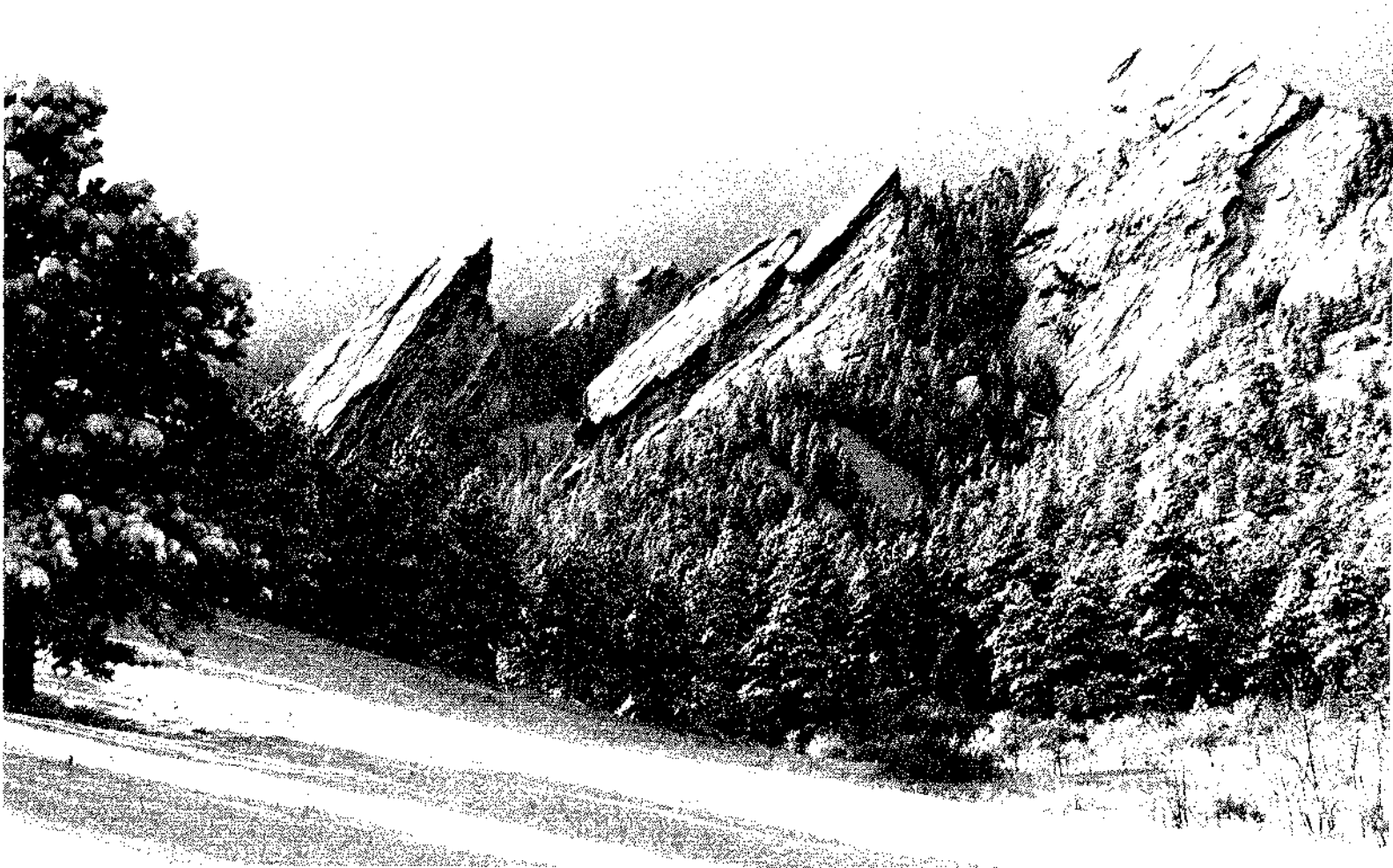
INSTITUTE FOR TELECOMMUNICATION SCIENCES
OF THE
NATIONAL TELECOMMUNICATIONS AND
INFORMATION ADMINISTRATION

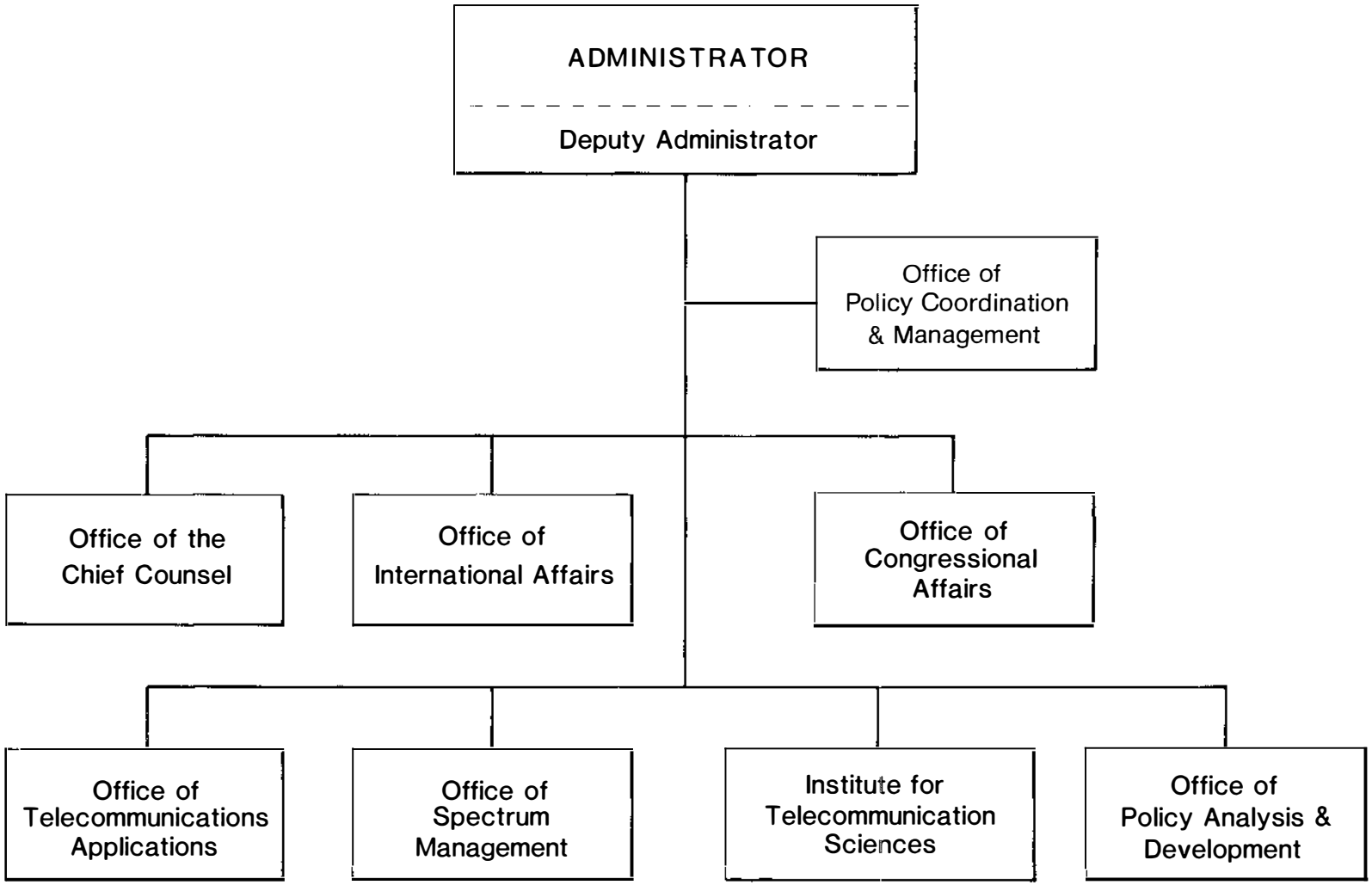
ANNUAL TECHNICAL PROGRESS REPORT 1986

For the period Oct. 1, 1985, through Sept. 30, 1986



U.S. DEPARTMENT OF COMMERCE

National Telecommunications and Information Administration



ITS

ANNUAL TECHNICAL PROGRESS REPORT 1986

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

Alfred C. Sikes, Assistant Secretary
for Communications and Information

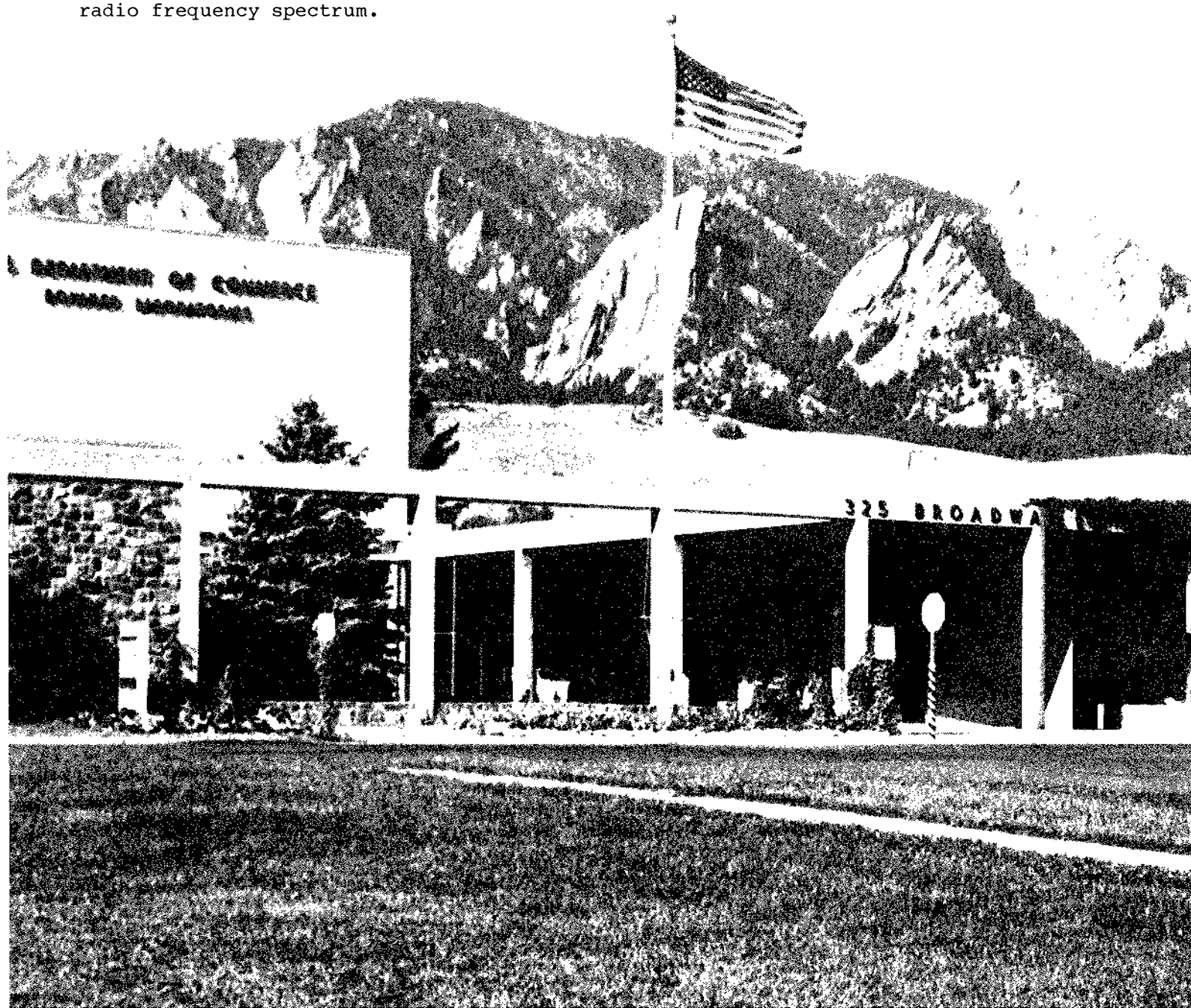
cover photo by Kenneth Spies, ITS

staff photos by Lenora Cahoon, ITS

THE ITS MISSION

★ As the chief research and engineering unit of the National Telecommunications and Information Administration, the Institute for Telecommunication Sciences (ITS) supports Administration telecommunications objectives such as enhanced domestic competition, improved foreign trade opportunities for U.S. telecommunication firms, and more efficient and effective use of radio frequency spectrum.

★ ITS also serves as a principal Federal resource for assistance in solving telecommunication problems of other Federal agencies, state and local governments, private corporations and associations, and international organizations.



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OVERVIEW

The Institute for Telecommunication Sciences (ITS), located in Boulder, Colorado, is the chief research and engineering arm of the National Telecommunications and Information Administration (NTIA), U.S. Department of Commerce. ITS employs approximately 100 permanent program staff. Many of these employees bring substantial engineering and scientific backgrounds and skills to our technically oriented programs. Indeed, 44% of our employees are electronics engineers, 11% are mathematicians, 6% are physicists, 6% are computer scientists, and 6% are computer programers. During FY 1986, ITS support consisted of $3.2 M of direct funding from Commerce and $5.4 M in work sponsored by other Federal agencies.

ACTIVITIES

In achieving its mission, the Institute performs state-of-the-art telecommunications research, planning, and engineering in each of the following functional areas:

- **Spectrum Use Analysis**
  Performing technical analysis of radio usage in selected frequency bands and preparing U.S. technical positions for use at international spectrum allocation conferences.

- **Telecommunication Standards Development**
  Contributing to and developing Federal national and international telecommunication standards.

- **Telecommunication Systems Performance**
  Forecasting how individual communication elements will perform together and then testing them in a laboratory or operational environment.

- **Telecommunication Systems Planning**
  Relating needs of end users to the capabilities of a planned network.

- **Applied Research**
  Modeling the way radio waves travel from point to point in various frequency bands and evaluating the way information is carried by radio signals, including modulation and coding.

BENEFITS

The Institute's work significantly benefits both the public and private sectors in several areas including:

- **Spectrum utilization**
  Optimizing Federal spectrum allocation methods, identifying available frequencies and potential interference through field measurements, and promoting technology advances aid in more efficient and effective use of the scarce spectrum resource.

- **Telecommunication negotiations**
  Developing negotiation support tools such as interference prediction programs and providing expert technical leadership improve the preparation for, and conduct of, telecommunication negotiations at various international conferences.

- **International trade**
  Promulgating broadly based, nonrestrictive international telecommunication standards helps to remove technical barriers to U.S. export of telecommunication equipment and services.

- **Domestic competition**
  Developing user-oriented, technology-dependent methods of specifying and measuring telecommunication performance gives users a practical way of comparing competing equipment and services.

- **National defense**
  Improving defense network operation and management, enhancing survivability, expanding network interconnection and interoperation, and improving planning for emergency communications restored contribute to the strength and cost effectiveness of U.S. national defense forces.

- **Technology transfer**
  Making available Institute technology evaluations and application studies hastens and expands the beneficial use of research results for industry in meeting specific user telecommunication needs.

OUTPUTS

Major outputs of the Institute's research and engineering activities include:

- **Engineering tools and analysis**
  Predictions of transmission media conditions and equipment performance, test design and data analysis computer programs, complete laboratory and field tests of experimental and operational equipment, systems, or networks.

- **Standards, guidelines, and procedures**
  Contributions to and development of national and international standards in such areas as network interconnection and interoperation, performance evaluation, and information protection.

- **Research results**
  Models for electromagnetic wave propagation, noise, and interference characterization.

- **Expert services**
  Training courses and workshops to communicate technology advances and applications to industry and Government users.

ORGANIZATION

To carry out its activities, ITS is divided organizationally into two main program divisions--Spectrum Research and Analysis, and Systems and Networks Research and Analysis--and an Executive Office to handle administrative matters. Each of the program divisions is further divided into functionally oriented groups. Work performed by the Spectrum Division involves analyses directed toward understanding radio wave behavior at various frequencies and determining methods to enhance spectrum utilization. The Systems and Networks Division focuses on assessing and improving the performance of Government and private sector telecommunication networks, developing domestic and international telecommunication standards for telecommunication networks, and evaluating new technologies for application to future needs. Activities carried out within the two divisions are complementary and often synergistic. The Executive Office handles the Institute's budget and program planning functions as well as interacts with various administrative offices within other parts of Commerce to achieve its payroll, procurement, personnel, facilities management, civil affairs, and publications requirements.

ITS Hosts Workshop

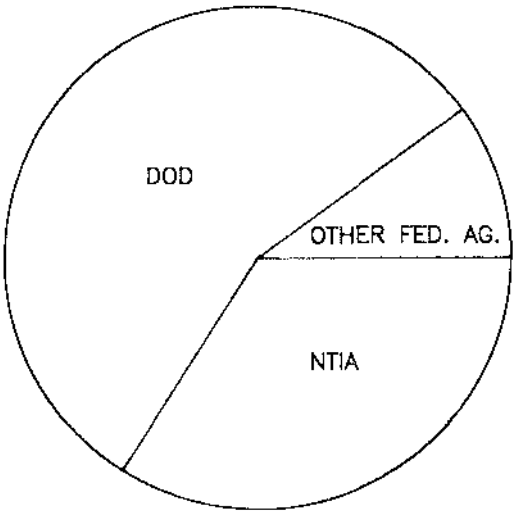
HISTORY

ITS had its organizational beginning during the 1940's as, first, the Interservice Radio Propagation Laboratory and then later the Central Radio Propagation Laboratory (CRPL), each located within the Commerce Department's National Bureau of Standards. In 1965, CRPL was transferred to the Environmental Science Services Administration and given a new name--Institute for Telecommunication Sciences and Aeronomy (ITSA). In 1967, ITS and the "A" organization were split. ITS was transferred into the newly formed Office of Telecommunications (OT). Finally, under the President's Reorganization Act #1 of 1977, OT and the Office of Telecommunications Policy merged to form NTIA. Since that time, ITS has been responsible for performing telecommunication research programs within NTIA and for providing technical engineering support to other elements of NTIA as well as other agencies on a reimbursable basis.

Dwight D. Eisenhower Dedicates
Department of Commerce Boulder Laboratories
September 14, 1954

SPONSORS

The activities of the Institute are undertaken through a combination of Commerce-sponsored and other-agency sponsored programs. NTIA/ITS policy provides that other-agency sponsored work results in contributions to and reinforcement of NTIA's overall program and is directed toward supporting Commerce goals. Various Army, Air Force, Navy, and other Department of Defense (DoD) components provide the majority of ITS' other agency funding. Non-DoD sponsors typically include the Department of Transportation, the U.S. Information Agency, and the Department of Agriculture. Because of its centralized Federal position, ITS is able to provide a cost-effective, expert resource that does not require duplication throughout many Federal agencies.



ITS Funding Sources

Scientific research and engineering are critical to continued U.S. leadership in the provision of telecommunications and information equipment and services. In the pages that follow, this annual technical progress report summarizes specific FY 1986 technical contributions made by ITS that have significance for the public and/or private sectors.


O'Day


Rush


Utlaut


Seitz


Salaman


Walters

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Robert F. Linfield, Associate Deputy Director

Program Planning and Evaluation
Val M O'Day

Budget and Administration
William D. Walters

Technical Publications
Lenora J. Cahoon

Propagation Model Development and Application
Dr A Donald Spaulding, Chief

Spectrum Management Analysis and Concept Development
Jean E. Adams, Chief

Spectrum Use Measurement
Robert J Matheson, Chief

System Performance Standards and Definition
Dr Edmund A Quincy, Chief

System Performance Engineering Analysis
James A Hoffmeyer, Chief

Switched Networks Analysis
Dr William A Kissick, Chief

Satellite Network Analysis
Raymond D. Jennings, Chief

SPECTRUM USE ANALYSIS

The National Telecommunications and Information Administration (NTIA) is responsible for managing the radio spectrum allocated to the Federal Government. Part of NTIA's responsibility is to: "...establish policies concerning spectrum assignment, allocation and use, and provide the various departments and agencies with guidance to assure that their conduct of telecommunications activities is consistent with these policies." In support of these requirements, ITS conducts a variety of studies and field measurement activities directed toward ensuring efficient, effective and equitable use of the radio spectrum resource. A prime objective of these analyses is to increase spectrum usefulness by developing ways for using presently congested portions of the spectrum more efficiently and for opening up new portions of the spectrum for productive use.

In conjunction with these spectrum analyses, ITS supports NTIA's active role of developing and advocating the United States' position at various international spectrum allocation conferences. Decisions taken at these conferences significantly affect the amount of the spectrum resource, and the methods of using it, available to the United States.

Through a variety of its project activities, ITS uses its scientific and engineering research expertise to develop computer programs to assist the Federal Government in the most productive methods of utilizing this available spectrum. These methods are useful for the private sector as well and, therefore, ITS has established a computerized method of transferring this technology to all interested parties on a reimbursable basis.

AREAS OF EMPHASIS

International Radio Conference Support

Includes projects funded by the National Telecommunications and Information Administration and the U.S. Information Agency

Domestic Spectrum Analysis

Includes projects funded by the National Telecommunications and Information Administration

Spectrum Usage Measurements

Includes projects funded by the National Telecommunications and Information Administration

Telecommunications Analysis Services

Includes a project funded by reimbursement from subscribers

International Radio Conference Support

Outputs

* Models to be used to determine U.S. positions at radio conferences
* Techniques and methods to assist ITU in preparation for radio conferences
* Determination of locations of emitters that jam Western broadcasts

The Institute participates actively in developing and defending U.S. positions for international radio conferences held under the auspices of the International Telecommunication Union (ITU). Preparation for radio conferences includes providing overall technical support for the Second Session of the HF Broadcasting Conferences [WARC-HFBC(2)] and the World Administrative Radio Conference on the Use of the Geostationary Orbit and the Planning of Space Services Utilizing It (WARC-ORB). These activities are highly coordinated with other organizations within NTIA (particularly the Office of International Affairs and the Office of Spectrum Management) and other Government agencies (Department of State and FCC, for example).

The Institute has been the principle U.S. agency in studying all the technical criteria needed to develop the U.S. positions for WARC-HFBC(2). The Institute has developed an HF broadcast planning algorithm that follows directly from the decisions taken at the First Session of the HF Broadcasting Conference. It is very similar to that implemented by the International Frequency Registration Board (IFRB). The algorithm enables all HF broadcasting requirements to be analyzed and placed into appropriate broadcast bands. The interference that results between requirements in the same band is used as the basis for determining which requirements can be satisfied and which cannot.

The Institute has recently undertaken a detailed analysis of the results of the

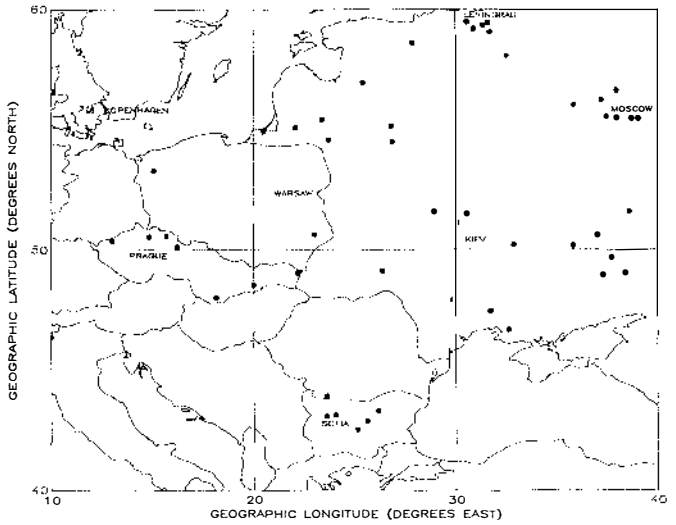
Project personnel (l. to r.) Les Berry, Ray Jennings, Hiroshi Akima, Charlie Rush, Jim Washburn, and Mary Sowers

IFRB planning algorithms in final preparation for WARC-HFBC(2). Of particular concern is the fact that only 60 to 70 percent of the U.S. broadcasting requirements appear to be satisfied by the planning procedures adopted by the IFRB. Plans for three seasons--December 1985 (D85), June 1986 (J86), and March 1988 (M88)--have been analyzed. The percentage of HF broadcasting requirements that are satisfied by the planning process for the U.S. for each of the three seasons is given below. The results are being used to determine the final U.S. positions that will be taken at WARC-HFBC(2).

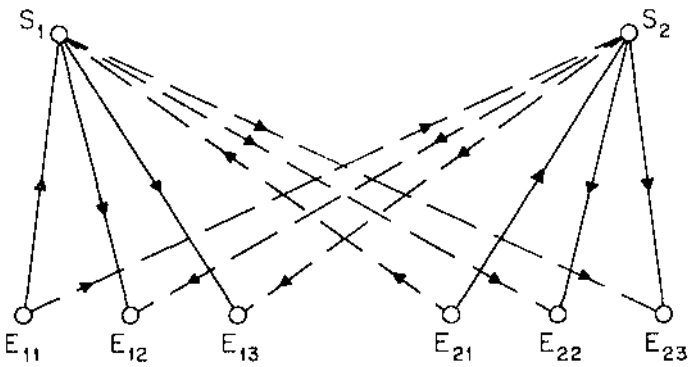
	Percentage of Requirements Satisfied		
	D85	J86	M88
United States	69	72	59

A separate but related WARC-HFBC(2) issue has been the work undertaken by the Institute to determine the location of emitters that are observed to jam Western broadcasts. Working closely with many countries throughout the world, observations have been gathered and analyzed by Institute engineers and scientists to determine the countries in which the jammers are located. A recent finding by the ITU

corroborates the results that jammers of Western broadcasts are located in Russia, Poland, and Czechoslavakia. An indication of the locations of jammers to the HF broadcasts of Western countries is given in the map shown below. The locations of the jammers are marked by a dot (°).

