. The source is a coaxial toroidal coil, and the end effects of drill stem have been treated by an approximate method.

In various applications in subsurface communications and geophysical probing, an estimate of the attenuation caused by the metal casing of a drill hole is required. Calculations of the external fields of either a magnetic dipole or a two-dimensional source located within the metal casing have been performed for a wide variety of parameters. It has been shown that the combined effect of conductivity and permeability of a steel casing will severely attenuate the fields even at frequencies as low as 100 kHz.

Future work will deal with numerous aspects of leaky-feeder communications in mine environments. Although some working systems have been installed, some aspects of leaky feeder cables (such as excitation, mode conversion, and shield characterization) are still poorly understood. The problem is even more complicated in a realistic mine tunnel environment where wall roughness and cross-cut tunnels are important. Some further work is also anticipated on through-the-earth propagation where previous work will be extended to include realistic earth layering and inhomogeneities.

Side Looking Radar Resolution. Synthetic aperture radars (SAR) can be used for aerial mapping independently of light or seeing conditions, for example through clouds. The resolution of such maps is limited by the distortion from atmospheric turbulence. Relatively little information is available about the turbulence as it effects SAR results. In this project, an airborne microwave refractometer (Figure 3-16) was used to measure the structure function parameter, C_n, as a function of altitude up to about 30,000 feet (Figure 3-17). Data were taken in Florida and Colorado to observe climatic effects and for a range of weather conditions. The results are presented in OT Technical Memorandum 77-233.

Kodiak Site Study. The work done for the Coast Guard by ITS is generally in support of their HF communication system needs. The variety of analyses performed vary from simple, routine ionospheric predictions to large network coverage and trade-off studies.

The one major study undertaken this fiscal year is Phase I of a complete antenna siting study for the Kodiak (Alaska) communication station. The ultimate objective is to determine the antenna/siting configuration that best meets the MF and HF communications needs of that station, in addition to maximizing the overall communication reliability and minimizing the equipment requirements. The objective of Phase I is to determine the radiated powers and antennas needed to obtain the desired coverage.

Another feature of this Coast Guard project is the prediction of the MF (500 kHz) propagation loss for the design of the MF

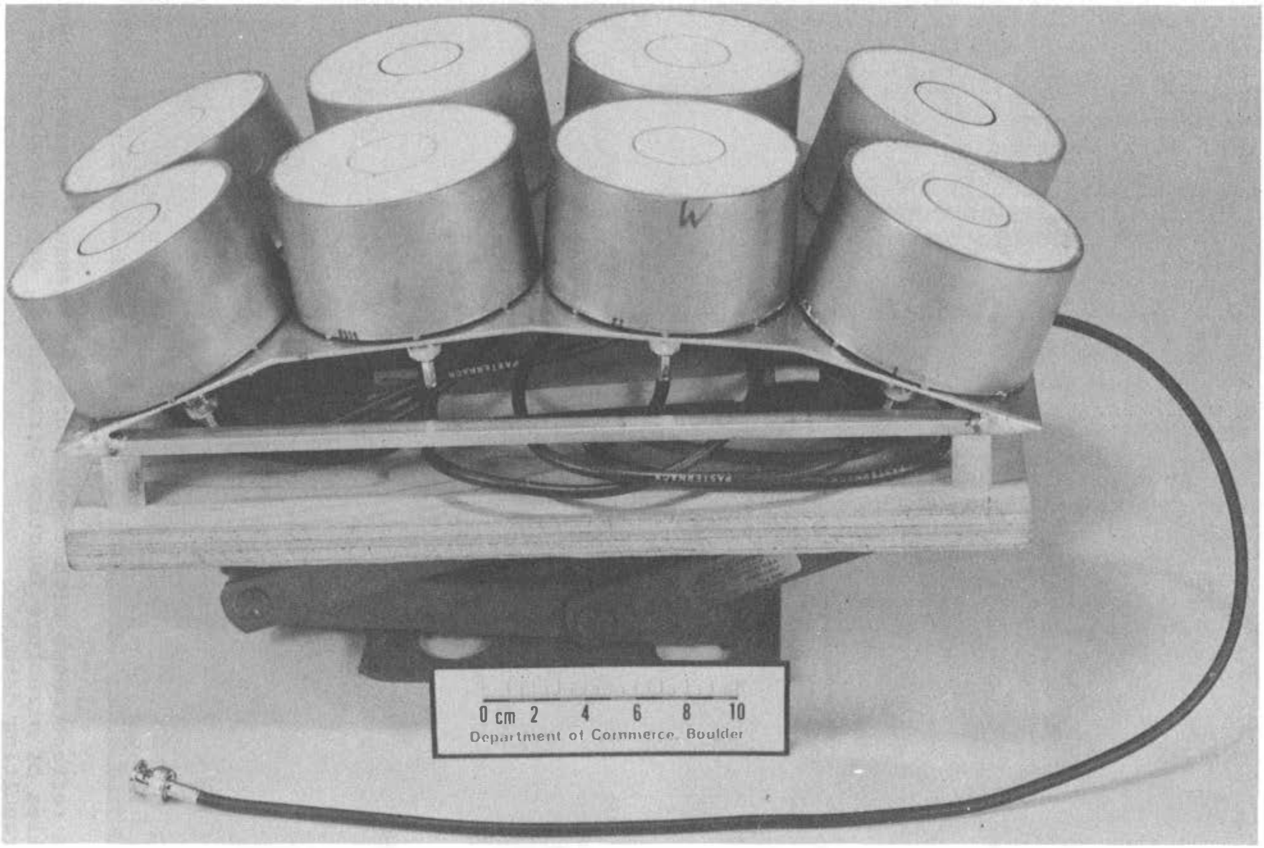


Figure 3-15. Circularly polarized cavity helix array antenna designed to operate below ground at 1.04 GHz.

Figure 3-16. Sensing cavity of microwave refractometer with temperature and pressure sensors mounted on nose of aircraft. Profiles of structure function parameter C_n are calculated up to 30,000 feet altitude from resulting data.

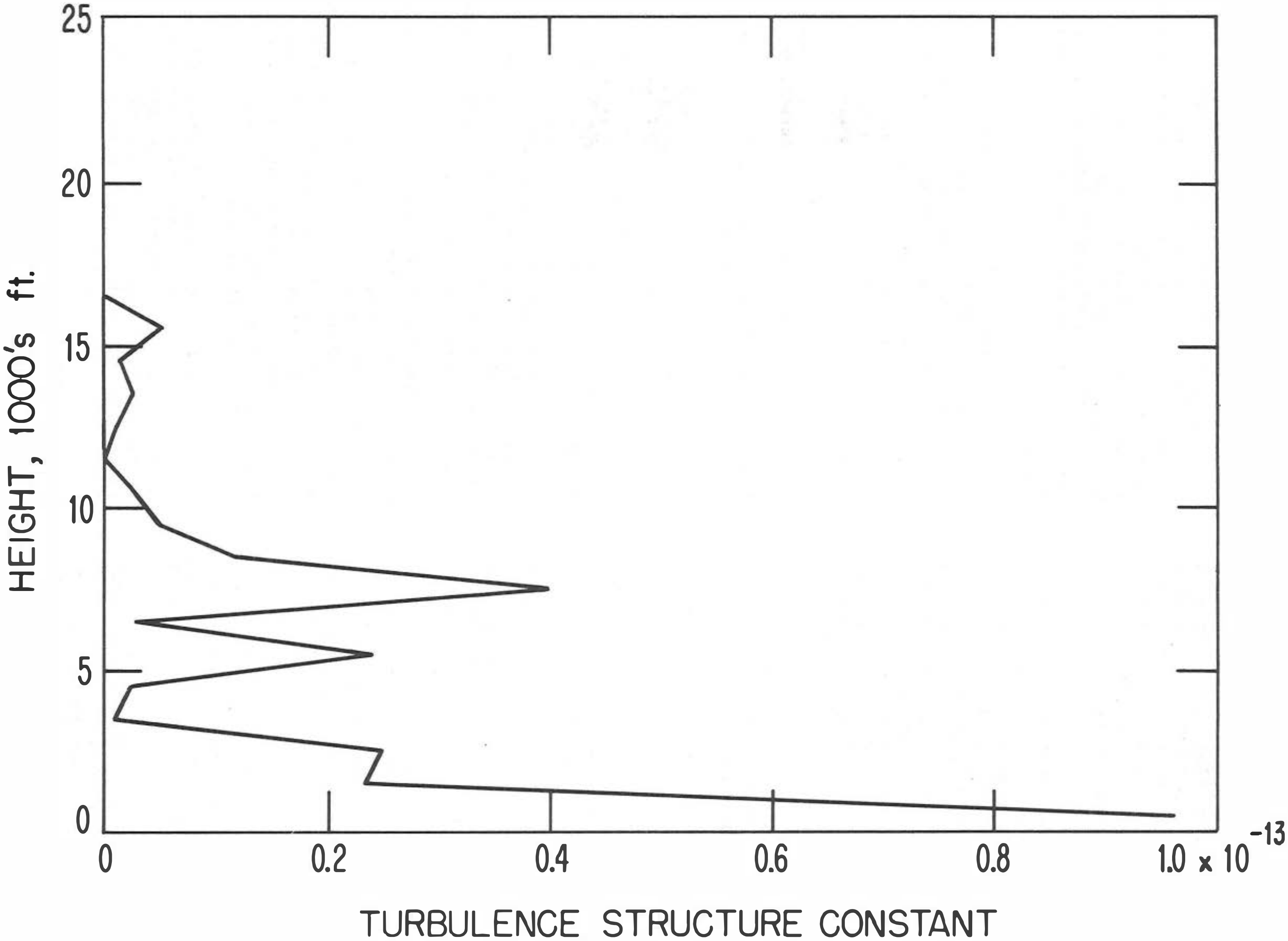


Figure 3-17. Plot showing large variations of C_n with height as determined from airborne refractometer measurements.

system. Radio waves at this frequency usually propagate as surface waves following the earth's surface, hence the modeling is terrain dependent. Radials centered on the Kodiak station define the needed terrain profiles (Figure 3-18). One of these profiles is shown in Figure 3-19 along with the prediction of the excess, terrain-dependent loss. This loss is relative to the loss experienced over seawater with no obstructions. The losses for all the radials shown in Figure 3-20 are used to determine the minimum required radiated power needed to obtain the desired coverage.

The information used in the HF portion of of the study is a circuit reliability prediction for each sky-wave path between Kodiak and an array of simulated ship positions for various seasonal, diurnal, and solar activity conditions. The array of simulated ship positions covering the region of interest is shown on the computer drawn map in Figure 3-21. The reliabilities for the various conditions are then analyzed to determine the antennas required to obtain the desired coverage.

The final choice of antennas and their siting will be performed in concert with the cognizant Coast Guard engineering personnel in Phase II of the Kodiak project and will be undertaken next fiscal year.

3.5.3. Transmission Through the Atmosphere: Applications

Firescope Communications Design. The U.S. Forest Services Riverside Forest Fire Laboratory, Riverside, California, has directed a research, development, and application program designed to increase the effectiveness of fire protection agencies involved in multi-jurisdictional fires or other emergency situations. The program FIRESCOPE conducted in cooperation with other state and local government fire-fighting agencies of the Southern California region specified a communications system, infra-red telemetry capability, a meteorological data collection and transfer network, and a computer based fire-spread model.

