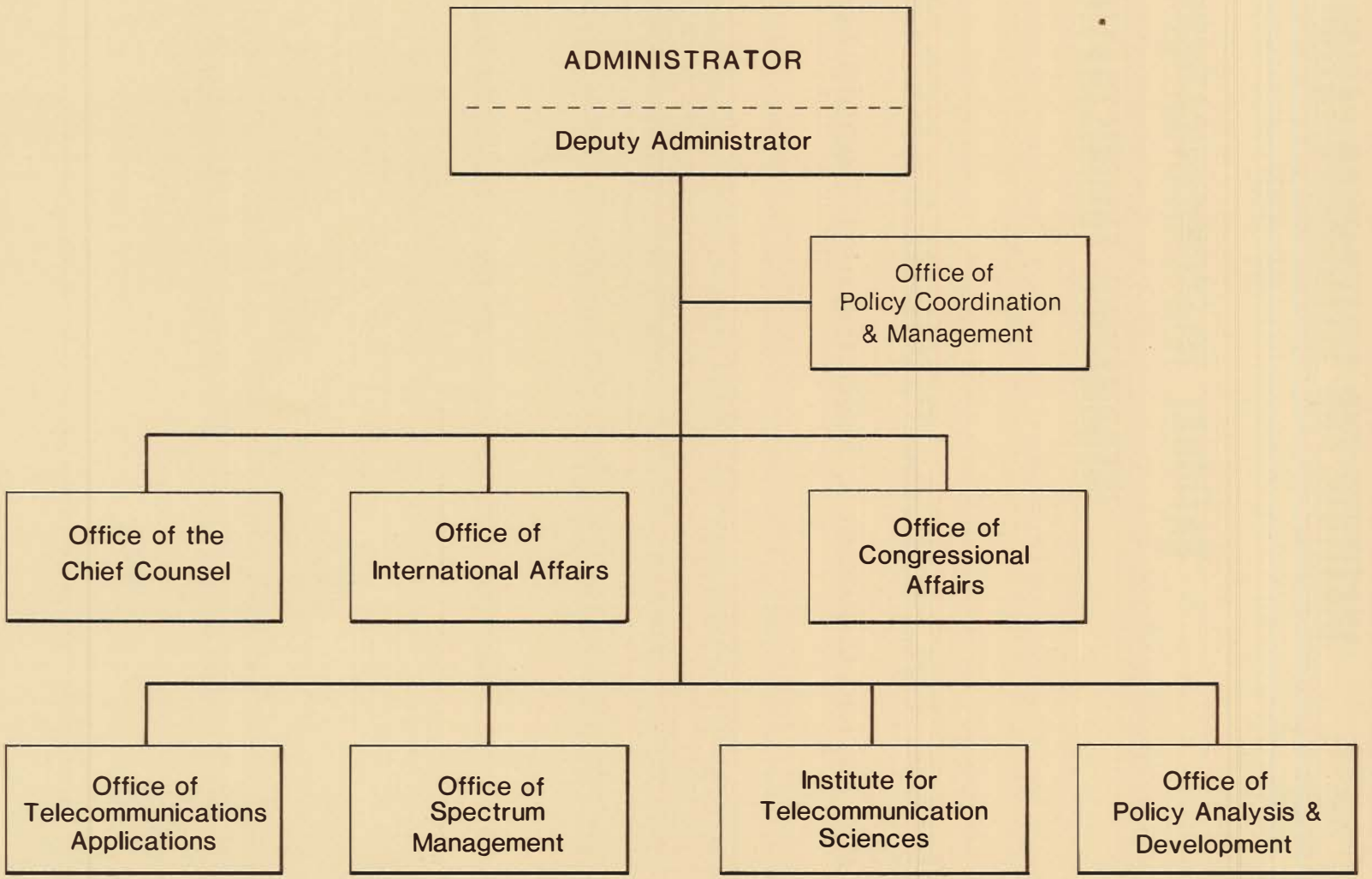
INSTITUTE FOR TELECOMMUNICATION SCIENCES
OF THE
NATIONAL TELECOMMUNICATIONS AND
INFORMATION ADMINISTRATION

ANNUAL TECHNICAL PROGRESS REPORT 1987

For the Period October 1, 1986, through September 30, 1987

U.S. DEPARTMENT OF COMMERCE

National Telecommunications and Information Administration



ITS

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U.S. DEPARTMENT OF COMMERCE
C. William Verity, Secretary
Alfred C. Sikes, Assistant Secretary
for Communications and Information

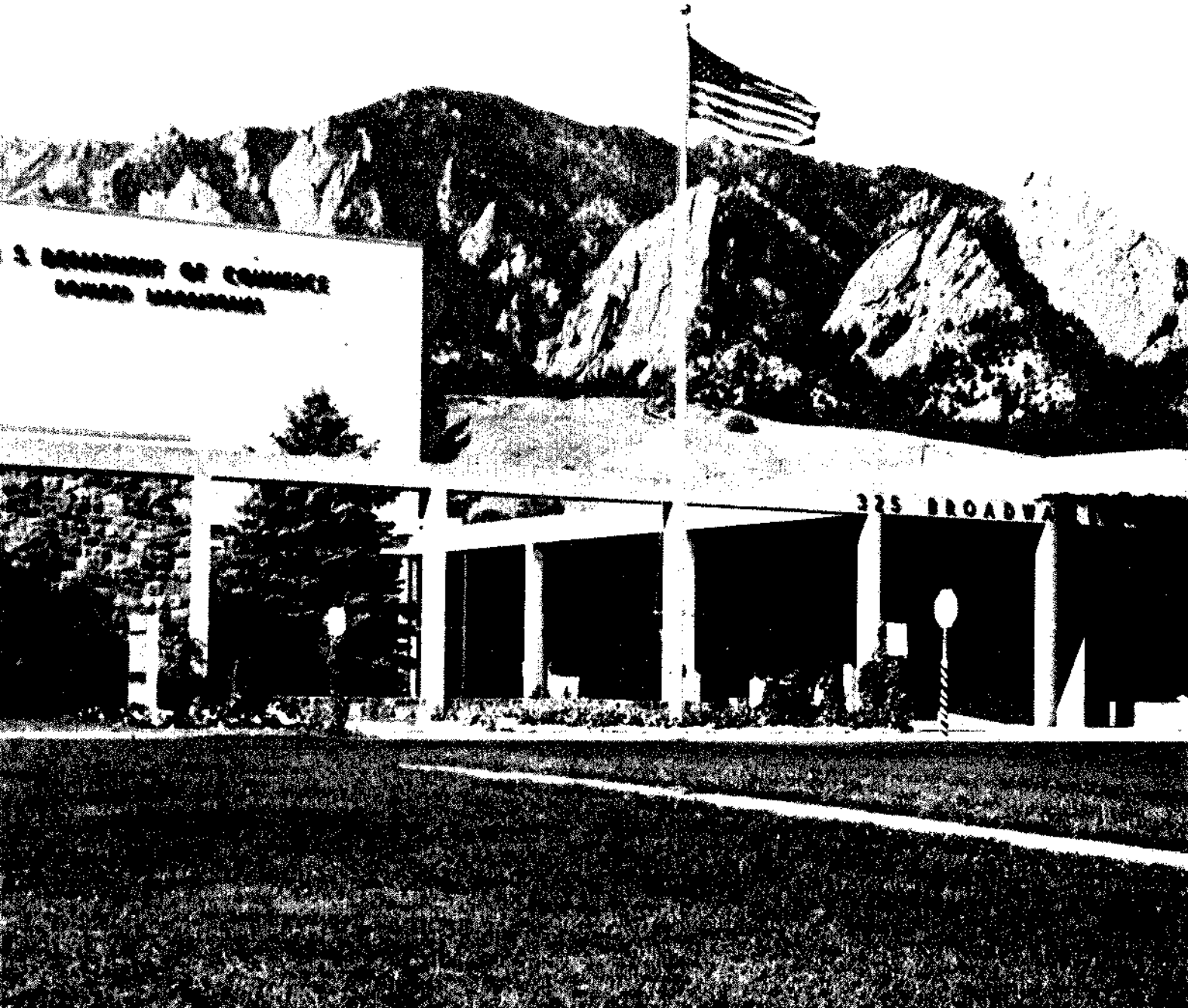
cover photo by Kenneth Spies, ITS

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.



CONTENTS

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 $3.4 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 International Broadcasters' Meeting

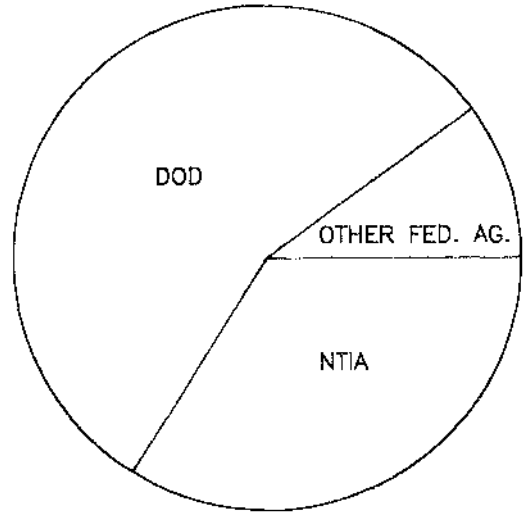
HISTORY

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

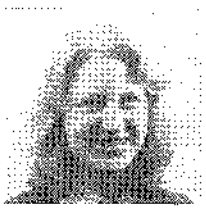
SPONSORS

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 1987 technical contributions made by ITS that have significance for the public and/or private sectors.


Bachinski


O'Day


Rush


Utlaut


Seitz


Salaman


Linfield

INSTITUTE FOR TELECOMMUNICATION SCIENCES


Cahoon


Quincy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Hoffmeyer


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SYSTEMS AND NETWORKS DIVISION
Neal B. Seitz, Deputy Director
Robert F Linfield, Associate Deputy Director

Program Planning and Evaluation
Val M. O'Day

Budget and Administration
Julia J. Bachinski

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

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 Air Force Systems Command, the National Bureau of Standards, the National Telecommunications and Information Administration, and the National Weather Service

Telecommunications Analysis Services

Includes a project funded by reimbursement from subscribers

International Radio Conference Support

Outputs

* Models to be used by the United States to determine positions at radio conferences
* Techniques and methods to assist the ITU in preparation for radio conferences
* Development of U.S. positions and defense at radio conferences

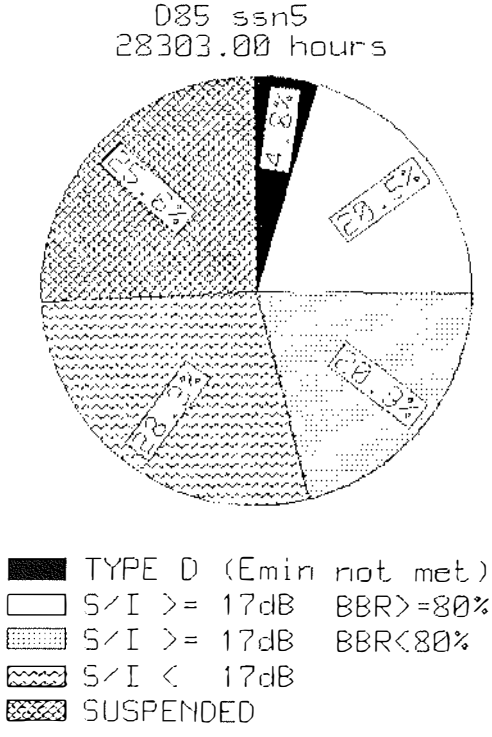
The Institute participated quite actively in the preparation of and defense of U.S. positions at a number of international and regional radio conferences. Institute personnel were key players in all aspects of U.S. activity leading up to and during the Second Session of the High Frequency Broadcasting Conference [WARC-HFBC(87)]. Major efforts by Institute engineers have done much to support preparation for the Second Session of the World Administrative Radio Conference on the Use of the Geostationary Orbit [WARC-ORB(2)]. This includes the development and utilization of computer software that will be used in allotment planning and preparation and presentation of technical papers to support U.S. positions at the Conference. These activities are coordinated within the framework that has been established for preparation for radio conferences, namely, with other offices of NTIA (in particular with the Office of International Affairs) and with other Government agencies such as the Department of State, the FCC, and NASA.

The Institute was the primary office responsible for the development of the technical criteria for the positions put forth by the United States at the Second Session of the High Frequency Broadcasting Conference. Institute personnel developed a planning algorithm that was used by the United States to determine whether or not it could support the results of the planning studies undertaken by the International Frequency Registration Board (IFRB) prior to the start of the Second Session. Using the results of the ITS implementation of its algorithm and comparing them against those obtained by the IFRB, Institute personnel were able to

Project personnel (l. to r.) Jim Washburn, Greg Hand, Mary Sowers, Frank Stewart, Charlie Rush, Jeanne Wakefield, and Les Berry

demonstrate that U.S. broadcasting objectives would be poorly served by adoption of the planning criteria that were implemented by the IFRB. In addition, Institute scientists were able to analyze the results of the IFRB plans in detail and were able to show a number of countries that have major HF broadcasting interests that the planning criteria used by the IFRB would yield results that would cause great harm to their broadcast services if they were to be implemented. An example of the results of the analysis performed by ITS is given on the following page which illustrates the number of broadcasting requirements that would have been satisfied in December of 1985 if the planning criteria used by the IFRB had been adopted. The pie chart shows the number of requirements that were satisfied with an acceptable level of protection, those satisfied with an unacceptable protection level, those not satisfied at all, and those requirements that did not meet the technical criteria that were established for broadcasting operations. This particular chart shows the results for all countries who submitted requirements for analysis. Similar charts for individual countries showed comparable results.

In addition to the technical studies related to planning, the Institute was a primary force in providing data to the IFRB that were used to determine the location of



Broadcasting Requirements Status
for December 1985 IFRB Plan

emitters that jam western broadcasts. These data were observed throughout the world as a result of a large-scale observing program that was coordinated by ITS. A report by the IFRB showing the location of the jammers was a major factor in the policy formation of the United States at the Conference.