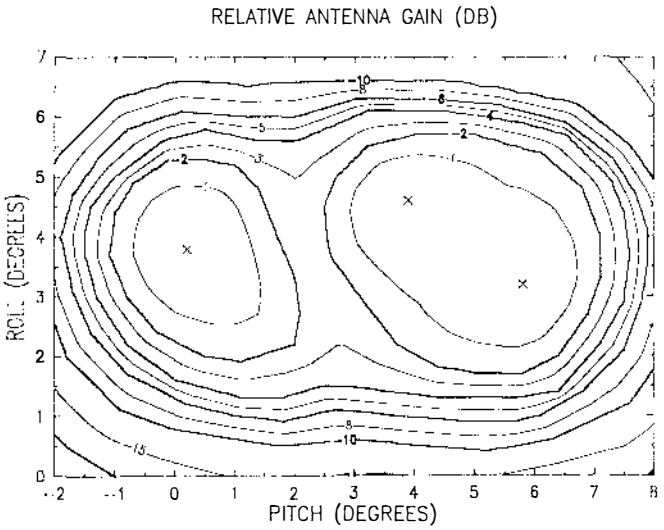


In support of the U.S. preparatory effort for the WARC-ORB, ITS has been developing computer software called GSOAP (Geostationary Satellite Orbit Analysis Program). GSOAP analyzes mutual interference among satellite communication networks as illustrated in the figure below. GSOAP implements all the antenna and propagation provisions adopted by the ITU and has some additional features.



solid line: wanted link
dashed line: interfering link

The Institute developed a computer model of a shaped-beam emission pattern of a satellite antenna and implemented it in GSOAP. This model calculates the antenna gain in the direction of an arbitrary Earth point when several contour lines for a set of gain values are given graphically on the surface of the Earth. In the figure of Relative Antenna Gain, heavier lines plot the input data to the model and the lighter lines plot contours based on the output of the model. The model was transferred to the International Frequency Registration Board at their request.



Recent ITS Publications

A Model of a Shaped-Beam Emission Pattern of a Satellite Antenna (by Akima)

Monitoring of Harmful Interference to the HF Broadcasting Service: I. Results of the October 1984 and March/April 1985 Coordinated Monitoring Period (by Sowers, et al.)

Technical Basis for GSOAP (by Akima)

The HF Broadcast Planning Model: 1985 NTIA/ITS Version (by Washburn, et al.)

User's Manual for GSOAP (by Akima)

Domestic Spectrum Analysis

Outputs

* Report on spectrum efficiency
* Report on Spectrum Resource Assessment

Executive Order 12046 and Department of Commerce Order 10-10 direct NTIA to develop, in cooperation with the Federal Communications Commission, a long-range plan for spectrum use. As part of this planning effort, the Interdepartmental Radio Advisory Committee directed its Technical Subcommittee to develop quantitative definitions of terms relating to spectrum efficiency and to test these definitions by applying them to representative systems in the fixed radio service and in the mobile radio service. The Spectrum Efficiency Studies and Spectrum Engineering Development projects have supported the Convenor of the Working Group that formulated the definition and have developed the computer models that tested the application of the definition to specific service bands.

In 1986, a computer model for calculating the Technical Spectrum Efficiency Factor (TSEF) for the land-mobile radio services was specified by the Working Group and was implemented at ITS. The computer model is a menu-driven, interactive computer program intended for use by an engineer familiar with land-mobile radio systems and the concept of the TSEF. The computer program was used to calculate the TSEF for three Government land-mobile radio systems, and the results are contained in the report "Application of the Technical Spectrum Efficiency Factor to the Land Mobile Radio Service."

The trial applications indicate that the TSEF can be computed accurately only if the communications requirement of the evaluated system is specified in sufficient quantitative detail. These data are in fact not available for most Government systems, either in the Government Master File or in the files of the user agencies. However, the TSEF concept

Project personnel (l. to r.) Bill Grant and Les Berry

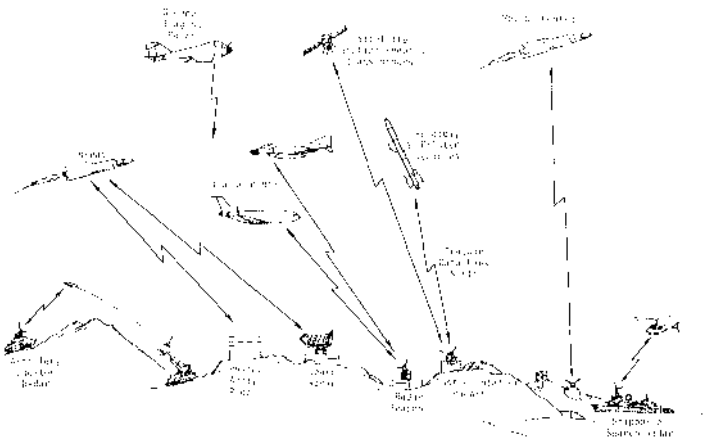
can be used for parametric studies of the sensitivity of the TSEF to system characteristics, communication requirements, and modeling assumptions. The effect of proposed changes in system hardware or traffic loads on technical spectrum efficiency can be simulated using the program.

The Institute further supports NTIA in its role of managing the radio frequency spectrum allocated to the Federal Government by identifying existing and/or potential electromagnetic compatibility (EMC) problems between systems of various departments and agencies, providing recommendations for resolving any compatibility conflicts, and recommending changes that result in more efficient and effective use of the spectrum and improving spectrum management procedures. Spectrum Resource Assessments (SRA) are studies of these areas for specific services or bands. This year ITS assessed the radiolocation services above 1605 kHz.

There are 20 radiolocation bands between 1605 kHz and 248 GHz. At the present state of the art, there is very little activity in the radiolocation bands above 36 GHz. Recent concern by users of the radiolocation bands in the United States was centered in loss of allocated

frequency spectrum for radiolocation purposes, increased sharing with incompatible services, and the downgrading of radiolocation from a primary service to a secondary service in some bands. These problems are even greater in other regions of the world as the erosion of radiolocation spectrum in the 1980s by other countries increasingly affects our peace-keeping forces that rely heavily on radar-equipped ground forces, aircraft, and ships.

The Government's use of the spectrum for radiolocation will be a continuing priority need for the foreseeable future. The use of radar techniques not only for the older, established uses (such as air, sea, and land surveillance, and air traffic control), but for newer areas (such as weapon delivery and control, missile tracking and control, multiple target tracking, new air combat and airborne early warning radar, space radar, terrain following radar, Doppler weather radar, and others) that are continually being updated and improved, makes this a critical service for national defense and national safety. The figure below shows some typical radiolocation uses.



As radar technology advances (such as the use of solid-state devices for both signal sources and signal processing, including very large-scale integration adaptive antennas, airborne Doppler radar, etc.), the amount of spectrum needed to support these systems will continue to increase. This is driven by the types of targets to be tracked. A radar used to track mortar rounds coming into a battlefield area and one used for tracking aircraft may work more effectively in different spectral bands. The introduction of stealth, active radar seekers, increasingly complex electronic counter measure environments, and target identification, as well as detection and tracking and other new technologies, has a tendency to require more bandwidth from radars. There are at least two important factors here that affect spectrum: (1) the need for frequency bands from the lowest radiolocation bands to the highest to support in the most effective way the detection tracking and identification of all the various modern-day targets and (2) the use of wider bandwidths to accomplish the more sophisticated radar techniques demanded by modern defense systems whether land based, shipborne, or airborne.

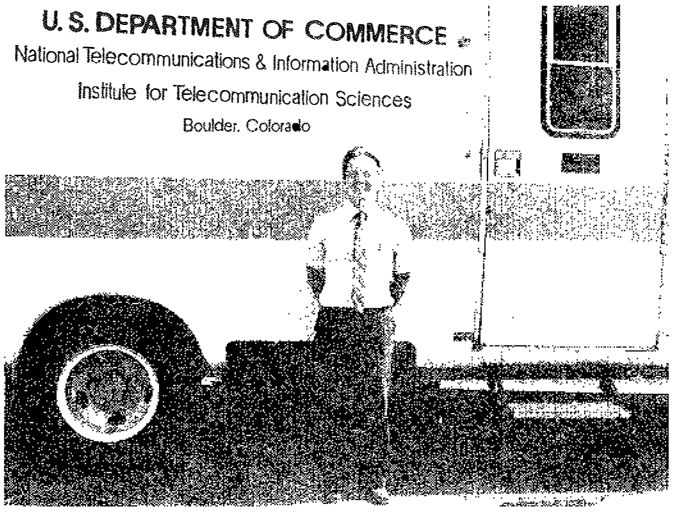
Federal agencies with critical missions such as national defense are dependent on radiolocation services. Under the Department of Defense, the various military departments, as appropriate, organize, train, and equip active duty and reserve forces for the preservation of peace, security, and the defense of our Nation. Radiolocation is a prime element in this planning and training effort.

The SRA looked at present and future radiolocation band usage, new technology, and future developments that impact needed spectrum for this important service. Spectrum management issues were identified and 14 recommendations were made, addressing areas that either need further study, improve spectrum management, or deal with the impact of new technology.

Spectrum Usage Measurements

Outputs

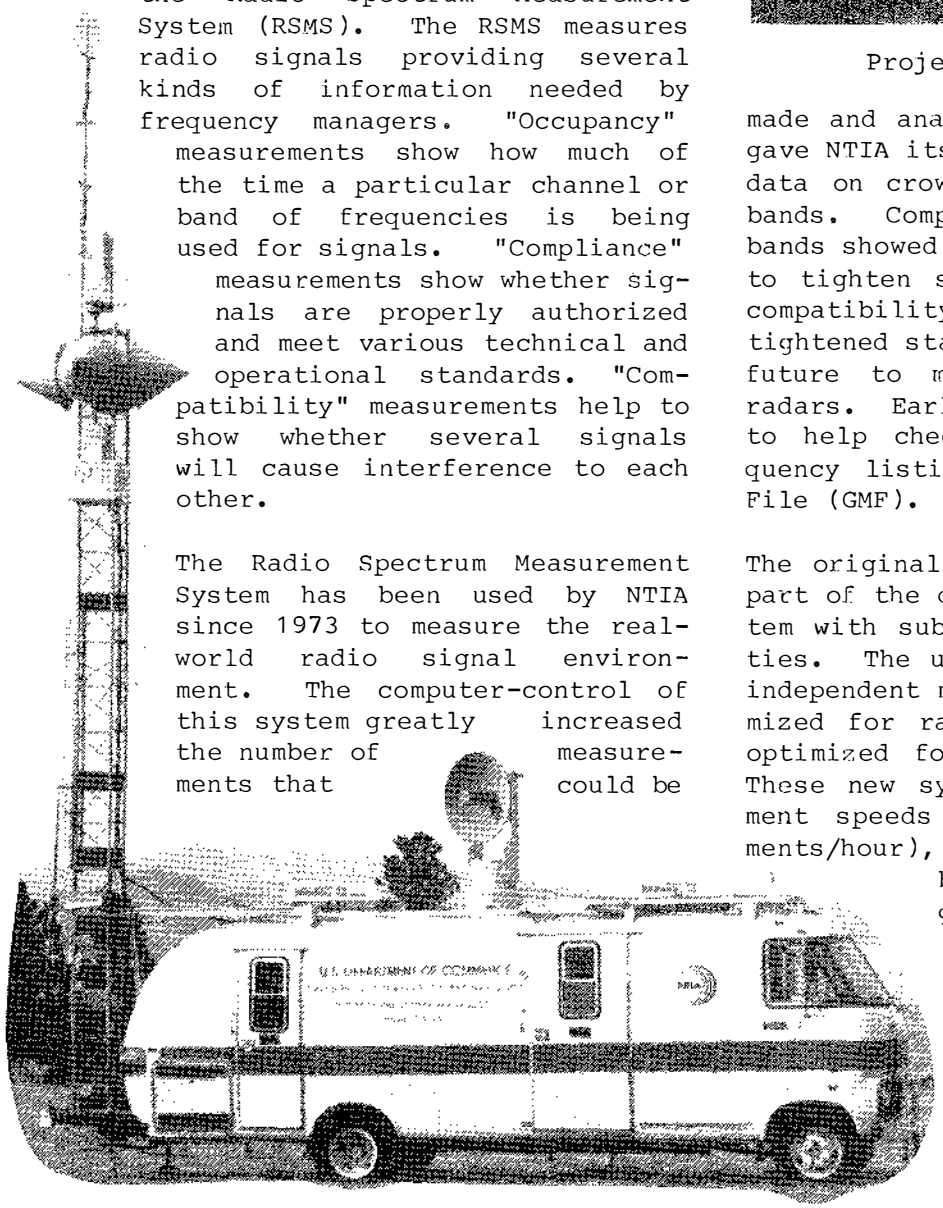
* Fully operational upgraded RSMS
* First of Usage Notebook series
* Prototype Operations Manual
* Special Projects:
  - Maritime mobile message statistics
  - Trunking systems in Government bands
  - Radar emission spectra



Project leader Bob Matheson

One of the functions of NTIA is to manage the use of radio frequencies for Federal agencies. In support of this frequency management effort, ITS operates the Radio Spectrum Measurement System (RSMS). The RSMS measures radio signals providing several kinds of information needed by frequency managers. "Occupancy" measurements show how much of the time a particular channel or band of frequencies is being used for signals. "Compliance" measurements show whether signals are properly authorized and meet various technical and operational standards. "Compatibility" measurements help to show whether several signals will cause interference to each other.

The Radio Spectrum Measurement System has been used by NTIA since 1973 to measure the real-world radio signal environment. The computer-control of this system greatly increased the number of measurements that could be made and analyzed. For example, the RSMS gave NTIA its first quantitative occupancy data on crowding in Government frequency bands. Compliance measurements in radar bands showed that technology was available to tighten some technical standards, and compatibility measurements showed that tightened standards would be needed in the future to minimize interference between radars. Early measurements also were used to help check the accuracy of the frequency listings in the Government Master File (GMF).

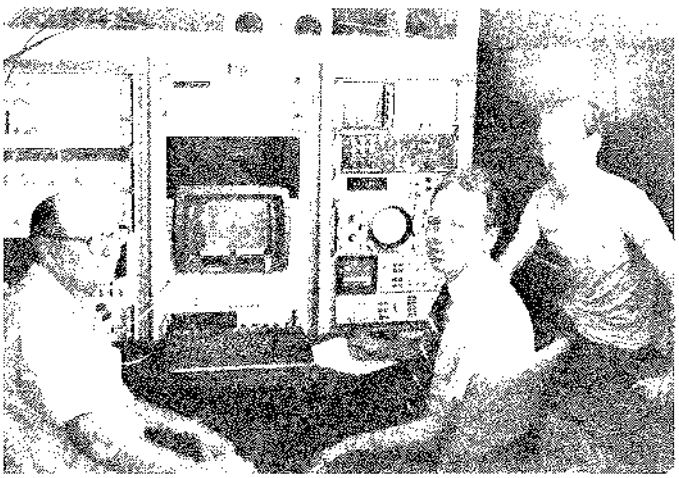


The original RSMS was retired recently as part of the development of an updated system with substantially improved capabilities. The upgraded RSMS now contains two independent measurement systems--one optimized for radar measurements, the other optimized for narrowband voice channels. These new systems permit higher measurement speeds (up to 10 million measurements/hour), better dynamic range, wider bandwidths (10 Hz-30 MHz), greater reliability, more automatic operation, and more flexible operator control of the measurements.

Although real-world measurements will always tend

to be expensive, the cost can be minimized by using a computer to perform most of the work. The RSMS uses calibration and self-check systems to allow accurate measurements to be made without operator intervention, in addition to allowing the operator to schedule in advance a sequence of 100 measurement tasks. Since the selected tasks can each last for many hours and can include system calibration or data transfer via telephone modems, many days of measurements can be made without having an operator present.

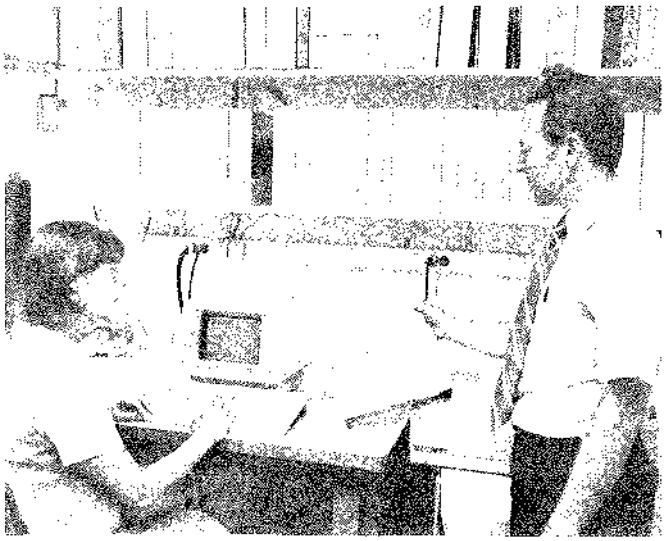
On the other hand, the RSMS also does jobs in which the operator must quickly see measured data and use the results to control the system. For example, when unknown signals are seen, the operator can instantly call routines to do automatic direction-finding, radar pulse-train separation, signal demodulation, or use other ways to help characterize and identify an unknown signal.



RSMS Radar Measurement Console

Measurements from the RSMS are processed in several ways. Some measurements are analyzed as they are made with statistical data being kept instead of saving millions of individual data points on magnetic tape for later analysis. Other measurements are recorded for later analysis in Boulder where they can be combined, plotted, compared to expected signal characteristics, identified, and checked off against the GMF, as needed to solve the problem at hand.

With the large number of measurements made each year, it is important that data be systematically cataloged so that needed measurements can be found. A major effort has been started to save occupancy data in a series of Usage Notebooks. Future work may see these data incorporated into a computer data base system. We have been careful to measure data compatibly so that data from many locations and from many years can be realistically compared, giving valuable information on long-term trends.



Measured Usage Library

Over the years, the RSMS has provided assistance to many Government agencies and private companies. Site surveys showing radio signals over a whole frequency range or occupancy measurements over a narrow band of interest can be easily provided. Specific equipment has been measured to show that it meets Government specifications and that it will not cause interference. Custom measurement techniques have been designed to study critical interference problems referred to us by other Government agencies. RSMS measurements have often been used in special studies of individual frequency bands. We expect that the RSMS will serve the frequency management community for many years.

Telecommunications Analysis Services

Outputs

* Easy access for U.S. industry and other government agencies to the latest in ITS research results and ITS engineering models and data bases
* Broad applications in telecommunication system design and evaluation of broadcast, mobile, link, and radar systems
* Standard method of system analysis for comparisons between competing designs or proposed telecommunication services

Telecommmunications Analysis Services (TASERVICE) is a reliable and efficient means of providing both industry and other government users quick access to the research and engineering of ITS. TASERVICE is based upon a friendly computer in Boulder that is accessible by ordinary telephone using standard modems and ASCII characters. It consists of a large menu of engineering models, scientific and informative data bases, and other useful telecommunication tools.

An example of one of the models is PROFILE. This model is used to determine the effects of terrain on the engineering of microwave links and on broadcast stations, depending on the user's interactions with the model. In the case of microwave links, the user can input the locations of proposed antennas and the model will then provide plots that are mailed to the user showing the clearance along the path for Earth radii of 2/3, 4/3, true, and flat Earth. For broadcast stations, the average terrain heights from 2 to 10 miles on radials every 45 degrees around the transmitter site are of interest. The PROFILE model will calculate these average terrain heights for the user and print them directly on their computer terminals. The terrain elevations are obtained from an ITS-maintained data base of terrain heights in the United States and Puerto Rico that is corrected and augmented as new data are obtained from ongoing ITS projects.

Project personnel (l. to r.) Yeh Lo and Jean Adams

A more recent addition to TASERVICE is a model called Communication System Performance Model (CSPM). This model will calculate the coverage of one or more VHF/UHF transmitters within a specified boundary and create a plot showing the areas covered with specified signal levels. The figure on the opposite page shows the 34 dBu coverage of a mobile transmitter near Boulder, Colorado. Since there are mountains to the west, the signal from the antenna located on Lee Hill has better coverage to the east, although due west from the transmitter, the signal reaches into several regions with higher elevations. Plots such as these are used to plan installations and to develop engineering requirements for towers, and antennas and for comparing the relative merit of different potential transmitter sites.

In order to use the service, a user establishes an account with ITS with at least a $500.00 deposit. The user then calls the service on an ASCII type terminal and interacts with the TASERVICE system to access the particular data or model(s) of interest with the costs of the use deducted from the user's deposit.

There are currently 17 active models in the system, which allow the analysis and engineering of systems from low-frequency

ground wave to systems operating at millimeter wavelengths. These models are:

PATH PARAMTRS Calculates great circle distances, bearings, etc., and provides delta H and average terrain heights at specific locations.

RAPIT Calculates basic transmission loss and signal levels over irregular terrain for broadcast and mobile radio systems.

FMFIND Lists FM station parameters from an FCC derived data base according to user specified search parameters.

TVFIND Lists TV station parameters from an FCC derived data base according to user specified search parameters.

AMFIND Lists AM broadcast station parameters in CCIR region 2 according to user specified search parameters.

TOWER FIND Lists tower locations and sizes from an FAA/FCC derived data base according to user specified search parameters.

RAIN Calculates increased attenuation of microwave and millimeter-wave signals due to the precipitation along the path.

BURST Calculates waiting times for meteor-burst communication systems and networks.

ITSGW Calculates system performance or basic propagation path loss for systems that use the ground wave between 10 kHz and 30 MHz as the means of propagation.

INMOD Lists intermodulation products in receiver bandpass (up to 40 transmitters, 40 receivers, up to seventh order, and up to 5 concurrently operating transmitters).

PROFILE Determines path profiles according to user specified parameters using the digitized topographic data base, and applies radio refractive affects on the signal path for microwave path clearance. Optionally returns average terrain heights.

HORIZON Plots radio horizon around a specified location in the United States using the digitized topographic data.

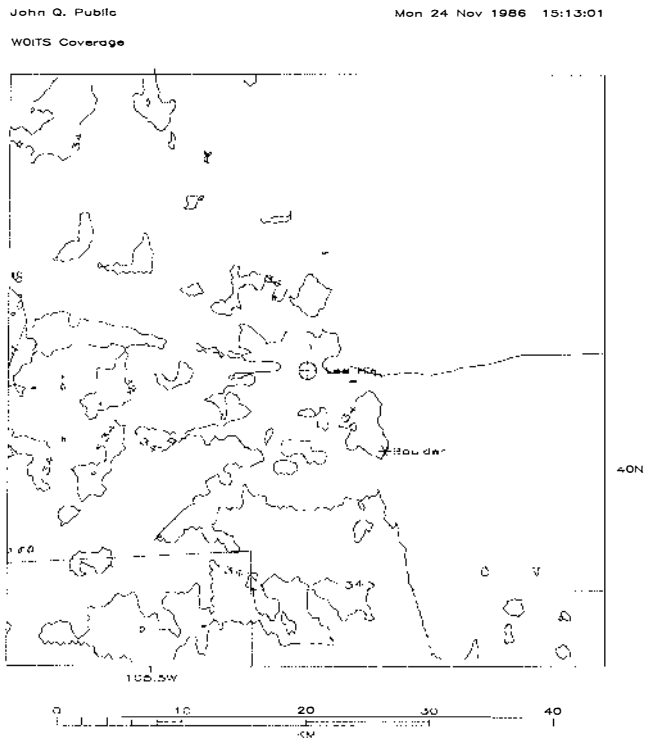
SHADOW Plots the radio line-of-sight regions around a specified location in the United States using the digitized topographic data.

COVERAGE Plots contours of signal coverage of transmitters using the FCC Broadcast Rules or the ITS Irregular Terrain Model and includes population estimates based on 1980 census data.

CSPM Communication System Performance Model determines system performance of mobile and broadcast systems in detailed plots with background political boundaries accoring to the ITS Irregular Terrain Model in point-to-point mode.

FMPLOT Calculates the coverage of FM stations with user input parameters. It can include interference and directional antennas.

SKYWAVE Calculates the performance of radio systems that use the frequencies from 3 to 30 MHz and ionospheric paths using the ITS ionospheric and radio noise data.



CSPM output showing 34 dBu field strength contour for a mobile transmitter on Lee Hill

TELECOMMUNICATION STANDARDS DEVELOPMENT

Much effort within ITS is focused on the development and application of national and international technical performance standards to facilitate competition in the provision of enhanced telecommunication products and services. Additionally, ITS develops standards for military communication applications.

Nationally, ITS efforts address a growing need for efficient means of relating the data communication performance requirements of end users with the capabilities of competing system and network offerings. The Institute has pioneered the development of methods and procedures for specifying and measuring performance of data communication systems and services as seen by the end user. Major end products are Federal and American standards, developed under the auspices of the Federal Telecommunication Standards Committee (FTSC) and the American National Standards Institute (ANSI), respectively.

The international effort addresses the need for technically strong, broadly based U.S. contributions to international standards organizations. The Institute participates in and contributes to the efforts of various international Study Groups functioning under the aegis of the International Telecommunication Union's International Telegraph and Telephone Consultative Committee (CCITT) and International Radio Consultative Committee (CCIR). Recommendations determined by these organizations significantly influence United States trade in telecommunication products and services. Recently, for example, special emphasis has been placed on the development of technical standards for Integrated Services Digital Networks (ISDNs). ISDNs are the currently evolving digital communication networks which will ultimately provide integrated voice, data, facsimile, and video services to subscribers on a worldwide basis. CCITT decisions affect both the implementation of ISDN in the United States and the size of our export markets for ISDN equipment and services.

AREAS OF EMPHASIS

CCIR Activities

Includes projects funded by the National Telecommunications and Information Administration

CCITT Activities

Includes projects funded by the National Telecommunications and Information Administration

Data Communication Standards Development

Includes projects funded by the National Telecommunications and Information Administration

Development, Revision, and Assessment of Standards

Includes projects funded by the Army Information Systems Engineering Support Activity and the Defense Communications Agency

CCIR Activities

Outputs

* Technical standards to support U.S. positions at radio conferences
* Leadership of U.S. participation in key CCIR Study Groups
* Coordinated U.S. positions on all issues related to CCIR reports and recommendations

The International Radio Consultative Committee (CCIR) is one of two (the other being the CCITT) consultative committees that are permanent organs of the International Telecommunication Union (ITU).

All member countries of the ITU and certain private organizations can participate in the work of the CCIR. This work provides the basis for compatible operation of telecommunication systems and for efficient utilization of the radio frequency spectrum. The reports and recommendations of the CCIR are used by regional and worldwide radio conferences in arriving at decisions pertaining to technical objectives of the conferences. Thus, it is extremely important that the material contained within the documentation of the CCIR is consistent with United States objectives for telecommunication usage and radio conference positions. The work of the CCIR is carried out by 13 Study Groups, listed in the table at right.

To expedite the work of Study Groups on some particularly urgent or very specialized problems, Interim Working Parties (IWP's) are set up by the Study Groups. The IWP's mainly work by correspondence and are generally in operation for a limited (2-4 years) period of time.