The Office of Telecommunications, Institute for Telecommunication Sciences, is near completion of a study considering the concept, design, and implementation planning aspects of the FIRESCOPE program communications components.

The study included a communications system design support report and the preparation of four sub-system design documents. The communications system report assessed fire-line and command post communications requirements, reviewed technological aspects of "900" MHz mobile radio, radio systems tone-controlled squelch and addressing, and voice-grade satellite relay links relative to application in the FIRESCOPE communications system.

The sub-system design documents are physical, electronic, and operational descriptions for procurement and implementation as follows:

1. Incident Mobile-Radio System. This design identifies a network of mobile radios operating in a mobile-to-mobile and mobile-to-base station mode. It is not a dispatch system, but does provide for a message center at the command-post, and tone-control squelch and signaling to optimize the network utilization. Repeaters are used to extend coverage in areas of difficult access.

2. Incident Telephone System. A small PABX system is specified to provide station-to-station communications among the more than 30 elements at the command post. An outside link (telephone, radio, or satellite relay) will provide 8 voice-grade channels to communicate with the FIRESCOPE Operations Coordination Center and local government agencies and supply sources. A manually operated radio-phone patch will provide direct communications between division supervisors on the fire-line and the command and logistics personnel at the command post.

3. Satellite Communications Systems. The requirements for and feasibility of implementing a current or future satellite relay capability to link the one or more fire incidents and the Operations Coordination Center were studied. Synchronous orbit satellites, small earth terminal equipment, and single-channel-per-carrier (SCPC) technology are considered in this design. The portability of one terminal of each link and the high-priority nature of the traffic increase the demands of the satellite relay system.

4. Van and Antenna System. Specifications have been made for a van to house the incident communications system. Equipment rack lay-out, operators consoles, and power and air-conditioning requirements were considered. The requirement for a number of antennas at the incident command post warranted the consideration of directive antennas and isolators to improve the EMC of the overall system.

In addition to the study and communications systems design, an active involvement has been undertaken to supply documents and to participate in briefings in support of applications for radio frequencies in the "900" MHz government band.

SAFEGUARDS Communications Analysis. A program was initiated with ITS by the Nuclear Materiel SAFEGUARDS Systems Division of the Nuclear Regulatory Commission to evaluate appropriate concepts and system configurations to support the transportation SAFEGUARDS requirements for non-weapon materiel.

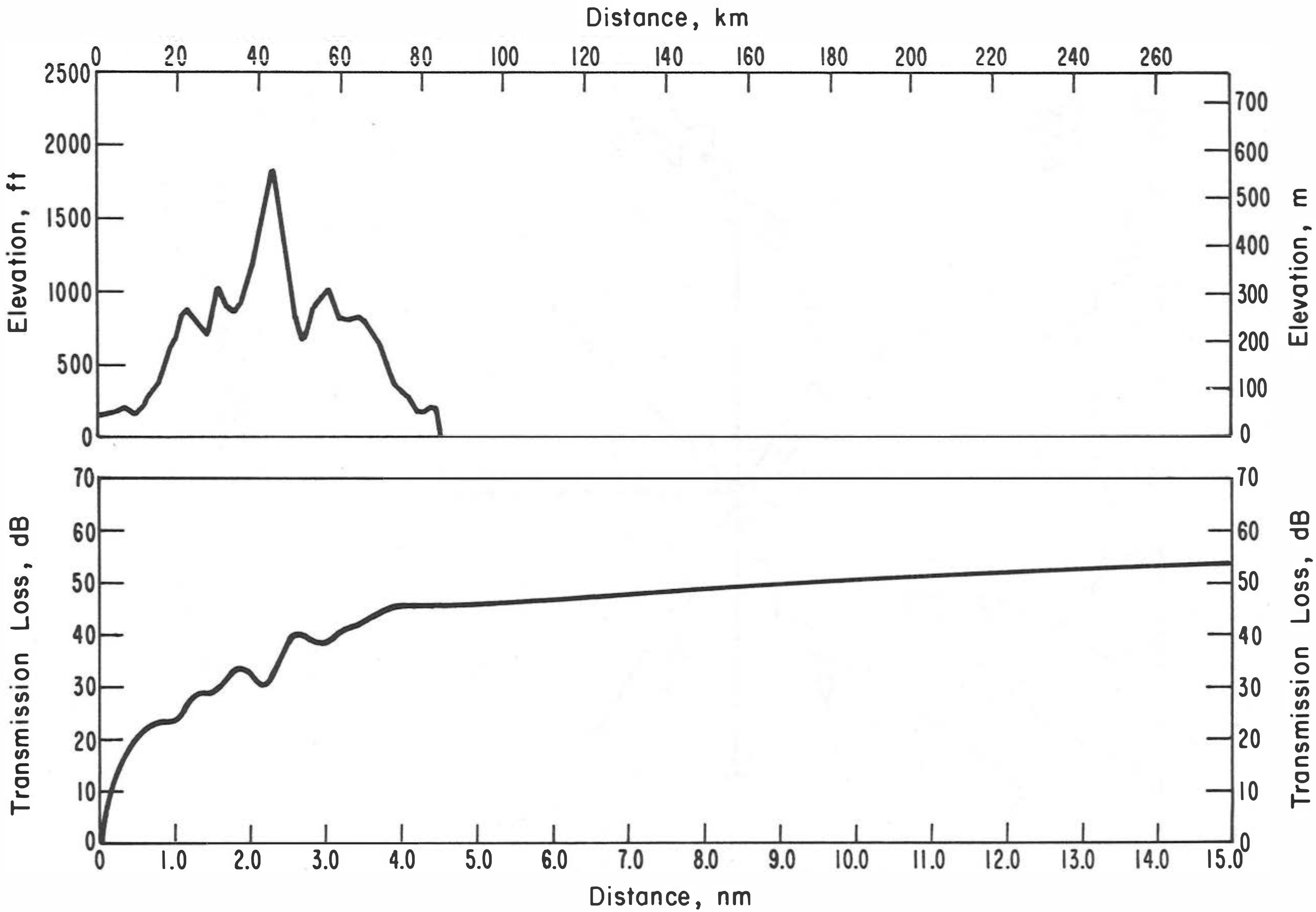


Figure 3-18. Top. The terrain profile for the 54 degree radial.

Figure 3-19. Bottom. The predicted loss due to the terrain only.

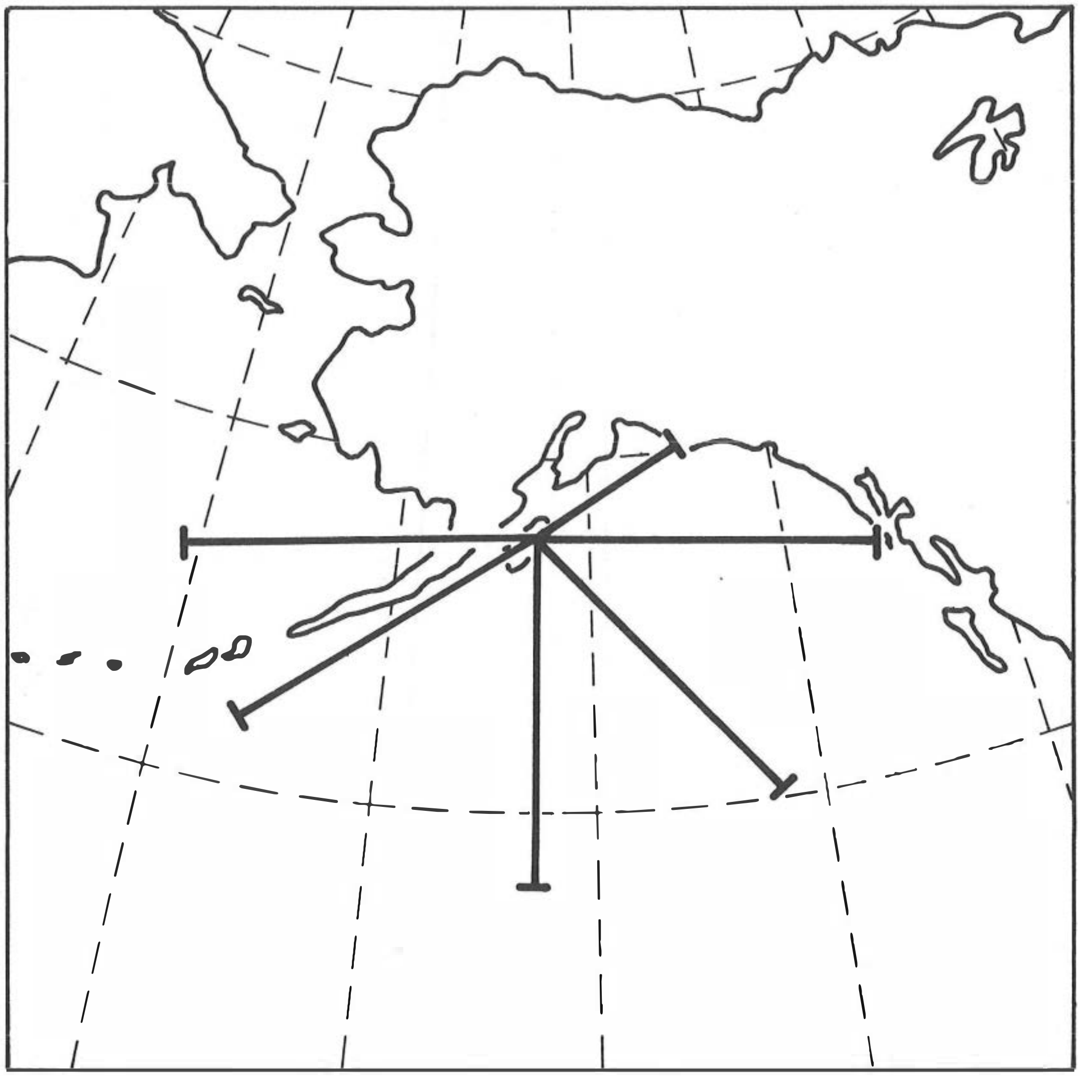


Figure 3-20. The radial paths from the Kodiak station used for the MH coverage predictions. The bearings, in degrees, are 54, 90, 135, 180, 240, and 270 clockwise from true north.