The decisions taken at WARC-HFBC(87) will require continued activity on the part of the United States. A third Conference will be held in the 1991-1992 timeframe. The Institute is currently addressing the major technical issues that are likely to be of concern at that Conference.

The IFRB has various responsibilities in preparing for WARC-ORB(2). Among those responsibilities, the Board is to conduct planning exercises that will guide in the development of the Allotment Plan. Very complex computer software is required to perform these planning exercises. The Board decided that software provided by the administrations of the United States and Japan would be integrated and used for these planning exercises. The Institute developed and provided to the IFRB a part of that software, namely, a program that computes the minimum area elliptical beam from a spacecraft antenna to cover a service area that is defined by a set of polygon points. Software provided to the Board by Japan has been installed on an Institute computer and used to examine various scenarios for possible Allotment Plans. This work has identified numerous deficiencies in the software. We have worked with the Japanese, the IFRB, and other interested agencies in the United States to resolve these deficiencies as quickly as possible. Numerous technical papers have been prepared and presented in meetings that are coordinating U.S. preparation for the Conference. One paper concerned with the characteristics of earth station antenna sidelobe characteristics was prepared and submitted to U.S. Study Group 4 of the CCIR; the paper subsequently was approved at the national level and forwarded for consideration at the international meetings of Study Group 4 and the joint meetings of all study groups.

Recent ITS Publications

A High Frequency Spectrum Utilization Model (by Rush, Washburn, and Berry)

Monitoring of Harmful Interference to the HF Broadcasting Service: III. Results of the June 1986 Coordinated Monitoring Period (by Sowers, Hand, and Rush)

The HF Broadcasting Planning Model: A Comparison Of Two Versions (by Washburn, Berry, and Rush)

Domestic Spectrum Analysis

Outputs

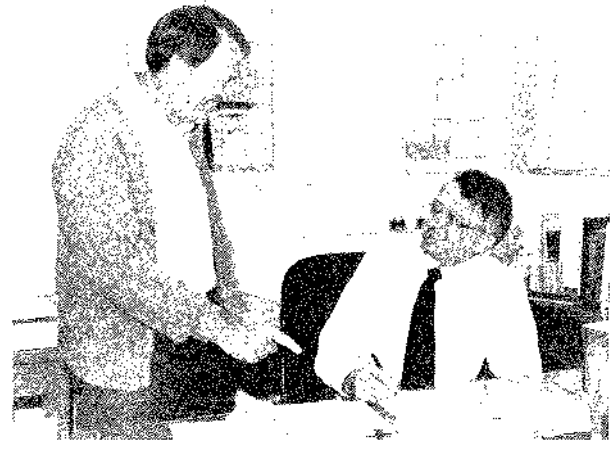
* Report on interference from multiple emitters

The NTIA in its role as manager of the Federal Government's use of the radio frequency spectrum undertakes a number of studies each year dealing with spectrum utilization, potential compatibility problems between systems of various departments and agencies, and congested areas of the spectrum. These studies, called spectrum resource assessments (SRA), provide recommendations for resolving any compatibility conflicts, recommend changes to improve spectrum management procedures, and recommend changes to promote efficient use of the radio spectrum.

One such study accomplished in FY 87 was to investigate the present utilization, areas of congestion, interference problems, and future Government domestic spectrum requirements in the high frequency (HF) bands (3-30 MHz).

Until the introduction of long cables, microwave links, and satellite communications, nearly all long-range services depended upon ionospheric propagation. The use of the HF band is currently growing despite the large expenditures for satellite dependent communication systems. This has come about for a variety of reasons including the sensitivity of military planners to satellite vulnerability and system cost. Federal emergency preparedness to respond to the full range of emergencies (natural, man-made, and nuclear) involves the use of a total telecommunication and data processing resource. Again, the HF spectrum plays a vital roll in this network.

The problem regarding the HF spectrum lies in the fact that both nationally and internationally it has become congested. Interference problems increase yearly to such an extent that certain subbands are regarded as not useful for high-reliability, high-priority communication links.



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

The HF spectrum (3-30 MHz) has more assignments per megahertz than any other portion of the electromagnetic spectrum. There are about 45,000 assignments in the Government Master File (GMF) in the HF band. The private sector also makes much use of these bands, particularly amateurs who use this band more than any other for worldwide communications.

Certain of the Government assignments in the HF band are covered by Limitation Notes or Special Notes as given in ANNEX A (Record Notes) of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management. Three of these notes (L012, S012, and S189) are of interest here. These three notes pertain to use of assignments only in emergencies regarding life, public safety, or property (L012); use by Military Reservists on a periodic basis (S012); and tactical and/or training operation (S189).

About 37.8 percent of the assignments in the HF band show some type of intermittent use. Many are for important emergency uses of the HF band and for military uses for national defense that during peacetime are used mainly for training purposes. From a spectrum use standpoint, the apparent congestion in many of the subbands may not be as serious as perceived from assignment statistics rather than actual use data.

New systems and technologies are having an impact on the use of the high-frequency radio spectrum. To provide for these new systems and to take proper advantage of the new technologies, changes in the frequency management of this band may be required. The issues involved may be divided as follows:

- o General Issues
  - Applicable to All Frequency Bands
  - Special HF System Issues
  - Normal Operations
  - Emergency Considerations
- o Specific Issues
  - Ionospheric Sounders
  - Over-the-Horizon (OTH) Radar
  - Nonlicensed rf Devices
  - Wideband Systems
- o Technological Advances
  - Spread-Spectrum Considerations
  - Digital Systems
  - Networking

The above issues are discussed in detail in the SRA, and 24 conclusions from the study are outlined along with 7 recommendations addressing future usage and spectrum management issues.

In addition to the spectrum resource assessments, the Institute conducts spectrum efficiency studies and develops analytical tools and computer models for spectrum engineering. For example, this year, the FCC proposed changing its Part 15 rules regarding the operation of nonlicensed radio frequency devices. There are many household devices that emit low-level electromagnetic radiation at radio frequencies. The power of one of these devices may be too small to interfere with radio receivers that are realistic distances from the device. However, if there are a great many of these devices in an area (for example, a large urban area) the power from all the devices may add up to significant interference to an aircraft flying over the area. This possibility was analyzed this year as part of NTIA's response to the FCC's proposed rulemaking.

The locations of nonlicensed devices cannot be known, so we assumed that the devices (for example, garage door openers) are randomly distributed over the area of interest, with K emitters per square kilometer. Radio waves (like light beams) are blocked by the curve of the Earth, so we assumed that emitters beyond the line of sight from the aircraft do not contribute to interference to the aircraft's electronics. Finally, we assumed that all emitters have the same power and that transmission loss between the emitters and the aircraft is the same as in free space. Under these assumptions, are some accurate geometrical approximations. A surprisingly simple formula for the mean value of interference to the aircraft, E(p), can be derived. It is

$$E(p) = (D/f^2)KP_E \log_e (2a/h)$$

where

$D=1.8(10^{-3})$,
P_E is the power emitted by the device,
f is the radio frequency in MHz,
K is the number of emitters per km^2,
a is the Earth's radius in km, and
h is the aircraft altitude in km.

The assumption most open to question in the above derivation is that transmission loss is the same as free space. To test the effect of this assumption, the power at the aircraft was computed numerically using computer models previously developed for calculating the statistical distribution of interference in congested environments. We found that the statistical distribution of the interference power had the same form as the one derived, but that its mean value was 4 or 5 dB lower. Thus, the formula gives a safe upper bound for the interference from multiple emitters to an aircraft.

Spectrum Usage Measurements

Outputs

* Spectrum surveys
  - San Diego
  - Los Angeles
  - San Francisco
* Radar emission spectra
* MSR-T4 tests
* Thailand monitoring system
* MOTES-R improvements

NTIA manages Federal Government use of the radio spectrum, a function similar to the FCC's responsibility for the use of radio frequencies for state, private, and commercial purposes. In support of the NTIA frequency management effort, ITS operates the Radio Spectrum Measurement System (RSMS). The RSMS provides

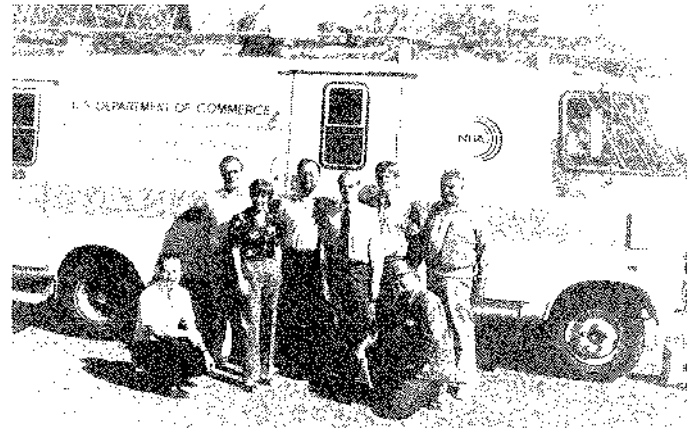
- o Occupancy measurements to show how much of the time a particular frequency is occupied by radio signals

- o Compliance measurements to show whether observed signals are properly authorized and meet applicable technical standards

- o Compatibility measurements to help to show whether several signals will cause interference to each other

The RSMS has been in use since 1973, providing information on real-world use of the radio spectrum. The main function of these measurements is to gather general information that will help form a technical basis for policy decisions in frequency management. Although we occasionally note signals that do not match the Government frequency listings--and we take appropriate action in these instances--the RSMS continues to be used mainly as a research tool for improved spectrum management.

A major upgrading of the RSMS was completed 2 years ago. The RSMS now contains two separate measurement systems in the same vehicle--one optimized for radar measurements and one optimized to measure narrowband voice channels (e.g., land mobile radio or LMR). The radar system makes



Project personnel (l. to r.) Bob Matheson, Vince Lawrence, Don Layton, Frank Sanders, Bob Achatz, Gary Gierhart, and John Smilley

measurements at frequencies up to 18 GHz with bandwidths of up to 30 MHz. Special hardware allows pulse train separation, peak detection, automatic direction finding, pulse blanking, and measurement of radar pulse modulation characteristics.

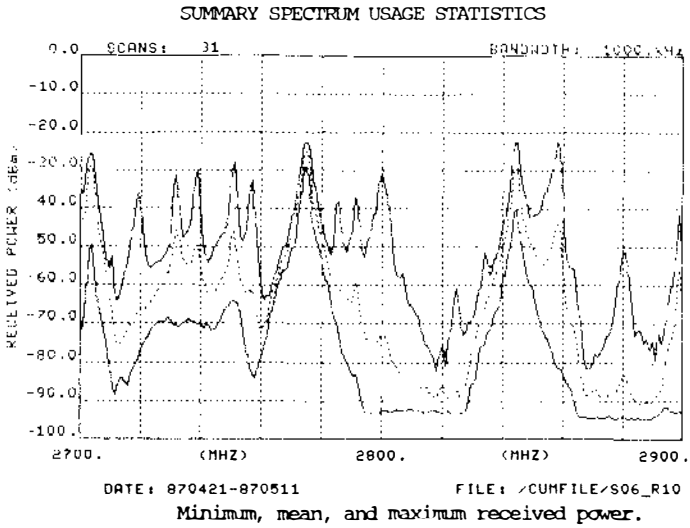
The LMR system operates up to 1 GHz using rectangular bandpass filters with bandwidths in the 3-30 kHz range. The system makes channel occupancy measurements at the rate of 120 channels/second.

Both measurement systems can continuously measure selected frequency bands, giving statistics on signals encountered. About 12 radar bands and 4 LMR bands are usually measured for a 2-week period at each site. These systematic usage measurements are included in a library of spectrum usage statistics in the following figure that show which frequency bands are crowded and which are not.

The RSMS also is used to assist other agencies in resolving interference problems or measuring technical characteristics of radio systems.

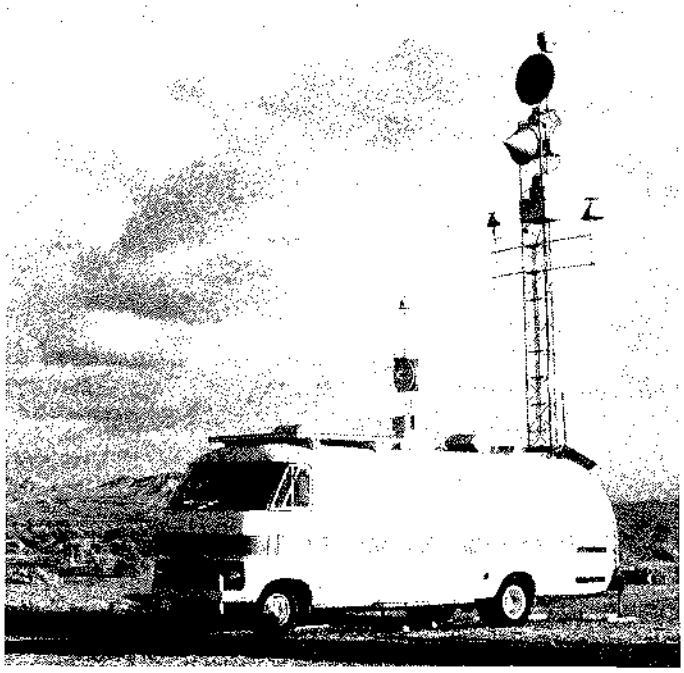
In these cases, the sponsoring agencies provide the funding to support the use of the RSMS. In FY 87 the RSMS measured a National Weather Service weather radar that was suspected of causing interference to a

nearby point-to-point microwave link. The RSMS also made effective radiated power and antenna pattern measurements on a series of Air Force radars associated with the MSR-T4. These radars are used in electronic warfare (EW) training missions.