Members of the Institute participate very actively in the work of Study Groups 1,3,5, and 6. An Institute member is the International Vice Chairman of Study Group 3, Fixed service at frequencies below about 30 MHz. Institute members serve as U. S. chairpersons of Study Group 1, Spectrum Utilization and Monitoring, and

Project personnel (l. to r.) Don Spaulding, Jean Adams, Les Berry, Charlie Rush, and Bill Utlaut

Study Groups

1 Spectrum Utilization and Monitoring
2 Space Research and Radioastronomy
3 Fixed Service at Frequencies Below about 30 MHz
4 Fixed-Satellite Service
5 Propagation in Non-Ionized Media
6 Propagation in Ionized Media
7 Standard Frequencies and Time-Signals
8 Mobile Services
9 Fixed Service using Radio-Relay Systems
10 Broadcasting Service (Sound)
11 Broadcasting Service (Television)
CMTT (joint with CCITT) Transmission of Sound Broadcasting and Television Signals over Long Distances
CMV (joint with CCITT) Vocabulary

Study Group 6, Propagation in Ionized Media. An Institute mathematician plays a prominent role both domestically and internationally in that part of Study Group 1 activities dealing with spectrum efficiency and utilization. Another Institute mathematician was responsible for the leadership of a major Study Group 6 IWP dealing with developing methods to improve the global representation of atmospheric radio noise.

Recent CCIR-related activity at ITS has tended to emphasize specific issues in the

Study Groups. In Study Group 1, for example, ITS initiated and chaired a drafting group to revise and extend one of Study Group 1's basic documents, Report 662, "Definition of Spectrum Use and Efficiency." This Report originated with the United States and has been added to at every meeting since its introduction. In addition, at international meetings of Study Group 1, the ITS Director chairs Working Group 1A, Principles and General Applications Related to the Efficient Use of the Radio Spectrum, which is the most active Working Group.

Institute activities related to Study Group 3 have been directed at recommending the required protection ratios for systems that will be sharing the expanded AM band. There are a number of existing broadcast systems in the 1605-1705 kHz band that will be affected by the expansion of the AM band. Study Group 3 has been developing required protection ratios for various emissions as an ongoing activity. Currently, an ITS member is the International Chairman of an Interim Working Party to complete the determination of protection ratios for every emission type that the fixed service uses or shares with other services. After lengthy discussions with the other countries, the protection ratios for AM interference to the various single sideband voice and digital systems of Study Group 3 were recommended for adoption.

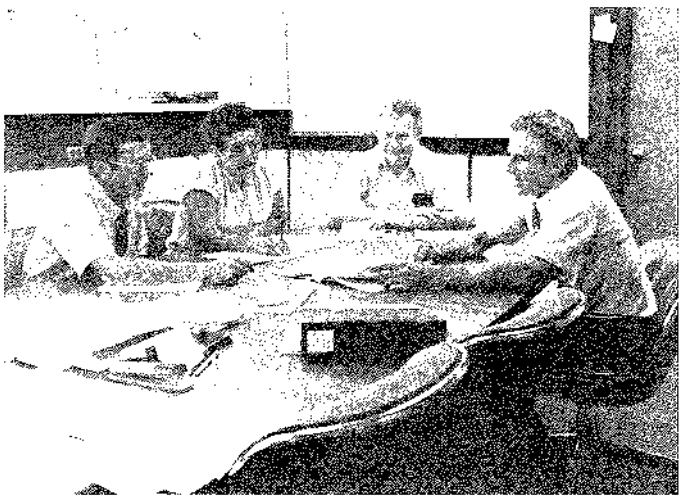
Support to Study Group 5, which deals with propagation in nonionized media, has been primarily in two areas. One of these is the improvement to a CCIR report dealing with propagation in the millimeter-wave portion of the spectrum. The other area of Study Group 5 work that the Institute has addressed is the improvements to the ground-wave propagation models. The Institute has worked closely with the CCIR Secretatiat in testing the most recent CCIR ground-wave propagation models, and numerous calculations and graphical displays were provided directly to the Secretariat.

The activity undertaken by the Institute to support the work of Study Group 6 has been directed in three major areas: (1) providing support for U.S. positions at the Second Session of the High Frequency Broadcasting Conference [WARC-HFBC(2)]; (2) improving global maps of the critical frequency of the F2 region (foF2); and (3) improving the representation of the global distribution of atmospheric radio noise. In the first of these areas, the activity is directed at assuring that the CCIR reports and recommendations contain material that is consistent with U.S. objectives for WARC-HFBC(2). In the area of improving global maps of foF2, the Institute has assumed the lead both nationally and internationally in developing new maps of foF2 that yield improved representation of the ionization distribution over ocean regions. This is particularly important because such regions are inaccessible to routine observation. The activity directed at improving the representation of the global distribution of atmospheric radio noise has resulted in the adoption by the CCIR of a major improvement to the report contained within the Study Group that deals with atmospheric noise. This work was completed as part of the CCIR IWP 6/2, which was chaired by an Institute staff member. World maps of atmospheric radio noise are now available that realistically represent the radio noise due to lightning that is likely to be encountered by a high-frequency radio system.

CCITT Activities

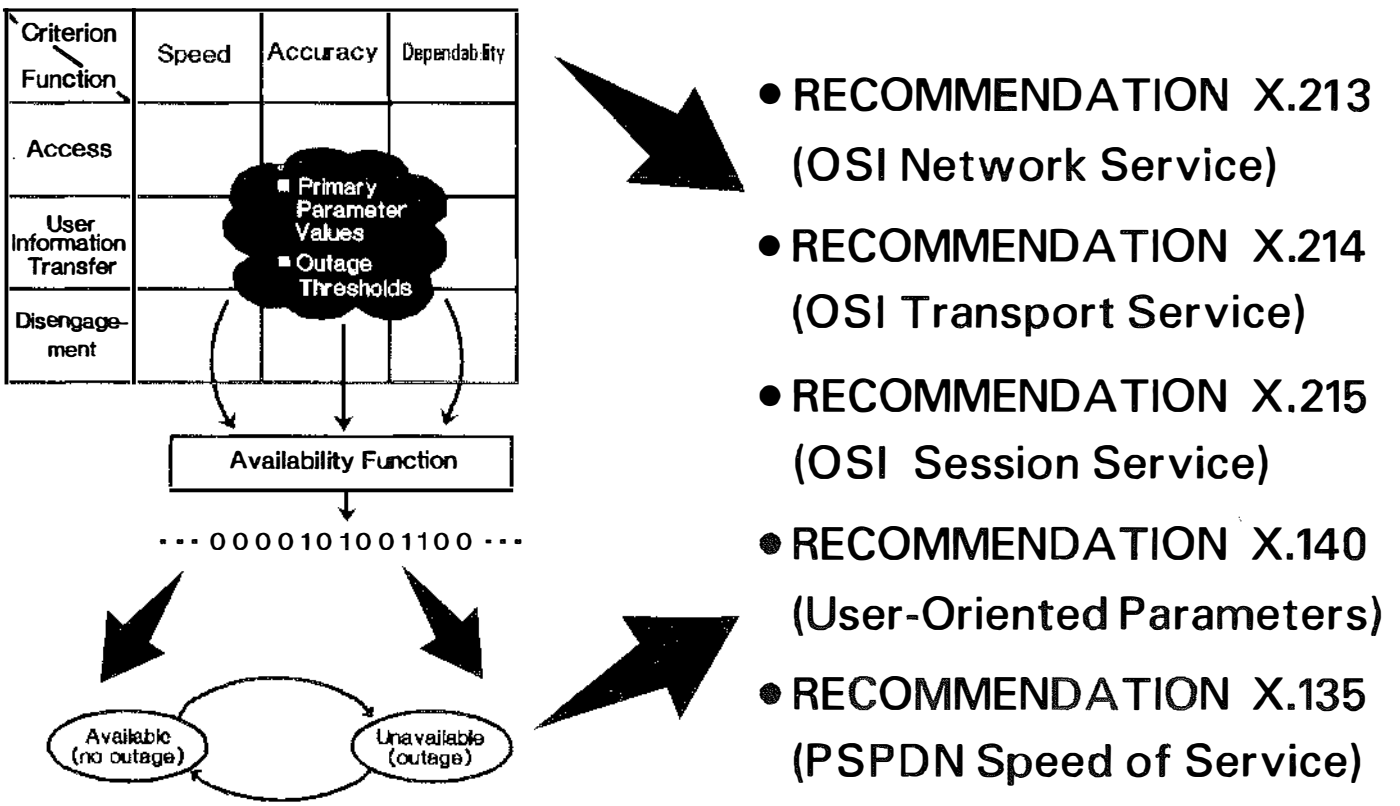
Outputs

* Leadership of U.S. participation in key international standards negotiations of the CCITT (under the auspices of the Department of State)
* Publications, presentations, and workshops that inform affected U.S. industry and government organizations of international standards issues
* Proposed texts for CCITT Recommendations defining quality of service in public data networks and ISDNs

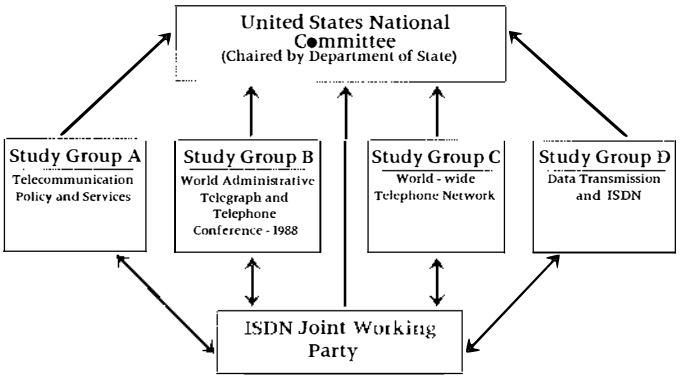


Project personnel (l. to r.) Ed Quincy, Dorothy Cerni, Ted de Haas, and Neal Seitz

The negative U.S. trade balance is a major economic issue confronting U.S. industry and government planners today. The competitiveness of U.S. telecommunication products and services in international markets is strongly influenced by international telecommunication standards--particularly those of the CCITT. The Institute contributes directly to the planning, development, coordination, and implementation of CCITT standards (Recommendations) in support of Commerce Department telecommunication trade objectives. This work has two long-term goals:



Matrix Framework and Relevant CCITT Recommendations



The U.S. Organization for the CCITT

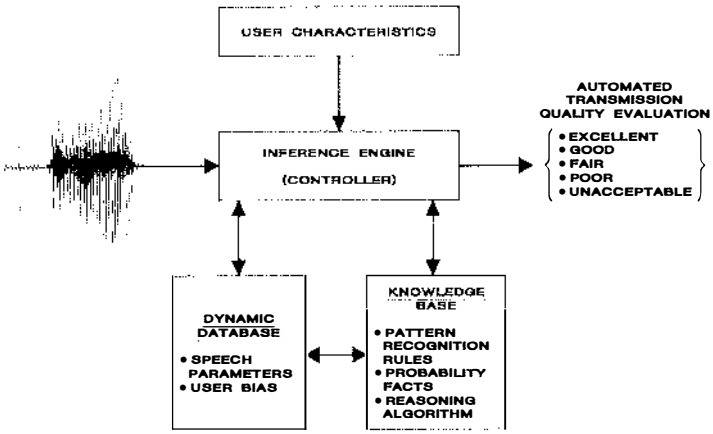
- o to enhance international trade opportunities for U.S. telecommunication providers by promoting the development of broadly-based, non-restrictive, international telecommunication standards

- o to ensure that the interests of competing U.S. telecommunication providers (and users) are fully represented in U.S. contributions to international standards committees in which ITS has leadership responsibilities.

The Institute directly supports the U.S. Department of State in leadership of the U.S. Organization for the CCITT. During FY 86, ITS personnel chaired two of the five permanent U.S. CCITT Study Groups: Study Group D, "Data Communications," which provides contributions to CCITT Study Groups VII and XVII, and the ISDN Joint Working Party (JWP), which provides contributions to Study Groups XVIII and XI on ISDN issues. Institute staff members organized and chaired seven U.S. CCITT preparatory meetings and headed the U.S. Delegations to six major CCITT meetings during FY 86.

The Institute provides information on a wide variety of CCITT activities to U.S. standards committees and the general public to broaden and strengthen U.S. participation in international standards development. During FY 86, Institute staff members developed contributions on the scope and organization of work in four key CCITT Study Groups.

Senior Institute staff members lead and contribute directly to CCITT standardization in areas of particular significance to Commerce trade objectives. These efforts have led to the adoption of an ITS-developed "matrix" framework for performance description in a number of important CCITT Recommendations. The matrix framework has also been accepted internationally as a basis for the development of network performance parameters in ISDNs. Other ITS research led to promising results in the application of expert pattern recognition techniques to the development of user-oriented, system-independent voice transmission quality measures. Contributions were presented to the ANSI Accredited Standards Committee Working Group T1Q1.1 detailing methodology, candidate objective parameters, and performance.



Voice Quality Expert System Structure

Recent ITS Publications

The OSI Network Layer Addressing Scheme, its Implications, and Considerations for Implementation (by Hemrick)

Contributions to Standards Committees

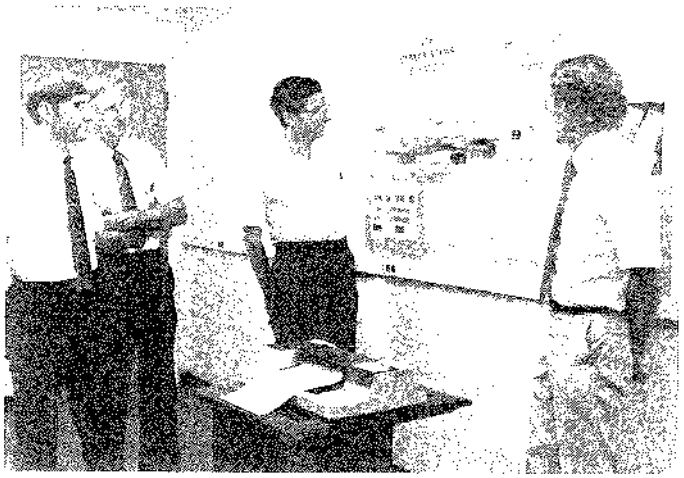
Revised CCITT Recommendation X.135, Speed of Service (Delay and Throughput) Objectives for Public Data Networks (by Seitz and Cerni)

Prolog Based Expert Pattern Recognition System Shell for Technology Independent, User-Oriented Classification of Voice Transmission Quality (by Quincy)

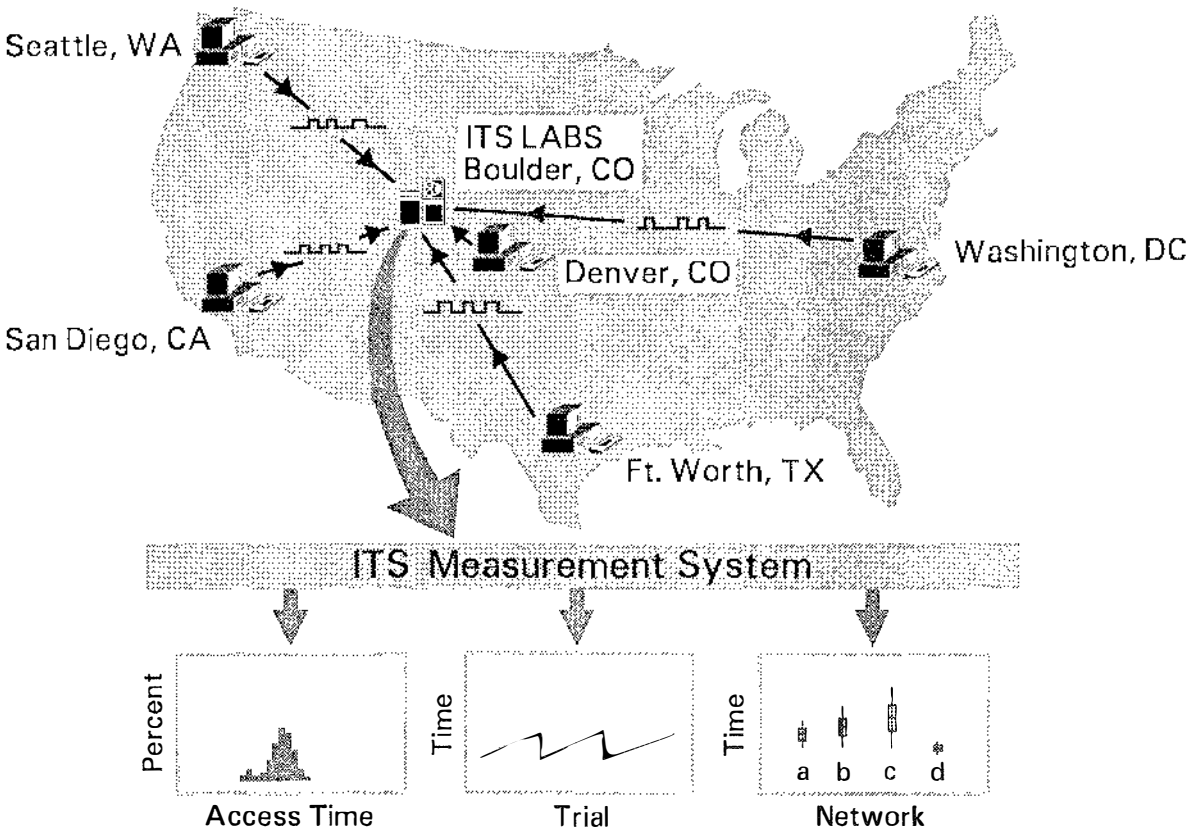
Data Communication Standards Development

Outputs

* Compatible industry and Federal standards defining user-oriented, system-independent data communication performance parameters
* Compatible industry and Federal standards defining measurement methods for user-oriented data communication performance evaluation
* NTIA Reports and open-literature publications describing the technical basis and intended application of each standard
* Machine-independent computer programs for measuring data communication performance in accordance with the standards--available to the public
* NTIA Reports and open-literature publications describing pilot applications of the standards (and the NTIA-developed measurement software) in the measurement of private and public data communication networks



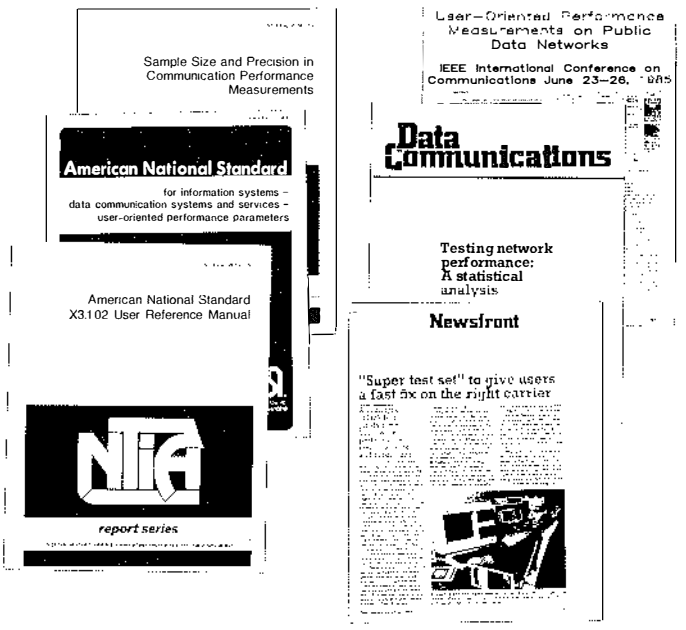
Project personnel (l. to r.) Dave Wortendyke, Ned Crow, Ken Spies, and Marty Miles



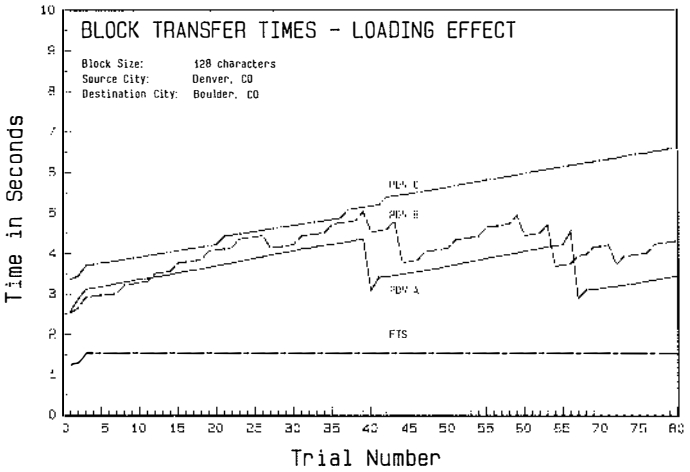
Performance Measurements of Public Data Networks

Deregulation, competition, and the rapid growth of computer communications have created an urgent need for uniform means of specifying and measuring the performance of data communication systems, subsystems, and services as perceived by users. The Institute is contributing strongly to U.S. industry efforts to meet that need through a Commerce-funded Data Communications project focused in three major areas:

Standards Development. Institute personnel chair the two U.S. industry standards committees most directly involved in data communication performance standards development--Working Group T1Q1.3, a component of the ANSI-Accredited T1 (Telecommunications) Committee, and Task Group X3S3.5, a component of the ANSI-Accredited X3 (Information Processing Systems) Committee. Institute personnel conduct state-of-the-art performance specification and measurement studies, serve as principal authors of proposed standards in both committees, and develop technical publications that explain the standards and illustrate their use.



Prototype Measurement System Development. Institute personnel develop experiment design, data extraction, data reduction, and data analysis software and procedures consistent with the standards to facilitate their use in actual performance measurements. Within available resources, Institute personnel assist U.S. industry and Federal Government data communication providers and users in developing and applying test systems conforming to the standards.



Typical Measurement Results

Demonstration Measurements. Institute personnel plan and conduct selective measurements of private and competing public data communication networks using the ITS-developed performance standards to demonstrate their practicality and to encourage test equipment manufacturers, data communication suppliers, and users to implement them. In a recent experiment, ITS-developed, microcomputer-based test sets were used in assessing the performance of three packet-switched public data networks and conventional circuit-switched telephone connections in transferring user data between five major Federal installations and the ITS Laboratories in Boulder.

Recent ITS Publications

Proposed American National Standard X3.141, Data Communication Systems and Services --Measurement Methods for User-Oriented Performance Evaluation (by X3S3.5 Committee; Seitz, chairman)

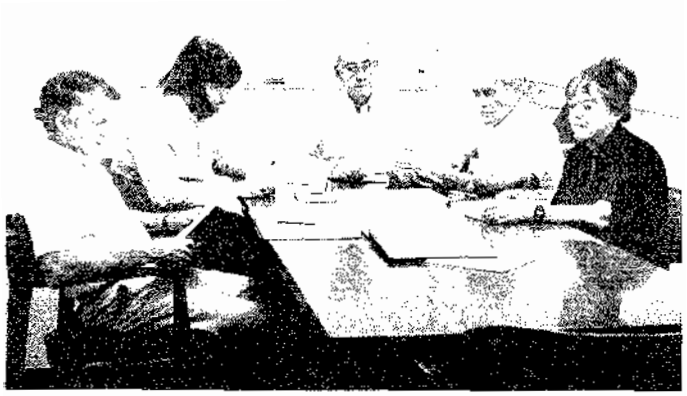
Testing Network Performance: A Statistical Analysis (by Miles and Seitz)

Development, Revision, and Assessment of Standards

Outputs

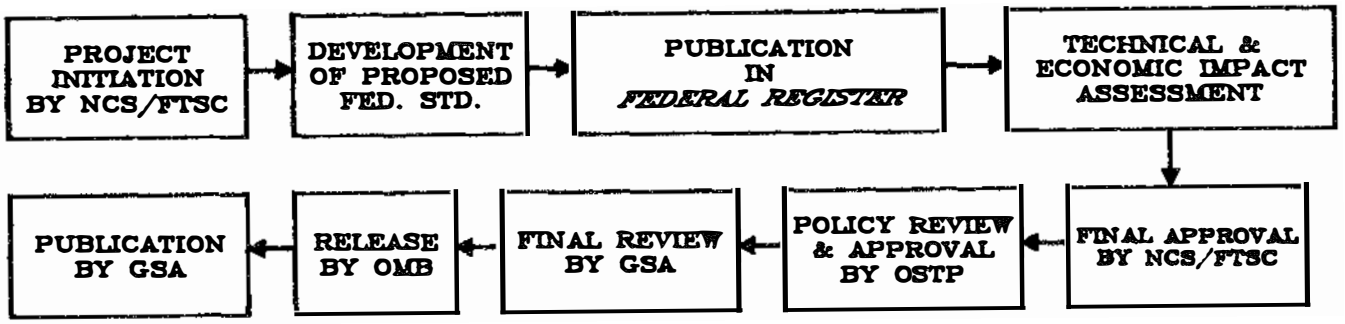
* Six proposed or revised Federal Standards
* Two impact assessments
* One technical report

The unprecedented use of computers in government, business, and industry; the concurrent rapid evolution of new technology such as fiber optic transmission systems; and the need for worldwide transfer of information have created the need for proactive (before implementation) standards. The deregulation of the common carrier industry has left the United States without a dominant producer of de facto standards that may be adopted as reactive (recognizing existing practices) standards. National and Federal standards assume very important roles in this new evolution and must be developed without conflict with each other or with international (e.g., CCITT) standards. Proactive standards should encourage technology evolution and promote interoperability. Representative examples of these proactive standards are the Open Systems Interconnection (OSI) Reference Model and the Integrated Services Digital Network (ISDN). These provide an architecture or framework for technology evolution.



Project personnel (l. to r.) Don Glen, Bill Ingram, Joe Hull, Glenn Hanson, and Evie Gray

Several projects at ITS involve developing telecommunication standards in keeping with the goals of promoting interoperability and advancement of technology. Participation on standards committees serves these goals and keeps ITS staff members current on the issues facing Federal as well as commercial users of telecommunications services and



Development Process for Federal Standards

equipment. Often ITS staff members are the only U.S. Government representatives on Electronic Industry Association (EIA) and American National Standards Institute (ANSI) committees and working groups. In addition, these ITS personnel may be the designated representatives of NCS, the National Communications System.

Besides providing Government representation, ITS is often deeply involved in the technical aspects of Federal standards, interoperability analyses, and technical and economic impact assessments, or in serving as coordinator and editor. An ITS staff member chairs the Fiber Optics Task Group (FOTG) of the Federal Telecommunications Standards Committee (FTSC), and works closely with the MIL-STD-188 series committees on tactical and long-haul communications. Two other staff members are helping develop and edit the latest version of ANS X3.100 (based on CCITT Recommendation X.25), which defines the data terminal equipment interface to packet-switched public data networks.

As shown in the list of proposed new standards, the work over the past few years has involved the development of modem standards, some development and editing of a National standard for the U.S. version of X.25, and coordination and development activities on high frequency radio automatic link establishment and the choice of optical fiber materials and sizes.