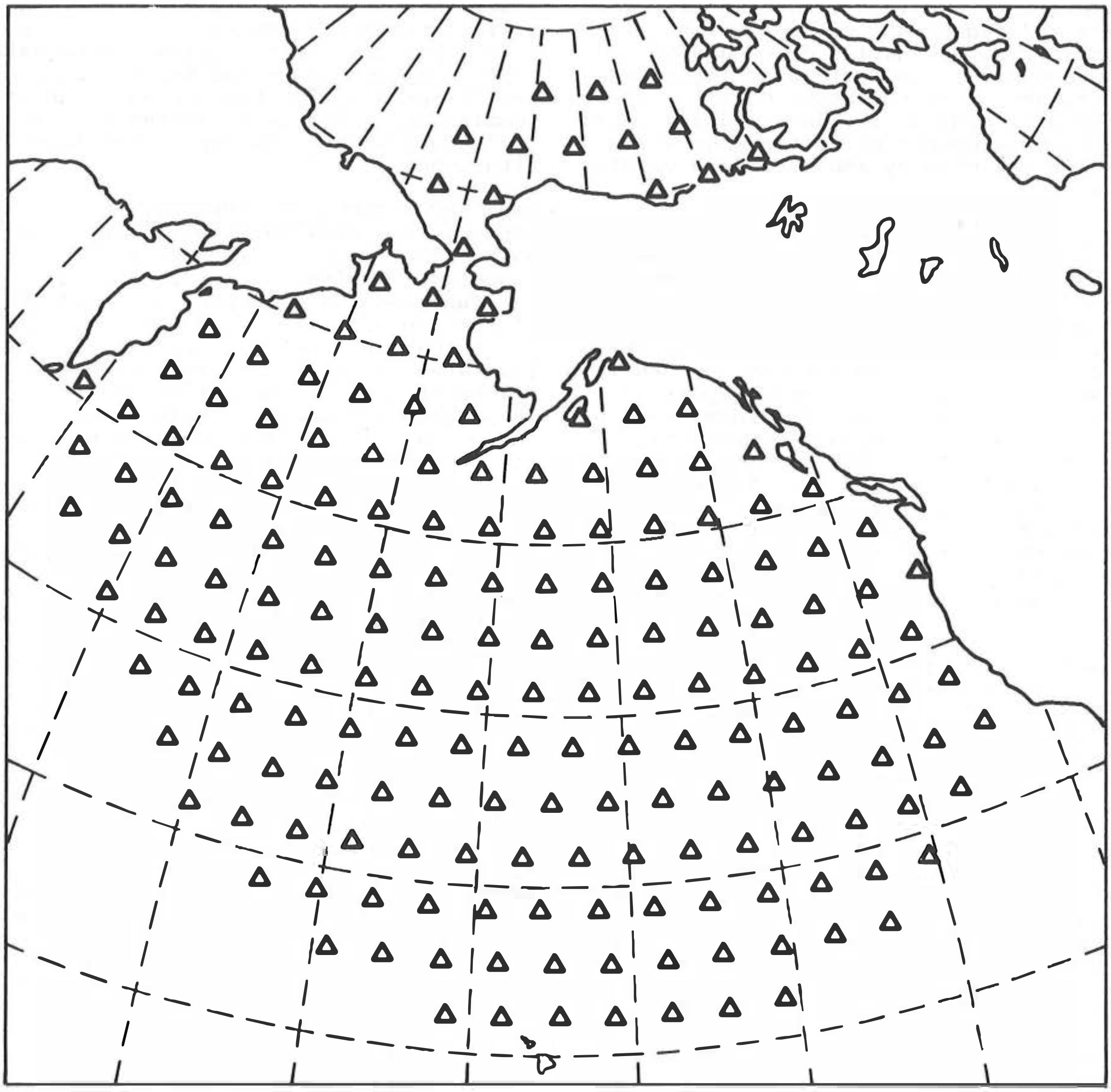


Figure 3-21. The simulated ship positions used for the HF coverage predictions.

This study is related to the ERDA SECOM systems engineering support program in general purpose and applications, and the utility of SECOM as a candidate for the NRC requirement.

The major elements of the program include an operations analysis to define critical events and functional communication relationships, an evaluation of candidate Federal communications systems (military and non-defense), the selection of the most appropriate systems for detailed analysis, and the development of an implementation plan for the primary and secondary candidates.

The operations analyses derived sets of operational timelines for the particular transport routes and modes of operation in an NRC/contractor environment. Event considerations include normal reporting cycles, accidents, and threat to survivability or damage. Communications concern information flow for the normal reporting function in relation to timeliness and accuracy of specific message components, the cost and delay tolerance for accident (non-threat) situations, and the different potential threat postures relating to capture/damage or blackmail. The basic analyses of the operational events employ a model structure similar to the SECOM management model.

Candidate systems include those currently operational and in the developmental phase for the Departments of Interior, Agriculture, Treasury, Defense, and ERDA. Considerations include deployments, availability of data channels, priority and protocol, and technical characteristics. From these analyses, the surviving candidates include the ERDA SECOM system, the Department of Justice network, and the DSCS-3. The latter is a satellite system in the early developmental stage, and preliminary cost effectiveness evaluations indicate that the complexity and cost of equipment could only be justified if one accepts the most severe threats to the NRC operations. Since the probabilities of an attack of this nature are not high, the satellite system has been relegated to a secondary consideration.

With the two cited primary candiates, a detailed set of timeline events and operational/functional linkages over the normal and abnormal event structures have been created. These are in the final stage of analyses to identify critical problems relative to the natural effects, EMC situations, and intentional interference environments. The mission profile for threat organizations includes two levels of EM attack against communications systems: active jamming with noise and deception equipment, and passive operations. Equipment characteristics for these threat scenarios have been derived from those devices and systems that are readily available in commercial or surplus markets in the United States and Europe.

A cost model to develop life cycle cost relationships is being organized as the final analysis stage for this concept program. Recommendations will be provided in a final technical report which will include a test program for the primary candidates to be implemented as the second phase of the ITS program for the Nuclear Regulatory Commission. This test program will include benign operations and replicated threat situations.

ERDA SECOM TECHNICAL SUPPORT. This program supports the ERDA Materiel Transportation SAFEGUARDS programs with the major thrust concerning systems engineering support to the functional enhancement and evaluation of the capabilities of the existing SECOM communications system. The program was initiated in FY 76, and concerned the development and implementation of an improved HF propagation model, mobile antenna evaluation, and the initial designs of a system management model.

The propagation model is a modified version of a newly developed HF model including a definition of multipath modes and temporal variations of ionospheric parameters that would be useful to predict error rates in digital transmissions. This model is being installed on the SANDIA Corporation computer facility. ERDA applications will include SECOM mission planning to assist in frequency selection and communications facility scheduling to maximize probabilities of communications systems performance. Real time support applications are also intended to assist in identifying unanticipated propagation-related problems and to provide guidance in control functions for the SECOM system, particularly in frequency selection and site antenna and processing control actions. Future applications will also involve multiple parametric software control features and signal discrimination, where intentional or unintentional interference events could occur.

The management model, as initiated in the previous year, concerned primarily an organization of the operational and functional timelines for the transport operations, intraconvoy communications, and SECOM system. This provided identification of normal, unintentional accident, and physical threat circumstances with appropriate events identified and communications support linkages.

For the current fiscal year, the emphasis in the management model concerned the development of the programs and supporting routines for the transport operations and the linkages to the communications event models. Communications models include VHF and the HF propagation modes, and system scoring models for the relay site and vehicle wquipments. The scoring process develops the patterns of digital errors with relation to the address, verification/authentication, and data components. This segmentation is necessary to allow direct coupling to the operations event model and, in the case of a physical threat situation, develop communications performance relationships for support forces and units that protect the transport vehicles.

Since the communications support to the transport vehicles must include the multiconvoy communications operations, the event and technical characteristic models for the VHF systems have also been designed. This system has only voice mode with little protection from external deception or interference. Different modes of operation including relay configurations have been examined, and recommendations submitted indicating reliability advantages for different options in procedure and configuration. The basic management model organization is diagrammed in Figure 3-22.

A major problem area relative to the HF SECOM performance has concerned the antennas originally designed for the mobile systems. Measurements regarding the antenna gain and efficiencies demonstrated serious problems in relation to the communications capability. A new antenna utilizing the electrically small (PARAN) concept was developed and evaluated at a contractor site and at the Table Mountain instrumentation facility. This indicated a significant reduction in directional sensitivity as well as implementation in gain. The antenna also provides a vehicle advantage in reduced size. Typical pattern comparisons for one operating frequency for the original whip and the electrically small (PARAN) antenna are presented in Figures 3-23 and 3-24, respectively. A coupler has been designed for the PARAN employing ferrites and a closed-loop form of tuning. This electronic device will improve the reliability as well as the functional efficiency of the antenna.

3.5.4. CCIR Participation

ITS has been involved in the preparations for the International Telecommunications Union (ITU) advisory International Radio Consultive Committee (CCIR) final meetings. OT/ITS personnel have actively participated in the preparation of 27 documents for the Study Group 5 meetings (September 1977) and of 31 documents for the Study Group 6 meetings (January 1978).

Most of the efforts of Study Group 6 were concentrated on re-organizing and combining existing texts in accordance with the new structure adopted by Study Group 6, Geneva, 1976. In conjunction with this, a new report on ionospheric properties was prepared by Margo PoKempner.

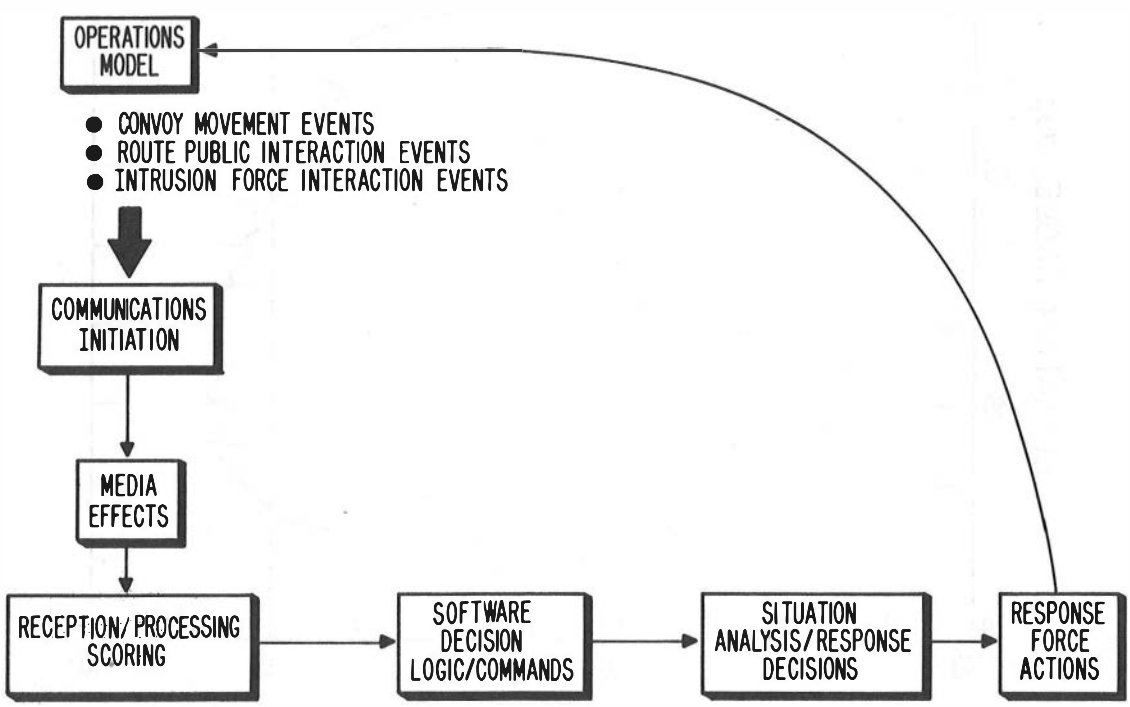


Figure 3-22. Management model organization.