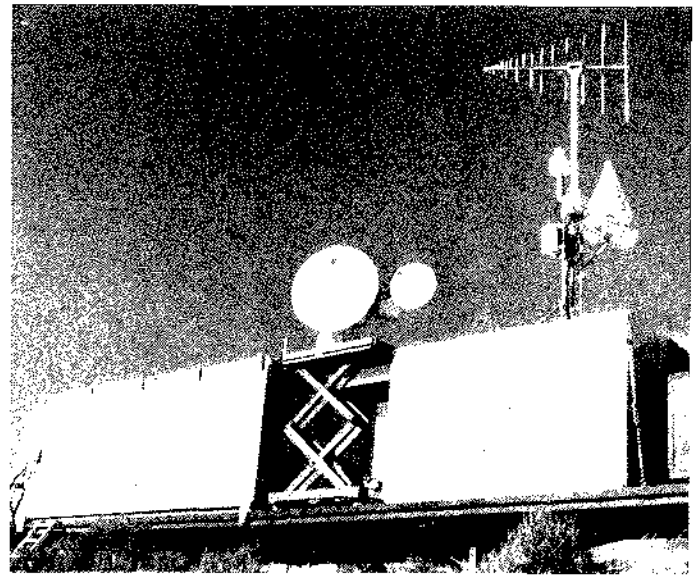


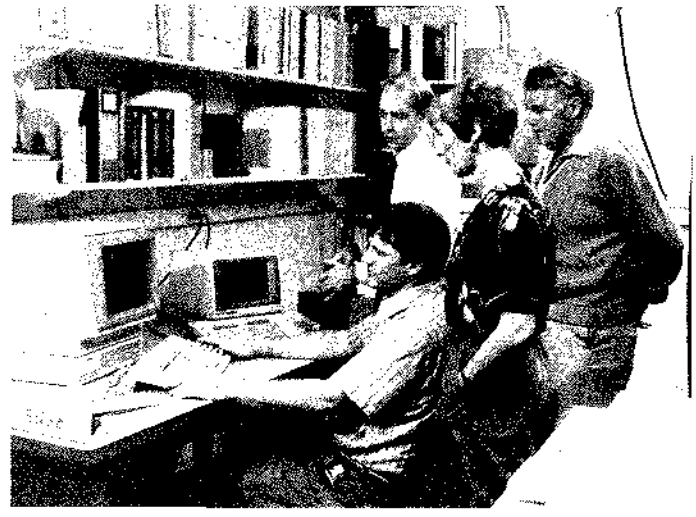
Minimum, mean, and maximum received power.

The experience gained with the RSMS and similar systems has been used to help other organizations to make more effective use of monitoring systems. Personnel from the RSMS operation helped the government of Thailand specify radio monitoring systems used in their frequency management process.


Exterior View of RSMS with Antennas for 150-18,000 MHz Site Survey

We have assisted the Air Force in a substantial modernization of their MOTES-R measurement system, which was originally built by ITS 10 years ago. This system is used to observe various radar and EW systems under operational conditions. By the completion of this project, ITS will have built some new rf system front-end components, improved and maintained major parts of the tracking system, reconfigured the system racks, and installed new computers and software.


MOTES-R Measurement System


Spectrum Use Measurements personnel Bob Achatz (seated) and (l. to r.) Frank Sanders, Jane Russell, and John Smilley.

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

TASERVICES is an acronym for Telecommunications Analysis Services. It is composed of a dynamic set of computer models and data bases that are accessed by both industry and government customers in the United States. The purposes of TASERVICE are to make available the latest technical and informational advances of the Institute in the shortest time possible and to give support to U.S. industries in competing internationally.

The service is available on a computer in Boulder, CO, and interfaces with the users via ASCII terminals or personal computers. The interface is very friendly and supportive of the user through a menu approach to all of the models. After completing the telephone connection and providing unique log-on information, the user chooses a model that is designed to solve specific problems and/or give the desired information from the data bases. The user can choose to interact with the model in a verbose, concise or edit mode. The verbose mode gives the user an explanation of the input quantity requested along with the range of values that would be reasonable for the input. In the concise mode, the user is keyed with just one or two words for the required input quantity. A third mode is the edit mode in which the user inputs the line item of the quantity to be changed, and changes only that one quantity. The programs are designed with a tree structure so that only quantities that

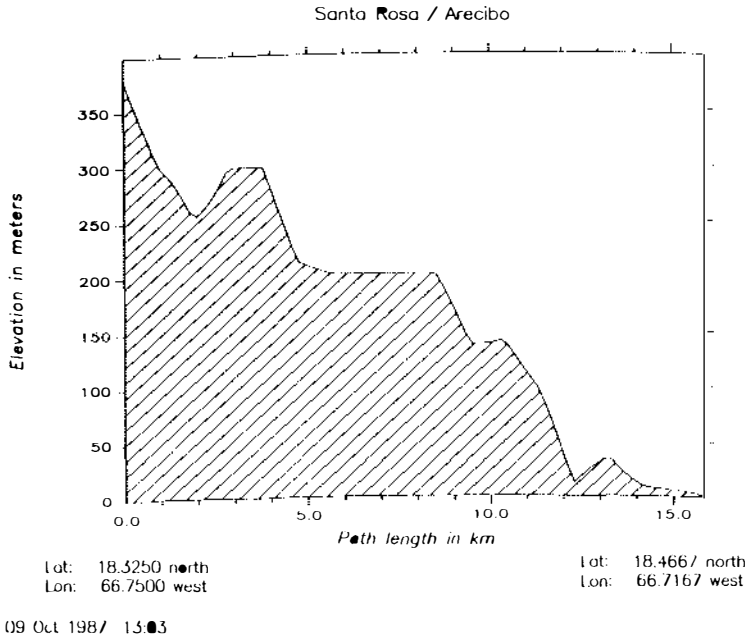
Project personnel (standing l. to r.) Jean Adams, Susan Rothschild, Greg Hand, Laura Senter, Eldon Haakinson, and (seated) Yeh Lo, Mary Luyk, and Renee Gurule

are required for the users problem need to be entered. The models also have default values for each question that is a reasonable value in case the user has limited knowledge of some of the quantities.

After the user has entered a quantity in response to some question, the new quantity becomes the default value. This approach makes it very easy for the user to examine the effects of varying a single input quantity such as antenna height on the output quantity such as signal level when all other parameters are held constant.

All the user needs to do after the initial run of the model is go into the edit mode, change the single quantity, and process the data again.

An example of one of the models is called PROFILE. This model accesses an ITS data base of topographic data and processes it in a number of ways for the user. It is easy to look at the elevations of terrain between any two points in the United States and to have plots made that correct for varying refractive atmospheres. The figure following shows a profile of elevation values between the city of Arecibo, PR, and a relay on a mountain top. This profile could be used in the design of microwave links or for determining radio line of sight for other types of radar or radio



systems. Another option in PROFILE lets the user calculate the average terrain height on a selected radial around a particular location.

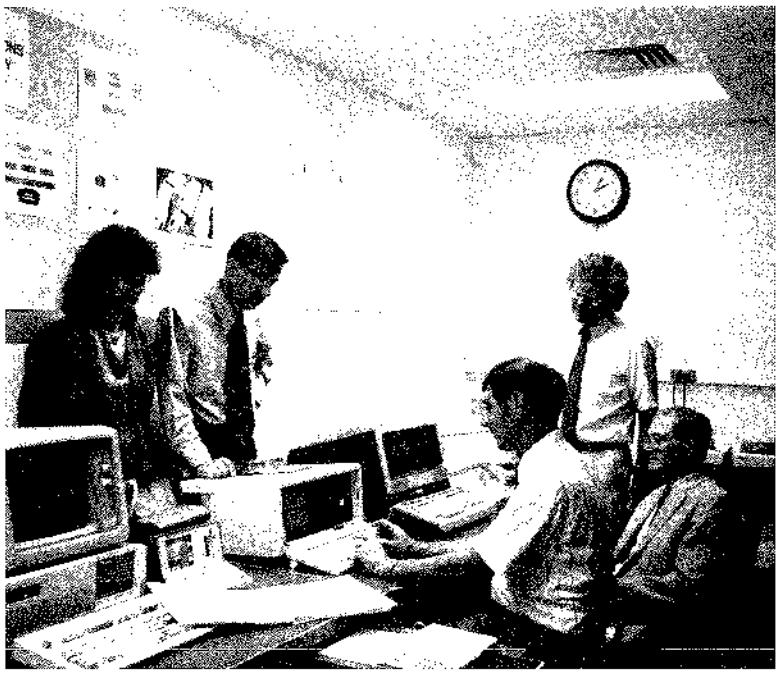
The user can select the radial using the incremental bearing option so that PROFILE automatically determines end points of the radial from a reference site on user-selected bearings and distances. The output of this option is reproduced below to show where the terrain is averaged over distances from 2 to 10 miles and on radial spaced 45 degrees around a transmitter site in Honolulu, HI. The user's guide to TASERVICES is available and describes the other 14 models currently on the system as well as the administrative and technical details of operation.

PROFILE
Heights Above Average Terrain and Average Elevations
Tue 13 Oct 1987 09:22

From: Honolulu HI No. 1 21,18,48 N 158, 2, 6 W
21.3133 N 158.0350 W
Antenna Center of Radiation above Ground = 200.0 ft
61.0 m
Antenna Base Height above Mean Sea Level = 13.0 ft
4.0 m

To:	Avg Elev from 2 to 10 mi (ft)	Antenna Height above Avg Terrain 2 to 10 mi (ft)	No. of Elev Points Avg'd 2 to 10 mi
0.000 DEG AZ	294.5	-81.5	81
45.000 DEG AZ	133.6	79.4	81
90.000 DEG AZ	-.0	213.0	81
135.000 DEG AZ	0.0	213.0	81
180.000 DEG AZ	0.0	213.0	81
225.000 DEG AZ	-.0	213.0	81
270.000 DEG AZ	6.7	206.3	81
315.000 DEG AZ	746.3	-533.3	81
21.4157 158.1450			

For bearings from 0.0 to 315.0 degs,spaced every 45.0 degs,
the average terrain height from 2 to 10 mi is 147.6 ft.



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 Oceanic and Atmospheric Administration, the National Telecommunications and Information Administration, and the U.S. Navy

Voice Quality Standards Development

Includes projects funded by the Defense Communications Agency

Development, Revision, and Assessment of Standards

Includes projects funded by 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 the two consultative committees of the International Telecommunication Union (ITU). The International Telegraph and Telephone Consultative Committee (CCITT) is the other consultative committee. Both of these committees are permanent organs of the ITU.

All the member countries of the ITU as well as certain private organizations can participate in the work of the CCIR. This work provides the basis for decisions leading to efficient use of the spectrum for telecommunication applications. The reports and recommendations of the CCIR are used at radio conferences to establish technical criteria that can form the basis for spectrum allocation decisions and spectrum use on a global and regional scale. The material contained within the documentation of the CCIR must be consistent with U.S. positions at these conferences if the United States is to be successful in defending its positions on purely technical grounds.

The CCIR is organized into Study Groups, each Study Group addressing a specific area of radio system technology. There are 13 Study Groups in the CCIR ranging from such applied areas as fixed satellite service (Study Group 4) and mobile service operations (Study Group 8) to more scientifically oriented work of Study Group 5 and Study Group 6 dealing with propagation in nonionized and ionized media, respectively. A listing of the CCIR Study Groups is given in the following table.

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

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

The CCIR cycle of activity results in approved modifications to its texts about every 4 years. These modifications are approved at the Plenary Assembly of the CCIR. In preparation for the Plenary Assembly, the CCIR meets at an Interim Meeting followed by a Final Meeting roughly in 2-year intervals. At times, the work the CCIR must undertake is of such a pressing nature that it cannot be delayed. In this instance, the CCIR creates an Interim Working Party (IWP) to address the issue and generate a report or other

document that is forwarded for approval either by correspondence or at the next meeting of the Study Group under whose auspices the Interim Working Party falls.

Within the United States, the organization of work in support of CCIR activities is under the purview of the Department of State (DOS). A National Committee chaired by DOS personnel oversees the U.S. contributions to the CCIR. Because of its preeminent position in the field of telecommunication research and development, members of the Institute participate very actively in the work of the CCIR at the national and international levels. An Institute member serves as the International Vice Chairman of Study Group 3. Institute members serve as U.S. chairpersons of Study Group 1 and Study Group 6. Other Institute personnel play prominent roles in Study Groups 1, 5, and 6. These efforts address issues related to spectrum efficiency and use, modification of the texts of Study Groups 5 and 6, and development of methods to improve on the global representation of atmospheric radio noise and ionospheric parameters.

Efforts at ITS that are directed to U.S. CCIR concerns in the past year have emphasized preparation for the upcoming Interim Meetings. In Study Group 1, Institute engineers have prepared an input document for the Spectrum Management Handbook for IWP 1/2 and have coauthored a proposed new report on interference to aircraft from multiple ground-based emitters. In addition, they have analyzed a Russian conference paper that is a potential input document and prepared a proposed U.S. position on that document.

Institute activities related to Study Group 3 have been directed at establishing the criteria for sharing the expanded AM broadcast band 1605-1705 kHz between the broadcast service and other services in preparation for the Second Session of the Region 2 Conference on broadcasting in the band 1605-1705 kHZ. In addition, because of the international leadership role held by a member of the Institute in Study Group 3 (Vice Chairman), efforts have been expended in preparing the schedule of work at the Interim Meeting of Study Group 3.

In the area of support to Study Group 5, the Institute has concentrated its efforts on the improvement of the CCIR report dealing with millimeter-wave propagation. Institute scientists and engineers have made substantial advances in understanding the propagation effects associated with millimeter-wave transmission. The results of these studies are of importance to the world community, particularly as applied to spectrum extension above 20 GHz. Also, Institute personnel have reviewed most of the documents attributed to Study Group 5 to assure their currency and consistency with U.S. positions related to the Second Session of the Conference dealing with the allocation of the geostationary orbit.