One notable activity was the revision of FED-STD-1037 into FED-STD-1037A, Glossary of Telecommunication Terms. The principal ITS role in 1037A was in editing and recording the glossary meetings. ITS also contributed to the new fiber optics terms and developed definitions dealing with deregulation, computers, the OSI Reference Model, and ISDN technology.

Use of the glossary should facilitate interoperability among equipment and systems, and it should enhance communication among vendors and purchasers, among designers and users, and among standards writers at large.

New and Revised Standards

FED-STD-1037A Glossary of Telecommunication Terms

FED-STD-1007A Telecommunications: Coding and Modulation Requirements for Duplex 9600 Bit/Second Modems

Proposed FED-STD-1009 Telecommunications: Coding and Modulation Requirements for Duplex 14,400 and 12,000 Bit/Second Modems

FED-STD-1045 HF Radio Automatic Link Establishment

Proposed ANS X3.100 Interface Between DTE and DCE for Operation with Packet-Switched Data Networks (PSDN), or Between Two DTEs by Dedicated Circuit

Proposed FED-STD-1070 Standard Optical Fiber Waveguide Material Classes and Optional Sizes

Impact Assessments

FED-STD-1006A Telecommunications: Coding and Modulation Requirements for 4800 Bit/Second Modems

FED-STD-1065 Telecommunications: Facsimile Coding Schemes and Coding Control Functions for Group 4 Facsimile Apparatus

Recent ITS Publications

Local Network Assessment (by Glen)

Networks, Signaling, and Switching for Post-Divestiture and the ISDN (by Glen)

TELECOMMUNICATION SYSTEMS PERFORMANCE

A number of activities are undertaken at ITS that apply the results of more basic studies to improve the performance and design of telecommunication systems.

Through other-agency sponsored projects, ITS develops techniques for systems and network performance prediction measurement, and evaluation. The Institute uses these techniques to forecast how individual communication elements will perform together and then tests them in a laboratory or operational environment.

AREAS OF EMPHASIS

HF Systems Assessment

Includes projects funded by the Board of International Broadcasting, the Army Information Systems Engineering Support Activity, the Army Intelligence and Security Command, and the U.S. Information Agency

Microwave Performance Assessment

Includes projects funded by the Air Force Electronic Systems Division, the Air Force Systems Command, and the Army Information Systems Engineering Support Activity

Microwave and Millimeter-Wave Radio Performance Prediction

Includes projects funded by the Army Communications Electronics Command, the Army Information Systems Engineering Support Activity, the Army Intelligence and Security Command, the Naval Air Systems Command, and the Federal Aviation Administration

Test Methodology and System Performance

Includes projects funded by the National Bureau of Standards and the Army Electronics Proving Ground

Systems Monitoring, Evaluation, and Control

Includes projects funded by the Air Force Electronic Systems Division

HF Systems Assessment

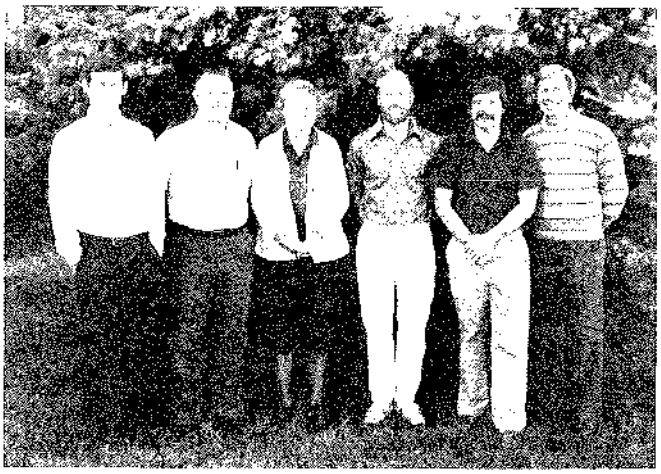
Outputs

* Develop analytical techniques for government agencies' operational use
  Develop interactive sky-wave and ground-wave models
* Implement sky-wave and ground-wave models on personal computers
* Develop performance analysis standard for HF broadcasting

For several years, ITS has provided support to various government agencies in technical areas pertaining to High Frequency propagation system performance. In the initial planning, or in the modification of many communication systems, there may be appreciable delay between the circuit planning and the actual circuit construction or modification. This is of particular importance for high-frequency circuits with marked time and geographic variations in optimic frequency, required power, and system performance.

Predictions of ionospheric characteristics and techniques may be used to anticipate the performance of HF communication circuits and provide the lead time for necessary equipment selection and frequency selection.

The Ionospheric Communications Analysis and Prediction Program (IONCAP) is an integrated system of models designed to predict high-frequency sky-wave system performance and analysis ionospheric parameters. These computer-aided predictions may be used in the planning and operation of high frequency communication systems using sky waves. The Ground Wave Automated Performance Analysis (GWAPA) computer program is an integrated system of models designed to predict high-frequency, ground-wave performance. Both IONCAP and GWAPA have interactive capabilities to allow design engineers and frequency managers ease of use and fast turnaround of predictions. The IONCAP program and the Homogeneous Earth ground-wave model with GWAPA have been implemented on



Project personnel (l. to r.) Nick DeMinco, Frank Stewart, Carlene Mellecker, Greg Hand, Larry Teters, and Eldon Haakinson

a personal computer to give even more flexibility to the design engineer and frequency manager. Predictions from the IONCAP program are available from ITS, and have been supplied to a variety of government agencies and to the private sector.

Efforts have been undertaken to interface the IONCAP program input to the GWAPA program to obtain ground-wave, field-strength predictions that can be compared with the sky-wave predictions. The IONCAP program is also being redesigned to allow for more optimal use in area coverage. This effort should allow more flexibility in modification and replacement of various analysis models and incorporation of new models as they are developed.

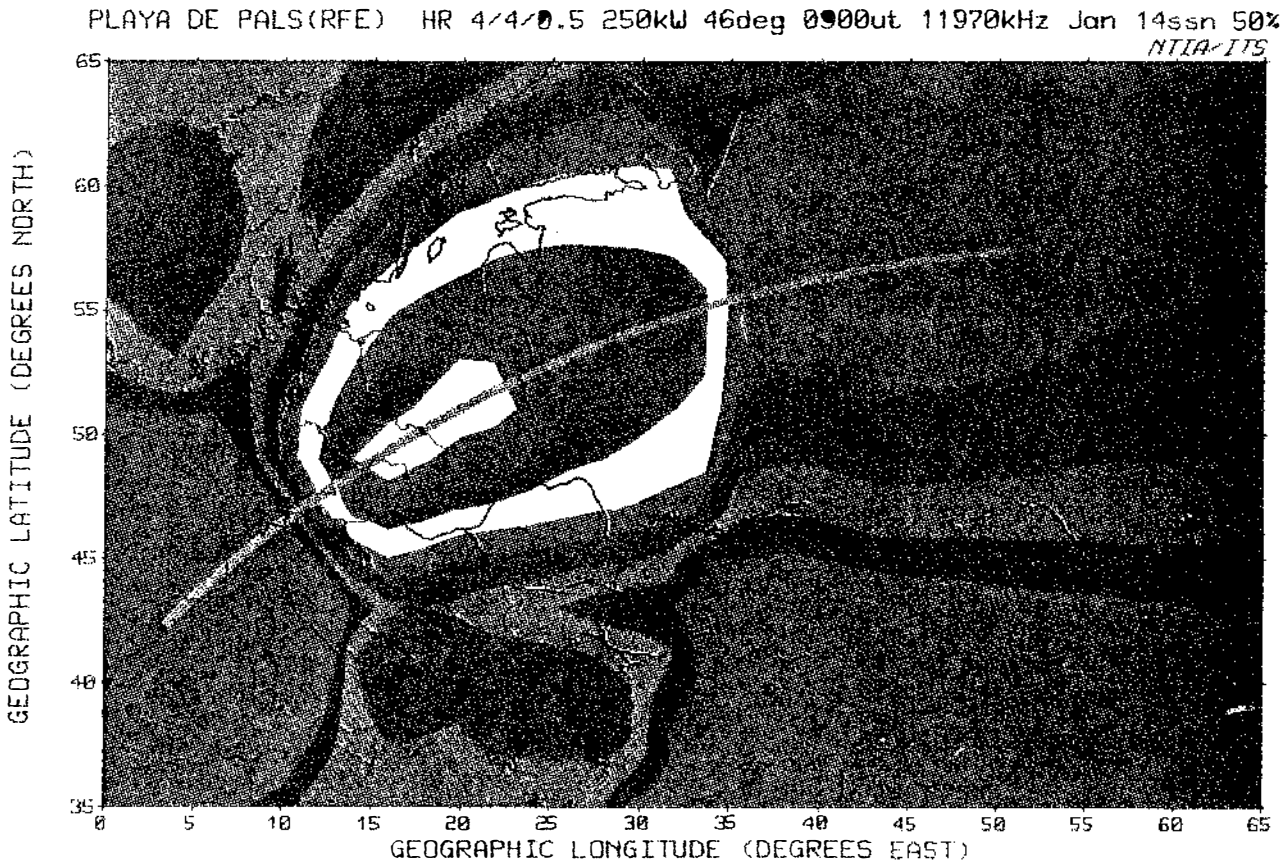
An effort to develop a generalized high frequency interference assessment procedure utilizing the IONCAP program has been indicated. This should allow a method of determining propagation characteristics with cochannel and adjacent-channel protection ratios to determine the degree of interference and a method of evaluating the degree of interference under various user specified scenarios.

The Institute is also developing methods to enable summarizing the many calculations of system performance from the

IONCAP program. The results of this effort can be used to help in the design of optimal antennas. Other studies include incorporation of a polar ionospheric model into the IONCAP program and the development of a point-to-area version of IONCAP.

The results of sky-wave propagation predictions have also been used to simulate the expected broadcast coverage from various transmitters around the globe. This effort utilizes the HFBC84 computer program. This program provides a relatively rapid estimate of the field strength of a given HF radio wave. A procedure has been developed with this model that enables coverage maps to be produced that display the predicted field strength in any service area. An example of this is given below for a Radio Liberty transmission out of Spain on 11.970 kHz during January 1986 at 0900 h UTC.

The results of several of the above efforts can be used to develop a performance analysis standard for HF broadcasting to support the major international broadcast organizations of the United States in upgrading and modernizing their facilities.

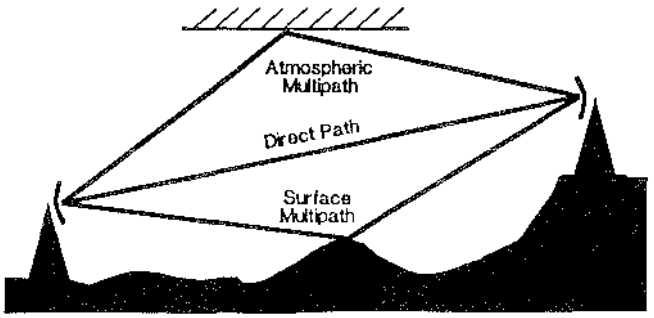


Microwave Performance Assessment

Outputs

* Radio performance data
* Propagation data
* Channel models
* ECM equipment performance data

The Institute has long been active in field testing microwave radio systems. One objective of this testing is to analyze the system performance in a fading environment. Digital microwave radios, such as those used by the telephone companies, are especially vulnerable to frequency selective fading caused by atmospheric multipath. In a typical microwave radio field test program, several characteristics of the channel must be measured and correlated in time with the performance of the radio. The Institute has developed channel probes and data acquisition systems to facilitate such correlated field testing.



Typical Radio Multipath Environment

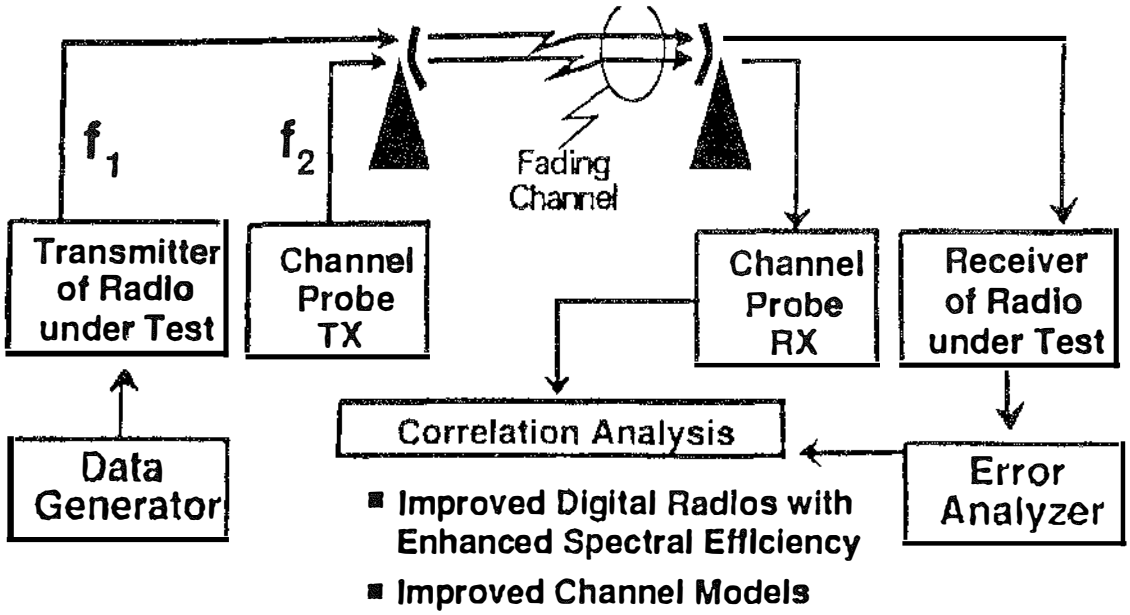
The objective of these test programs is to evaluate radio performance in a fading environment. To do this, a known digital bit stream is injected into the radio under test. At the receive end of the link, the received data are compared to that transmitted. Error statistics are then derived which are measures of the radio's performance. This information is then correlated with measures of the propagation channel. The end objective is to determine if the radio meets performance standards during periods of poor propagation.

Project personnel (l. to r.) Jim Hoffmeyer, John Lemmon, and Wes Beery

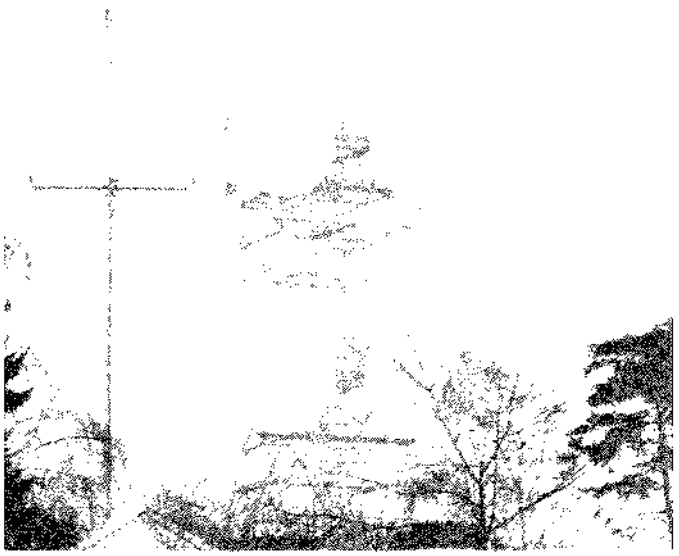
Channel probes are the devices used to measure propagation characteristics of the channel such as multipath delay spread, received signal level, and rate of fading. This information is useful for two purposes: 1) as a measure of propagation conditions at the time that radio performance measurements are made and 2) as the basis of a channel model for use in channel simulator and radio performance prediction programs.

The Institute has built channel probes for use on microwave line-of-sight (LOS), tropospheric scatter, and millimeter-wave transmission links. These instruments have been used in both research and development programs and in acceptance testing of operational transmission networks. They have been used in a variety of tests worldwide, including some tests of critical Department of Defense command, control, and communications networks.

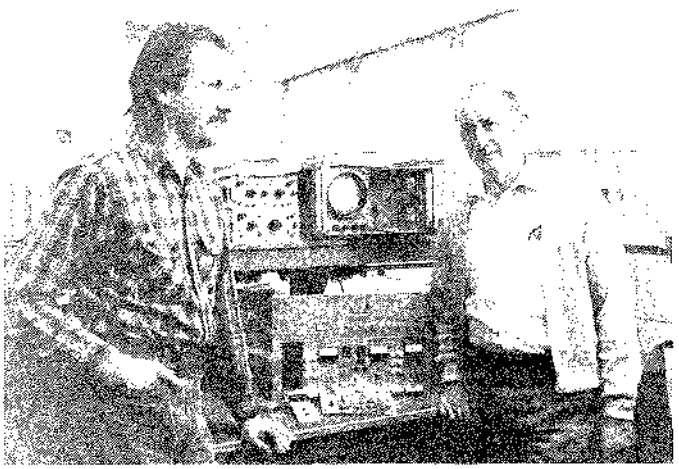
During FY 86, the ITS tropospheric channel probe was used as part of a test program on a communications link between West Berlin and Bocksberg, West Germany. This is the first operational digital tropospheric scatter communications link in the Defense Communications System. The ITS probe was a key part of the testing of this link.



Typical Digital Radio Field Test Configuration



Troposcatter Antennas in Berlin



Tim Riley, Lauren Pratt, and Test Equipment

The Institute is in the process of building a more sophisticated tropospheric channel probe for the U.S. Air Force. The first application of this probe will be in testing U.S. defense communications links in Europe.

The LOS channel probe has been widely used in test programs in Germany, Italy, Korea, and many locations within the continental United States.

The Institute is also involved in testing the effectiveness of U.S. electronic countermeasures equipment. The Institute has provided technical support to the Air Force during the procurement of a new receiver system. The receiver is designed to acquire, analyze, and output key operational parameters of electronic countermeasure equipment. It is based on a prototype model developed at ITS.

Recent ITS Publications

Digital Microwave Transmission Tests at the Pacific Missile Test Center, Pt. Mugu, California (by Hubbard)

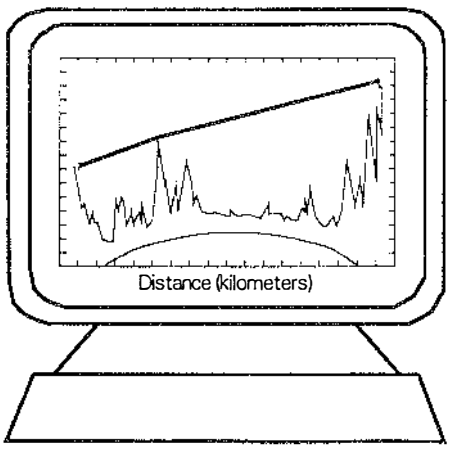
Results and Analysis of Static and Dynamic Multipath in a Severe Atmospheric Environment (by Kolton)

Microwave and Millimeter-Wave Radio Performance Prediction

Outputs

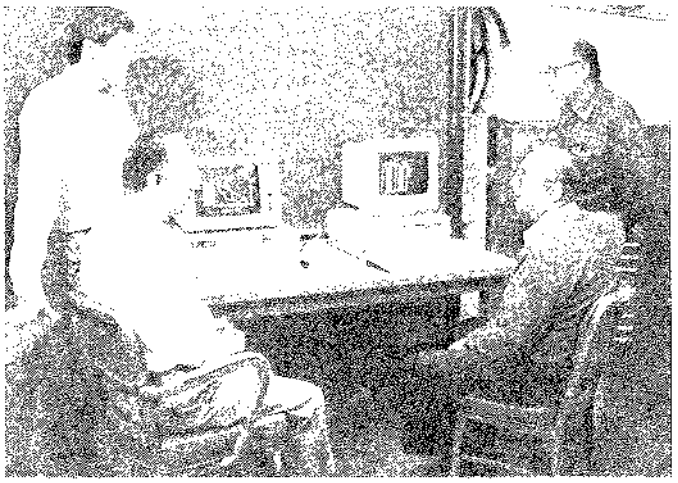
* Microwave radio link performance prediction software
* Millimeter-wave radio performance prediction software
* Consultative services for radio performance prediction

The Institute has developed several sets of programs for predicting performance on line-of-sight microwave, beyond-the-horizon microwave, and millimeter-wave radio links. These program sets are engineering tools useful in designing either microwave or millimeter-wave radio transmission links. They have been implemented on small desktop minicomputers.



Typical Output for Prediction Program

The microwave link design programs can be used for the performance prediction of both digital and analog systems including transmission links that contain passive repeaters. These programs permit workers with moderate skill levels to perform the calculations necessary for the design of microwave links for both analog and digital systems. Atmospheric and terrain multipath are taken into consideration in calculating the performance of these systems. The algorithms used in performing these calculations are based on models derived from theory and empirical data from field measurement programs. The algorithms include:



Project personnel (l. to r.) Rob DeBolt, Larry Hause, Jean Adams, and Gary Gierhart

- o repeater link Earth geometry
- o path profile data and effective Earth radius
- o primary antenna height optimization
- o terrain reflections
- o ray trajectory
- o obstacle diffraction
- o tropospheric scatter
- o site antenna or reflector layout
- o repeater site loss and antenna gain
- o median basic transmission loss
- o basic transmission loss variability
- o link carrier-to-noise ratio probability distribution
- o analog radio system single receiver transfer characteristic
- o analog link performance
- o digital link performance.

The microwave link engineering software is being used by the sponsoring U.S. Army agency to predict the performance on links being developed as part of the worldwide Defense Communications System.

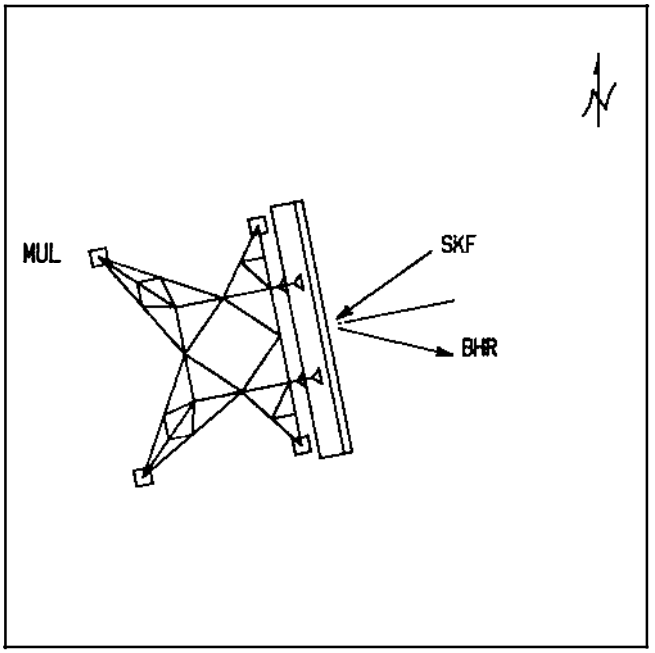
The software was also used during FY 86 to analyze a microwave communications system being designed to support the U.S. Navy Tactical Air Combat Training System.

Radio-link Modeling on a Minicomputer

An EHF Telecommunications System Engineering Model (ETSEM) has been developed by ITS as an aid in the design of LOS communications systems from 10 to 100 GHz. ETSEM provides tabulation of path geometry parameters and analyzes ray-path and Fresnel zone clearances to help the engineer design the path. ETSEM also predicts the performance of both digital and analog systems based on state-of-the-art EHF propagation models and equipment specifications. Attenuation by rain, clear-air absorption, and multipath are modeled. ETSEM has been implemented on desktop computers.

The Institute has, for several years, provided a propagation analysis service to the Federal Aviation Administration (FAA). propagation models and software previously developed at ITS are being used as part of this consultative services project.

The Institute is providing consultation to the U.S. Army on wideband VHF/UHF channel measurements and channel modeling. The current wideband systems have been developed using existing propagation models that consider only narrowband signals. Experimental data are needed either to validate the existing models or to develop models valid at the bandwidths of the proposed system. The propagation data will be collected using channel probes similar to those built at ITS for use on line-of-sight microwave, tropospheric scatter, or millimeter-wave channels. The model, which will be derived from the wideband VHF/UHF channel measurements, will be used to update the link engineering software models described above.



Automated Generation of Antenna Design

Recent ITS Publications

Algorithms used in ARROWS: Autodesign of Radio Relay Optimum Wideband Systems (by Hause)

EHF Telecommunication System Engineering Model (by Allen)

Propagation Predictions for Marginal LOS Microwave paths (by Hause)

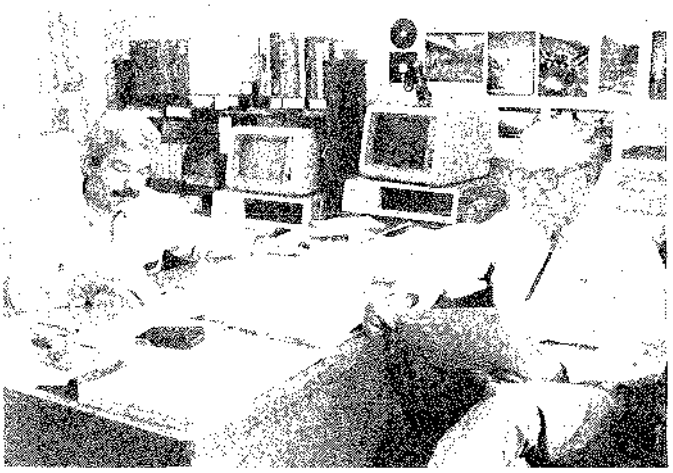
Test Methodology and System Performance

Outputs

* ACSB--What is Adequate Performance? Paper presented at the 1986 International Carnahan Conference
* The Performance of Amplitude Companded Sideband Interim Report: A Review and Measurement Plan, NBS-GCR-86-511

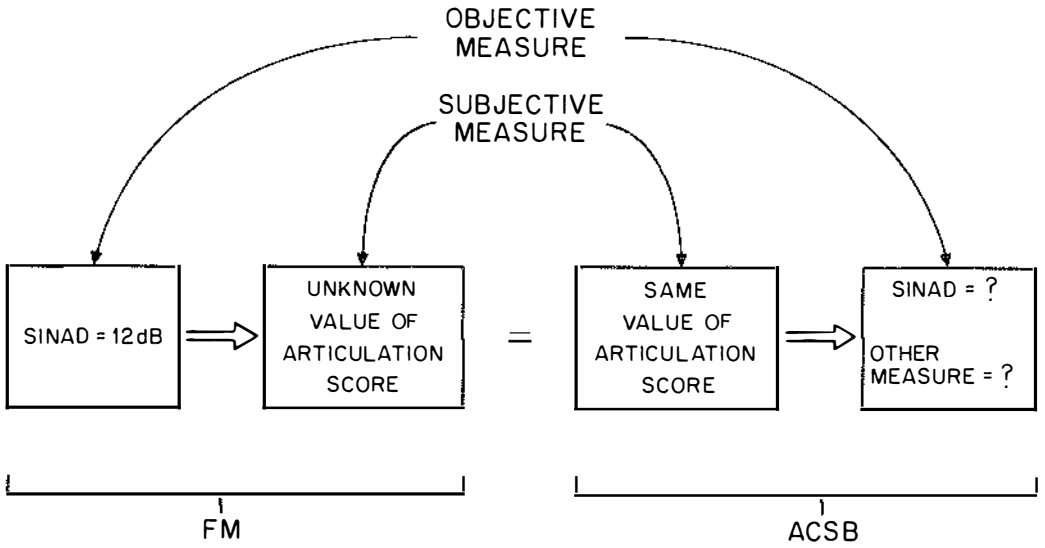
Performance testing can be a prelude to standards development or used for the determination of acceptability. Performance testing often involves the identification of appropriate performance measures, or "figures of merit," prior to the design and implementation of a measurement program.