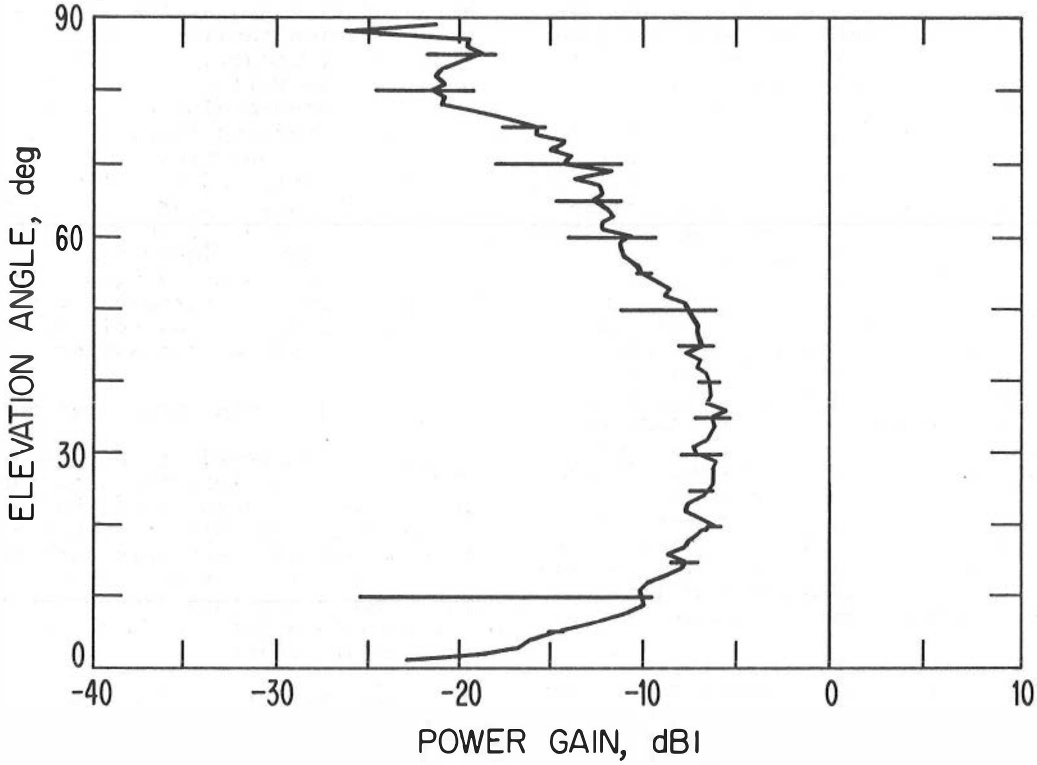


Figure 3-23. ERDA whip pattern.

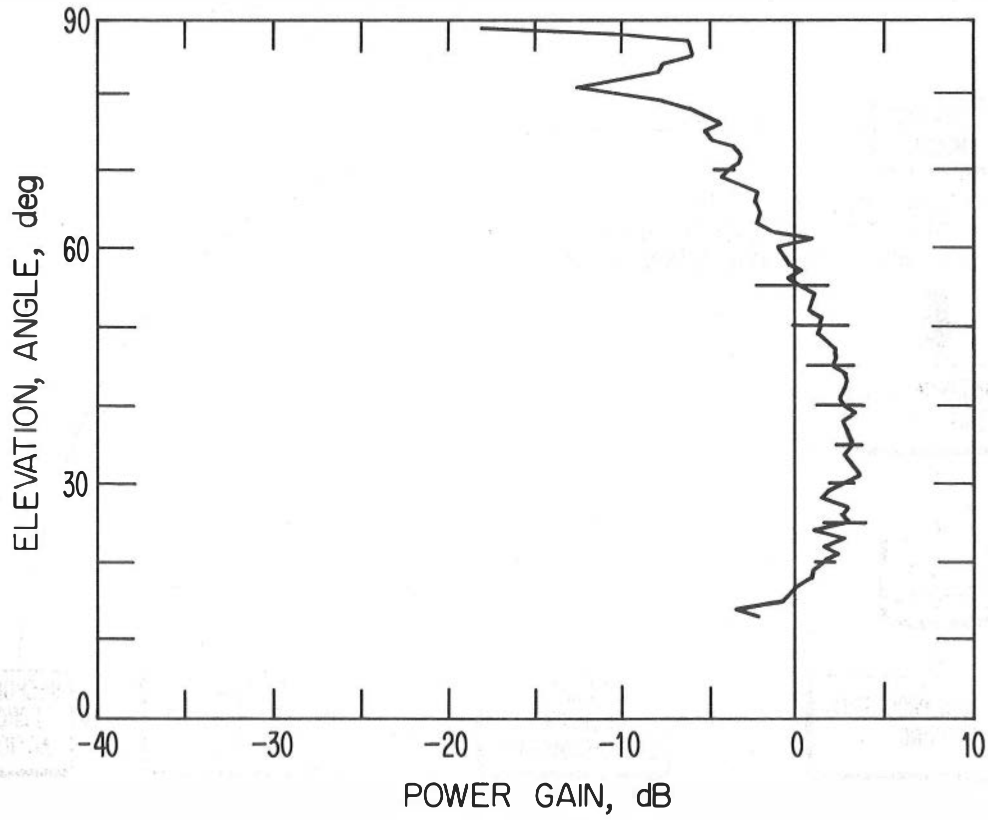


Figure 3-24. PARAN antenna pattern.

ANNEX I
ITS PROJECTS FOR FY 77
ORGANIZED BY DEPARTMENT AND AGENCY

Project	Title	Leader
AGRICULTURE, DEPARTMENT OF		
9103483	Firescope Communication Design	Morrison
COMMERCE, DEPARTMENT OF (DOC)		
9107114	Anom. Detection of Unwanted Signals	Adams
9107200	EM Wave Transmission M+S	Lucas
9107201	Transmission Measurement in the 10-100 GHz Band	Thompson
9107202	Channel Transfer Characteristics	Dougherty
9107203	Time-Variant Channel Characteristics - The Scattering Function for Atmospheric Turbulence	Ott
9107204	60 GHz Absorption	Liebe
9107205	Signal Scintillation and Depolarization Study	Ott
9107206	Leaky Coax	Wait
9107209	Optical Polarization Measurement	Chandler
9107220	Engineering & Evaluation of Systems M+S	Hull
9107221	Engineering and Evaluation of Systems (Data Communications)	Seitz
9107222	Engineering and Evaluation of Systems (Optical Communications)	Bloom
9107231	Communications Research	Murray
9107232	Trade-Offs in Spectrum Use	Berry
9107234	Needs Study	Murray
9107236	Delivery Mechanisms, Improvement & Interference Susceptibility	Murray
9107237	Spectrum Studies	Haakinson
9107250	Direct Satellite Communications	McManamon
9107251	Satellite Polarization Measurement	Chandler
9107260	Propagation Models and Data Bank	Lucas
9107261	Orbital Standards Platform (OSP) Preliminaries	Dougherty
9107262	Urban Propagation Modeling	Hufford
	Maritime Administration (MARAD)	
9102419	Marad Assistance	deHaas
	National Bureau of Standards (NBS)	
9103439	LESL Standards	Blair
	National Oceanic & Atmospheric Administration (NOAA)	
9101410	Spectroscopic O_2 Studies	Liebe
9102376	NDBP - Shore Station	Agy
9102440	NOAA Sea Scatter	Tveten
9103412	Microwave Ranging Errors	Chandler
9103414	GOES Radio Set Testing	Bolton
9103417	WSR-74C Weather Radar RFI Surveys	Tary
9103454	Improvement of GOES Interrogation Link	Glen
9103460	NWS RAPIT Model	Paulson
9103477	Transit Time Lidar System	Warner
DEFENSE, DEPARTMENT OF (DOD)		
	Air Force Communication Systems (AFCS)	
9103455	Automatic Measurement System Upgrade	Wortendyke
9103476	Dau-Mount Cabuyo Link Measurement and Analysis	Hause
9103484	Automatic Measurement System Upgrade	Wortendyke

Project	Title	Leader
DEFENSE, DEPARTMENT OF (DOD) (Continued0		
	Air Force Systems Command (ESD)	
9103424	DEB Path Tests	Hubbard
9103479	Parameter Analysis Program	Smith
	Air Force Space & Missile Command (SAMSO)	
9101463	Buried Antenna Studies - MX	FitzGerrell
	Air Force Miscellaneous	
9103421	Wire Mesh Studies	Hill
9103441	MSR-T1 Multiple Receiver	Barghausen
9103468	Side Looking Radar Resolution	Thompson
9103485	Nuclear Effects on Communications	Berry
9103486	Propagation Over Irregular Terrain	Ott
9103487	Radio Channel Capacity Limit	Linfield
9103492	TAC - Signal Analysis System	Barghauser
9103493	Power Fading Statistics	Hufford
	Naval Research Laboratory (NRL)	
9102370	Project Nonesuch	Tveten
9103469	Radar Reliability	Tary
	Pacific Missile Range (PMR)	
9103467	EATS EMC Analysis	Haakinson
9103497	Ground/Air Propagation Predictions	Gierhart
	Navy Miscellaneous	
9103481	NSSC Consultation	Gallawa
	Army Communication Command (USA/CC)	
9103382	Army Van Project	Carroll
9103405	FKV Technical Direction & Integration	Skerjanec
9103427	Army EMC Systems	Carroll
9103434	Local Digital Distribution Systems	Nesenbergs
9103437	EMC System Training	Chandler
9103440	AN/TSC-38B Study	Lloyd
9103442	Rainfall Data/Terrestrial Links	Dougherty
9103443	LF Beacon Coverage	Lucas
9103444	TRITAC/Ft. Huachuca Communication Systems Performance	Jennings
9103446	Army Field Application Program	Johnson
9103447	Fiber Interconnect	Bloom
9103458	High-Speed Digital Cable Analysis	Bloom
9103463	Operation Sky-Wave	Carroll
9103465	Electromagnetic Cosite Analysis Capability	Adams
9103470	EMC Remote Extension	Wood
9103471	Short-Term MUF Predictions	Lucas
9103472	Analysis of Alternative Cable Specifications	Bloom
9103473	Optimum Combiner Techniques	Hause
9103474	Automated Digital Topographic Data Techniques	Spies
9103478	EMC Van, Part III	Carroll
9103491	Follow-on Maintenance	Stewart
9103499	Video Tapes on TAEMS	Tary
	Army Security Agency (ASA)	
9103464	Path Loss Model Revision	Jennings

DEFENSE, DEPARTMENT OF (DOD) (Continued)

Army Miscellaneous

Project	Title	Leader
9103430	Set Antenna Measurements	FitzGerrell
9103452	EMC Data Recording System	Harr
9103475	Improved Longley-Rice	Longley
9103496	Satcoma Software	Stewart
9103498	Long Distance Propagation Study	Lloyd

Defense Communications Agency (DCA)

Project	Title	Leader
9101534	MEECN Simulation	Watterson
9102431	MEECN Transmission Models	Berry

National Security Agency (NSA)

Project	Title	Leader
9101518	NSA Consulting	Spaulding
9103495	Transmission Loss Predictions above 30 MHz	Lloyd