The activity undertaken by Institute personnel to support Study Group 6 work has been derived primarily to assure sound technical bases for U.S. high-frequency broadcasting interests as well as reviewing and updating the texts of Study Group 6 where appropriate. As a result of the decisions taken at the Second Session of the High Frequency Broadcasting Conference, an Interim Working Party has been formed by the CCIR to address the need to obtain more data to verify the propagation prediction method that forms the basis for frequency assignment and interference assessment.

Institute personnel were major contributors to the success of the U.S. interests at the Second Session of the High Frequency Broadcasting Conference and are participating in the work of the new Interim Working Party to assure that U.S. positions are well served. In another area related to Study Group 6 activity, engineers at ITS have undertaken the revision of two major texts in Study Group 6 dealing with ionospheric properties and propagation effects due to the structure of the high latitude ionosphere. These documents are of fundamental importance to Study Group 6, and their usefulness depends critically on assuring that the latest concepts and ideas are incorporated into the texts.

CCITT Activities

Outputs

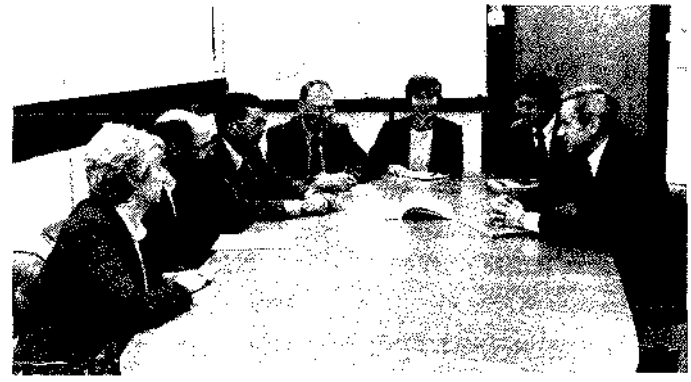
- U.S. contributions to CCITT on Integrated Services Digital Network (ISDN) standards
- CCITT recommendations on packet-switched service performance
- Leadership of U.S. participation in key CCITT study groups

The Institute contributes directly to the planning, development, and coordination of international standards within the CCITT. This work includes both technical studies and leadership activities. It has strongly impacted CCITT recommendations on both ISDNs and packet-switched public data networks.

Technical studies include defining performance parameters, developing statistical measures of these parameters, and conducting measurements on real networks to demonstrate data extraction, reduction, and analysis techniques. Leadership activities include heading delegations to CCITT meetings, chairing United States preparatory groups, and providing international work leaders (Rapporteurs) for particular Study Groups. The ITS standards products are presented in technical contributions to U.S. CCITT Study Groups and related U.S. telecommunication standards committees (such as T1D1, T1Q1, and T1Y1).

The Institute strongly supports the U.S. Department of State in leadership of the U.S. organization for the CCITT. During FY 87, ITS personnel chaired the Joint Working Party (JWP) on ISDN, which provides U.S. contributions on ISDN issues to CCITT Study Groups XI (Telephone Switching and Signalling) and XVIII (Digital Networks). Institute staff members organized and chaired six U.S. CCITT preparatory meetings, served on the U.S. CCITT National Committee, and headed the U.S. Delegations to two major CCITT meetings during FY 87.

Institute staff members lead and contribute directly to CCITT standardization in areas of particular significance to Commerce



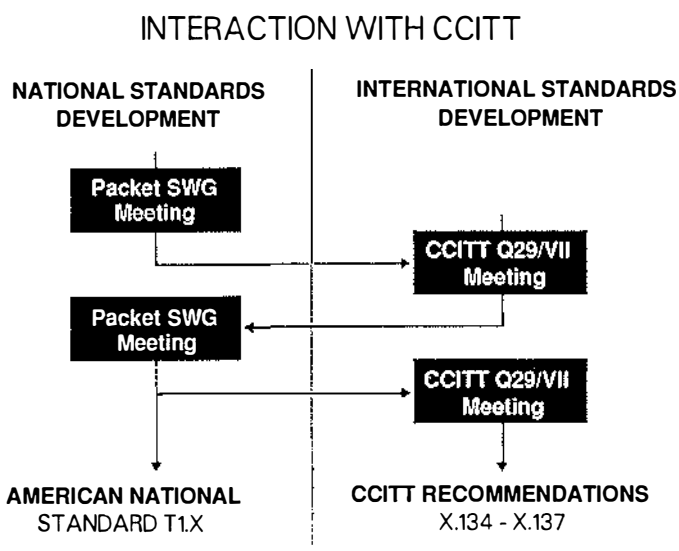
Project personnel (l. to r.) Lorna Kent, Bob Kubichek, Ed Quincy, Bill Utlaut, Marcie Geissinger, Randy Bloomfield, and Neal Seitz

trade objectives. Staff members chair and support the work of Committee T1's ISDN Technical Subcommittee (T1D1), which has coordination responsibility for the development of all standards affecting the implementation of ISDN.

The T1D1 Subcommittee also provides a forum for the preparation and coordination of U.S. inputs to international CCITT meetings. T1D1 outputs destined for CCITT feed directly into the U.S. CCITT JWP. During its six Plenary Sessions in FY 87, T1D1 logged 346 documents and forwarded 164 documents to the JWP as U.S. contributions to CCITT, mainly for Study Groups XI and XVIII.

Institute personnel have succeeded in coupling U.S. efforts to develop packet-switched service performance standards (under the T1Q1.3 Digital Packet Sub-Working Group) with similar international standards efforts (under the CCITT Special Rapporteurs Group on Question 29/VII). That coupling has improved the pace of work in both groups, and should improve compatibility between U.S. and related international standards.

The packet standards were developed in three basic steps. The first step was to establish a reference model to use as the basis for parameter definition. The model

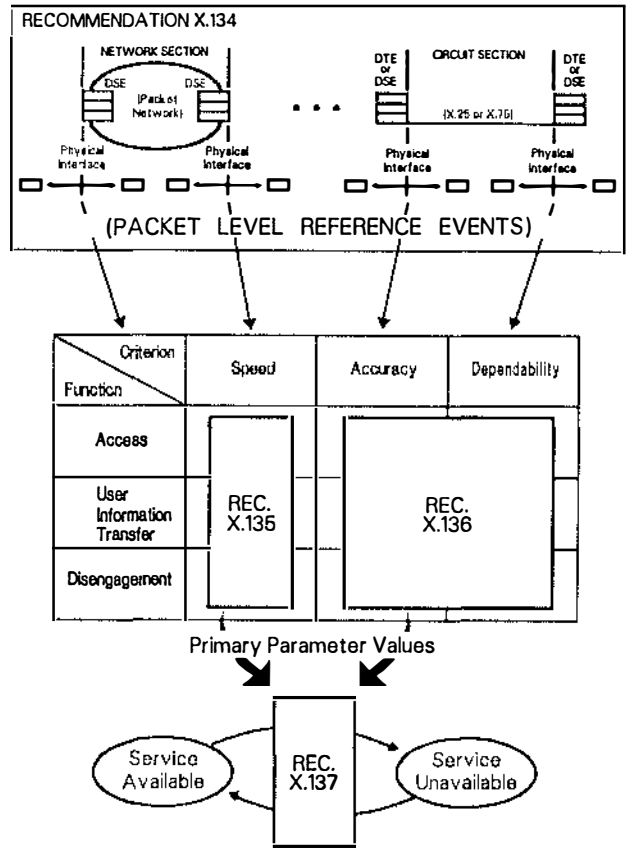


involves two types of elements: a packet network, which is delimited on each side by a three-layer protocol stack; and the physical link that interconnects two network protocol stacks.

The second step was to define specific performance parameters based on the reference events. The communication process is characterized in terms of three primary functions: access, user information transfer, and disengagement. Each function is considered with respect to three general outcomes that can be observed on any individual performance of a function: successful performance, incorrect performance, and nonperformance. These three outcomes correspond to three general performance concerns (or "criteria") that are frequently expressed by users: speed, accuracy, and dependability.

The third step was to develop a way of expressing availability. Institute contributions suggested that the packet standards focus on the availability of the service provided at the section boundaries, rather than the availability of particular transmission or switching facilities within a section. This approach maximizes provider design options.

The figure to the right shows the structure of the packet-switched service performance Recommendations developed in cooperation with the Question 29 group. The performance model is defined in Recommendation



X.134; the speed of service parameters (and values) is defined in Recommendation X.135; the accuracy and dependability parameters (and values) are defined in Recommendation X.136; and the service availability parameters (and values) are defined in Recommendation X.137. These four Recommendations are expected to be approved for publication at the CCITT Plenary Assembly in 1988.

Contribution to Standards Committees

Error Probabilities for Embedded Channels (by Vogler and Seitz)

Revised Drafts of CCITT Recommendations X.134-X.137 (by Seitz)

Revised Draft Recommendation X.135-Annex C: Representative End-to-End Speed of Service Performance Objectives (by Bloomfield and Seitz)

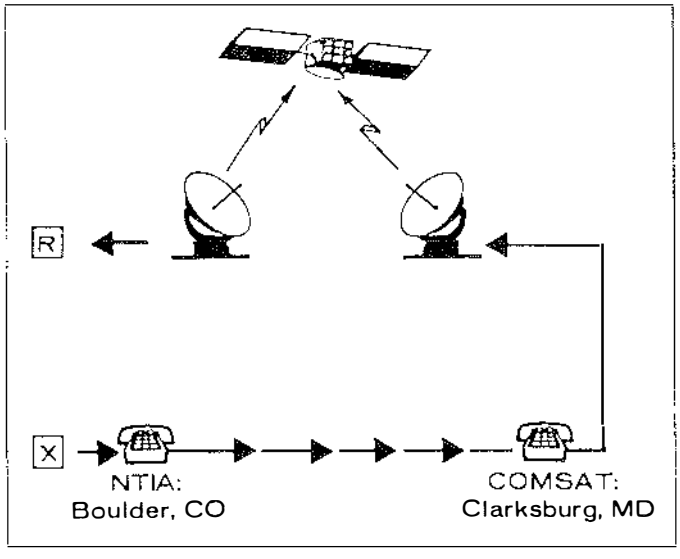
Revised Draft Recommendation X.135-Annex D: Methods for Calculating Mean Delays and Throughputs of Packet-Switched Services (by Crow)

Data Communication Standards Development

Outputs

* Promulgation of data standards
* Implementation and demonstrations of data standards
* Publications describing applications
* Transfer software to industry

The telecommunications industry is currently undergoing rapid transition. Deregulation, AT&T divestiture, and the ensuing competitive environment have hastened the introduction of new products and services. Although many benefits have occurred, so too have new issues arisen. One result of the competitive, multivendor environment is an increased emphasis on telecommunication standards: standards to assure interoperability, to assess performance, and to permit new services to be compatible. The Government's role in this standards-making process is an important one. Federal contributors are uniquely capable of providing two essential ingredients to standards-making bodies: impartiality and a global view. The Institute continues to support industry engaged in creating standard means of specifying and measuring the performance of data communication systems. Three projects where the current effort is focused are described below.



Project personnel (l. to r.) Ed Quincy, Ken Spies, Dave Wortendyke, Ned Crow, Marty Miles, Bill Grant, Dan Tomich, and Kathy Edgar

Standards Development and Demonstration Measurement. Institute personnel continue to participate in Working Group T1Q1.3, a component of the ANSI-accredited T1 committee. A major report that describes the Institute's multiyear effort conducted in cooperation with industry to specify, measure, and assess the performance of data communication services will be published late in 1987. The report describes a series of tests conducted by the Institute to demonstrate the implementation of measurement methods and to characterize the performance of data communication services in accordance with parameters defined in American National Standard X3.102, Data communication Systems and Services--User-Oriented Performance Parameters. Other reports will describe the software used to implement American National Standard X3.141, Data Communication Systems and Services--Measurement Methods.

Measurements of access time, block transfer time, throughput, and disengagement time were also made over an SBS-3 satellite link. One experimental setup is shown in the adjacent figure. With this configuration, the round trip performance parameters were measured over a terrestrial telephone link with the satellite link as the return path. The objective of this experiment was to obtain real-world data for use in CCITT

Recommendation X.135, which related to speed of service for public data networks providing international services.

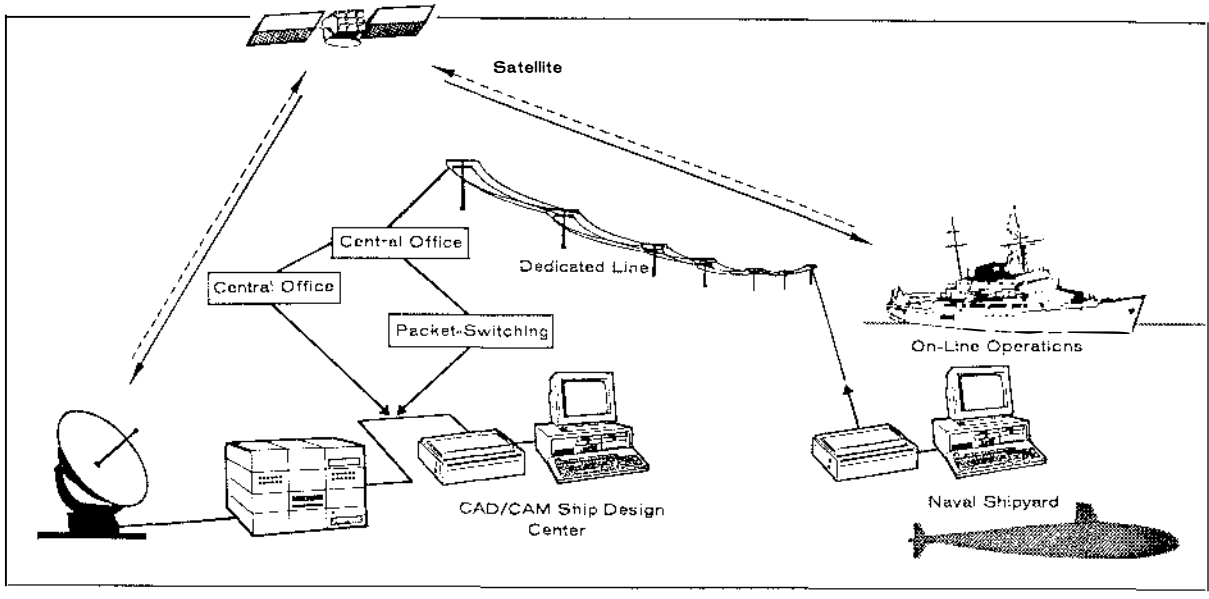
Navy CAD/CAM Systems Support. The U.S. Navy is modernizing their Computer-Aided-Design, Computer-Aided-Manufacturing (CAD/CAM) capability to incorporate the next generation of state-of-the-art CAD/CAM technology. Significant telecommunication capabilities will be required to support this transition to a computer-based technical information system. The Navy therefore has contracted with ITS to help them identify and define their data communications and networking needs. The overall concept is illustrated in the figure below.