One of the projects at ITS involves the assessment of the voice quality of amplitude companded sideband (ACSB)--an enhanced form of single sideband modulation. Since ACSB operates with channel widths of about 5 kHz, it can be an effective solution to the spectral crowding in the VHF and UHF land-mobile bands. A recent ruling by the FCC allows the use of "narrowband technologies," such as ACSB, in bands that had been reserved for FM using 25 or 30 kHz channels.



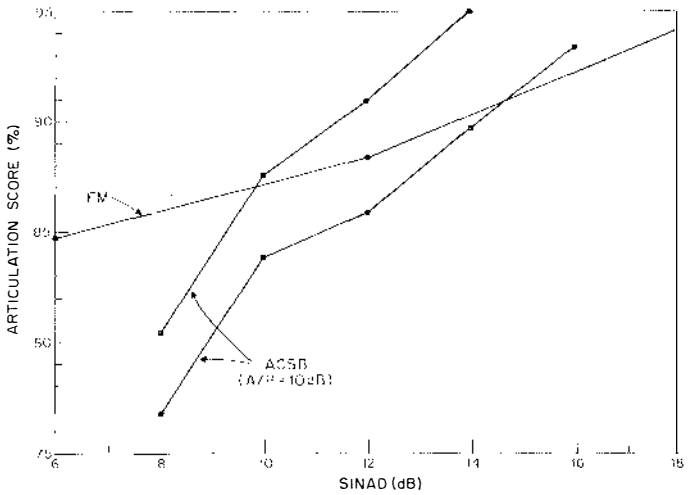
Project personnel (l. to r.) Bill Kissick and Ernie Morrison

In the context of land mobile radio, using FM as a reference, the goals of the ITS work are to identify the appropriate performance measures for ACSB, and then to determine the values of such measures that represent the minimum level of acceptable performance. That minimum level of performance, as shown in the figure below, is assumed to be expressed in terms of the speech intelligibility for an FM system operating at 12 dB SINAD. The SINAD is an objective performance measure that has become the de facto standard for FM land-mobile radio performance.



The Definition of Minimum Performance for ACSB Is Expressed in Terms of Speech Intelligibility--The Same Intelligibility Exhibited by FM Operating at 12 dB SINAD

Using the articulation score (AS) as the subjective measure of intelligibility, the conclusion that 12 dB SINAD represents the same level of performance for ACSB as it does for FM is easily reached. The figure below gives the AS vs. SINAD for an FM radio and the AS vs. SINAD (with an audio-to-pilot ratio of 10 dB) for each of two ACSB radios--one from each of the two U.S. manufacturers. The AS of one ACSB radio is a little higher than the AS for FM at 12 dB SINAD, and the AS for the other ACSB radio is a little lower.

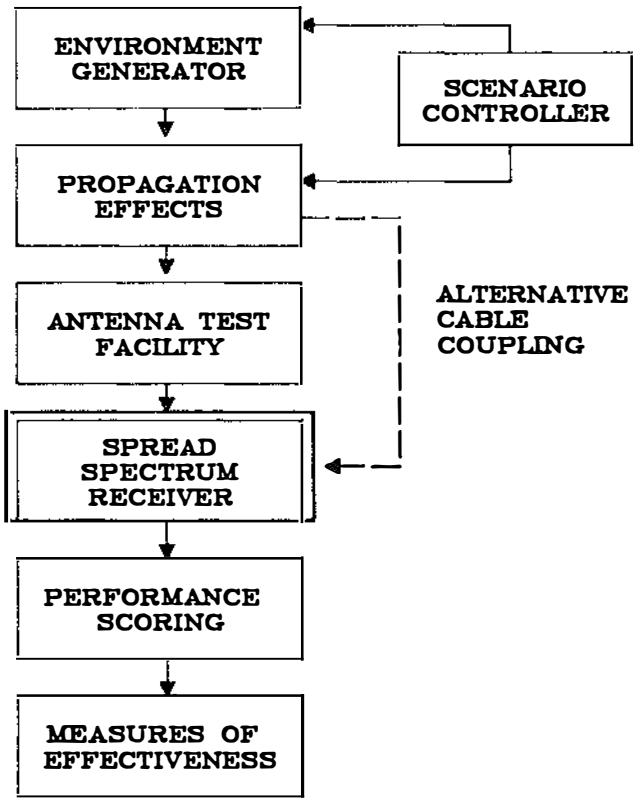


Another project at ITS requires the development of methods for testing military communications systems using spread-spectrum modulation. Communications systems make use of spread-spectrum techniques to enhance signal security and spectrum use efficiency. At the same time, spread-spectrum techniques reduce the susceptibility to electronic countermeasures and to direction finding.

The goal of the ITS work is to develop test methods to be used during the development phase of frequency-hopped systems that operate in the frequency spectrum at HF and higher frequencies. The methods being developed will primarily provide information on the system susceptibility to mutual interference and receiver susceptibility to to narrowband jammers.

An early step in developing the test methods is to develop the ranges of signal-to-jammer ratios to be used and the expected variability in signal levels due to propagation phenomena. These become inputs to any simulation, done either on a computer or with the actual equipment in a test facility, as shown below.

The test design and execution procedures being developed are consistent with current accepted methodologies. Performance profiles for both graceful and catastrophic degradation will be developed from the test results in a way that allows extrapolation, with reasonable confidence, into areas of extended application.



Systems Monitoring, Evaluation, and Control

Outputs

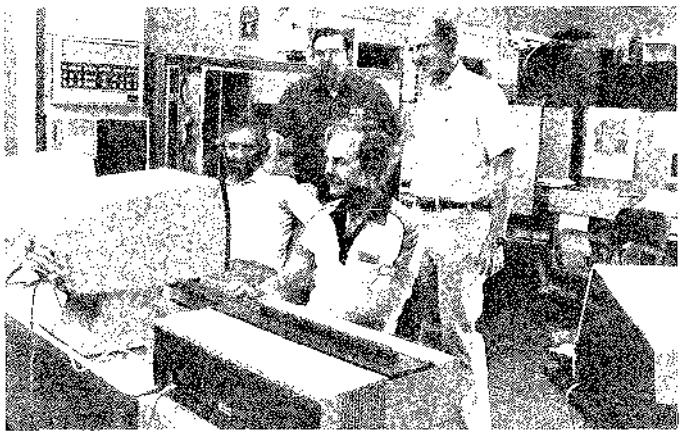
* System design of TRAMCON system
* Software: 200,000 lines of source code

The presence of U.S. military forces in allied nations requires that a command and control communication system be available to support these forces and to coordinate their activities. For that purpose, the Department of Defense owns and operates an extensive telecommunication plant, which, in Europe, is referred to as the Digital European Backbone (DEB) network.

One of the new tools for managing the network is the TRAnsmission Monitor and CONtrol (or TRAMCON) system developed by ITS.

When fully deployed in Europe, TRAMCON will consist of a network of 25 minicomputers that monitor the equipment at 250 communication sites across the continent.

Two elements constitute the TRAMCON facility: a master unit and a remote unit. A master unit (see photo inset) consists of a minicomputer, disk storage, a tape drive, and display terminals. The **master** unit

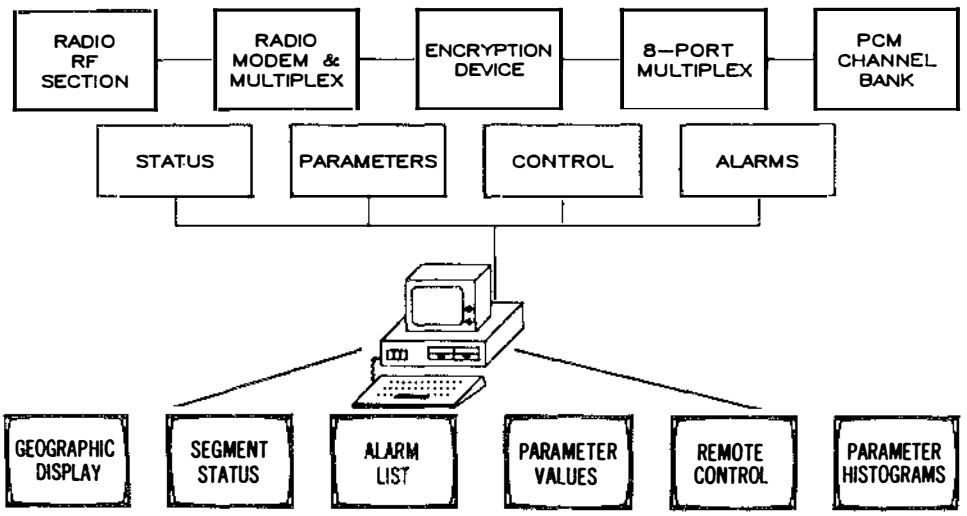


Project personnel (seated l. to r.) Rick Statz and Bob McLean, (standing l. to r.) Joe Farrow and Dick Skerjanec

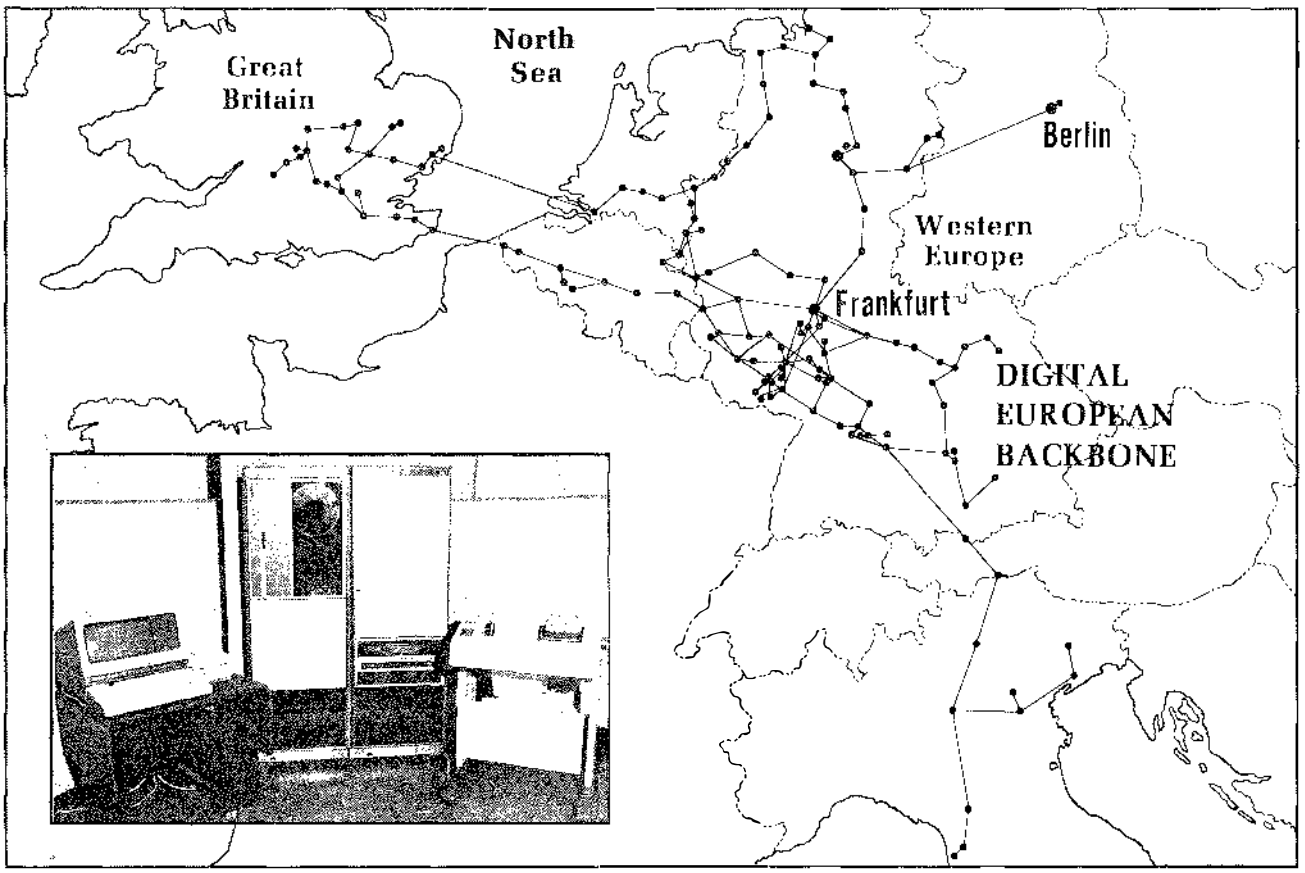
- o collects status and parameter information from all the remote units within its control,
- o assembles the responses into English text displays for the manager, and
- o maintains a near-term history of system status and performance.

A **remote** unit is a hard-wired logic system that

- o senses electrical parameter changes that indicate communication equipment status at remote sites,



TRAMCON Function Flow Chart



A Map of the Digital European Backbone Network. Inset: TRAMCON Master Station

- o samples analog voltages,
- o counts any random pulses,
- o formulates responses from changes,
- o transmits to the master unit information on changes in equipment status at the remote site, and
- o provides relay contact closure.

By manipulating relay contact closures, computers permit control of digital microwave transmission systems by monitoring, collecting, and displaying data reflecting the status of remote sites in the network.

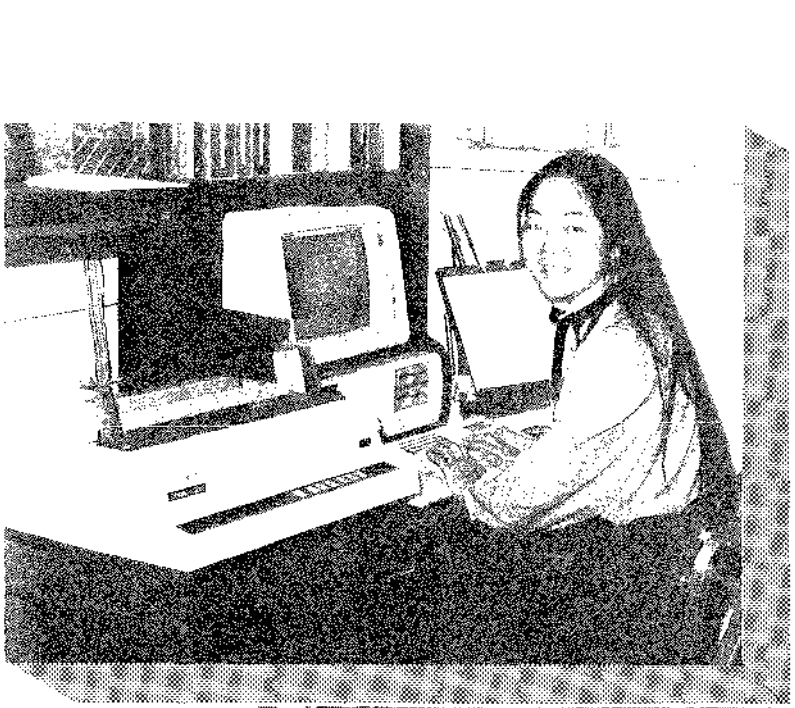
The TRAMCON system has been designed to accommodate alarm, status, and parameter data from any form of transmission equipment. The TRAMCON system monitors digital microwave and troposcatter radios, analog radio systems, digital multiplexers, cryptographic equipment, optical fiber transmission systems, and wire span-line drivers. Any set of two-state indicators, parameters, and switch controls that can be described sufficiently to give each point an English title can be monitored by TRAMCON. The software is designed to handle any transmission mode, equipment manufacturer, modulation technique, or multiplex hierarchy. The benefits of the TRAMCON monitoring and control system include:

- o improved performance
- o improved fault isolation
- o improved network availability
- o reduced operating costs
- o centralized control and maintenance
- o centralized dispatch
- o reduced site staffing.

Recent ITS Publications

A Computer-Based Transmission Monitor and Control System (by Farrow and Skerjanec)

Transmission Monitoring and Control of Strategic Communication Systems (by Farrow and Skerjanec)



TELECOMMUNICATION SYSTEMS PLANNING

The Institute is tasked to serve as a central Federal resource to assist other agencies of the Government in the planning, design, maintenance, and improvement of their telecommunications activities. In order to solve specific telecommunication problems of other Federal agencies, ITS applies its expertise in performing user requirements analysis, system design, and network architecture development. The Institute's efforts are directed toward effectively relating the needs of end users to the capabilities of a planned network, taking into consideration a variety of environments and conditions.

AREAS OF EMPHASIS

Near-Term Systems Planning

Includes projects funded by the U.S. Information Agency and the U.S. Coast Guard

Advanced Systems Planning

Includes projects funded by the Air Force Electronics Systems Division, the Army Electronics Proving Ground, the Army Information Systems Engineering Support Activity, the Army Information Systems Management Activity, and the Defense Communications Agency

Planning for Special Communication Environments

Includes projects funded by the Army Electronics Proving Ground, the Defense Communications Agency, and the Naval Ocean Systems Center

Near-Term Systems Planning

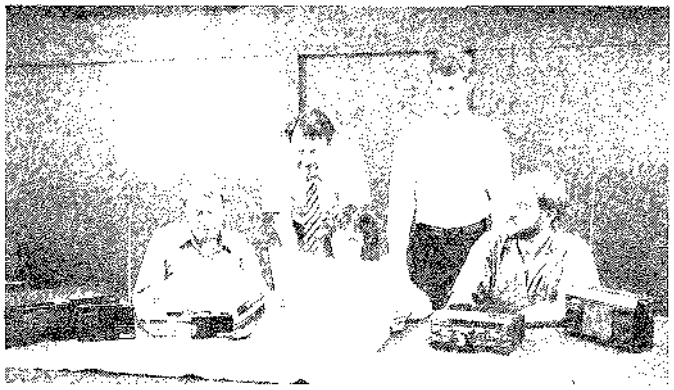
Outputs

* Model of gain patterns for curtain array antenna
* Models for HF broadcast coverage
  Models for MF broadcast coverage and interference analysis
* Analysis of HF communications in maritime emergencies

For many broadcast or communications systems, circumstances can require the system operator to modify system parameters. For example, the HF band is strongly influenced by solar activity; the transmission frequency that is best this month may not be optimal, or worse, may not work at all, next month. For this situation, the operator wants to know in advance what frequency should be used, what transmitter power is required, and where the antenna's main beam should be pointed. As another example, the MF band has frequencies allocated to international broadcasts. As the United State or other administrations attempt to bring up new or modified broadcast facilities, existing broadcast signals may receive intolerable interference. Based upon the characteristics of the current facilities, the system planner would like to know what parameters will have to be modified so that the new and existing transmitters can coexist without intolerable interference imposed on their listeners.

These and many similar examples fall under near-term systems planning; the telecommunications system has to be able to adapt or evolve in response to changing environmental conditions. ITS aids the system planners by developing engineering tools that help answer the "what if ... " questions. The following paragraphs describe some of these analysis and planning aids.

MF Interference Model. This past year, ITS has been developing an interactive MF interference analysis model that the U.S. Information Agency's Voice of America engineers will use to design MF broadcast systems. The model allows the engineer to select among several ground-wave and sky-wave algorithms, several transmitter and receiver antenna gain pattern algorithms, the transmitter power, and the locations of the transmitter and receiver(s). After the engineer selects a candidate transmission frequency, the program retrieves from national and international station assignment data bases all cochannel and adjacent-channel transmitters that may cause interference at the receiver sites. The interference levels are compared with the desired signal levels to determine if the interference violates signal protection ratios. If the protection ratios are not met, the interactive model lets the engineer alter system parameters or change transmission frequency so that the final design is acceptable in performance and does not cause harmful interference to other broadcast facilities.



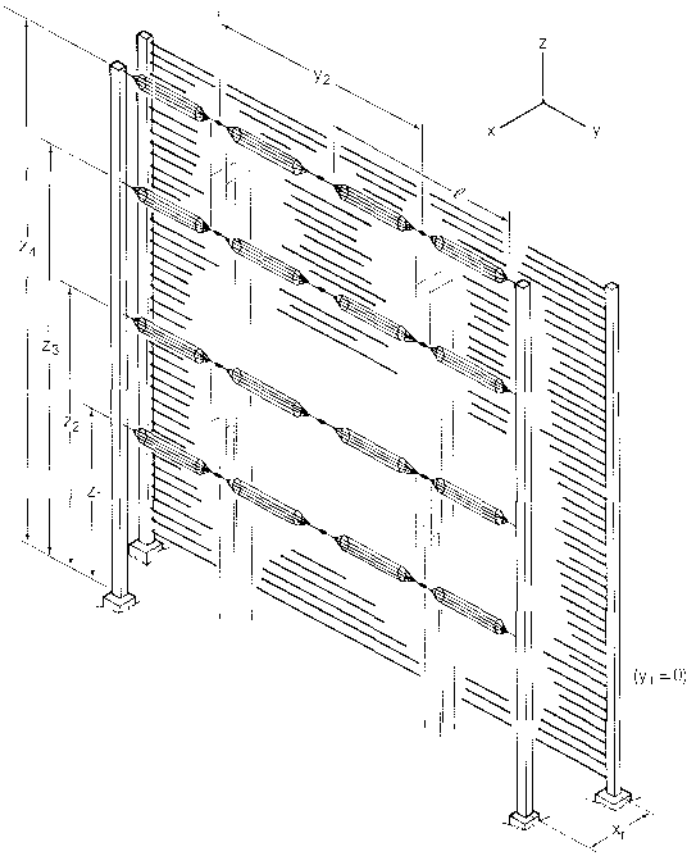
Project personnel (l. to r.) John Godwin, Nick DeMinco, Susan Rothschild, Martin Nesenbergs, and Eldon Haakinson

HF Antenna Pattern Generator. ITS developed an interactive HF curtain array pattern generator for use by the Voice of America in determining coverage from their broadcast antennas. For any particular broadcast hour some portion of the ionosphere will support the transmission from the transmitter to the broadcast reception area better than other portions of the ionosphere. To save transmitter power and to efficiently use the ionospheric trans-

mission channel, the VOA would like to use electronically steerable HF curtain array antennas that can point narrow beams at the right portion of the ionosphere with just enough beamwidth to cover the reception area. The antenna generator model lets the engineer design the antenna and then produces a contour plot of the antenna pattern that can be overlayed on the required power-gain plots. In this manner the engineer can optimize the antenna design/broadcast coverage tradeoffs in response to the near-term changes of the ionosphere.

Coast Guard Maritime Emergency Communications. During periods of maritime emergencies, the Coast Guard wants to ensure with a high probability that a vessel with an emergency can communicate with the Coast Guard. Last year, ITS developed a technique to analyze the feasibility of using shore stations located throughout the world as a network of receiver sites ready to receive emergency transmissions from distressed ships. Assuming a ship was located in the North Atlantic with standard HF equipment and the network was composed of 26 shore stations, the analysis shows that if the ship used up to four HF frequencies, then the probability of communicating the emergency was greater than 95 percent over all hours, seasons, and sunspot conditions. If other shore stations were added to the existing network, the communications probability could be increased. By analyzing only the near-term ionospheric conditions, the Coast Guard could publish those frequencies that would offer the most reliable means of communications during emergencies over, say, the next 3 months. The analysis would be repeated each successive 3 months as the new ionospheric conditions become known, and the results would be published for the maritime shippers.

Because of the cost of time (during emergencies), of power (of high power transmitters), of lost communications (due to intolerable interference), or of any other measure that indicates inefficiency, system planners need engineering tools that allow them to make operational decisions based upon near-term conditions. ITS has been instrumental in developing those tools.



Curtain array with conducting screen (2 bays, 4 stacks)

Recent ITS Publications

Communication probability for the U.S. Coast Guard Digital Selective Calling System in the North Atlantic (by Adams and Cavcey)

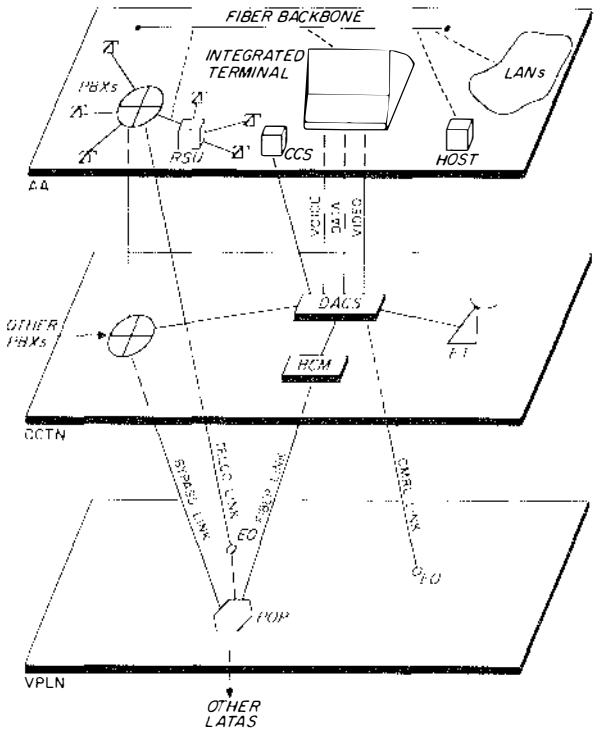
Advanced Systems Planning

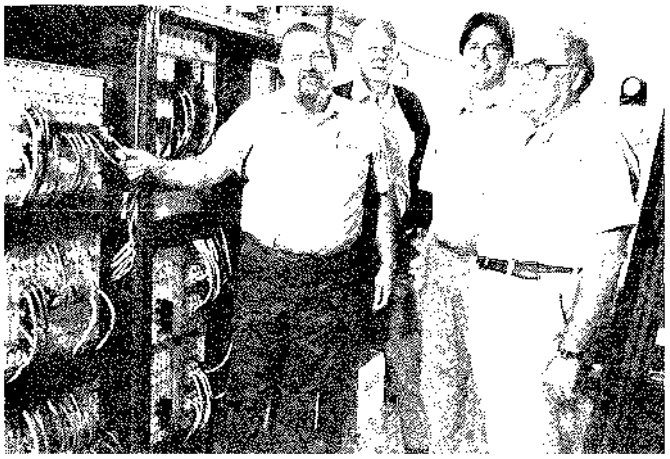
Outputs

* Nodal architectures
* Antenna test facility
* Local area network consulting

The Institute conducts a number of programs relating to future plans in the information services area. This includes Defense Switched Network (DSN) access studies for the Defense Communications Agency, Local Area Network studies for the U.S. Air Force, antenna test facility planning for the U.S. Army, and information policy studies for NTIA. The following paragraphs describe specific programs in these areas.