Miscellaneous DOD

Project	Title	Leader
9103422	Federal Communications Glossary	Hull

U.S. ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION (ERDA)

Project	Title	Leader
9103450	ERDA SECOM Technical Support	Morrison

ENVIRONMENTAL PROTECTION AGENCY (EPA)

Project	Title	Leader
9102430	EPA Antenna	FitzGerrell

FEDERAL COMMUNICATIONS COMMISSION (FCC)

Project	Title	Leader
9103462	VHF Drop-In Study	Hufford

INTERIOR, DEPARTMENT OF (DOI)

Project	Title	Leader
9101453	BOM Analysis of EM Waves	Wait

NATIONAL AERONAUTICS & SPACE ADMINISTRATION (NASA)

Project	Title	Leader
9103453	Disaster Warning Reception	Wells
9103494	OSP Analysis/Proposal	Dougherty

OFFICE OF TELECOMMUNICATIONS POLICY (OTP)

Project	Title	Leader
9107520	RSMS Development	Matheson
9107521	RSMS Operations	Matheson
9107522	Spectrum Analysis Support	Haakinson
9107524	TSC Support	Murray
9107527	SED Propagation Development	Hufford

TRANSPORTATION, DEPARTMENT OF (DOT)

Federal Aviation Administration (FAA)

Project	Title	Leader
9101477	Air Navigation Aids	M.E.Johnson
9102460	Emission Spectrum Simulation	Spaulding
9103456	Objective Intelligibility Measurement	Hartman
9103489	Technical Support/Propagation and Spectrum Engineering	Hubbard
9103500	ATC Radio Services	Hartman

U.S. Coast Guard (USCG)

Project	Title	Leader
9101532	Consulting USCG	Haakinson
9103488	Kodiak Antenna Improvement	Adams

Miscellaneous DOT

Project	Title	Leader
9102410	Automotive Radar Research	Chandler
9103459	FRA Communications	Morrison

U.S. INFORMATION AGENCY (USIA)

Project	Title	Leader
9101498	VOA Time Share Service	Boggs
9101499	VOA Predictions	Agy
9101501	Developing/Improving Prediction Formats	Haydon
9101503	VOA Consulting Service	Agy
9102444	Selection of S/I Ratio	Haydon

U.S. POSTAL SERVICE

Project	Title	Leader
9103432	USPS/EMS Program	McManamon

OTHER

Project	Title	Leader
9101583	LF Models	Berry
9101585	GOES Equipment Certification	Bolton
9101586	Tropo Predictions	M.E.Jonnson
9101587	Numerical Prediction Service MFA	Agy
9101594	Data Reduction Facility	Hull
9102580	Analysis Services	Adams

Miscellaneous Federal Agencies

Project	Title	Leader
9101504	Propagation Advice	Haydon
9103482	Safeguards Communication Analysis	Morrison

Miscellaneous Non-Federal Agencies

Project	Title	Leader
9101561	HF Fleet Sub	Lloyd
9103466	Computer Modeling HF Frequency	Agy
9103480	Kwajalein N-Meter	Thompson
9103490	Wagner + Termap	Ott

ANNEX II
ORGANIZATIONAL DIRECTORY
INSTITUTE FOR TELECOMMUNICATION SCIENCES
OFFICE OF TELECOMMUNICATIONS, DEPARTMENT OF COMMERCE
325 Broadway, Boulder, Colorado 80302
(303) 499-1000 (FTS dial 323 + extension)

NAME	EXT.	ROOM
DIRECTOR'S OFFICE (O/D)		
CROMBIE, Douglass D. (Director)	4215	3020
UTLAUT, William F. (Deputy Director)	3500	3020
WALTERS, William D. (Budget and Accounting Officer)	4414	3019
HATFIELD, Dale N. (Program Policy Specialist)	4215	3013
WAIT, James R. (Consultant, also with NOAA and CIRES)	6471	227 (RB 1)
WIEDER, Bernard (Assistant to the Director for Program Development)	3484	3014
DIVISION 1 - SPECTRUM UTILIZATION		
MURRAY, John P. (Associate Director)	4162	4533
1.1 Radio Spectrum Occupancy MATHESON, Robert J.	3293	2221
1.2 Antenna Performance FitzGERRELL, Richard G.	3737	4524D
1.3 FMC Analysis & Development ADAMS, Jean E.	4301	4517
1.4 VHF/UHF Models & Mobile Systems HUFFORD, George A.	3457	4523
DIVISION 2 - SYSTEMS TECHNOLOGY & STANDARDS		
HULL, Joseph A. (Associate Director)	4136	2034
2.1 Channel Characterization HUBBARD, Robert W.	3414	2243
2.2 New Technology Development BLOOM, Louis R.	3485	2245A
2.3 Systems Engineering & Analysis HULL, Joseph A. (Acting)	4136	2034
2.4 Systems Technology deHAAS, Thijs	3728	2246
2.5 Systems Assessment McMANAMON, Peter M.	3570	2237
DIVISION 3 - APPLIED ELECTROMAGNETIC SCIENCE		
LUCAS, Donald L. (Associate Director)	3821	3421
3.1 Ionospheric Transmission Technology LUCAS, Donald L. (Acting)	3821	3421
3.2 Advanced Analysis & Spectrum Extension LUCAS, Donald L. (Acting)	3821	3421
3.3 Advanced Communications Technology THOMPSON, Moody C.	3508	3442A
3.4 Microwave Theory & Predictions DOUGHERTY, Harold T.	3913	3453
3.5 Methodology & Operations Research MORRISON, Ernest L.	4473	3415

ANNEX III
INSTITUTE FOR TELECOMMUNICATION SCIENCES
OFFICE OF TELECOMMUNICATIONS
DEPARTMENT OF COMMERCE
Alphabetical Listing of ITS Employees
July 30, 1977

Name	Ext.	Room
ADAMS, Jean E.	4302	4517
ADAMS, Steven W.	3513	3442
AGY, Vaughn L.	3659	3441
AKIMA, Hiroshi	3392	2210M
ALLEN, Kenneth C.	3513	3442B
BALLARD, Marie G.	3823	3423M
BARGHAUSEN, Alfred F.	3384	3443
BEASLEY, Keith R.	3731	4528C
BEERY, Wesley M.	3677	3430B
BERRY, Leslie A.	4474	3420E
BLOOM, Louis R.	3485	2245A
BOLTON, Earl C.	3104	2236M
BROOKS, Minnie	3929	3451
CAMERON, Donald C.	4125	4520A
CANADAY, Lois S.	3634	3417
CARROLL, John C.	3601	3459
CHAVEZ, Richard	3584	3430
CHILDS, Gregg E.	3211	2222M
CHILTON, Charles J.	3815	3420
CLAYTON, Gary C.	3506	2246
COURTNEY, Brenda L.	4162	4528
CROMBIE, Douglass D.	4215	3020
CROW, Edwin L.	3452	2210
DAVIS, Robert M., Jr.	3419	3450
deHAAS, Thijs	3728	2246
DETMER, Maureen J.	4215	3020
DIEDE, Arthur H.	3103	3458B
DOUGHERTY, Harold T.	3913	3453
DUTTON, Evan J.	3646	3454C
ESPELAND, Richard H.	3882	3410M
FALCON, Glenn D.	4361	2222C
FARROW, Joseph E.	3607	2230
FitzGERRELL, Richard G.	3737	4524D
FRITZ, Olive M.	3778	2213
GALLAWA, Robert L.	3761	2217
GIBSON, Beverle J.	4215	3020
GIERHART, Gary D.	3292	2222M
GLEN, Donald V.	3893	2236M
GODWIN, John R.	4302	4515
GOULD, Beverly A.	3588	4525
GRANT, William B.	3998	3419
GRAY, Evelyn M.	3307	2210B
HAAKINSON, Eldon J.	4304	4511
HAIDLE, Leroy L.	3233	4524C
HANSEN, Ruth B.	3513	3442C
HANSON, A. Glenn	4449	2223
HARMAN, John M.	3655	2030
HARR, Thomas A., Jr.	4191	4518B
HARTMAN, William J.	3606	2210D
HASKIN, Lawrence J.	4162	4527
HATFIELD, Dale N.	4215	3013
HAUSE, Laurance G.	3945	2230B

Name	Ext.	Room
HAYDON, George W.	3583	3420C
HETHERINGTON, Jo	4129	4518
HIEBERT, Jorgeann	3562	3413
HILDEBRANDT, Thomas	3175	2230
HILL, David A.	3472	2209
HOROWITZ, Renee B.	4162	4529
HOWARD, Allen Q.	3635	2236M
HUBBARD, Robert W.	3414	2243
HUFFORD, George A.	3457	4523
HULL, Joseph A.	4136	2034
HYOVALTI, Duane C.	3447	3450A
JEFFREYS, Charlene E.	4414	3021
JENNINGS, Raymond D.	4303	4513
JOHNSON, Mary Ellen	3587	4522C
JOHNSON, Walter E.	3501	3463
JUNEAU, Robert I.	3512	2238
JUROSHEK, John R.	4362	4518C
KIMMETT, F. George	3945	2230B
KISSICK, William A.	4258	4520C
KORT, Teresa K.	4162	4529
KUHLEMIER, Melody K.	3883	3449
LANDERS, Mary R.	3821	3421
LAYTON, Donald H.	3584	3430
LIEBE, Hans J.	3310	3426
LINFIELD, Robert F.	4243	2236A
LLOYD, John L.	3701	3419M
LONGLEY, Anita G.	3470	4521
LUBEN, Robert A.	3396	4524A
LUCAS, Donald L.	3821	3425
MA, Mark T.	3800	3409
MAJOR, Jeanne C.	4122	4520B
MARLER, F. Gene	3412	3446B
MATHESON, Robert J.	3293	2221
MARTIN, William L.	3195	3424
MAYEDA, Kathy E.	3815	3420
MELLECKER, Carlene M.	3330	3458A
MENDOZA, John R.	3584	3430
MILES, Martin J.	3506	2246
MILLER, Anne F.	4388	4518A
MILLER, Charles M.	4496	3454A
MINISTER, Carl M.	3805	2242
MITZ, Albert R.	3513	3442
MOLLARD, Jean R.	4337	3015
MONTGOMERY, Carole J.	3291	2219
MORENO, Patricia A.	4166	2237
MORGAN, Lisa A.	3396	4524A
MORRISON, Ernest L.	4473	3415
MURAHATA, Sueki	3513	3442
MURRAY, John P.	4162	4533
McCOY, Elizabeth L.	4281	2245
McLEAN, Robert A.	4458	3458
McMANAMON, Peter M.	3570	2237
McQUATE, Paul L.	3778	2213