During FY 1987, ITS provided consultation to the Navy regarding CAD/CAM "Functional Area Network" performance specification based on the X3.102 and X3.141 ANSI Standards. ITS also began surveying sites involved in Navy CAD/CAM procurement to assess user requirements for long-haul CAD/CAM telecommunications. Leading areas of ITS expertise, namely, data communication performance, ISDN development, and planning associated with intergateway networks, will directly support the Navy mission of horizontal integration of CAD/CAM systems within the Navy.

Data Communications for Wind Profiler. The National Oceanic and Atmospheric Administration's Environmental Research Laboratories (NOAA/ERL) have demonstrated the feasibility of measuring wind profiles from the Earth's surface up into the stratosphere using a Doppler radar system called the wind profiler. NOAA is deploying a network of 31 wind profilers in 17 states throughout the Midwest. These remote wind profilers will be connected via data communication links to a data processing center (HUB) located at Boulder.

Each profiler has three antenna beams; one beam points in the vertical direction and the other two point toward the north and east at angles of approximately 15 degrees from vertical. The profiler collects returned transmitted radar signals scattered by the atmosphere, performs real-time signal processing, and transmits its data to the HUB. This cycle requires 6 minutes to complete so there are 10 data messages per hour from each profiler.

Because of the system performance standards work at ITS, NOAA has contracted the group to help them procure data communication services. This involves conducting a preliminary analysis of the data communication requirements, specifying performance parameters, and writing system specifications for the statement of work. ITS will also assist NOAA in the technical evaluation of the proposals and in defining and conducting the acceptance tests for each communication link.



Voice Quality Standards Development

Outputs

* Contributions to standards committees
* Pattern recognition software
* Expert system development

The Institute is developing a methodology for objective measurement of voice quality based on statistical pattern recognition (PR) and expert systems techniques. This computer-based system will allow users to obtain reliable, repeatable, and cost effective measures of voice transmission system performance.

Objective measures of voice transmission quality are urgently needed by increasing numbers of potential end-users. For instance, providers and procurers of communication systems require voice quality measures to gauge the performance of new systems. Also, telecommunication standards organizations need impartial methods for comparing coding algorithms and transmission schemes. Benefits of the new ITS system include increased competition among providers as well as better capability of procurers and standards organizations to evaluate new systems.

Traditional techniques for estimating voice quality are based on analog measures such as loss, noise, and talker echo. These are not applicable to many new types of distortions found, for example, in modern digital transmission systems. In such cases, human listeners are required to subjectively evaluate distortion effects on voice quality. Unfortunately, this approach is time consuming and expensive, and results can vary radically.

The ITS computer-based approach uses statistical techniques to remove this unwanted human variability from the quality estimate. Pattern recognition is used to classify speech into five levels of quality (ranging from 1 = unacceptable to 5 = excellent) with minimum probability of error. Quality estimates are based on "speech parameters" that are measured directly from the voice signal. Possible

Project personnel (l. to r.) Dan Tomich, Bob Kubichek, and Ed Quincy

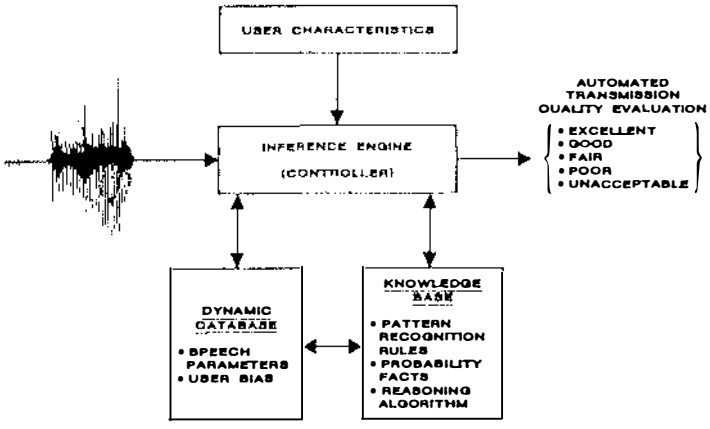
parameters include linear predictive coding (LPC) coefficients, cepstral coefficients, and other measures related to voice quality.

Figures at far right illustrate part of this process. The top three figures represent the estimated probability of a given quality class for two voice parameters labeled "feature 1" and "feature 2." Probability functions for three classes of voice quality are shown: good or excellent, fair, and poor or unacceptable. The "Bayes" strategy for choosing the most likely quality class is simply to select the class having the highest probability.

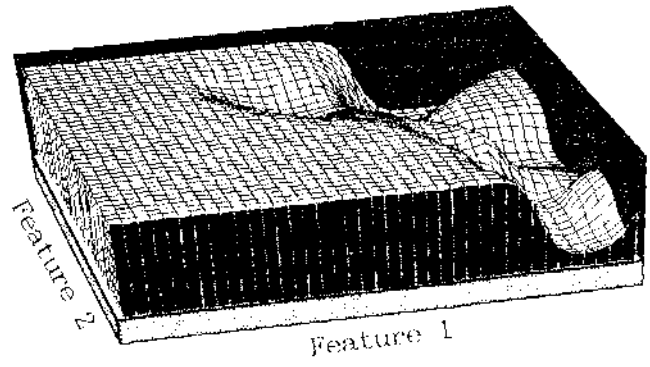
The bottom figure is a map showing regions of highest probability and the corresponding quality class. Maps such as this may easily be used to estimate the quality of transmitted voice. Values of feature 1 and feature 2 are measured from the speech signal. The map location defined by these two values directly determines the most likely class of voice quality.

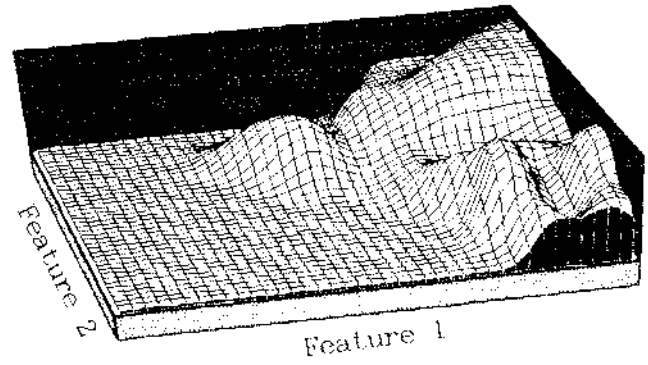
Unfortunately, these PR results cannot be employed directly. Ideally, the channel should be tested using speakers of different sexes and ages, resulting in separate quality estimates for each speaker. An expert system can combine these multiple measures of voice quality using both

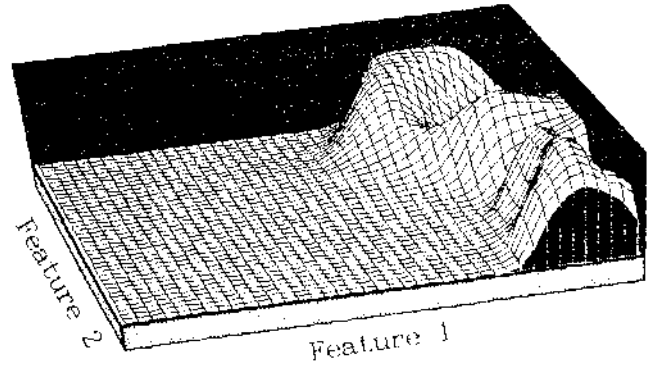
heuristic and statistical rules. The expert system also incorporates rules about perception. Adjustments can be made for user biases such as listener hearing impairment, age and nationality. A high-level diagram of the complete system is shown below.

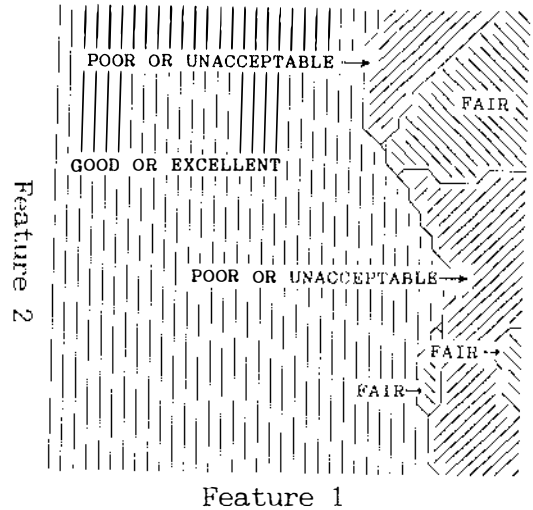


Voice Quality Expert System Structure









Publications and Standards Contributions

Bayes Techniques for Objective Evaluation of Voice Transmission Quality (by Kubichek and Quincy)

Parameter Measurement, Evaluation and Selection for Determining Voice Transmission Quality Using an Expert Pattern Recognition System (by Kubichek and Quincy)

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

Selection of Objective Voice Quality Parameters for an Expert Pattern Recognition System (by Kubichek and Quincy)

Standard Project Proposal: Technology-Independent, User-Oriented, Objective Classification of Voice Transmission Quality (by Quincy and Kubichek)

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

Development, Revision, and Assessment of Standards

Outputs

* Coordinated detail specification for a single-size, multimode fiber to become an ANSI/EIA standard for building and campus communications applications
* Significant draft Glossary of Terms, relating to Telecommunication Architectures for Building and Campus applications, to be adopted by the Canadian Standards Association and the Electronic Industries Association (EIA) in the United States
* Reviewed status of pFS 1045, organized a subcommittee, and made recommendations regarding the development of a new pFS 1045 (Automatic Link Establishment) High Frequency Communications Standard

During FY 1987, Proposed Federal Standard (pFS) 1070, Standard Optical Fiber Waveguide Material Classes and Optional Sizes, was modified to recommend only one multimode fiber size. This work began with the objective of recommending a Federal Standard to be mandatory for all Federal agencies. This standard would prevent a proliferation of incompatible fiber optic installations in Federal buildings and would promote transportability of user terminals within or among such buildings.

During a technical review of the new draft pFS 1070, it was suggested that ITS develop a proposed industry standard for fiber optic cables based on the EIA 492-series specifications (Generic, Sectional, and Blank Detail Specifications). The EIA 492-series specifications provide a set of parameters and measurement methods that are consistent with International Quality Control Standards recommended by the International Electrotechnical Commission (IEC). These specifications recommend that special attention be paid to tolerances, quality assurance, and performance verification. Using information obtained from fiber manufacturers, ITS prepared a draft Detail Specification for the 62.5/125-μm

Project personnel (l. to r.) Bill Kissick, Bill Ingram, Joe Hull, Tom Jones, Evie Gray, and Glenn Hanson

Core/Cladding diameter multimode fiber. This optical fiber Detail Specification is the first to be developed within the EIA. It will be adopted, by reference, in the new pFS 1070.

Cables containing fiber optic waveguides that meet this Detail Specification will be used for on-premises applications such as Government and commercial office buildings and campus complexes. The EIA plans to recommend such cable usage in the backbone elements of the wiring architecture shown in the accompanying figure.

This work illustrates a methodology whereby the Government works closely with industry to obtain the best technical specification of an emerging product. The Institute held detailed technical discussions with each of five fiber manufacturers and obtained consensus on the technical characteristics to be identified in the Detail Specification. The resultant specification has now undergone coordination with 88 representatives participating in various standards committees of the EIA. Both Government and industry benefit from this cooperation.

The above work grew out of the deliberations of a Fiber Optics Task Group, a subcommittee of the Federal Telecommunications

Standards Committee. The summary records of the meetings of this Task Group and a technical report defining the basis for recommending the proposed Federal Standard are contained in two ITS reports.