Nodal Architecture Development. The System Performance Standards and Definition Group is currently conducting long-range telecommunication planning studies for the Defense Communications Agency. The future Defense Switched Network in the continental United States is expected to consist primarily of two parts--a private line network and a virtual private line network as shown in the figure below. The ITS studies are focused on defining candidate architectures





Project personnel (l. to r.) Joe Farrow, Bob Linfield, Randy Bloomfield, and Ernie Morrison

for the switching nodes that will interconnect these long-haul networks with base communication facilities.

In performing the DSN work, the Institute has visited a number of military bases (Ft. Monmouth, NJ; Ft. Huachuca, AZ; and Scott AFB, IL) where the future plans are being developed for military information services. The Institute has also visited nonmilitary installations, such as the University of Colorado, where new switches and cable facilities are being installed to provide integrated voice, data, and video services representative of an information-intensive "campus of the future." The results of this work will be documented in two interim reports and a final report to be issued in 1987.

Antenna Test Facility. Developmental military communication-electronics (C-E) systems exploit advanced antenna technologies because of complex and congested electromagnetic (EM) environments and the related spectrum management issues. These antenna applications primarily concern beam switching and signal search, low or ultra-low side lobe, and multiple null capabilities. Array antennas are required to provide these functional features for radar, communications, EM and weapons control system applications.

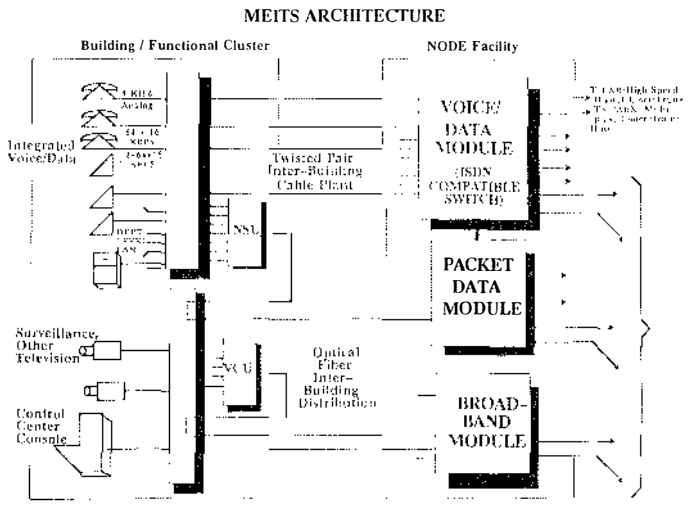
This program, sponsored by the U.S. Army at Ft. Huachuca, addresses antenna test requirements, design concepts, and analysis for measuring antenna system performance. Specific tasks include:

- o analyzing Army development C-E systems, emphasizing antenna functional characteristics and operational EM environments
- o developing antenna system parameter measurement requirements based on C-E system performance and environment variations
- o developing specifications for a Compact Antenna Test Range (CATR)
- o comparing parametric sensitivity between single paraboloid and dual-cylindrical CATR geometries
- o assessing concepts for multiple signal illumination of a test system through a CATR
- o analyzing antenna system measurement requirements unique to the C-E functions defined in the Army Space Initiative Study.

Local Area Network Consulting. The Institute is providing assistance to the Air Force for 1) the Mission Essential Information Transmission System (MEITS), 2) the Logistic Command, Control, Communication, and Intelligence (LOG C^3I Network), and 3) the Interim Host-to-Host Local Area Network (LAN).

The intent of the MEITS program (see figure) is to develop a local and wide area network architecture and equipment list that will allow information transfer networks to interconnect and interact with a minimum of conversion hardware and software.

The LOG C^3I Network will interconnect the eight Air Force logistic centers and will provide a logistic information system for crisis conditions. The system initially will comprise 3 host computers and about 90 terminals spread over the continental United States.



MEITS Architecture

The Interim Host-to-Host LAN task involves installing two terminal LANs at Air Force Logistic Command sites. Off-the-shelf equipment built to the IEEE 802.3 standard will be installed between two computers at Wright-Patterson AFB in Dayton, OH, and Tinker AFB in Oklahoma City, OK.

Information Technology Policy. Under this Commerce program, ITS performs technical studies and analyses to support NTIA's domestic policy goals. Specific objectives are to enhance the offerings of intellectual property, to improve international trade for the information industry, and to express administration views in the regulatory arena. In one recent project, ITS developed in part the "building block" concept, which the FCC calls Basic Service Elements (BSEs). The provision of BSEs by the dominant carriers will help to ensure that potential competitors have comparably efficient interconnection to potential bottleneck facilities in the dominant carrier networks, thereby enhancing competition. This provision should also make it possible to relax line-of-business restrictions on these carriers to further enhance competition.

Recent ITS Publications

Military Access Area Characterization (by Linfield and Nesenbergs)

Planning for Special Communication Environments

Outputs

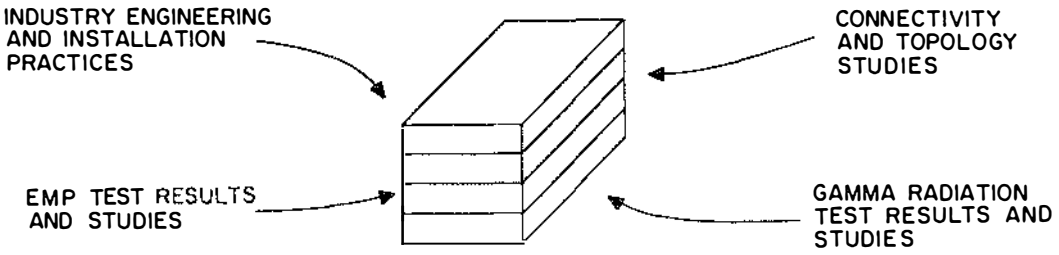
- Trends Toward a More Stress-Resistant Fiber Optic Telecommunication Installation, NTIA Technical Memorandum by David F. Peach
- Briefing for the Commanding General and staff of U.S. Air Force Space Command in Colorado Springs
- Briefing for the DoD Joint Steering Committee on Long-Haul and Tactical Standards

Project personnel (standing l. to r.) Ray Jennings, Dave Peach, Joe Hull; (seated l. to r.) Bill Pomper and Martin Nesenbergs

Whether natural or man-made, certain conditions or a special environment, coupled with certain performance requirements, can require innovative telecommunication techniques. The conditions or environment can be defined as stress, and system performance can be quantitatively assessed as changes in the values of system performance metrics. Several ITS projects involve the development of system performance metrics, environment definitions, and/or the use of the performance metrics to assess the effects of stress on a communication system.

One project involves end-to-end security for a meteor-burst network and seeks answers to specific questions. Transmissions in such a network are random in both time of occurrence and duration, and the average data rate is low. How is cryptographic synchronization achieved with very low overhead? How is a plain text message header provided for routing, and at the same time, the header information protected from disclosure during transmission?

A special environment of national priority is that caused by nuclear weapons, speci-



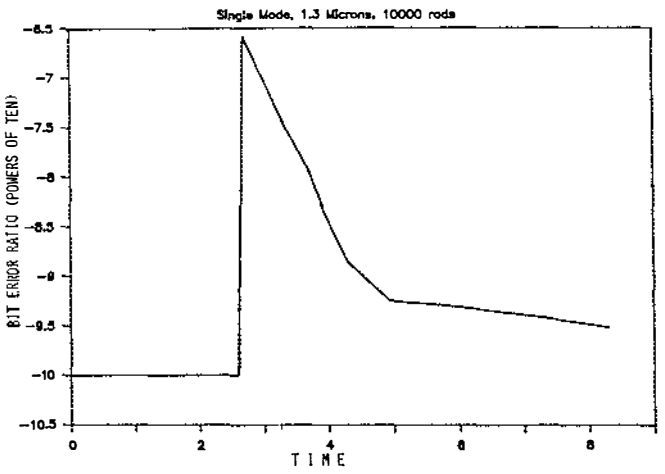
Multitier Specification for National and Regional Fiber Optic Communication Systems

fically electromagnetic pulse (EMP) and gamma radiation. To enhance, or at least to assess, the survivability of commercial long-haul fiber optics networks, ITS is developing a multitier specification of mitigation factors for networks that must operate in a special environment. Many parameters are defined in the specification and each tier of the specification represents an increased level of system hardness or resistance to nuclear effects and to a variety of natural disasters.

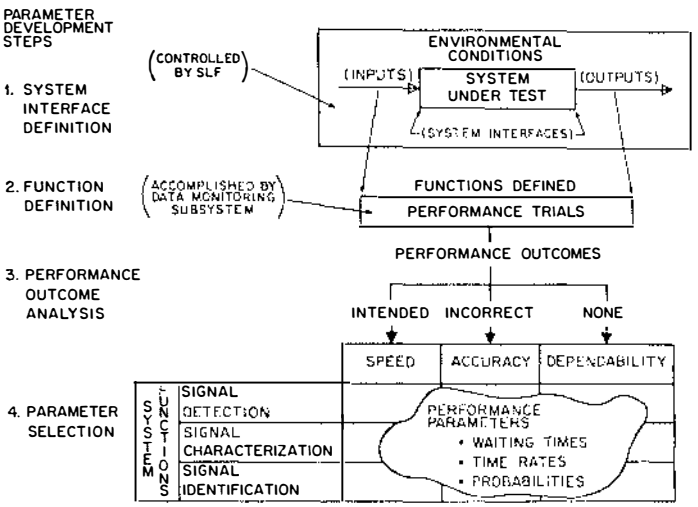
The multitier specification will provide the information needed by designers to ensure that the network meets a given degree of hardness. The multitier specification can also be used as a rating tool by Government agencies or others who must procure services or capacity on such commercial networks. If interstate highway rights-of-way are offered to carriers in return for National Security/Emergency Preparedness enhancements, then the network survivability and connectivity are enhanced as well.

One of the analysis tools developed by ITS to support the use of the multitier specification is a model that predicts the bit error ratio on a fiber optic link that is exposed to gamma radiation. The gamma radiation causes a darkening of the optical fiber, thus reducing the received light level. In addition, the radiation can affect the photodiode detector. This particular tool runs on a personal computer.

In another approach, a special environment can be simulated--for test and evaluation purposes. An example of this is the Stress Loading Facility (SLF) operated by the U.S. Army Electronic Proving Ground. The SLF synthesizes and emits (in a closed environment) many interfering, or electronic warfare (EW) signals. An ITS project seeks to define environment classes, test methods, and measures of performance for systems that can be tested with the SLF. The entire process of environment classification and the definition of system functions, in terms of users' perceptions of performance, and the parameters to characterize the system performance is illustrated below. The four parameter development steps are applied to any system; the parameters and their values are chosen to suit the specific system being tested.



Bit Error Ratio Versus Time



APPLIED RESEARCH

The use of the electromagnetic spectrum, in telecommunications, has grown dramatically in the last four decades. This growth stems from population increases, new technologies, and new services. To accommodate this growth, the limited usable spectrum must be expanded to higher frequencies, and existing spectrum must be managed more efficiently. To these ends, ITS continues a historic program to better understand and use higher frequencies.

The radio wave portion of the electromagnetic spectrum may be adversely affected by propagation conditions in the medium constituted by the Earth's surface, the atmosphere, and the ionosphere. These conditions may be permanent or time varying (seasonal or sporadic), and the severity of the adverse effects is frequency dependent. A prime purpose of the Institute's applied research effort is to study conditions in the transmission medium and provide models and prediction methods for cost-effective and spectrum-efficient radio system design. This research includes both terrestrial systems as well as satellite-based systems.

The Institute has a long history of radio wave research and propagation prediction development that provides a substantial knowledge base from which state-of-the-art methods for developing, testing, and utilizing telecommunication systems is made possible. Transferring this technology to the user community, both public and private, to enhance spectrum use is the Institute's ultimate aim.

AREAS OF EMPHASIS

Millimeter-Wave Studies

Includes projects funded by the National Telecommunications and Information Administration, the Army Communications Electronics Command, the Army Missile Command, the Army Research Office, and the Naval Ocean Systems Center

VHF/UHF Propagation Studies

Includes projects funded by the National Telecommunications and Information Administration and the Department of Defense

HF Studies

Includes projects funded by the Department of Defense

Signal Processing Studies

Includes projects funded by the Department of Defense, the Air Force Systems Command, and the Naval Research Laboratory

Satellite Studies

Includes projects funded by the National Telecommunications and Information Administration

Radio Environment Simulators

Includes projects funded by the Army Information Systems Engineering Support Activity and the Joint Tactical Command, Control, and Communications Agency

Millimeter-Wave Studies

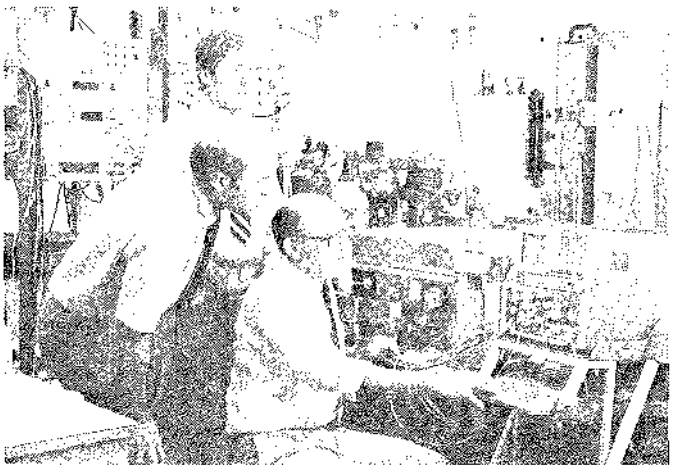
Outputs

* A Millimeter-Wave Propagation Model containing an improved model of the water vapor continuum absorption
* A new technique for inferring the raindrop size distribution from measured attenuation rates
* Measurements of the climatic dependence of specific attenuation of millimeter waves by rain
* A millimeter wave telecommunication system engineering design model

The millimeter-wave program at ITS is a comprehensive program for telecommunication applications. As such, it provides a central focus within the Government for millimeter-wave propagation studies so that duplication of efforts by separate governmental agencies can be avoided. The program provides information to a variety of users for purposes that include governmental regulation of the radio spectrum, development of defense systems, and design of telecommunication systems by U.S. industry to be sold at home and abroad.

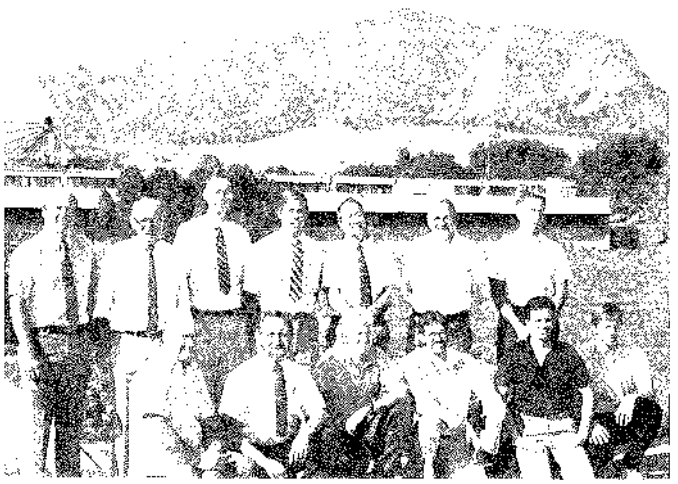
The program involves laboratory measurements, field measurements, and model development. The measurements and models are available to the rest of the millimeter-wave community through publication of the results. Application models in the form of computer programs are also produced to serve as tools for other governmental agencies and private industry in the design of millimeter-wave telecommunication systems.

The propagation of millimeter waves includes many effects that can degrade the performance of telecommunication systems. Hydrometeors in the form of rain, snow, ice crystals, hail, fog and clouds scatter and absorb the waves, resulting in a loss of signal power. Water vapor and oxygen in the atmosphere attenuate millimeter waves by absorption due to molecular resonance. The turbulent atmosphere causes signals to scintillate.



Project personnel (top to bottom) Rob DeBolt, Ken Allen, and Hans Liebe

atmosphere causes signals to scintillate. The stable atmosphere, on the other hand, can have a refractivity structure that bends the path of the radio waves. This may result in the transmitted signal being diverted away from the receiving antennas. Echoes can also result from the reflection of millimeter waves from terrain features along the path. In some environments, such as urban and suburban areas, there may be many potential surfaces for reflecting the waves along the path. Other propagation effects of concern include the effects of vegetation on propagating millimeter waves.

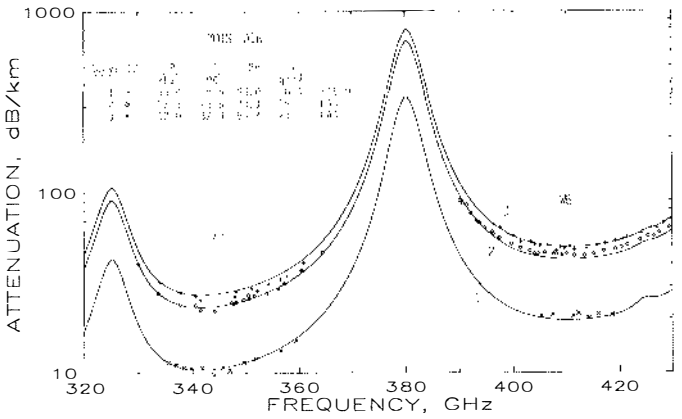


Millimeter Wave Program Staff

Very high attenuation rates of millimeter waves occur in rain. Rain is the primary influence limiting the performance capabilities of millimeter-wave telecommunication applications. In FY 1985, ITS made measurements of the attenuation rate on short paths in California and Colorado. In FY 1986, these measurements were extended to a third climatic region, Alabama. The results are significant. A strong dependence on the type of rain, convective vs. orographic, was found. For example, for a rain rate of 30 mm/h, the expected attenuation rate of 96 GHz is 6.5 dB/km in Colorado (convective); while in California (orographic), it is 16 dB/km.

The equipment used for these measurements includes transmitters and receivers at 11.4, 28.8, 57.6, and 96.1 GHz which are contained in mobile vans. The receiving site of the Alabama installation is shown in the photograph below.

Although the attenuation rates due to rain can exceed those of clear air absorption, the effects of water vapor and oxygen cannot be ignored. These effects result in a signal loss that is always present. Frequencies where the attenuation rates are lower are the most likely location for most telecommunication applications. The attenuation in these regions is dominated by the water vapor continuum caused by extremely strong infrared lines. An example of how this attenuation behaves is given in the figure in the next column.



ITS has developed models that are specifically formated for use by system design engineers. The EHF Telecommunication System Engineering Model (ETSEM) predicts the performance of a millimeter-wave system design so that the designer can conveniently evaluate design alternatives. The model is described in more detail in the **Microwave and Millimeter-Wave Radio Performance Prediction** section.

Recent ITS Publications

An Updated Model for Millimeter-Wave Propagation in Moist Air (by Liebe)

Effects of Drop-size Distribution and Climate on Millimeter-Wave Propagation Through Rain (by Dutton)

EHF Telecommunication System Engineering Model (by Allen)

Observed Wide-Band Digital Performance at 30.3 GHz (by Allen et al.)

Rain Attenuation Measurements at 28.8, 57.6, and 96.1 GHz on a 1-km Path (by Espeland et al.)

The Millimeter-Wave Behavior of Rain Attenuation Based on Recent Experimental Data (by Dutton)

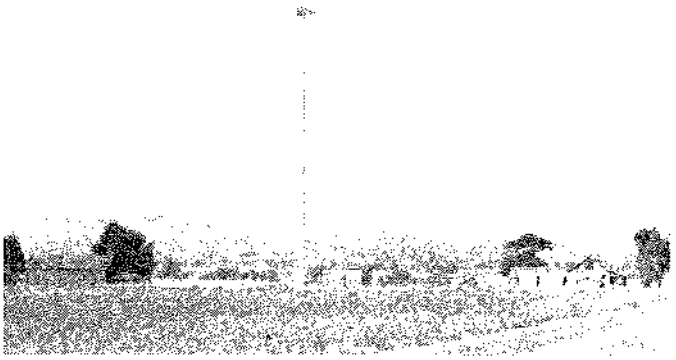
VHF/UHF Propagation Studies

Outputs

* Develop and implement a land-mobile path loss measurement system
* Implement improvements to the ITS Irregular Terrain Model

The ITS Irregular Terrain Model, ITM, (formerly referred to as the Longley-Rice model) was developed to provide a means of predicting radio system performance in a given environment. This model is based on a large set of measurements over a wide range of frequencies, times, and locations, although all of the measurements were made using fixed paths. This year, a new approach has been taken in making the measurements. Instead of making spot measurements with the transmitter and receiver in a fixed location, the receiver was mounted in a mobile vehicle. This provided a new perspective from which to evaluate the performance of the ITM.

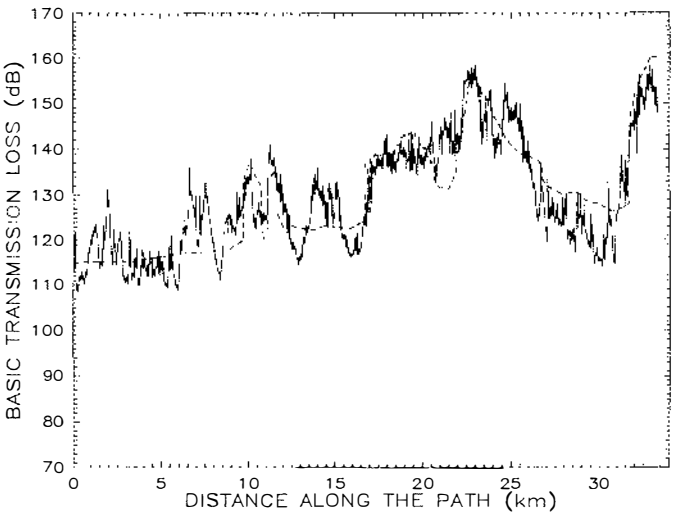
The measurements were made using emissions from local 800 MHz cellular telephone transmitters over several routes near Boulder, Colorado. A picture of a typical cellular base station is shown below.



The vehicle used in the measurements was equipped with instrumentation that would record the received signal level as a function of the vehicle's relative location. The signal data were processed in an effort to smooth the multipath fluctuations without disturbing the terrain induced characteristics.

Project personnel (l. to r.) Ray Thompson, Eldon Haakinson, Brent Bedford, and Bill Riddle (atop vehicle)

Predictions of the expected signals were generated by the ITM for the same routes over which the vehicle was driven. Then the predicted signal data were plotted along with the measured data on the same graph producing a comparison as shown in the figure below.

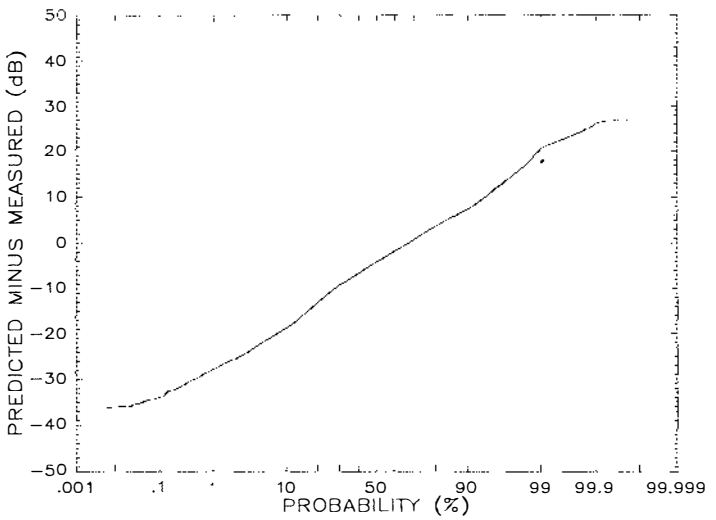


In this figure, the dashed curve shows the ITM-predicted median signal level and the solid curve shows the measured data. The measured data were taken approximately every wavelength (one-third meter) along the path. To remove the multipath, the median of the data in each 20-meter section of the path (about 60 values) was

calculated and plotted on the figure. The ITM was used to make a prediction of signal level over the intervening terrain from the transmitter to the same 20-meter path section and the predicted signal was plotted.

These measurements were made over terrain that can best be described as rolling hills. As the vehicle traveled over the top of the hills, the propagation mode would change from line-of-sight mode to diffraction mode. The ITM model's ability to follow the change in signal level in most terrain is generally very good. However, in the worst case of the comparisons, the model predicts a 30 dB change in the signal level that is not present in the data. This variation between prediction and measurements is due to the differences between actual terrain along the path and the terrain obtained from the topographic data base used in the predictions. The topographic data base that was used has point elevation values on a grid with spacing of 30 seconds in longitude and latitude (approximately every 925 meters). The terrain elevations used in the ITM are interpolated from the four closest data base grid elevations at each point along the path.

In order to illustrate the model's performance in a quantitative way, a cumulative distribution of the difference between the predicted and measured values of transmission loss was compiled as shown below.



This distribution represents the performance of the model over nine of the measurement routes. The expected difference for 80 percent of the time ranges from +7.5 dB to -19 dB. The distribution is skewed toward the negative values. This is due to the environmental clutter that is not explicitly accounted for in the model. The ITM user should consider this when making predictions for environments containing vegetation or man-made obstructions, neither of which are included in the topographic data base. A typical output of the ITM model for the signal from one transmitter is shown below.