Name	Ext.	Room
NESENBERGS, Martin	3337	2210M
NEY, Linda	3396	4524A
OLSON, Marylyn N.	4136	2030
OTT, Randolph H.	3353	3467
PAULSON, Sara J.	3874	4519
PAYNE, Judd A.	3200	2214A
PHILLIPS, Robert E.	4125	4520A
POKEMPNER, Margo	3460	3413
PRATT, Lauren E.	3826	2234B
RANDELL, Holly L.	3786	4515
REASONER, Rita K.	3184	4522A
ROSICH, Rayner K.	3109	3415M
RUSSELL, Jane L.	3387	4524B
SAUER, Joseph A.	4122	4520B
SEITZ, Neal B.	3106	2214
SEXTON, Alma B.	3883	3449
SHELTON, Lenora J.	3572	3011
SKERJANEC, Richard E.	3157	2230
SMILLEY, John D.	4218	2222M
SMITH, Dean	3661	2223
SPAULDING, Arthur D.	4201	2222C
SPIES, Kenneth P.	4275	4516B
STEELE, Francis K.	3815	3420
STEWART, Frank G.	3336	3450C
STONEHOCKER, Garth H.	3756	4516D
STONER, Russell B.	3572	3009

Name	Ext.	Room
TARY, John J.	3702	3450
TEITELBAUM, Jeremy T.	4275	4516B
TELFER, Thelma L.	4162	4529
TETERS, Larry R.	4430	3417M
THOMPSON, Moody C., Jr.	3508	3442A
TVETEN, Lowell H.	3621	3445
UTLAUT, William F.	3500	3020
VanSTORY, Carol B.	3267	3017
VIOLETTE, Edmond J.	3703	3446A
VOGLER, Lewis E.	3668	3450
WALLER, Freda L.	3618	2246
WALTERS, William D.	4414	3019
WARNER, Billie D.	4496	3454B
WASHBURN, James S.	3798	3413M
WASSON, Gene E.	3584	3430
WATTERSON, Clark C.	3536	2241
WELCH, William M., III	4321	3458A
WELLS, Paul I.	4368	2235
WIEDER, Bernard	3484	3014
WORTENDYKE, David R.	4241	2234B

ANNEX IV

ITS PUBLICATIONS - FISCAL YEAR 1977

Adams, J. E., and W. A. Kissick (1977), An analysis of the maritime high-frequency single-sideband voice communication system for the North Atlantic and the South Pacific, OT Report 77-113, Vol. I: 137 pp. (NTIS Access. No. PB265850/AS); Vol. II: 180 pp. (NTIS Access. No. PB265851/AS); Vol. III: 187 pp. (NTIS Access. No. PB265852/AS).

Adams, J. E., J. R. Juroshek, W. A. Kissick, and J. P. Murray (1976), Electromagnetic compatibility of the Department of Defense Ground Mobile Forces transportable earth terminals with terrestrial systems within the 7.2 - 8.4 GHz spectrum, OT Report 76-99, August, 168 pp. (NTIS Access. No. PB258619/AS).

Agy, V., K. D. Boggs, G. W. Haydon, J. L. Lloyd, and M. PoKempner (1976), FY 76 progress report to United States Information Agency, Voice of America, Contract IA-17748-23, OT Technical Memorandum 76-230, December, 33 pp.

Akima, H. (1976), Modulation studies for the acoustic coupler project of the Naval Undersea Center (U), OT Technical Memorandum 76-224C (CONFIDENTIAL), July, 56 pp.

Akima, H. (1976), Modulation studies for direct satellite communication of voice signals, OT Report 76-108, December, 60 pp. (NTIS Access. No. PB263888/AS).

Akima, H., and A. D. Spaulding (1976), A simulation model for analyzing performance of some simple communication systems on a digital computer, Dept. of Transportation Report No. FAA-RD-76-181, November, 74 pp.

Akima, H., and A. D. Spaulding (1977), Development of a computer simulation model for analyzing performance of communication systems, Proc. 1977 IEEE International Symposium on Electromagnetic Compatibility, Seattle, WA, Aug. 2-4, pp. 47-52.

Barsis, A. P., C. A. Samson, and D. Smith (1976), Microwave system performance studies over long line-of-sight links, Proc. of ICC '76, Philadelphia, PA, June 14-16, Vol. 3, pp. 46-12 - 46-17.

Berry, L. A. (1976), Output oriented measures of spectrum efficiency, Proc. of IEEE 1976 International Symp. on Electromagnetic Compatibility, Washington, D.C., July 13-15, pp. 59-61.

Berry, L. A. (1977), Probabilistic tradeoffs for efficient spectrum use with a "CB" example, OT Report 77-117, April, 64 pp. (NTIS Access. No. PB266669/AS).

Bolton, E. C. (1976), Man-made noise study at 76 and 200 kHz, IEEE Trans. on Electromagnetic Compatibility EMC-18, No. 3, August, pp. 93-96.

Bolton, E. C. (1977), Comparative statistics of atmospheric radio noise and man-made radio noise below the HF band, Proc. 2nd Symposium & Technical Exhibition on Electromagnetic Compatibility, Montreux, Switzerland, June 28-30, pp. 341-346.

Burch, L. B., R. H. Doherty, and J. R. Johler (1976), Loran calibration by prediction, Navigation: Jl. of The Institute of Navigation 23, No. 3, Fall, pp. 195-200.

Crombie, D. D., Ed. (1976), Lowering barriers to telecommunications growth, OT Special Publication 76-9, November, 260 pp. (SupDocs Stock No. 003-000-00504-6).

Crow, E. L., and M. J. Miles (1976), A minimum cost, accurate statistical method to measure bit error rates, Proc. of Third International Conf. on Computer Communication, Toronto, Canada, Aug. 3-6, pp. 631-635.

Crow, E. L., and M. J. Miles (1977), Confidence limits for digital error rates from dependent transmissions, OT Report 77-118, March, 156 pp. (NTIS Access. No. PB267777/AS).

Davis, R. M., Jr., and L. A. Berry (1977), A revised model of the electron density in the lower ionosphere, Defense Communications Agency Report TR 111-77, February, 75 pp.

de Haas, T. (1977), Digital selective calling and direct printing techniques in the mobile maritime service, IEEE J. Oceanic Eng. OE-2, No. 3, July, pp. 218-222.

Dougherty, H. T., and B. A. Hart (1976), Anomalous propagation and interference fields, OT Report 76-107, December, 69 pp. (NTIS Access. No. PB262477/AS).

Dougherty, H. T., and W. J. Hartman (1977), Performance of a 400 Mbit/s system over a line-of-sight path, IEEE Trans. Commun. COM-25, No. 4, April, pp. 427-432.

Dougherty, H. T., and E. K. Smith (1976), The CCIR and radio propagation--A mini-review, IEEE Trans. Ant. Prop. AP-24, No. 6, November, pp. 910-912.

Dutton, E. J. (1976), Computer software for EWCS performance prediction, OT Technical Memorandum 76-225, August, 94 pp.

Dutton, E. J. (1977), Earth-space attenuation prediction procedures at 4 to 16 GHz, OT Report 77-123, May, 86 pp. (NTIS Access. No. PB269228/AS).

Espeland, R. H., D. H. Layton, B. D. Warner, L. R. Teters, and E. L. Morrison, Jr. (1976), Electromagnetic interference effects on motor vehicle electronic control and safety devices, Vol. I: Summary, Dept. of Transportation Report No. DoT HS-802 107, November, 24 pp.

Espeland, R. H., D. H. Layton, B. D. Warner, and L. R. Teters (1976), Electromagnetic interference effects on motor vehicle electronic control and safety devices, Vol. II: Measurements, analysis, and testing, Dept. of Transportation Report No. DoT HS-802 108, November, 139 pp.

Espeland, R. H., and E. L. Morrison, Jr. (1976), Electromagnetic interference effects on motor vehicle electronic control and safety devices, Vol. III: Automotive EMC guidelines, November, 89 pp.

Espeland, R. H., and Yung-Kuang Wu (1977), Subsystem susceptibility testing, Proc. 1977 IEEE International Symposium on Electromagnetic Compatibility, Seattle, WA, August 2-4, pp. 344-347.

Farrow, J. E., and R. E. Skerjanec (1977), FKV pilot digital system evaluation, OT Technical Memorandum 77-238, Vol. IV: Data acquisition system hardware, July, 129 pp.

FitzGerrell, R. G., and L. L. Haidle (1976), Two ways to plot sidelobe patterns, Microwaves 15, No. 7, July, pp. 59-60.

Gallawa, R. L. (1976), Considerations in the use of optical waveguides in submarine cable systems, OT Report 76-103, September, 56 pp. (NTIS Access. No. PB260722/AS).

Gallawa, R. L. (1977), Conventional and optical transmission lines for digital systems in a noisy environment, OT Report 77-114, March, 67 pp. (NTIS Access. No. PB265799/AS).

Gimmestad, G. G., D. Llewellyn-Jones, and H. Gebbie (1976), Millimeter wave oxygen attenuation measurements, J. Quant. Spectr. Rad. Trans. 16, No. 10, October, pp. 899-900.

Glen, D. V., H. Akima, and E. C. Bolton (1976), Evaluation of the GOES data-buoy interrogation link, OT Report 76-106, September, 70 pp. (NTIS Access. No. PB261872/AS).

Gonzalez, G., and L. A. Berry (1977), On the saddle point evaluation of LF/VLF path integrals for a vertical electric dipole, Can. J. Phys. 55, No. 12, June, pp. 1092-1101.

Gray, E. M. (1977), Information products resulting from satellite studies at the Institute for Telecommunication Sciences, OT Special Publication 77-15, May, 91 pp. (SupDocs Stock No. 003-000-00521-6).

Haakinson, E. J., and D. E. Skinner (1977), Power and beam pointing restrictions for geostationary orbit avoidance: Program ORBITCHECK user's manual, OT Report 77-119, April, 41 pp. (NTIS Access. No. PB267027/AS).

Haakinson, E. J., D. E. Skinner, K. P. Spies, and G. J. Bridgewater (1977), Automated computing and plotting of geostationary satellite earth footprints: Program FOOTPRINTS user's manual, OT Report 77-120, April, 88 pp. (NTIS Access. No. PB267953/AS).

Haakinson, E. J., A. C. Stewart, J. E. Adams, and L. E. Vogler (1977), Extended area test system in the 136-148 MHz band--An EMC assessment, OT Report 77-122, May, 212 pp. (NTIS Access. No. PB269226/AS).

Haidle, L. L., and R. G. FitzGerrell (1977), Hemispherical power gain pattern measurements at 7.5 GHz, IEEE Trans. Ant. Prop. AP-25, No. 3, May, pp. 373-376.

Hartman, W. J. (1977), Antenna tilting experiments over radar microwave links, Dept. of Transportation Report No. FAA-RD-77-51, January, 34 pp.

Hartman, W. J. (1977), Objective performance measures for voice systems, Proc. 2nd Symposium & Technical Exhibition on Electromagnetic Compatibility, Montreux, Switzerland, June, 28-30, pp. 521-524.

Hartman, W. J., and S. F. Boll (1976), Voice channel objective evaluation using linear predictive coding, U.S. Dept. of Transportation Report No. FAA-RD-75-189, August, 50 pp.

Hartman, W. J., and A. Q. Howard, Jr. (1976), How good is tapped delay line simulation?, IEEE Trans. Comm. COM-24, No. 9, Sept. pp. 1029-1032.

Haydon, G. W., M. Leftin, and R. K. Rosich (1976), Predicting the performance of high frequency skywave telecommunication systems (The use of the HFMUFES 4 program), OT Report 76-102, September, 154 pp. (NTIS Access. No. PB258556/AS).