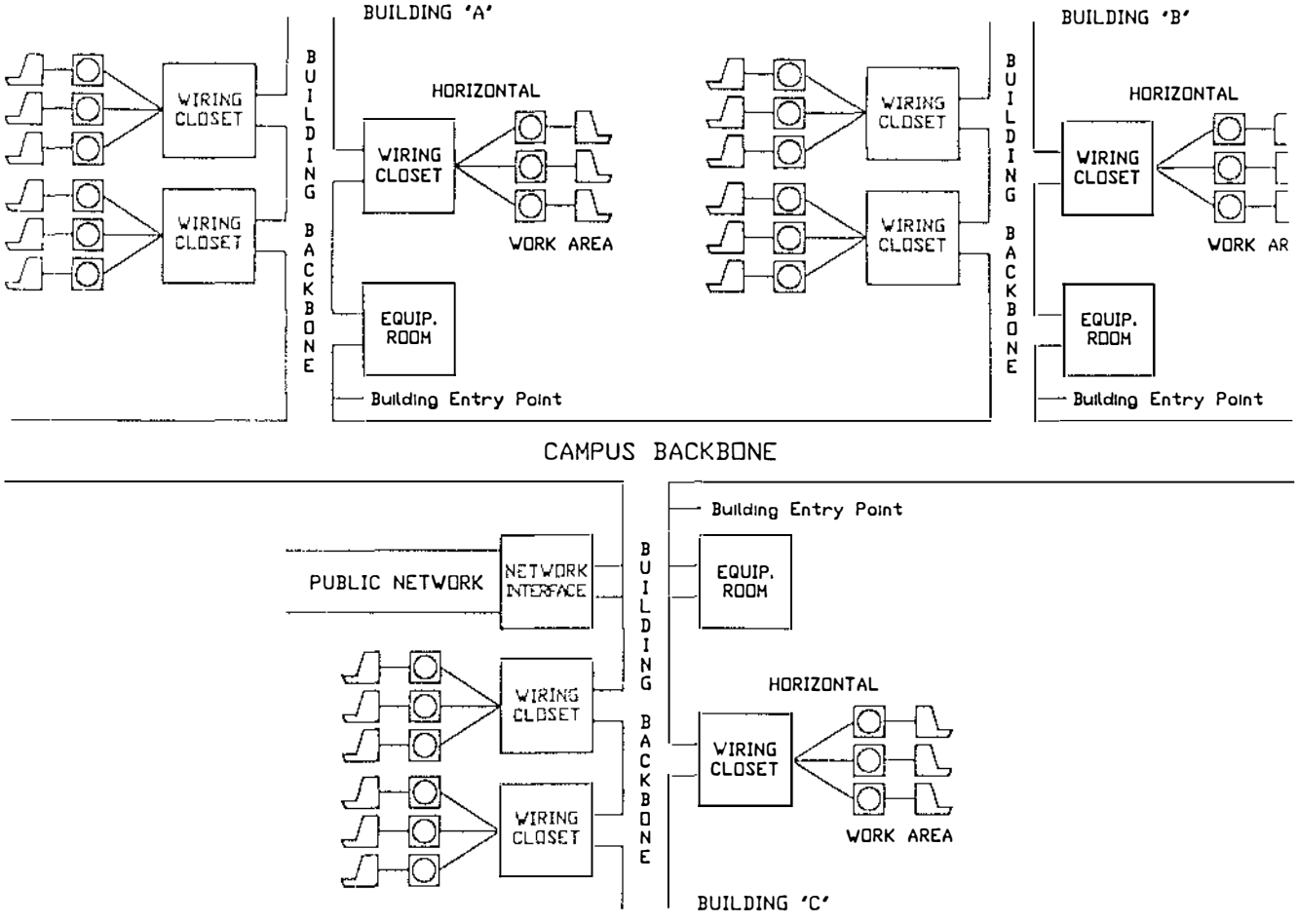
Another notable activity that grew out of the FED-STD-1037A Glossary of Telecommunication Terms, mentioned in last year's report, is a new Glossary of Terms for Building Telecommunication Architecture in the EIA TR 41.8.3. This will be adopted by both the EIA and the Canadian Standards Association (CSA). This effort is cochaired by ITS and a representative from CSA. The document preparation and editorial work is being done by ITS.

Recent ITS Publications

A Summary Record of Presentations to the Federal Telecommunication Standards Committee/Fiber Optics Task Group (by Hanson)

On-Premises Digital Communications Upgrades With Emphasis on Fiber Optics (by Hull and Hanson)

Reference Manual for Packet Mode Standards (by Glen)



National Telecommunications and Information Administration

Helping America Grow Through Telecommunications and Information

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

AM Stereo Receiver Performance

Includes projects funded by the National Telecommunications and Information Administration

MF Systems Assessment

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

HF System Assessment

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

Test Methodology and System Performance

Includes projects funded by the Naitonal Bureau of Standards

Transmission System Performance Measurement, Monitoring, Evaluation, and Control

Includes projects funded by the Air Force Electronic Systems Division, the Defense Communications Agency

Microwave Communications Link Testing

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

Transmission System Modeling

Includes projects funded by the Army Information Systems Engineering Integration Center, the Army Information Systems Engineering Support Activity, and the Department of Defense

AM Stereo Receiver Performance

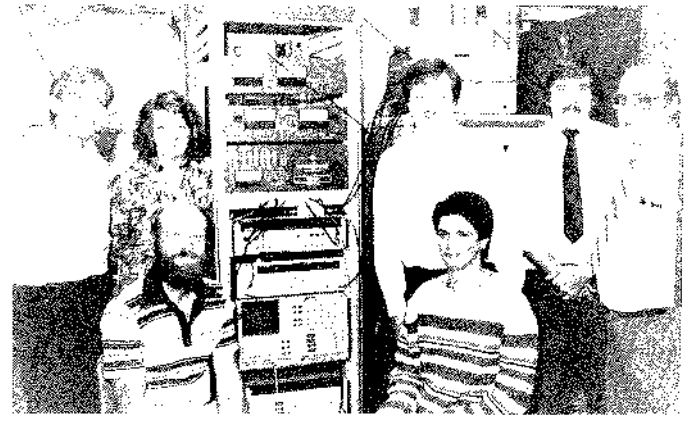
Outputs

* Improved AM broadcasting band usage
* Advancement of AM stereo
* Improved AM broadcasting signal and interference prediction methods

According to a recent NTIA report, the AM broadcast industry has operated under a handicap due to the lack of a firm decision by both the FCC and the marketplace in selecting a standard for AM stereo broadcasts. In the NTIA report it was suggested that the use of automated AM receivers that could decode any of the most popular forms of AM stereo broadcasts might be a means to help the industry become more competitive to the other forms of broadcasts. In this regard, ITS was assigned the problem of determining the technical feasibility of automatic multiple system decoders.

One way to demonstrate the feasibility of these decoders was to compare the performance of receivers that operated with multiple-system stereo decoders to receivers that operated with single-system decoders. The premise was that if a receiver could be found that had comparable performance to one of the best performing single-system decoder receivers, then at a minimum, we could conclude that automatic, multiple, stereo system decoders are technically feasible.

We began by reviewing the existing operating rules and conditions of the AM broadcasts and then designing a series of tests we could make on AM stereo receivers. These tests had to measure the performance of the receivers under all of the expected operating conditions and for conditions that would tend to stress the automated decoding features of the receivers. We decided that we would use distortion as a primary measure of receiver performance, and we also included tests of receiver sensitivity and receiver interference rejection as additional tests. We also decided to measure the presence of the stereo indicator during the tests. The stereo indicator would tell us if the receiver



Project personnel (standing l. to r.) Eldon Haakinson, Mary Luyk, Brent Bedford, Val O'Day, Jean Adams, and (seated l. to r.) Greg Hand and Bill Riddle

was in stereo mode, and hence, determine if it was in a wideband mode or perhaps giving a false indication of stereo.

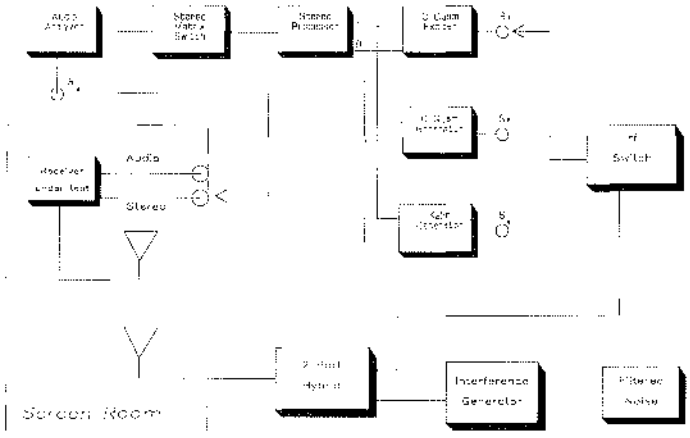
In actual operating conditions, the stereo receiver would be expected to operate with interference from cochannel transmitters at 26 dB below the desired signal at the fringe of the desired signal and interference from adjacent channels at 0 dB relative to the desired signal. We, therefore, planned the testing to include tests for conditions as shown in the test matrix below and for the following additional conditions:

modulation levels of 30%, 90%, and 125%
rf signal levels of 10 mv/m, 0.5 mv/m, and 0.1 mv/m
audio stereo matrix of left only, right only, left = right, and left = - right

This combination of conditions should test the extremes of operation expected over all combinations of signals that could stress the audio decoders.

We set up an AM stereo broadcast system in the laboratory that would generate the necessary stereo signals and allow a controlled repeatable environment for the receiver testing. The entire tests were then automated using the IEEE-488 bus controlled instrumentation. We used a

laboratory signal generator modulated with shaped noise for an interfering signal. The block diagram of the measurement system is illustrated below. The audio analyzer generated audio tones used to modulate the test signal sources whose rf output was connected either to a standard loop or directly to the receivers under test through dummy antenna networks as appropriate. The audio output and stereo indicator voltage from the receivers was then returned to the audio analyzer which made the distortion, signal-to-noise ratio, and stereo indicator measurements.



We measured the performance of eight receivers that used both single-system AM stereo decoders and multiple-system AM stereo decoders over all of the input and output parameters described above.

We then analyzed the performance data by first calculating the differences in measured distortion between single-system decoder receivers and those measured for multiple-system decoder receivers for the same identical input parameters. This generated a distribution of differences in distortion that gave key statistical inferences to the relative performances between receivers.

An example showing the decile values for the differences between receiver nos. 7 and 8 is shown below. As a result of these tests, we concluded that multiple-system stereo decoders are technically feasible.

Receiver No. 7 minus Receiver No. 8
for individual interference conditions

	Distortion (%)				Signal/Noise (dB)				Signal/Interference (dB)			
	LD	MD	UD	No.	LD	MD	UD	No.	LD	MD	UD	No.
No interference	-3	0	1	564	-4	0	2	576				
25 Hz offset	-2	0	2	527	-1	0	10	527	-5	0	5	527
15 Hz offset	-1	0	3	523	-3	0	1	523	-2	0	10	523
-10 kHz offset	-3	0	41	530	-1	0	3	530	-5	0	5	530
10 kHz offset	-3	0	14	550	-1	0	2	550	-2	0	10	550

where: LD = lower decile; MD = middle decile; UD = upper decile;
No. = number of data sample

Receiver No. 7 minus Receiver No. 8
for all conditions

	Decile level								
	1	2	3	4	5	6	7	8	9
Distortion (%)	-3	-1	0	0	0	0	1	2	10
Signal-to-noise (dB)	-2	-1	0	0	0	0	1	1	3
Signal-to-interference (dB)	-3	0	0	0	0	0	0	3	10

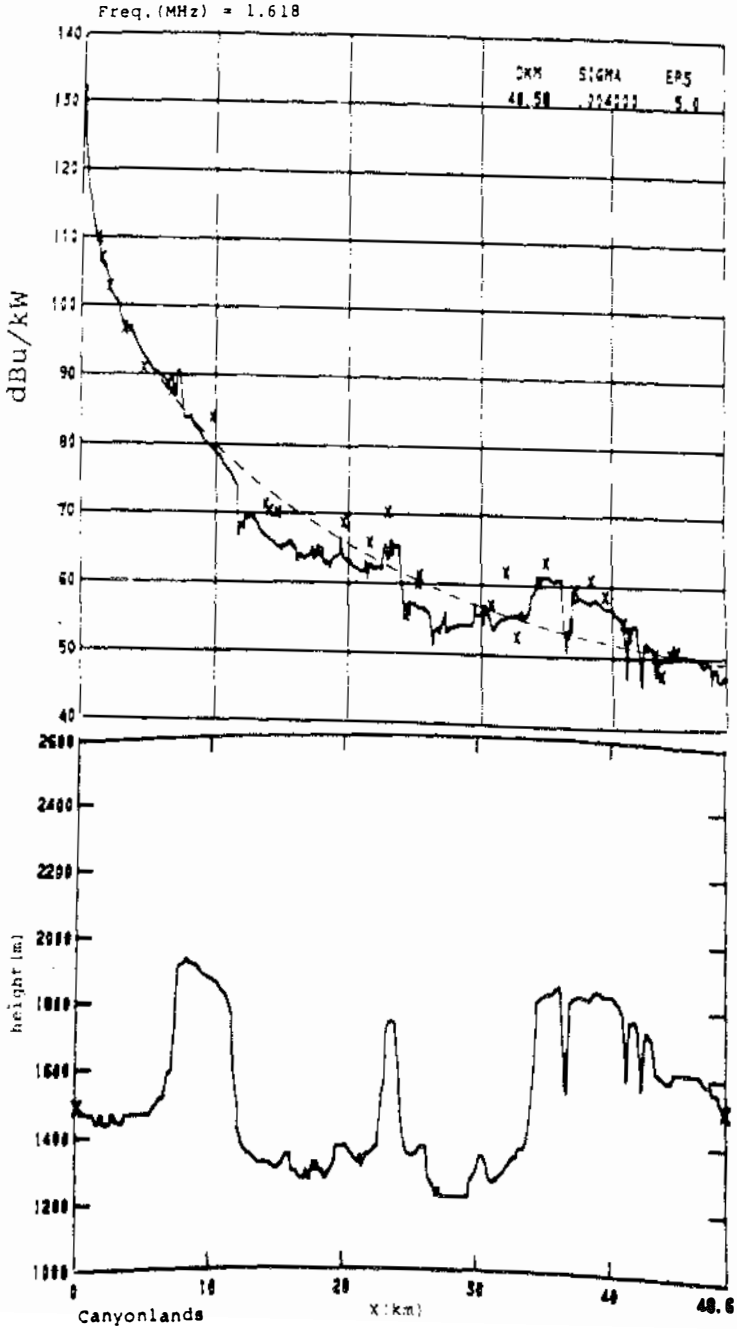
MF Systems Assessment

Outputs

* Interactive models to assist the planning of broadcast facilities in the MF band

The Institute has been a source of the development of models to predict losses over smooth Earth at medium frequency (MF) and lower frequencies for homogeneous and mixed paths. The ground-wave models have been used in the development of the curves used by both national and international organizations to compute coverage and interference from MF broadcast transmitters. For the last decade, ITS has worked on extending the MF models to include the effects of irregular terrain and obstacles such as buildings and forests on the propagation loss.