Prediction Confidence	Predicted maximum basic transmission loss (dB) with a minimum reliability of: 10%	50%	90%	95%	99%
10%	118	122	134	137	143
50%	120	131	143	147	153
90%	127	139	152	156	164

This shows the expected spread of the data as a function of reliability and the prediction confidence for a mobile case. The prediction confidence is a measure of how the model's prediction compares with the measured data upon which the model itself is based. In other words, a prediction confidence of 10 percent means 10 percent of the model's measured situations had losses that were less than the prediction; 50 percent means half of the situations had losses that were less than the prediction, etc. For this study, a prediction confidence of 50 percent was chosen. The values are read from the table as, for example, "for a prediction confidence of 50 percent or for half of the paths that are from similar situations, the basic transmission loss will not exceed 131 dB for more than 50 percent of the time/locations nor will the loss exceed 153 dB for more than 99 percent of the time/locations." Again, for this comparison of measured data with predictions, the reliability of 50 percent has been chosen.

HF Studies

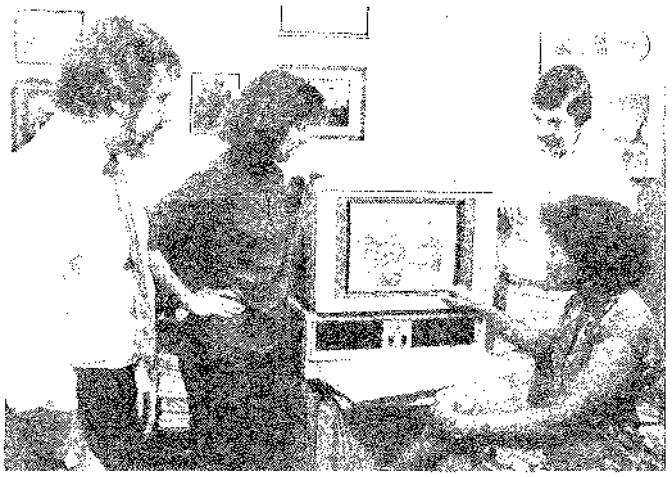
Outputs

* Improved techniques to predict HF system performance
* More accurate ionospheric specification
* Reports describing application to HF system assessment

Along with the developments to improve high frequency propagation assessment capabilities discussed earlier, ITS has a long history of investigating methods that can be used to improve the specific prediction of the ionosphere. Because the ionosphere is the medium by which HF sky waves are propagated, improvements in the ability to forecast and predict the state of the ionosphere yield corresponding improvements in the ability to predict the expected performance of telecommunication systems that use the HF spectrum.

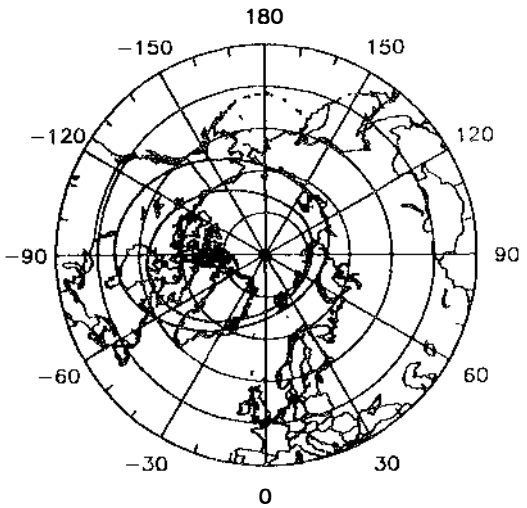
One major effort under way at ITS involves improving the prediction of the global variation of the critical frequency of the F2 region, foF2. The parameter is a key parameter relating to the state of the ionosphere. It determines the highest frequency that can be propagated via the ionosphere between two points on the Earth. Maps of foF2 determined from numerical coefficients form the basis for many HF prediction programs. An example of such a map is shown at right. Contours of foF2 (in megahertz) are shown for a time period corresponding to average conditions during March 1976, 0600 h UTC.

The maps are generated from data observed at locations throughout the world. These locations are not evenly distributed over the globe. This results in maps of questionable accuracy in data-sparse areas, such as oceans. In an attempt to improve the accuracy of the maps and make them more physically realistic, ITS scientists and engineers have used sophisticated theoretical ionospheric models to supplement the available data. The map shown was generated from data that were observed at specific locations as well as data that



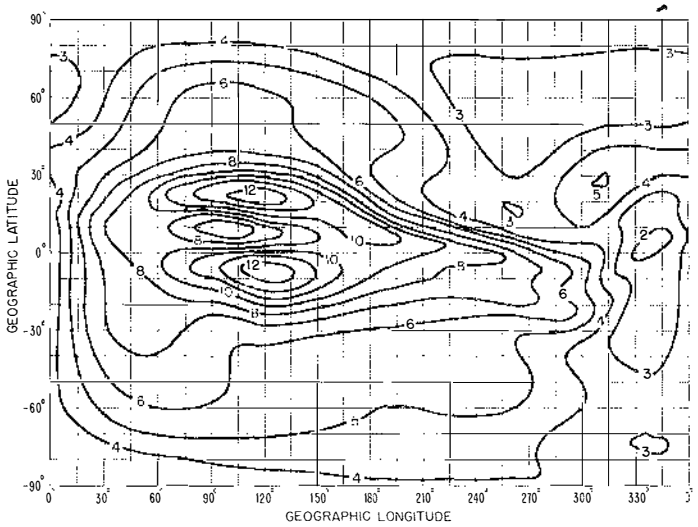
Project personnel (standing l. to r.) Charlie Rush, Mary Sowers, Larry Teters, and Terryll Nemeth (seated)

were derived from theoretical calculations. The features seen on the map accurately represent the known ionospheric structure. A companion effort relates to improving the predicted structure of the polar ionosphere. The polar ionosphere is a highly variable medium characterized by dynamic processes of ionospheric and magnetospheric origin. Many of the features of the polar ionosphere-ionization troughs, electron density enhancements, and irregularities in ionospheric structure are associated with the auroral oval. This oval is the region in which there is



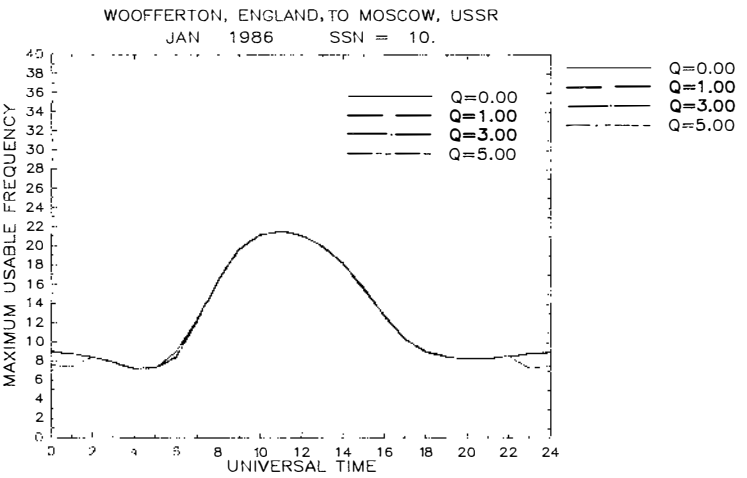
AURORAL OVAL — NORTH POLE
Q = 4 JULY

a high probability of the occurrence of visible aurora. The auroral oval moves with time, season, and magnetic activity. An illustration of the location of the oval in the Northern Hemisphere is given in the figure below. It shows the oval location during July at 1200 h UTC for moderately disturbed (Q=4) magnetic conditions.



Changes to the ionospheric representation given in the IONCAP HF propagation prediction program were made to include the auroral oval-related features. This has enabled the results of the IONCAP program to be used to assess changes to propagation conditions that are likely to be associated with the passage of radio waves through the polar ionosphere. Changes to the maximum usable frequency (MUF) that can propagate between two points is being studied to determine the impact of the highly variable polar ionosphere on the performance of international short-wave broadcasting services. Broadcast circuits that are typical of those currently being operated by the Voice of America have been chosen for simulation using the IONCAP computer program in its unmodified state and with the polar ionospheric features incorporated.

The figure below illustrates the results that have been obtained for the circuit Wooferton, England, to Moscow, USSR. Calculations of the MUF were performed in this case for the month of January 1986 for a level of solar activity equal to 10 units. Various levels of magnetic activity (Q values) were taken into account in simulating the effects of the polar ionosphere on this broadcast circuit. It can be seen that between the hours of 2200 and 0200 UT, the MUF is depressed significantly when proper account is taken of the polar ionospheric structure. This depressed MUF will result in a narrower range of frequencies that can be used to provide the required program to the service area. Further, studies related to accounting for the polar ionospheric structure in Voice of America broadcast planning activities are continuing.



Recent ITS Publications

Ionospheric Radio Propagation Models and Predictions--a Mini-Review (by Rush)

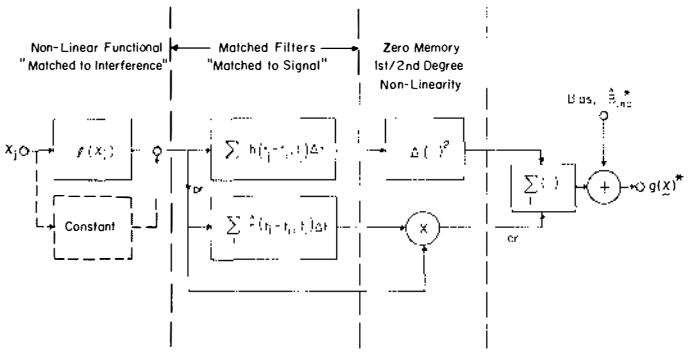
Some Ionospheric Factors Affecting the Coverage of an HF/VHF Direct Broadcasting Satellite Service (by Rush et al.)

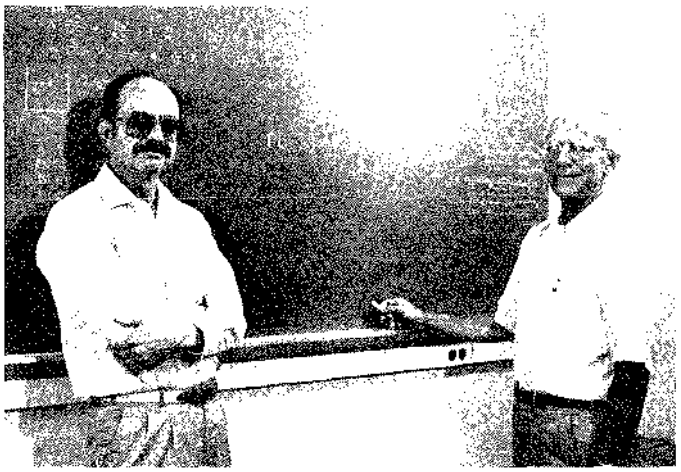
Signal Processing Studies

Outputs

- ✱ Statistical-physical models of non-uniform, quasi-static EM signal and non-Gaussian noise fields
- ✱ Locally optimum threshold signal detection software algorithms
- ✱ Monte Carlo simulation performance results for parametric, nonparametric, locally optimum, and sub-optimum nonlinear detectors
- ✱ An extended signal-error-state model for bit error statistics

The real-world interference environment is almost never Gaussian in character, yet receiving systems in general use are those designed to be optimum for white Gaussian noise. Since Gaussian noise is the worst kind of interference in terms of minimizing channel capacity, very large improvements in the performance of systems can be achieved if the actual statistical characteristics of the interference are properly taken into account, thereby greatly improving spectrum conservation and utilization. For the actual non-Gaussian interference confronting us, the overall optimum system cannot be realized physically (or economically), but if the signal is "small enough," optimum threshold detectors can be realized. The resultant nonlinear receivers take the general form shown below.





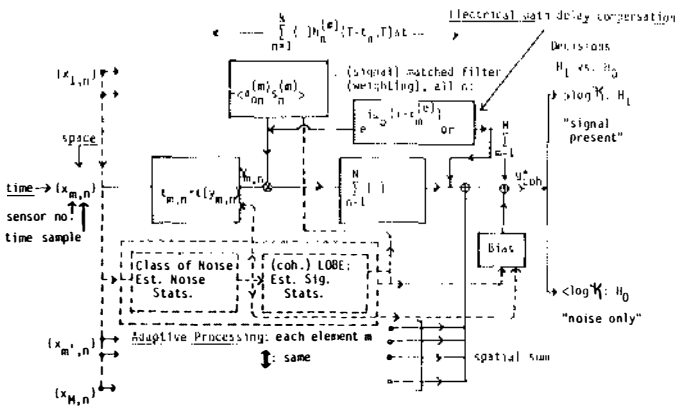
Project personnel (l. to r.) Don Spaulding and Lew Vogler

Such a receiving system can be 20, 30, or more decibels better than the normal linear receiver in that a signal-to-noise-ratio of 20 or more decibels less than currently required will produce the same performance.

Unfortunately, such a gain is achievable only if the number of independent, received waveform samples is large for each detection interval (baud). This can greatly reduce information throughput.

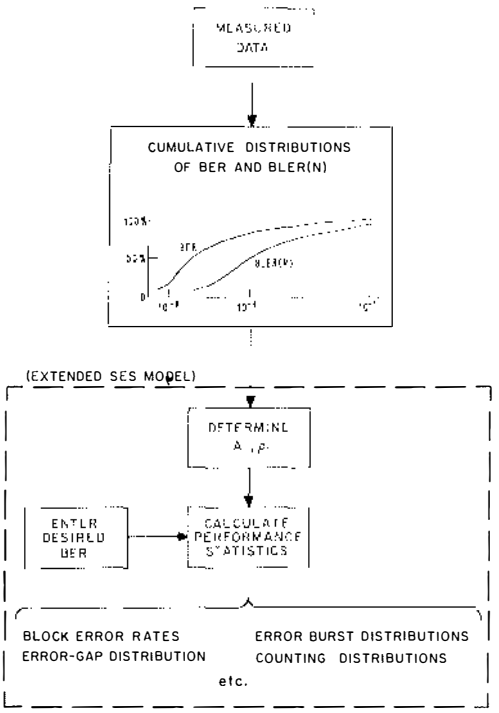
One way to overcome the requirement for a large number of samples is to use both spatial and time sampling. This requires the development of detection algorithms appropriate for interference fields and the extension of the earlier physical-statistical non-Gaussian interference models to vector/tensor nonuniform electromagnetic interference field models. A canonical theory of threshold detection in non-Gaussian space-time fields has been developed and implemented for general models. Both optimum threshold and "good" suboptimum processing algorithms have been obtained and their performance evaluated in the general weak-signal regimes. The major extensions to recent studies at ITS include the effects of nonuniform, spatial noise fields on beam forming and

signal detection with arbitrary arrays. Such a receiver structure is shown below.



The characterization of error statistics in digital communication channels is essential for the investigation of error-control schemes and in system performance studies. An important characteristic of digital communication channels is the fact that changing physical conditions will alter the channel bit error rate (BER). A statistic such as the block error rate [BLER(N)]--the probability of one or more errors in a block of N bits--is a function of BER and will change as channel conditions change. Most prediction models present equations and algorithms for obtaining the statistics of interest, but the models are limited to a single long-term or "average" BER that presumably characterizes the channel under consideration. The only model that has existed for evaluating statistics at other BER is that based on the binary symmetric channel (BSC). Unfortunately, the BSC is not an adequate model for many real channels.

A new model has been proposed by ITS that offers a more realistic description of channels and that also allows the evaluation of statistics as a function of BER. The model is an extension of Fritchman's single-error-state (SES) model by which, at a particular BER, the channel is statistically described by a set of "fitting" parameters, A_i and p_i. From these parameters, any statistic, e.g., the block error rate or the error burst distribution, can be calculated for the channel at that BER. The extension provides a method for determining the A_i and p_i for any other desired value of BER. The procedure for characterizing the error statistics of a channel using the extended SES model is outlined in the block diagram below.



Major benefits of the new model will be in its use for the design of error control strategies and as an analytic tool in performance evaluations of digital sytems and networks.

Recent ITS Publications

A Tutorial Review of Elements of Weak Signal Detection in Non-Gaussian EMI Environments (by Middleton & Spaulding)

An Extended Single-Error-State Model for Bit Error Statistics (by Vogler)

Comparisons of the Two-State Markov and Fritchman Models as Applied to Bit Error Statistics in Communication Channels (by Vogler)

Locally Optimum and Suboptimum Detector Performance in a Non-Gaussian Interference Environment (by Spaulding)

Space-Time Processing for Weak Signal Detection in Non-Gaussian and Non-uniform Electromagnetic Interference (EMI) Fields (by Middleton)

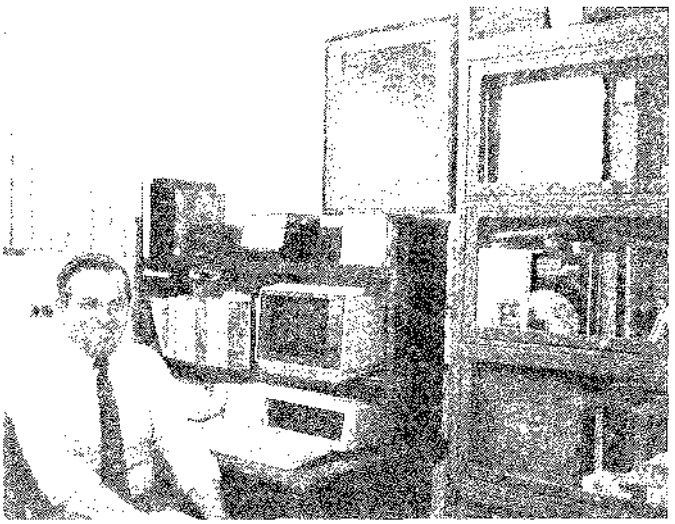
Satellite Studies

Outputs

- ✱ Outline of proposed experiments using ACTS
- ✱ Experiments planning coordination with NASA
- ✱ Operational satellite interference analysis model
- ✱ Analysis of earth station antenna side-lobe characteristics

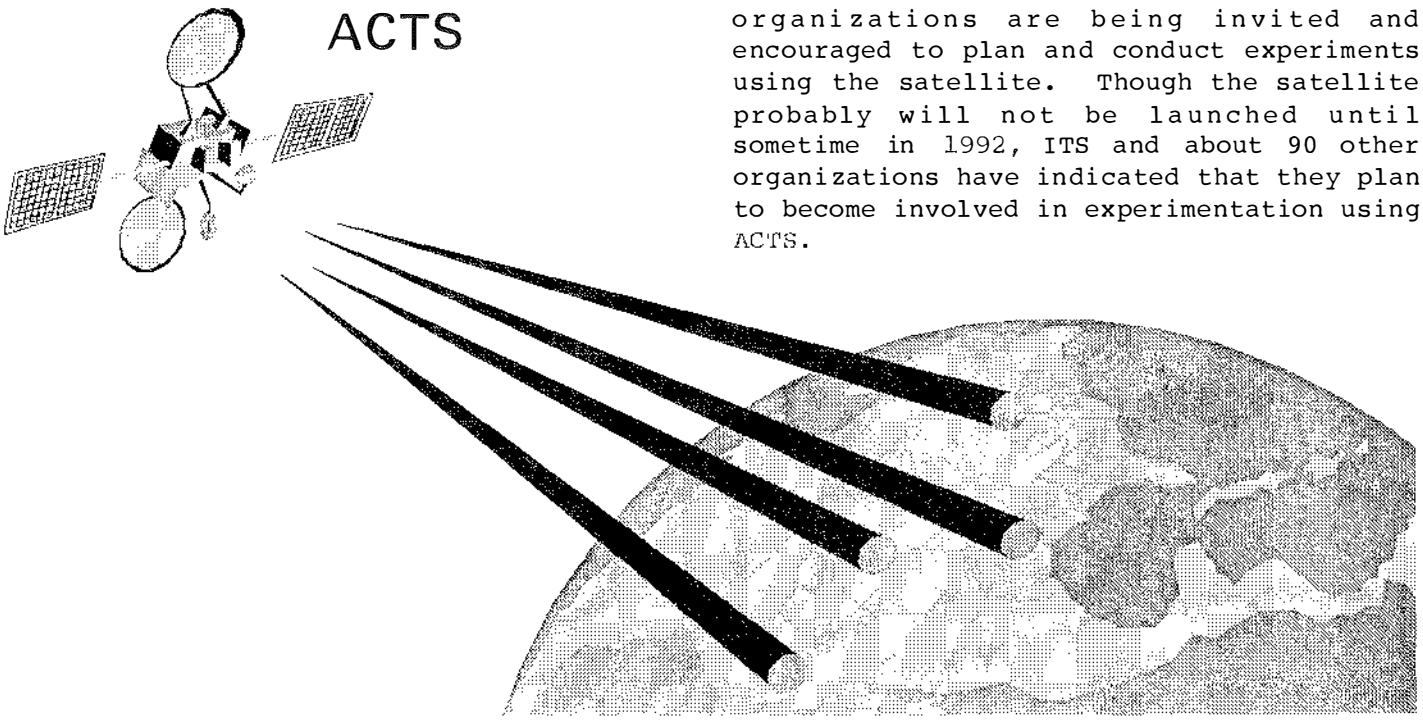
The evolution of communication satellites has been driven by the need for increased service capacity and lower service costs. A new generation of advanced, "smart," communication satellite systems, now in its embryonic stage of development, will respond to these requirements through the application of digital technology that is compatible with onboard signal processing and switching capabilities and the use of hopping spot beams that provide coverage to relatively small geographical locations, as illustrated below.

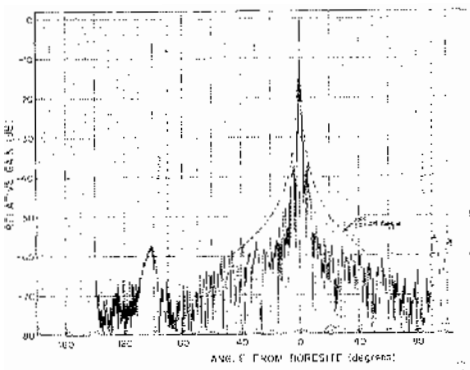
These features also will alleviate orbit and spectrum congestion and, through the use of 30/20 GHz (Ka-band) frequencies, provide much greater channel capacities.



Project leader Ray Jennings

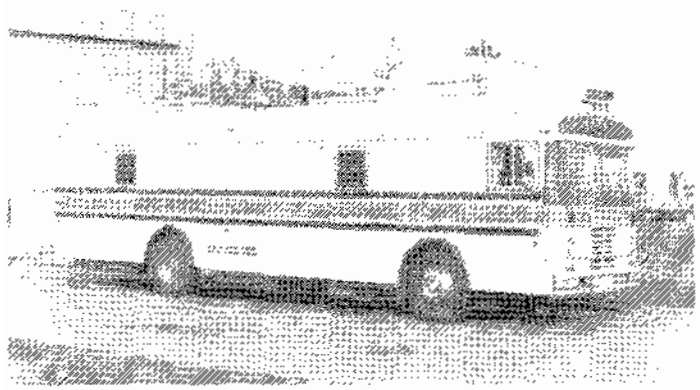
There is need for a broad range of empirical and analytical studies to characterize the performance of this new class of communication satellites (and their associated networks). The National Aeronautics and Space Administration (NASA) is developing and will launch an experimental satellite, which is called the Advanced Communications Technology Satellite (ACTS). Other Government agencies, universities, and commercial organizations are being invited and encouraged to plan and conduct experiments using the satellite. Though the satellite probably will not be launched until sometime in 1992, ITS and about 90 other organizations have indicated that they plan to become involved in experimentation using ACTS.





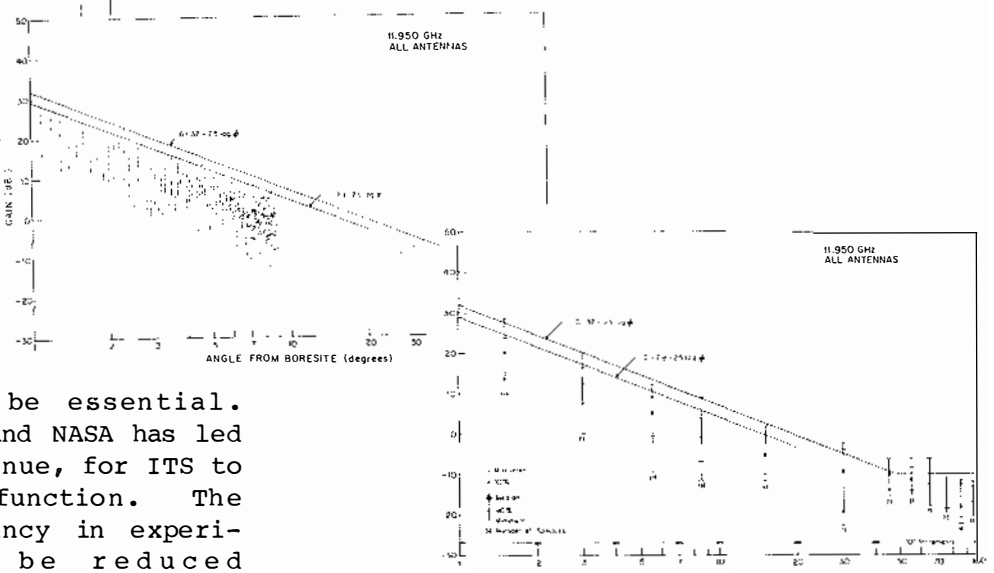
With a large number of experimenters and a broad range of interests in the experiments that will be planned, it is apparent that substantial experiments coordination will be essential. Mutual concern by both ITS and NASA has led to planning, that will continue, for ITS to provide this coordination function. The benefits are that redundancy in experimental efforts will be reduced substantially and the coordinated experimental results will provide aggregated benefits that exceed the benefits of the individual contributions.

As an experimenter, ITS is planning a unique complement of experiments that will characterize network (system) performance using parameters that describe users' perceptions of the system performance and service provided. The Institute also plans to update the Portable Earth Terminal (originally developed by NASA for use with the Advanced Technology Satellite series of experiments) for use in the experiments that will be conducted using ACTS.



Portable Earth Terminal

In other satellite studies, ITS has used measured data obtained from antenna manufacturers and the FCC to analyze the sidelobe characteristics of earth station antennas that operate at 14/11-12 GHz (Ku-band). Analysis has involved digitization



of analog patterns to form sets of data that have been statistically analyzed and plotted, in accordance with techniques recommended by the CCIR, as shown.

Another element of the satellite studies has been the development of a satellite network interference analysis model known as GSOAP (Geostationary Satellite Orbit Analysis Model). More description of this model is given in the **International Radio Conference Support** Section of this report.