Hill, D. A., and J. R. Wait (1976), Propagation along a braided coaxial cable located close to a tunnel wall, IEEE Trans. Microwave Theory Tech. MTT-24, No. 7, July, pp. 476-480.

Hill, D. A., and J. R. Wait (1976), Analyses of electromagnetic scattering from wire-mesh structures, Electron. Letters 12, No. 17, August, pp. 427-428.

Hill, D. A., and J. R. Wait (1976), Analysis of radio frequency transmission along a trolley wire in a mine tunnel, IEEE Trans. Electromagnetic Compatibility EMC-18, No. 4, November, pp. 170-174.

Hill, D. A., and J. R. Wait (1977), Electromagnetic surface wave propagation over a bonded wire mesh, IEEE Trans. Electromagnetic Compatibility EMC-19, No. 1, February, pp. 2-7.

Hill, D. A., and J. R. Wait (1977), Coupling between a dipole antenna and an infinite cable over an ideal ground plane, Radio Sci. 12, No. 2, March/April, pp. 231-238.

Hinkle, R. L., R. M. Pratt, and R. J. Matheson (1976), Spectrum resource assessment in the 2.7 to 2.9 GHz band, Phase II: Measurements and model validation (Report No. 1), OT Report 76-97, August, 280 pp. (NTIS Access. No. PB258511/AS).

Howard, A. Q., Jr. (1977), Pulse distortion in coaxial cable, OT Report 77-111, February, 37 pp. (NTIS Access. No. PB 266659/AS).

Hubbard, R. W. (1977), Path tests on DEB stage I links in northern Italy, OT Technical Memorandum 77-234, May, 60 pp.

Hubbard, R. W. (1977), Link performance measurements on the MATTS microwave system, OT Technical Memorandum 77-236, June, 53 pp.

Hubbard, R. W., L. E. Pratt, and W. J. Hartman (1977), The measurement of microwave multipath in an airport environment, Dept. of Transportation Report No. FAA-RD-76-163, January, 74 pp.

Hufford, G. A. (1976), FM broadcast coverage of the coterminous United States, OT Report 76-93, July, 40 pp. (NTIS Access. No. PB257013/AS).

Hufford, G. A. (1977), Techniques for the evaluation of proposed VHF TV drop-ins, OT Report 77-112, July, 160 pp. (NTIS Access. No. PB271212/AS).

Juroshek, J. R., and G. E. Wasson (1976), Measurements of digital systems in Gaussian additive noise and interference, OT Report 76-104, September, 68 pp. (NTIS Access. No. PB259249/AS).

Juroshek, J. R. (1977), An approximate method for calculating the performance of CPSK and NCFSK modems in Gaussian noise and interference, OT Report 77-109, January, 26 pp. (NTIS Access. No. PB246131/AS).

Janes, H. B., and M. C. Thompson, Jr. (1976), Fading at 9.6 GHz on an experimentally simulated aircraft-to-ground path, OT Technical Memorandum 76-227, August, 81 pp.

Kissick, W. A. (1976), Predicted HF coverage reliabilities for the USCG SSB small craft communication system in the Alaskan region, OT Technical Memorandum 76-226, August, 85 pp.

Kissick, W. A. (1977), Predicted reliabilities and coverage areas for HF maritime communications, Proc. Radio Technical Commission for Marine Services Conference, Valley Forge, PA, April 18-21, 1, Sect. D, 15 pp.

Kissick, W. A., and D. N. Rebol (1977), A program description of "ORBIT - PRINTS": Contours of power density at the geostationary orbit, OT Report 77-126, June, 89 pp.

Liebe, H. J. (1977), Transfer properties of clear air between 20 and 200 GHz (in German), Kleinheubacher Berichte 20, pp. 329-331, FTZ-Darmstadt, BRD.

Liebe, H. J. (1977), EHF properties of air, NTZ Communications J. NTZ-30, No. 1, January, pp. 76-84.

Liebe, H. J., G. G. Gimmestad, and J. D. Hopponen (1977), The EHF spectrum of atmospheric oxygen, Proc. URSI Commission F Open Symposium, La Baule, France, April 28 - May 6, pp. 619-624.

Liebe, H. J., G. G. Gimmestad, and J. D. Hopponen (1977), Atmospheric oxygen microwave spectrum--experiment versus theory, IEEE Trans. Ant. Prop. AP-25, No. 3, May, pp. 327-335.

Liebe, H. J., and J. D. Hopponen (1977), Variability of EHF air refractivity with respect to temperature, pressure, and frequency, IEEE Trans. Ant. Prop. AP-25, No. 3, May, pp. 336-345.

Linfield, R. F., R. W. Hubbard, and L. E. Pratt (1976), Transmission channel characterization by impulse response measurements, OT Report 76-96, August, 55 pp. (NTIS Access. No. PB258577/AS).

Ma, M. T., and H. T. Dougherty (1976), Atmospheric impairments for digital systems, Proc. of ICC '76, Philadelphia, PA, June 14-16, 1, pp. 12-7 - 12-13.

Nesenbergs, M. (1976), Error control for large and reliable satellite networks, Proc. National Telecommunications Conf., Dallas, Texas, Nov. 29-Dec. 1, 1, pp. 13.2.1 - 13.2.5.

Nesenbergs, M., and R. F. Linfield (1976), Parametric cost alternatives for Local Digital Distribution Systems, OT Report 76-95, July, 126 pp. (NTIS Access. No. PB258510/AS).

Ott, R. H. (1977), Temporal radio frequency spectra of multifrequency waves in a turbulent atmosphere characterized by a complex refractive index, IEEE Trans. Ant. Prop. AP-25, No. 2, March, pp. 254-260.

Ott, R. H. (1977), Observed temporal amplitude and phase spectra from ATS-6 radio beacon experiment at 40, 140, and 360 MHz, Radio Sci. 12, No. 2, March/April, pp. 319-325.

Ott, R. H., and M. C. Thompson, Jr. (1976), Characteristics of a radio link in the 55 to 65 GHz range, IEEE Trans. Ant. Prop. AP-24, No. 6, November, pp. 873-877.

Ott, R. H., and M. C. Thompson, Jr. (1977), Coherence bandwidth in turbulence, Proc. URSI Commission F Open Symposium, La Baule, France, April 28 - May 6, pp. 437-440.

Payne, J. A. (1976), Access time measurements of the ARPA network, OT Technical Memorandum 76-229, November, 40 pp.

Payne, J. A. (1977), Host to host disengagement time on the ARPANET, OT Technical Memorandum 77-237, July, 36 pp.

Pratt, R. M., and R. J. Matheson (1977), Air traffic control radar beacon system (ATCRBS) interference investigation in the Los Angeles area, OT Report 77-125, June, 166 pp. (NTIS Access. No. PB270944).

Pyatt, K. W. (1977), FKV pilot digital system evaluation, OT Technical Memorandum 77-238, Vol. V: Data acquisition system software, July, 164 pp.

Samson, C. A. (1976), Refractivity and rainfall data for radio systems engineering, OT Report 76-105, September, 166 pp. (NTIS Access. No. PB260723/AS).

Seitz, N. B., and P. M. McManamon (1976), Review of responses to the FCC quality and reliability inquiry (Docket 18920), OT Report 76-101, August, 150 pp. (NTIS Access. No. PB258678/AS).

Seitz, N. B., and P. M. McManamon (1977), Telecommunications: Digital communication performance parameters, Federal Register 42, No. 35, February 22, pp. 10352-10375.

Skerjanec, R. E., and J. E. Farrow (1977), FKV pilot digital system evaluation, OT Technical Memorandum 77-238, Vol. I: System summary, July, 19 pp.

Skerjanec, R. E., and J. E. Farrow (1977), FKV pilot digital system evaluation, OT Technical Memorandum 77-238, Vol. II: Operation and maintenance analysis, July, 54 pp.

Skerjanec, R. E., J. E. Farrow, and P. L. McQuate (1977), FKV pilot digital system evaluation, OT Technical Memorandum 77-238, Vol. III: Engineering analysis, July, 108 pp.

Smith, D., and F. G. Kimmett (1976), Radar microwave link pilot system upgrade and evaluation, Dept. of Transportation Report No. FAA-RD-76-184, December, 66 pp.

Spaulding, A. D. (1977), Stochastic modeling of the electromagnetic interference environment, Proc. IEE '77, June 12-15, Chicago, IL, 3, pp. 42.2-114 - 42.2-123.

Spaulding, A. D. (1977), Optimum reception in the presence of impulsive noise, Proc. 2nd Symposium & Technical Exhibition on Electromagnetic Compatibility, Montreux, Switzerland, June 28-30, pp. 509-514.

Stonehocker, G. H. (1977), An FAA polar flight solar cosmic radiation forecast/warning communication system study, Pt. II of A Study of the Capability for Rapid Warnings of Solar Flare Radiation Hazards to Aircraft, NOAA Technical Memorandum ERL SEL 46, April, pp. 49-81.

Tary, J. J., and E. M. Gray (1977), Radar reliability studies, OT Technical Memorandum 77-240, August, 35 pp.

Thompson, M. C., Jr. (1976), Measurements of wavefront distortion, Atmospheric Effects on Radar Target Identification and Imaging, Proc. of NATO Advanced Study Institute, Goslar/Harz, F.R.G., Sept. 22-Oct. 3, 1975, ed. H.E.G. Jeske, (D. Reidel Publishing Co., Dordrecht-Holland/Boston, Mass.), pp. 289-299.

Thompson, M. C., Jr., F. E. Marler, and K. C. Allen (1977), Measurement of refractive index parameters for calculating limits of SAR image resolution, OT Technical Memorandum 77-233, April, 105 pp.

Thompson, M. C., Jr., R. H. Ott, and E. J. Violette (1976), Report on 1976 Millimeter-Wave Conference, OT Special Publication 76-11, September, 11 pp.

Thompson, M. C., Jr., L. E. Wood, and K. C. Allen (1977), A calibrated test range for evaluation of refraction correction methods, OT Technical Memorandum 77-235, May, 20 pp.

Utlaut, W. F. (1976), Ionospheric modification induced by high-power HF transmitters - potential for communication and plasma physics research, Proc. of AGARD Specialists' Meeting on Artificial Modification of Propagation Media held in Brussels, Belgium, April, pp. 6-1 - 6-4.

Violette, E. J., M. C. Thompson, Jr., and A. R. Mitz (1977), A coherent multi-band link for millimeter wave propagation studies, OT Technical Memorandum 77-232, April, 32 pp.

Wait, J. R. (1976), Electromagnetic theory of the loosely braided coaxial cable, Part I, IEEE Trans. Microwave Theory Tech, MTT-24, No. 9, September, pp. 547-553.

Wait, J. R. (1977), Excitation of a coaxial cable or wire conductor located over the ground by a dipole radiator, Archiv fur Elektronik und Ubertragungstechnik (AEU) 31, pp. 121-127 (Errata, p. 230 of same volume).

Wait, J. R. (1977), Electromagnetic field analysis for a coaxial cable with periodic slots, IEEE Trans. Electromagnetic Compatibility, EMC-19, No. 1, February, pp. 7-13.