Project personnel (l. to r.) Jeff Wepman, Susan Rothschild, Brent Bedford, Eldon Haakinson, and Nancy Kuester



The figures to the left show a terrain path profile for Canyonlands, UT, in the lower plot and a comparison of predicted versus measured data along the path at 1.618 MHz in the upper plot. The measured data are shown by the x's; the smooth, homogeneous Earth predictions are shown by the dashed line; and the irregular terrain, homogeneous Earth predictions are shown by the solid line. The predictions are not only sensitive to the terrain at these frequencies, they are sensitive to changes in conductivity. For example, if the conductivity is changed from .004 S/m to .008 S/m, a factor of 2 change, the predicted field increased by 8 dB at 10 km and by 12 dB at 50 km. It is evident from the plot that to obtain accurate predictions, knowledge of both terrain changes and conductivity changes along the path are needed.

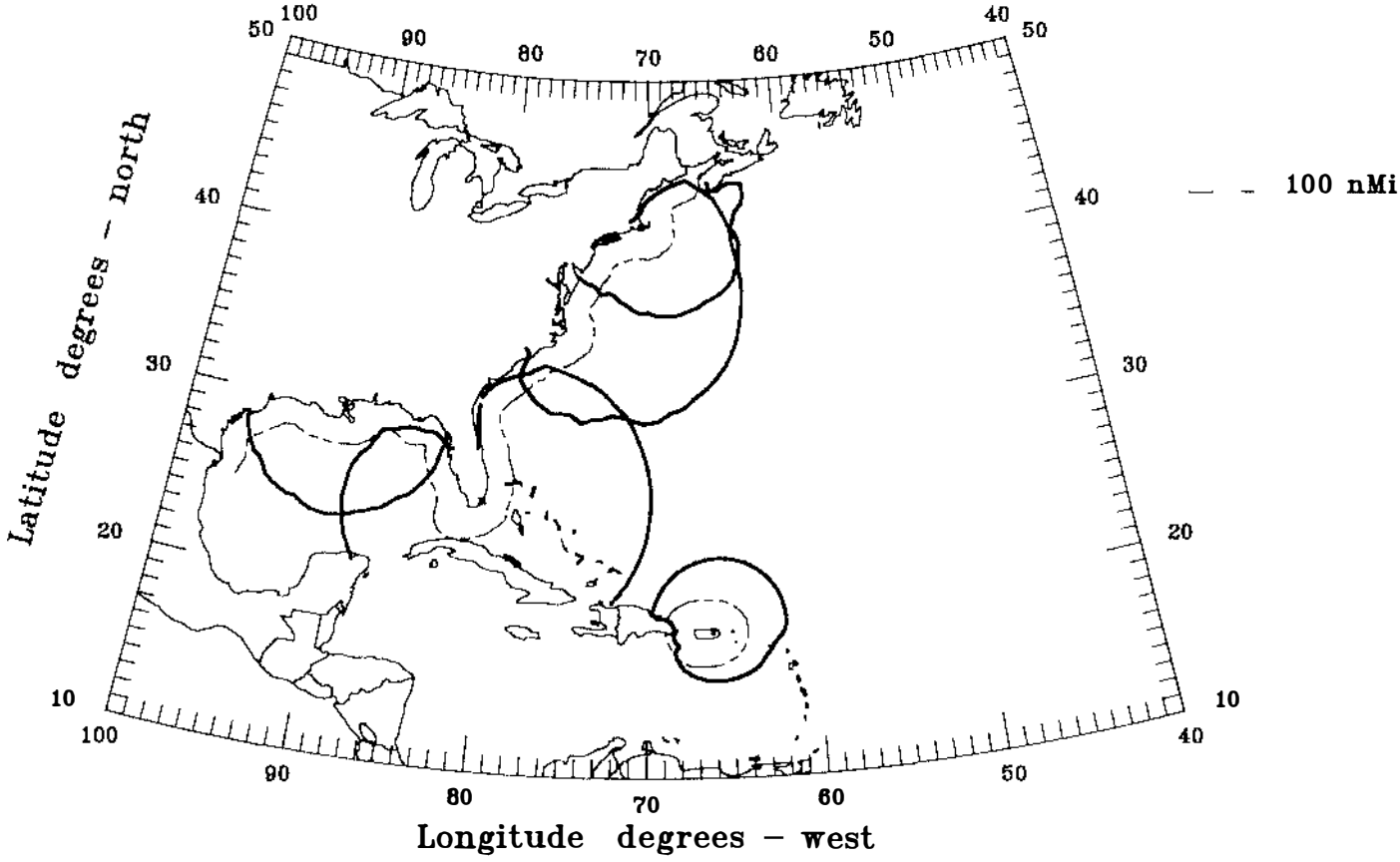
During the daytime, MF sky-wave signals are absorbed by the ionosphere; however, at nighttime, the sky-wave signals are reflected back to Earth, which allows for large coverage areas but also many interference situations. The FCC's sky-wave curves are used throughout the United States regardless of the transmitter latitude whereas regional and international regulators use models that depend upon the transmitter's and receivers' latitudes. Depending upon which model is chosen for the analysis, the transmitter's coverage and interference areas will change in size. In order to compare the models, ITS has developed the algorithms for the national, regional, and international MF prediction programs so that all can be run with common input and have common outputs.

The Institute has developed an interactive program that allows the user to select a ground-wave model and a sky-wave model from the models listed above.

The user may also select from different transmitting and receiving antennas. The program computes the sky-wave signal, the ground-wave signal, and the noise at the user-selected points. In this manner the user can test various trade-offs as they relate to national, regional, and international MF broadcast requirements.

Another use of the MF ground-wave irregular terrain model is to predict the coverage around coastal MF transmitters. Certainly over water, the coverage contour should be a constant radius from the transmitter. However, agencies such as the Coast Guard have responsibilities to cover inland waterways, harbors, and other water routes that are protected by land. The figure below shows the results of applying the ground-wave irregular terrain model to five Coast Guard stations on the East Coast transmitting at 518 kHz.

East Coast NAVTEX service area



HF System Assessment

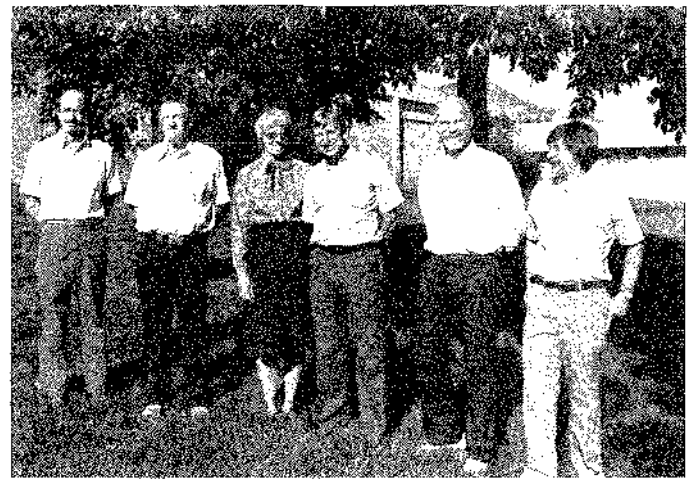
Outputs

* Improved techniques to predict HF system performance
* More accurate ionospheric specification
* Analytical techniques for Government agencies' HF operational use
* Interactive HF sky-wave and ground-wave models
* Performance analysis standards for HF broadcasting

The Institute has provided support to other Government agencies in various areas pertaining to high-frequency (HF) propagation system performance and in 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 predict the state of the ionosphere provide corresponding improvements in the ability to predict the expected performance of telecommunication systems that use the HF spectrum, providing the lead time necessary for equipment and frequency selection.

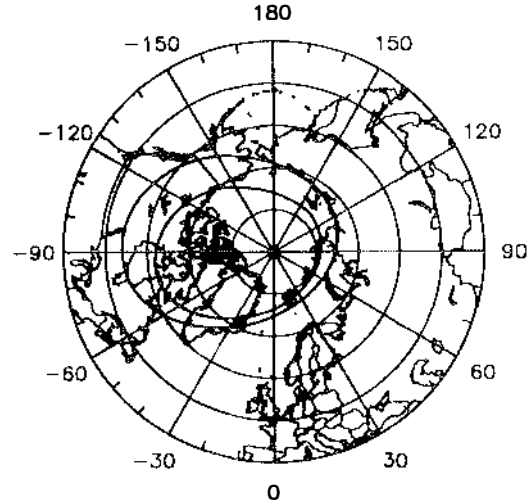
One study that was undertaken by the Institute that relates to high-frequency propagation is directed at assessing the impact of gradients in the electron density on the expected performance of HF systems operating in and near high latitudes. Using the data that were collected during campaigns to determine the location of jammers to the HF broadcasting service, observations were grouped according to the magnetic activity index. The observations constituted measurements of signal bearings that were gathered at monitoring stations located in the United States and Europe. The sources of the signals were emitters located in the Soviet Union. Observations with ionospheric reflection points located at high latitudes were analyzed.

These data were investigated to determine to what extent the bearings from particular locations were changed when the magnetic activity increased. Changes in magnetic activity were identified by the use of the



Project personnel (l. to r.) Don Spaulding, Frank Stewart, Rita Reasoner, Eldon Haakinson, Jim Washburn, and Larry Teters

Q index that relates to the position of the auroral oval. The region in and near the oval is characterized by the occurrence of large gradients in the ionosphere. An illustration of the relative position of the oval during quiet magnetic conditions is given in the figure below. As the oval



AURORAL OVAL – NORTH POLE
Q = 4 JULY

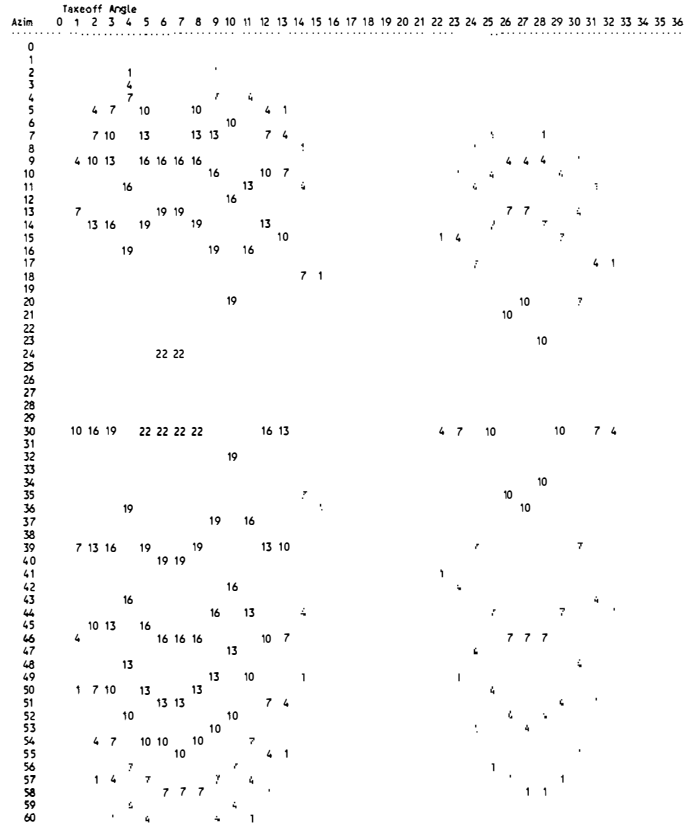
moves equatorward with increasing magnetic activity, signals whose ionospheric reflection points are located at lower latitudes show larger bearing deviations. The amount of the deviation is dependent on a number of complex, interactive phenomena such as the local time, Q value, and season

of the year. This study is continuing with emphasis on predicting the likely interference that results to other services when broadcast signals are deviated out of the great circle propagation path.

The Ionospheric Communications Analysis and Prediction Program (IONCAP) is an integrated system of models designed to predict high-frequency, sky-wave systems performance and analyze ionospheric parameters. The IONCAP program is provided with built-in antenna evaluations. The set of antennas is called the ITSA-1 antenna package. Another set of antennas was developed for the HFMUFES propagation predictions program and, although there is some overlap, the HFMUFES package contains antennas not included in the ITSA-1 package. The HFMUFES antenna package has been implemented on the IBM-PC/AT version of IONCAP. This implementation allows the user to have access to an expanded set of antennas from the IONCAP propagation prediction programs.

The United States uses HF transmitters located all over the world to broadcast news and entertainment. The broadcasts are conducted in various languages besides English, such as Russian or Polish. The organizations that administer these international broadcasts are currently upgrading their transmitting facilities. By electronically shaping and steering the antenna beam, the facility can direct the signal to those listeners who speak the language of the broadcast. For example, a Polish language broadcast would call for a relatively narrow antenna beam, while a Russian or an English broadcast would require a wide antenna beam. The use of the electronically controlled antenna increases the spectrum efficiency of the broadcast network and in the long run it saves money because less transmitter power is required to broadcast with the narrow, high-gain antenna beams.

The Institute has developed computer programs that are used to assess the broadcast planning problem. This starts with determining the required antenna gains and pointing angles from the transmitter to the reception area. Then antenna patterns such as those shown in the following figure are computed and proposed for the transmitter for a particular azimuth and takeoff angle from the transmitter for an HRS 4/6/0.5 curtain array (4 dipoles wide and 6 dipoles high) that is steered 30 azimuth at 8.75 MHz. Finally, the programs help select which patterns and frequencies will optimize the broadcast schedule by providing the most coverage to the listeners at the least cost in transmitter power.