Recent ITS Publications

A Model of a Shaped-Beam Emission Pattern of a Satellite Antenna for Interference Analysis (by Akima)

Sidelobe Gain Characteristics for Ku-Band Earth-Station Antennas (by Harman and Jennings)

Technical Basis for the Geostationary Satellite Orbit Analysis Program (GSOAP) Version 2 (by Akima)

User's Manual for GSOAP Version 2.6 (by Akima)

Radio Environment Simulators

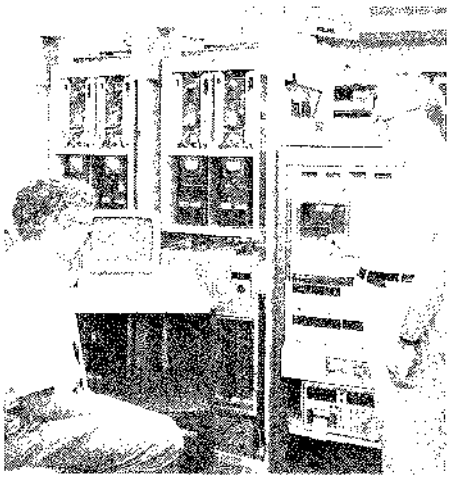
Outputs

* Microwave LOS channel simulator
* EW threat simulator

The need for channel simulation becomes apparent when one considers the complexity of analytically evaluating digital radio performance or the difficulty and expense in field testing digital radios. This is true for many different types of transmission media including microwave line-of-sight (LOS), tropospheric scatter, and high frequency (HF) channels.

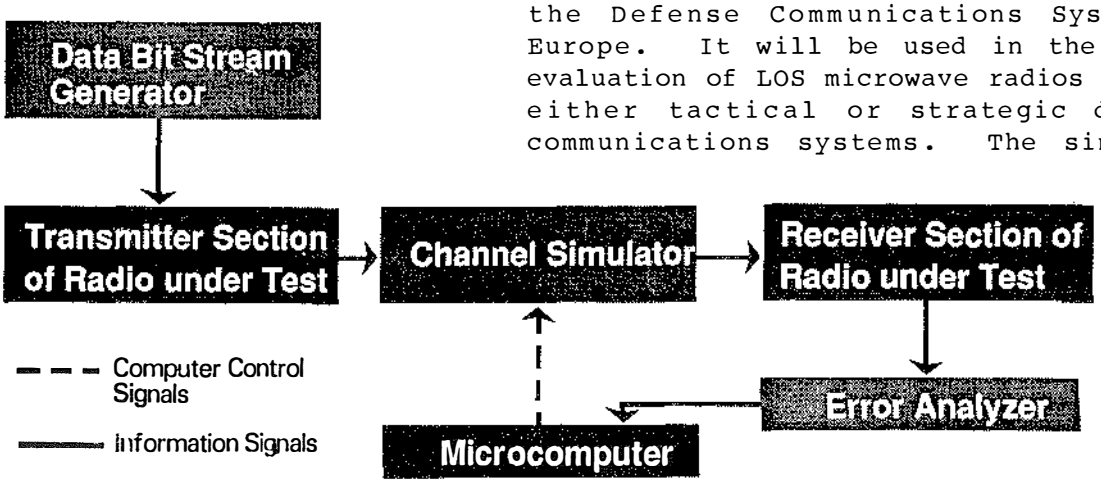
Frequently, one is confronted with the problem of comparing the performance of two or more radios. The evaluation of the radios' performance in a fading propagation channel is a major part of the total testing process. It is difficult and expensive to perform such evaluations in the field because one cannot control the test conditions, i.e., the fading characteristics of the channel. As a result, field testing requires the simultaneous testing of all radios being compared. Often this is not possible. It is also not possible to test the radios under a full range of fading conditions.

Simulation of channel fading conditions is a more cost-effective approach to radio performance evaluation. For digital radio tests, a known digital bit stream is injected into the radio under test. Simulated channel fading causes distortion in the received signal. This distortion can cause errors to occur in the digital bit stream output from the radio receiver. Because the fading conditions can be precisely controlled, the performance of different radios can be evaluated under identical conditions.



Project personnel (l. to r.) Jim Hoffmeyer and Ernie Morrison

During FY 85 and FY 86, an LOS simulator was developed. This simulator has already been used to evaluate the performance of a digital radio that is an integral part of the Defense Communications System in Europe. It will be used in the future evaluation of LOS microwave radios used in either tactical or strategic defense communications systems. The simulator



Functional Diagram of ITS Simulator

could also be used for testing microwave radios used in the private sector (e.g., radios used by the telephone companies).

The Institute has long been active in narrowband (less than 12 kHz) HF channel simulation. During FY 86, a study to determine the feasibility of building a wideband HF channel simulator was undertaken.

The Institute is also conducting a program in electronic warfare simulation. Many defense communications systems are susceptible to various electronic warfare (EW) threats. These threats include various active and passive actions having a range of sophistication. As a result, EW susceptibility and electronic counter-countermeasure (ECCM) requirements are included in the engineering design and development phases of communications system acquisition programs. This leads to a need for a methodology for evaluating the effectiveness of the ECCM designed into the system. This need, like the need for evaluation of radio performance in a fading environment, is best met through the use of a simulator. In the EW scenario, the need is to simulate the jamming threat rather than fading propagation.

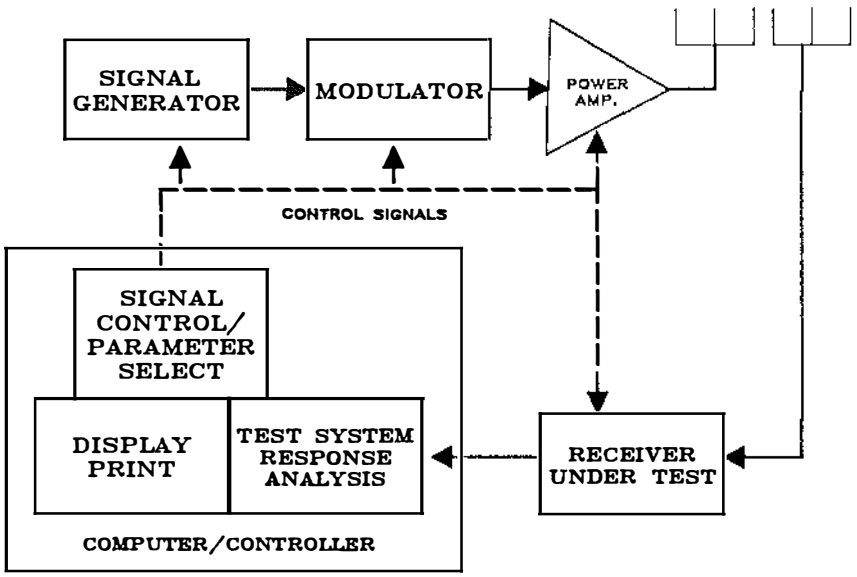
The ECM (electronic countermeasures) simulator under development at ITS addresses the ECM testing of U.S. Army developed communications systems. The simulator couples jammer signals into the test system antenna(s). Jammer antennas are positioned with minimum separation from the test system antenna. Compensation is made for the near-field rather than far-field coupling of the signal between antennas. Continuous wave spot jammers, narrowband and wideband jammers, railing jammers, and frequency modulated jammers can be simulated. Jammer output parameters for each test are programmed to be within the signal-to-jammer ratio specified by military EW threat definitions.

Recent ITS Publications

Line-of-sight Channel Simulation--A New Approach (by Hartman, Hoffmeyer, and Pratt)

LOS Microwave Channel Simulation--A Survey of Models, Realizations and New Concepts (by Hoffmeyer and Hartman)

Performance Evaluation of LOS Microwave Radios Using a Channel Simulator (by Hoffmeyer, Pratt, and Riley)



Functional Diagram of ITS Electronic Warfare Simulator

ITS Tools and Facilities

Antenna Turntable Platform - ITS has an antenna turntable located at its Table Mountain Radio Quiet Zone facility. The turntable is 37 feet in diameter, and its surface is flush with the test range. It is capable of rotating a 22,000-pound test antenna or vehicle up to three revolutions per minute. The turntable is the roof of a below-ground equipment room. There is a 100-ft dielectric tower that can be used to position sources for test-site illumination. This facility is available for use by private parties on a reimbursable basis.

Data Communication Laboratory Test Bed - This ITS test facility is used as a tool for:

- Verifying the validity of new and developing Federal and ANSI data communication standards. It provides realistic data and suggestions for refinements and improvements of a developing standard to the working standards committees.
- Building a representative data base of user-oriented performance parameter values for real-world data communication systems such as the ARPANET, several public data networks, and in the future local area networks, gateways, and alternate services (since deregulation).
- Evaluating the performance of alternative data communication technologies, systems, and services in terms of specified user needs.

Three computers, including a transportable desk-top UNIX system, comprise a portion of the equipment used in the testing. Normally one of the computers serves as the local host to one or more networks and the transportable machine is taken to a distant city to function as the user of the network under test. This test facility is available for use by private parties on a reimbursable basis.

Laboratory Atmospheric Simulator - ITS has a unique laboratory atmospheric simulator facility to measure the radio refractive index of moist air. This simulator is designed to provide highly accurate measurements of millimeter wave attenuation in the frequency range 10 to 220 GHz. The laboratory atmospheric simulator permits the pressure to be varied over six orders of magnitude (10^{-3} to 10^{3} millibars), the relative humidity to be varied between 0 and 100 percent, and the temperature to be varied between 270 to 320 degrees Kelvin. The simulator provides a means to conduct millimeter wave propagation experiments in a controlled environment that can represent atmospheric heights from the Earth's surface to 120 km. This latter height provides a realistic basis to conduct experiments that are representative of satellite heights for most applications. This tool is available for use by private parties on a reimbursable basis.

Microwave Line-of-Sight (LOS) Channel Simulator - ITS has developed this tool to simulate channel fading conditions in a controlled environment in order to evaluate the performance of different radios under identical conditions. ITS developed the simulator to perform evaluations for the DoD; however, it could also be used for testing microwave radios used in the private sector.

Mobile Millimeter-Wave Measurement Facility - ITS has a highly sophisticated, fully computerized 10 to 100 GHz channel probe for determiniing the performance of potential communications paths. Each terminal (transmit and receive) can be fixed or mounted on vans that provide a means to perform path measurements in environments ranging from urban to isolated locations. Measurements and analysis from remote terminals (via wire or telephone) can be conducted to determine occurrence of signal fades and identification of fade

mechanism (rain attenuation, multipath phase interference, antenna beam decoupling, ray defocusing, etc.) as well as channel distortion across a 1.5 GHz bandwidth. Instrumentation to measure meteorological parameters such as rain rate, refractive index, water vapor content, etc., is also available for simultaneous observation. This facility is available for use by private parties on a reimbursable basis.

Portable Earth Terminal - This tool, originally developed by NASA for use during the Communication Technology Satellite experiments, has been obtained from NASA for use during the Advanced Communication Technology Satellite (ACTS) experiments. Radio frequency components of the terminal will be upgraded for operation at the 30 GHz transmit and 20 GHz receive frequencies used by ACTS. The vehicle provides an excellent mobile laboratory and is equipped with a roof-mounted antenna, a full complement of equipment racks, and two 12 kW motor generators.

Radio Spectrum Measurement System - The system is used by ITS to support management of the radio spectrum. The RSMS contains two independent computer-controlled receiving systems capable of automatic surveys of spectrum usage, as well as detailed measurements on particular signals. This system operates up to 18 GHz and is easily deployed in a motorhome type of vehicle, complete with an electrically-raised antenna tower and a mobile telephone system.

The Table Mountain Radio Quiet Zone - This is a very unique facility (one of only two in the Nation), which is controlled by public law to keep the lowest possible levels of unwanted radio frequency energy across the spectrum from impinging on the area. This situation allows research concerned with low signal levels (from deep space, extraterrestrial, low signal satellite, very sensitive receiver techniques, etc.) to be carried out without the ever-present interference found in most areas of the Nation. As the use of electronic systems (garage door openers, computers, citizen band radios, arc welders, appliances, etc.) increases and the number of radio and TV stations increases along with many new uses for the radio frequency spectrum, the average level of electromagnetic energy across the spectrum increases. This occurrence is important to companies involved in developing very sensitive receivers and radio signal processing equipment since the front ends of these receivers are often times saturated by background noise (interference). This facility is available for use by private parties on a reimbursable basis.

Telecommunication Analysis (TA) Services - ITS offers an on-line, fully-automated service that provides subscribers with access to many ITS-developed computer programs. This service has been developed as a conduit for applied research and engineering and is available to both Government and private sector entities on a reimbursable basis. The TA Services menu includes models that provide data on transmitters, signal coverage, topographical profiles, population density, rain rates, atmospheric radio noise, ionospheric spatial parameters, and other data affecting radio propagation.

UHF Propagation Measurement Van - ITS uses this mobile facility to measure the performance of UHF systems. The receiver is placed on a mobile van and the transmitter antenna is fixed. The receiver system makes continuous measurements of the received signal level as the van moves along a planned measurement path. The measurement system is capable, in the UHF band, of taking samples at every wave length. ITS makes measurements using this facility to improve and validate a computer model that provides UHF system designers and users with performance prediction capabilities.

ITS Projects for Fiscal Year 1986 Organized by Department and Agency

BOARD OF INTERNATIONAL BROADCASTING (BIB)

BIB Analysis Standards - Gregory R. Hand (497-5258) - Develop a performance analysis standard for HF broadcasting to be used by Radio Free Europe and Radio Liberty in their facility utilization studies.

COMMERCE, DEPARTMENT OF

National Telecommunications and Information Administration (NTIA)

1988 Space WARC Preparation Support - Raymond D. Jennings (497-3233) - Provide technical support to U.S. preparations for the 1988 World Administrative Radio Conference for Space Services and the intersessional work that will precede the conference.

Advanced Satellite Communication Technology Studies - Raymond D. Jennings (497-3233) - Develop experiment planning and equipment design in preparation for participation in the NASA sponsored Advanced Communications Technology Satellite program.

Data Communications - Edmund A. Quincy (497-5472) - Develop, promulgate, and demonstrate compatible Federal and American National Standards for specifying and measuring data communication performance.

HF Broadcasting WARC Planning - Charles M. Rush (497-3821) - Provide support, through computer model development and representation at appropriate meetings, to HF broadcasting policy makers in preparation for the Second Session of the HF Broadcasting Conference.

International Standards - Edmund A. Quincy (497-5472) - Provide leadership and technical support for U.S. participation in national and international standards setting bodies.

ISDN Technical - Edmund A. Quincy (497-5472) - Develop standards for Quality of Service for voice communications on ISDN networks.

Millimeter-Wave Model - Kenneth C. Allen (497-3412) - Perform studies and experiments necessary to develop a user-oriented millimeter-wave propagation model applicable to frequencies up to 300 GHz that will be useful in assessing millimeter-wave telecommunication system performance.

Spectrum Efficiency Studies - Leslie A. Berry (497-5474) - Methods for computing the technical spectrum efficiency factor for mobile services will be applied to the land-mobile bands.

Spectrum Engineering Development - Leslie A. Berry (497-5474) - Lead and participate in Working Group 13 of IRAC's Technical SubCommittee with the purpose of planning for improved spectrum management, and efficient and effective use of the spectrum resource.

Spectrum Resource Assessments - William B. Grant (497-3729) - Complete a study of the radiolocation bands from 1605 kHz to above 17.7 GHz showing the uses, the importance to the Government, the continuing need for spectrum, and the critical missions of Federal agencies who use radiolocation services.

RSMS Engineering Enhancements - Robert J. Matheson (497-3293) - Improve the measurement capabilities of the Radio Spectrum Measurement System as needed to provide improved measurement data.

RSMS Operations - Robert J. Matheson (497-3293) - Provide measurements of spectrum usage and other technical parameters of radio systems.

Note: Commercial users dial 303 + number shown. FTS users dial 8-320 + extension shown.

VHF/UHF Propagation Studies - Eldon J. Haakinson (497-5304) - Perform UHF mobile path loss measurements between a mobile receiver and a fixed transmitter in rural, suburban, and urban environments. Compare the measurements with predictions made by the ITS Irregular Terrain Model.

National Bureau of Standards (NBS)

Comparative Measurements of ACSB and FM - William A. Kissick (497-3723) - Review and measure amplitude companded sideband (ACSB) as compared to FM in the context of law enforcement, land-mobile communications needs.

DEFENSE, DEPARTMENT OF (DoD)

DoD Consulting - A. Donald Spaulding (497-5201) - Provide consultation and advisory services on such things as optimum system design and performance determination, detection algorithms, and interference modeling.

DoD HF Propagation Studies - Larry R. Teters (497-5410) - Develop simplified ground-wave considerations utilizing the IONCAP sky-wave input to permit assessment of received signal strengths of distances too short for sky-wave propagation.

foF2 Solar Cycle Predictions - Charles M. Rush (497-3821) - Develop numerical coefficients of foF2 and appropriate solar activity interpolation procedures that can be directly incorporated into HF propagation prediction programs.

MF Signal and Noise Measurement - Donald H. Layton (497-5496) - Study the signal and noise environment in the 25-100 kHz range in a typical office/business environment.

TAEMS Consulting - Forrest E. Marler (497-5321) - Provide technical support for NSA personnel in understanding modulation and spectrum analysis techniques to further their utilization of the spectrum analysis van designed and built by ITS.

TDOA Support - Charles M. Rush (497-3821) - Provide assistance and analysis expertise in the conduct of a time difference of arrival (TDOA) HF experiment.

Wide Area Propagation Model - Ray E. Thompson (497-3352) - Provide a validation of the Wide Area Propagation (WAP) model and software and determine the changes in reception probability in the presence of surface and elevated atmospheric ducts at 4 and 6 GHz from those values predicted by the WAP model, and incorporate those changes into an enlarged WAP model.

Air Force--Electronic Systems Division (ESD)

AFGL/LYT Refractometer Consultation - Forrest E. Marler (497-5321) - Refurbish and update AFGL's microwave refractometer.

TRAMCON 86 - Richard E. Skerjanec (497-3157) - Develop, test, and support the transmission monitor and control program (TRAMCON) that is being developed for the monitor and control of the digital transmission system for the Defense Communication System in Europe.

TRAMCON Master Upgrade - Richard E. Skerjanec (497-3157) - Evaluate alternatives for upgrading the hardware configuration for the TRAMCON master facility.

Troposcatter Channel Probe Development - James A. Hoffmeyer (497-3140) - Develop a quad-channel troposcatter channel probe and provide systems integration support to ESD.

USAF Local Area Network Consulting - Joseph E. Farrow (497-3607) - Provide ESD with assistance in their efforts to install local area networks at some 200 locations throughout the world.

Air Force Systems Command (AFSC)

AN/MSR-T4 Receiver System - Wesley M. Beery (497-3384) - Provide engineering technical support services during procurement, production, and testing of the AN/MSR-T4 Multiple Receiver System.

Error Statistics Modeling - Lewis E. Vogler (497-3556) - Develop and analyze a model for the error statistics of digital communication channels. Performance criteria from the model will be derived for use in designing terrestrial and airborne communication networks.

Army Communications--Electronics Command (CENCOMS)

Millimeter-Wave Studies of Propagation in Urban-Suburban Environments - Kenneth C. Allen (497-3412) - Determine millimeter-wave propagation characteristics in order to develop a model for predicting channel performance for LOS communication terminals located on urban-suburban streets.

Wide-band Consultation - Jean E. Adams (497-5301) - Provide technical support in application and modification of the Ground Network Communication Model developed by ITS, and provide technical support to Army's measurement of "wide-band" propagation characteristics in the UHF/VHF frequencies.

Army Electronics Proving Ground (EPG)

CATR Configuration Study - Ernest L. Morrison (497-5888) - Define configuration and optimum test zone parameter sets for a compact antenna test range to provide multiple electromagnetic environments required for testing adaptive communications-electronics systems.

SLF Methodology Investigations - Raymond D. Jennings (497-3233) - Develop measures of functional performance and recommendations for test methods to be used to stress those radio frequency systems whose performance is being tested using the Stress Loading Facility.

Spread Spectrum Communications Test Methodology - Ernest L. Morrison (497-5888) - Develop the methodology to evaluate the performance and operational support capability for spread-spectrum communications systems.

Army Information Systems Engineering Support Activity (ISESA)

Army HF Propagation Study - Larry R. Teters (497-5410) - Assist Army in the development and implementation of analytic techniques for tactical operation use.

Berlin-Bocksberg Data Analysis - John J. Lemmon (497-3485) - Analyze and interpret propagation, digital performance and meteorological data that were obtained during the link tests of the Berlin-Bocksberg digital troposcatter system.

Communications Support Study - Ernest L. Morrison (497-5888) - Develop traffic profiles and basic communications model configuration to evaluate the DoD combat support communications capabilities.

DRAMA Performance Tests - James A. Hoffmeyer (497-3140) - Conduct tests on the DRAMA system, seeking methods to improve performance in a multipath channel.

Enhancements to Radio Link Performance Algorithms - Laurance G. Hause (497-3945) - Update the interactive computer programs developed to predict the performance of three major types of terrestrial radio transmission systems.

EW Simulator Design - Ernest L. Morrison (497-5888) - Design, develop, and test one functional prototype of the EW simulator for Army communications facilities.

HF Ground-wave Model - Nicholas DeMinco (497-3660) - Develop an interactive HF ground-wave propagation prediction program to operate on a desk-top computer.

LOS Channel Simulator Development - James A. Hoffmeyer (497-3140) - Develop line-of-sight (LOS) channel simulators that are needed for the test and evaluation of digital radios that are being procured by the U.S. military.

Revision of Fed-Std 1037 - James A. Hoffmeyer (497-3140) - Provide editorial support for a major updating and revision of Fed-Std 1037, Glossary of Telecommunication Terms, the authoritative source of definitions for terms used in procurement of telecommunication services and equipment by Federal agencies.

Army Information Systems Management Activity (ISMA)

Access Area Engineering Services - Robert F. Linfield (497-5243) - Develop experiment strategies for the Experimental Integrated Switch Network (EISN), assess the impact of standards and regulations on the Defense Switched Network (DSN), and conduct studies of Local Area Networks (LANs).

Army Intelligence and Security Command (INSCOM)

ETSEM/PC - Robert O. DeBolt (497-5324) - Develop a version of the ETSEM program, which predicts the performance of line-of-sight terrestrial telecommunications links based on the design specifications, for operation on a personal computer; and enhance and extend the ETSEM model, data base, frequency range, and frequency modulation techniques.

IONCAP/PC - Frank G. Stewart (497-3336) - Develop a version of the HF propagation prediction program, IONCAP, for operation on a personal computer, and develop a generalized HF interference assessment algorithm for operation on a mainframe computer.

Army Missile Command

Millimeter-Wave Polarization Measurements - Kenneth C. Allen (497-3412) - Perform measurements of the effects of rain on the polarization of circularly polarized waves at 96 GHz.

Army Research Office (ARO)

Millimeter-Wave Laboratory Studies - Hans J. Liebe (497-3310) - Perform experimental research on millimeter-wave properties of moist air including haze conditions, in order to refine the atmospheric propagation model.

Defense Communications Agency (DCA)

Architecture Development Support for the WESTHEM DCS/DSN - Edmund A. Quincy (497-5472) - Define the mid-term to far-term preferred configuration of a WESTHEM DCS/DSN access node including the identification of services, functions, major components, and associated connectivity between components at the node and the relationship to other networks.

NSEP/FOCS - Joseph A. Hull (497-5726) - Establish "bench-mark" specifications or guidelines to facilitate quantitative evaluation of fiber optics installations in accordance with National Security/Emergency Preparedness requirements.

R&D/O&M Engineering Services for NCS - Joseph A. Hull (497-5726) - Provide technical consulting services to NCS in areas relating to development of Federal Telecommunication Standards and areas relating to technical evaluations in relevant technology areas.

Joint Tactical Command, Control, and Communications Agency

Wideband HF Channel Simulator Feasibility Study - James A. Hoffmeyer (497-3140) - Determine the feasibility of developing a wideband HF channel simulator that would ultimately be used in testing spread spectrum HF radios.

Naval Air Systems Command

Navy Microwave System Study - James A. Hoffmeyer (497-3140) - Analyze a new microwave communications system and perform predicted link availability calculations for each of three microwave links.

Naval Ocean Systems Center (NOSC)

Millimeter-Wave Propagation Model - Hans J. Liebe (497-3310) - Develop a reliable propagation model for the atmospheric transmission window centered around 94 GHz.

NOSC Communications Consulting - William J. Pomper (497-3730) - Provide engineering consulting services in support of the development of a classified Naval space communications system.

Naval Research Laboratory (NRL)

Noise Update - A. Donald Spaulding (497-5201) - Incorporate the new atmospheric noise model and the man-made noise model into the IONCAP noise subroutines and make other needed improvements and corrections.

U.S. INFORMATION AGENCY (USIA)

HIM/HER - Mary W. Sowers (497-3820) - Provide technical support to Voice of America in monitoring the effects of harmful interference on U.S. broadcasting operations.

MF Ground-Wave Model - Nicholas DeMinco (497-3660) - Modify the Ground Wave Automated Performance Analysis computer program to satisfy VOA's ground-wave analysis requirements for performance prediction for MF broadcasting purposes.

VOA Antenna Design - Charles M. Rush (497-3821) - Improve the capability of the Voice of America to optimize the selection of antennas for efficient broadcast performance.

VOA Interactive MF Interference Model - Eldon J. Haakinson (497-5304) - Design and implement an interactive MF interference assessment capability for ground-wave and sky-wave broadcasting purposes for the VOA.

VOA Predictions - Carlene M. Mellecker (497-3330) - Provide Voice of America with ionospheric predictions that are used in frequency planning and coordination.

VOA Studies and Support - Eldon J. Haakinson (497-5304) - Provide Voice of America with the capability to continue to effectively upgrade its broadcast facilities.

TRANSPORTATION, DEPARTMENT OF (DoT)

Federal Aviation Administration (FAA)

Air Navigation Aids - Gary D. Gierhart (497-3292) - Develop propagation models applicable to paths with airborne antennas, and implement these models into computer programs.

U. S. Coast Guard (USCG)

Consulting USCG - Jean E. Adams (497-5301) - Determine calculations of Navtex performance for 11 USCG sites, and plot coverage.

ITS Publications for Fiscal Year 1986

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Hoffmeyer, J. A. (1986), Voiceband quality-of-service issues in the post divestiture environment, NTIA Report 85-188, December, 132 pp. (NTIS Order No. PB 86-165149)

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AVAILABILITY OF PUBLICATIONS

NTIA Reports, Special Publications, and Contractor Reports are available from the National Techncial Information Service, 5285 Port Royal Road, Springfield, VA 22161. Order by number shown in publications listing. Requests for copies of journal articles should be addressed to the journal.

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