Wait, J. R., and D. A. Hill (1976), Electromagnetic scattering by two perpendicular wire grids over a conducting half-space, Radio Sci. 11, Nos. 8 & 9, August/September, pp. 725-730.

Wait, J. R., and D. A. Hill (1976), Attenuation on a surface G-line suspended within a circular tunnel, J. Appl. Phys. 47, No. 12, December, pp. 5472-5473.

Wait, J. R., and D. A. Hill (1976), Impedance of an electric dipole located in a cylindrical cavity in a dissipative medium, Appl. Phys. 11, December, pp. 351-356.

Wait, J. R., and D. A. Hill (1977), Influence of spatial dispersion of the shield transfer impedance of a braided coaxial cable, IEEE Trans. Microwave Theory Tech. MTT-25, No. 1, January, pp. 72-74.

Wait, J. R., and D. A. Hill (1977), Radio frequency transmission via a trolley wire in a tunnel with a rail return, IEEE Trans. Ant. Prop. AP-25, No. 2, March, pp. 248-253.

Wait, J. R., and D. A. Hill (1977), Electromagnetic fields of a dipole source in a circular tunnel containing a surface wave line, Int. J. Electronics 42, No. 4, April, pp. 377-391.

Wait, J. R., and D. A. Hill (1977), Sub-surface EM transmission in tunnel waveguides, Proc. URSI Commission F Open Symposium, La Baule, France, April 28 - May 6, pp. 125-128.

Wait, J. R., and D. A. Hill (1977), Electromagnetic shielding of sources within a metal-cased bore hole, IEEE Trans. Geosci. Electron. GE-15, No. 2, April, pp. 108-112.

Watterson, C. C., and C. M. Minister (1977), Comparative evaluation of 616A and Verdin modems, Phase II, Part 2 (U), OT Technical Memorandum 77-239C, August, 242 pp.

Wells, P. I., and P. V. Tryon (1976), The attenuation of UHF radio signals by houses, OT Report 76-98, August, 88 pp. (NTIS Access. No. PB258447/AS).

Wheeler, J. K., and E. J. Haakinson (1977), An automated technique for calculating interference from airborne transmitters to terrestrial receivers, OT Report 77-110, February, 71 pp. (NTIS Access. No. PB264519/AS).

OT Reports and Special Publications are available from the Superintendent of Documents and National Technical Information Service, as indicated in the publications list. OT Technical Memorandums are not generally available, but additional information may be secured by contacting the author. Requests for copies of journal articles should be addressed to the journal.

ANNEX V

GENERAL AND HISTORICAL INFORMATION OF ITS

The Institute for Telecommunication Sciences, largest component of the Office of Telecommunications, is located at the Boulder Laboratories of the Department of Commerce, and has (as of Sept. 30, 1977) a full-time permanent staff of 109 and other staff of 45. In FY 1977, its support consisted of $1.3 million of direct funding from Commerce and $9.0 million in work sponsored by other Federal agencies.

The Boulder Laboratories include research and engineering components of the National Bureau of Standards, the National Oceanic and Atmospheric Administration, and the Office of Telecommunications. Common administrative services are the rule in the Boulder Laboratories. The Radio Building, which houses ITS, is on the National Bureau of Standards campus at 325 Broadway. In addition to ITS, the Office of Telecommunications also has its Policy Research Division located in the 30th Street Building off Baseline Road in Boulder.

The following brief history shows its NBS beginnings. The Radio Section of the National Bureau of Standards was founded prior to World War I, and played a major role in the evolution of our understanding of radio propagation. Dr. J. H. Dellinger, its director for most of the period up until World War II, was strongly convinced of the importance of research and gave it practical application as first Chairman of the Study Group on Ionosphere Propagation in the CCIR.

During World War II, the Interservice Radio Propagation Laboratory (IRPL) was organized at the National Bureau of Standards, under the direction of Dr. Dellinger. His group provided a common focus for military needs in propagation during the war. In 1946, the Central Radio Propagation Laboratory (CRPL) was established, and in its early years had direct ties with the Defense Department; for example, senior officials of DoD would appear before Congress to defend the CRPL budget. In 1949, Congressional concern for the vulnerability of government laboratories located in Washington, D.C., and the crowding of the NBS Connecticut Avenue campus made it advisable for the radio research work to be taken elsewhere.

Three sites, one in California, one in Colorado, and one in Illinois, were considered, and Boulder, Colorado, was selected. The first group from CRPL, which at that time included radio standards work, moved to Colorado in 1951, and the move was completed in 1954, during which year President Eisenhower dedicated the NBS Radio Building. The Radio Standards program left CRPL at the time of the move to Boulder, and has pursued a parallel existence at Boulder in NBS since that time.

In 1954 CRPL consisted of two research divisions: Radio Propagation Physics and Radio Propagation Engineering. The Radio Systems Division was formed in 1959. In 1960 the Upper Atmosphere and Space Physics Division and the Ionosphere Research and Propagation Division were formed from the Radio Propagation Physics Division. In 1962, CRPL received a full-time Director, Dr. C. Gordon Little. In 1965, Dr. H. Herbert Holloman, first Assistant Secretary for Science and Technology in Commerce, implemented a decision to unify geophysics in Commerce with the creation of the Environmental Science Services Administration (ESSA), made up of the Weather Bureau, the Coast and Geodetic Survey, and the Central Radio Propagation Laboratory. At that time the CRPL was renamed the Institute for Telecommunication Sciences and Aeronomy (ITSA). In 1967, the Institute for Telecommunication Sciences came into being. It contained the telecommunications-oriented activities of ITSA. Dr. E. K. Smith served as an interim Director for one year and was followed by R. C. Kirby who was Director for the ensuing three years.

Meanwhile, in Washington, major attention was being given to the organization of telecommunications in the Federal establishment, and the Department of Commerce established an Office of Telecommunications in 1967. Reorganization Plan No. 1 of 1970 and Executive Order 11556 established the Office of Telecommunications Policy (OTP) in the Executive Office of the President, and assigned additional responsibilities to the Secretary of Commerce in support of OTP. To meet these responsibilities, the Office of Telecommunications (OT) was given expanded responsibilities on September 20, 1970, and ITS, along with its programs, property, personnel, and fiscal resources was transferred to OT. While no major organizational changes have transpired since that time, major changes in program emphasis have been made.

In 1971, Douglass D. Crombie became Director of ITS. ITS has shifted from its strong emphasis on radio wave propagation and antennas since 1970, in the direction of applications in spectrum management and in telecommunication systems.

ITS and its predecessor organizations have always played a strong role in pertinent scientific (URSI), professional (IEEE), national (IRAC), and internationalal (CCIR) governmental activities. The Director of CCIR from 1966 to 1974 was Jack W. Herbstreit, a former Deputy Director of CRPL and ITSA, and the current CCIR Director is Richard C. Kirby, formerly Director of ITS. At the present time, the U.S. preparatory work for three of the eleven Study Groups of CCIR is directed by members of ITS (U.S. Study Groups 1, 3, and 5), and staff members of ITS participate in many of the other Study Groups. ITS actively supports the Interdepartment Radio Advisory Committee (IRAC), and the Chairmen of its Standards Working Group (J. A. Hull) and the Propagation Working Group (W. F. Utlaut) of the Technical Subcommittee are members of ITS management.

The work which ITS does for other agencies in the government derives its legal authorities from 15 U.S.C. 272(e) "Advisory Services to Government Agencies on Scientific and Technical Problems" and 15 U.S.C. 272 (f) "Invention and Development of Devices to Serve Special Needs of Government." As a matter of Federal policy, the Office of Telecommunications does not accept work more appropriately done by other non-government or government organizations. It is also a matter of policy that all sponsored work reinforce OT's overall program and that it be clear that other agencies, industries, or universities could not serve equally well or better.

Within these policy guides, ITS aspires to being <u>the</u> Federal laboratory for research in telecommunications. It is clear that the government has a responsibility to pursue long-range studies in telecommunications which are not economically profitable for industry. It is also clear that the government must have its own, independent laboratories to assess the significance of research conducted elsewhere. Towards these ends, ITS strives to maintain a knowledgeable staff that is working on the frontiers of technology and is in touch with the telecommunications problems of the Federal Government. Its programs and future directions are succinctly given in the Foreword of this report by ITS Director D. D. Crombie.

The Department of Defense has long been the primary source of advanced technology. At the present time, the largest part of the other agency sponsorship of ITS comes from needs of the Department of Defense. However, there is also a clear need for relevance to national goals on the civilian side of the Federal establishment. ITS is therefore moving to increase its work with the civil side of the Federal Government. The agencies in the civilian sector are frequently also in the high technology area; for example, the FAA and NASA, for which ITS has done, and continues, very important work in navigation, collision avoidance, satellite communications, and related work.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977-781-223-/102

INSTITUTE for TELECOMMUNICATION SCIENCES

Director - Douglass D. Crombie
Deputy Director - Dr. William F. Utlaut
Secretary - Beverle J. Gibson

- **BUDGET & ACCOUNTING** — William D. Walters
- **PUBLICATION / INFORMATION** — Russell B. Stoner
- **CONSULTANTS** — Dr. James R. Wait; Dr. Frank S. Barnes
- **PROGRAM DEVELOPMENT** — Dr. Bernard Wieder
- **PROGRAM POLICY** — Dale N. Hatfield

DIVISION 1

SPECTRUM UTILIZATION

Associate Director - John P. Murray
Secretary - Thelma L. Telfer

- **RADIO SPECTRUM OCCUPANCY** — Robert J. Matheson
- **ANTENNA PERFORMANCE** — Richard G. FitzGerrell
- **EMC ANALYSIS & DEVELOPMENT** — Jean E. Adams
- **VHF / UHF MODELS & MOBIL SYSTEMS** — Dr. George A. Hufford

DIVISION 2

SYSTEM TECHNOLOGY & STANDARDS

Associate Director - Joseph A. Hull
Secretary - Marylyn N. Olson

- **ASSISTANT TO THE ASSOCIATE DIRECTOR** — John M. Harman
- **CHANNEL CHARACTERIZATION** — Robert W. Hubbard
- **SYSTEMS ENGINEERING & ANALYSIS** — Joseph A. Hull (Acting)
- **SYSTEMS TECHNOLOGY** — Thijs deHaas
- **SYSTEMS ASSESSMENT** — Dr. Peter M. McManamon
- **NEW TECHNOLOGY DEVELOPMENT** — Louis R. Bloom

DIVISION 3

APPLIED ELECTROMAGNETIC SCIENCES

Associate Director - Donald L. Lucas
Secretary - Mary R. Landers
Consultant - George W. Haydon
Advisor - Dr. Hans J. Liebe

- **ADMINISTRATION** — William B. Grant
- **PROGRAM DEVELOPMENT** — Ernest L. Morrison
- **IONOSPHERIC TRANSMISSION TECHNOLOGY** — Donald L. Lucas (Acting)
- **MICROWAVE THEORY & PREDICTIONS** — Dr. Harold T. Dougherty
- **ADVANCED COMMUNICATIONS TECHNOLOGY** — John C. Carroll (Acting)
- **METHODOLOGY & OPERATIONS RESEARCH** — Ernest L. Morrison
- **ADVANCED ANALYSIS & SPECTRUM EXTENSION** — Dr. Moody C. Thompson