Recent ITS Publications

An Updated Noise Model for Use in IONCAP (by Spaulding and Washburn)

Gain Evaluation for an Idealized Curtain Array Antenna (by Kuester)

User's Guide for the HF Broadcast Antenna Design and Validation Summary Programs (by Haakinson, Rothschild, and Godwin)

Test Methodology and System Performance

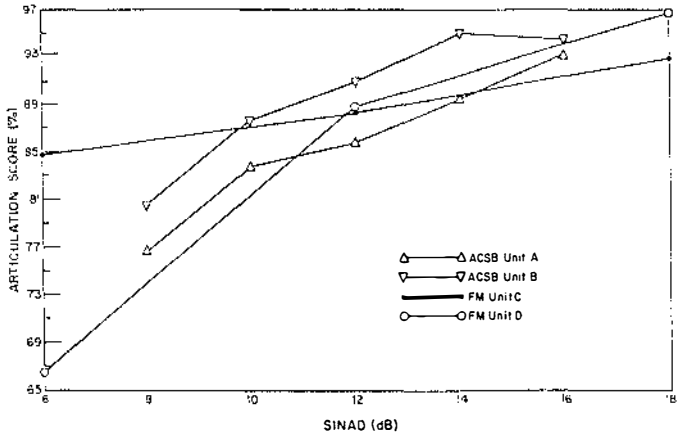
Outputs

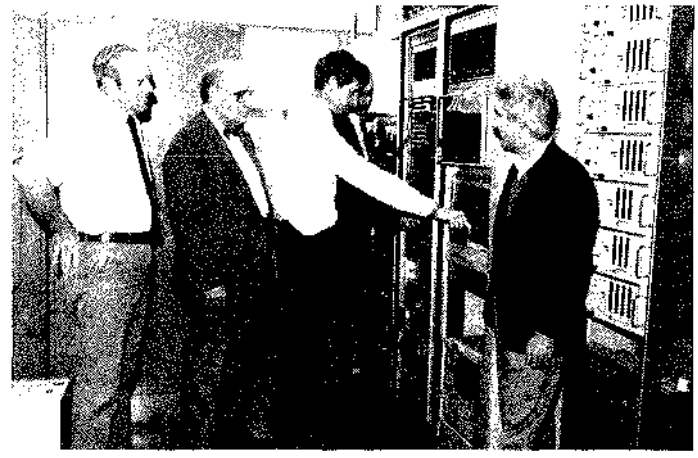
* Intelligibility of amplitude companded sideband modulation compared to conventional frequency modulation
* Recommended requirements and measurements for an NIJ standard for ACSB receivers
* Performance parameter definitions
* An NIJ report on mobile VHF/UHF antennas

The Institute recently completed a project that assessed the voice quality of amplitude companded sideband (ACSB)--a narrowband modulation technique allowing more efficient use of the radio spectrum. ACSB is currently authorized for use in the 150-MHz band. The FCC has initiated action exploring whether ACSB should be given "its own spectrum" in the 220-MHz band. Such action would further increase the application of ACSB in land mobile radio.

The ITS work, using FM land mobile radio as a reference, identified the appropriate performance measures for ACSB and identified the values of these measures that represent the minimum level of acceptable performance. That minimum level of performance, as shown in the figure below, is defined as the speech intelligibility for an FM system operating at 12 dB SINAD.

Using 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 to the left shows that at 12 dB SINAD the articulation scores of ACSB receivers bracket the articulation scores measured for FM receivers.

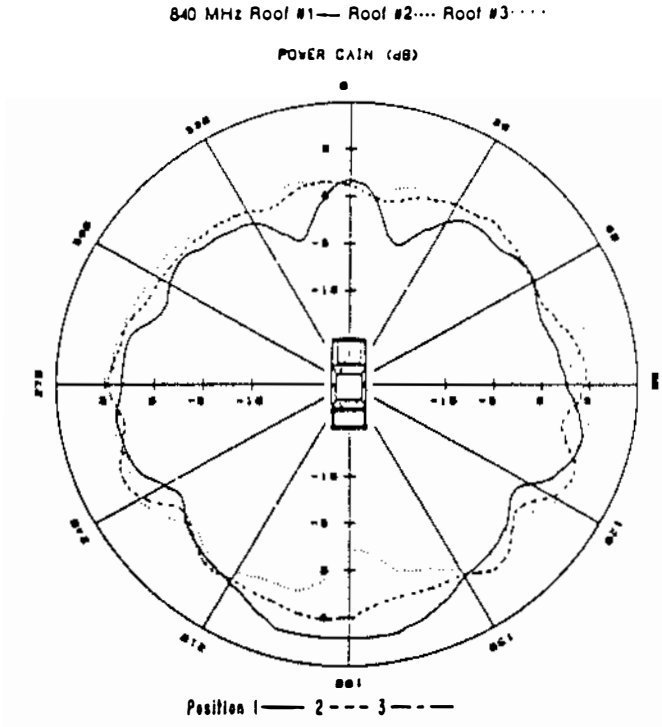




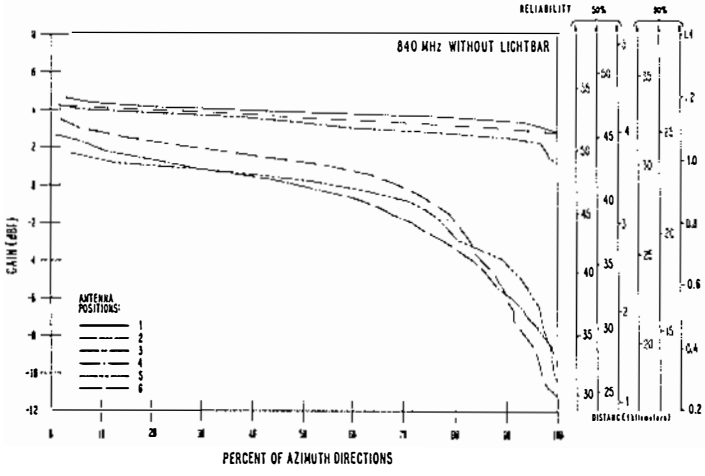
Project personnel (l. to r.) John Harman, Ernie Morrison, Nick DeMinco, Tom Jones, and Bill Kissick

Gain/Range Plots for Mobile VHF/UHF Antennas. The Institute has applied computer modeling to study the propagation of VHF/UHF mobile radio systems for the Law Enforcement Standards Laboratory of the National Bureau of Standards. A report prepared for the National Institute of Justice utilizes mobile antenna power gain radiation data to compute cumulative distributions of gain versus percent of azimuth for each of six separate vehicle antenna locations. The mobile antenna power gain radiation data is plotted in the next figure which is followed by a plot of the computed cumulative distribution of gain. The results provide a convenient means of comparing antenna performance and the expected propagation range. The propagation model allows the prediction of communication ranges by considering all of the system parameters including antenna elevations and the profile of the intervening terrain.

Stress Loading Facility Methodology Investigations. The Stress Loading Facility (SLF) under development at the U.S. Army's Electronic Proving Ground is an



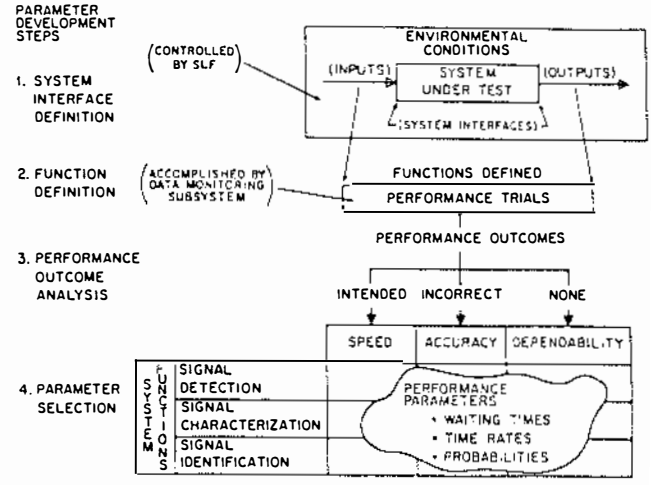
Power Gain Radiation Data



Computed Cumulative Distribution

integrated test system that produces a dense electromagnetic threat test environment for systems under test. Under severe electromagnetic stress conditions, the system's performance in terms of various response parameters may be degraded. Defining these performance parameters, developing techniques for monitoring them, and providing the methodology for data reduction, analysis, and display are the major objectives of the ITS program.

A structured approach that establishes uniform methods for specifying, assessing, and comparing system performance from a functional standpoint is used to develop parameters and measures of functional performance. This structured approach is based on three possible outcomes of performing a given system function--namely, intended performance, incorrect performance, or no performance. These outcomes then lead to parameter selections in terms of speed, accuracy, and dependability as shown in the figure.



Recent ITS Publications

ACSB: What is Adequate Performance? (by Jones and Kissick)

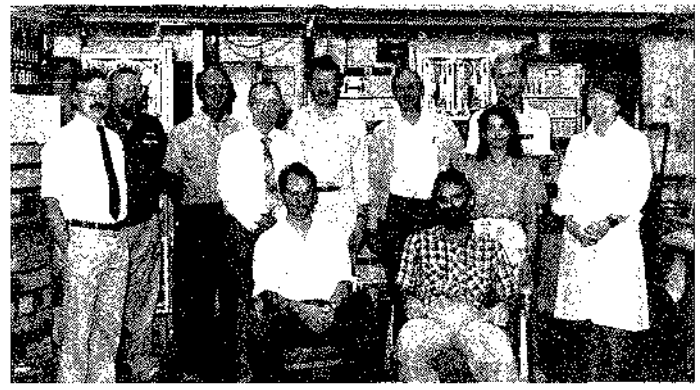
Investigations of Test Methodology for the Stress Loading Facility (by Jennings)

Transmission System Performance Measurement, Monitoring, Evaluation, and Control

Outputs

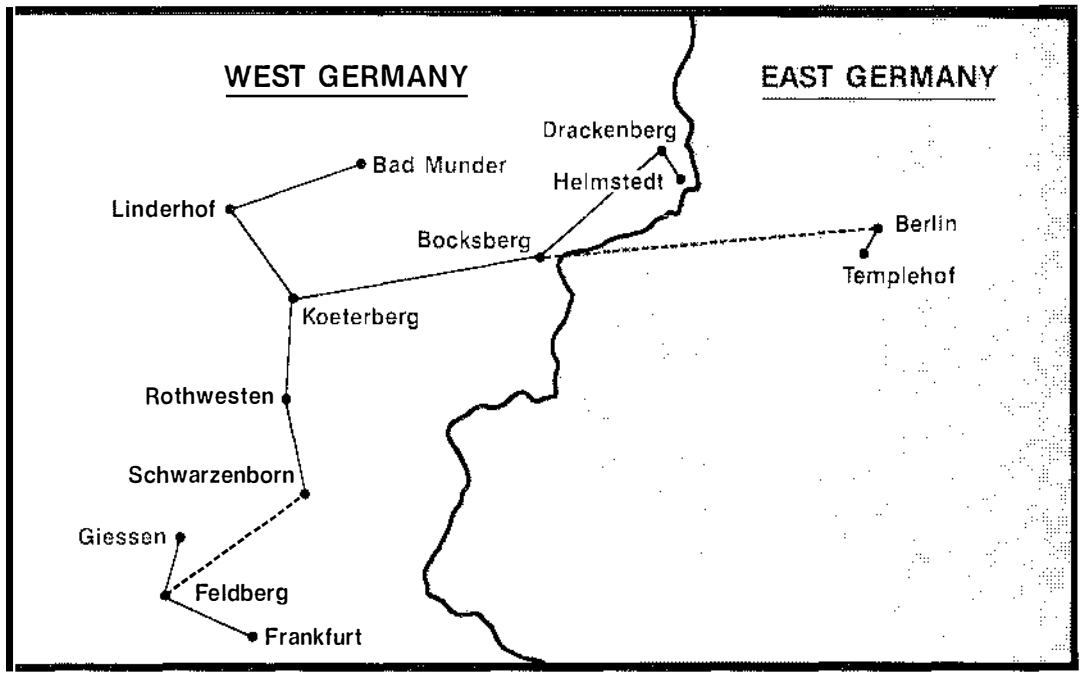
* Software: 300,000 lines of source code used for transmission system monitor and control
* Transmission performance standards
* Improved channel models
* Improved microwave transmission system design methodology
* Improved space diversity switching algorithms
* Recommendations regarding engineering changes to DCS radios

A major component of the Defense Communications System (DCS) is the Digital European Backbone (DEB). The DEB is a microwave transmission network that provides military communication services in Italy, Germany, Netherlands, Belgium, and the United Kingdom. The network carries critical command and control traffic as well as routine administrative traffic.



Project personnel (standing l. to r.) Jim Hoffmeyer, Joe Farrow, Dick Skerjanec, Larry Hause, Tim Riley, Lauren Pratt, Bob McLean, Suzy Bernal, Evie Gray, and (seated) Chris Behm and Rick Statz

The Institute has provided support to a variety of Department of Defense agencies during the course of the development of DEB. One of the primary projects has been the development of a system known as the



Frankfurt North Segment of the Digital European Backbone

Transmission Monitor and Control (TRAMCON) system. One major purpose of TRAMCON is to provide automated monitoring of the status of the communication equipment within DEB. A second purpose is to provide the means for remotely controlling system configuration and switching in redundant equipment in the event of failure. The TRAMCON system will eventually consist of 25 minicomputers that monitor DEB equipment at over 250 communication sites in Europe.

During FY 87, the Institute completed a new software version of TRAMCON, completed extensive documentation of the 300,000 lines of source code, and assisted in the testing of the TRAMCON system at field sites in Europe. The TRAMCON system is recognized as a critical part of the DEB network and is a crucial part of the network management and technical control for DCS.

The TRAMCON system provides vital input to a large performance measurement project that was initiated during FY 87. This project, known as the Network Performance Characterization/Link Performance Characterization Project, is a multiagency-funded project that will provide valuable data on the performance of the DEB network. The NPC/LPC project consists of measurements made on the Frankfurt North Segment of DEB. End-to-end performance measurements will be made on a communication channel between Berlin and a site near Frankfurt. Detailed measurements will be made on one link of this channel (the Schwarzenborn-Feldberg link).

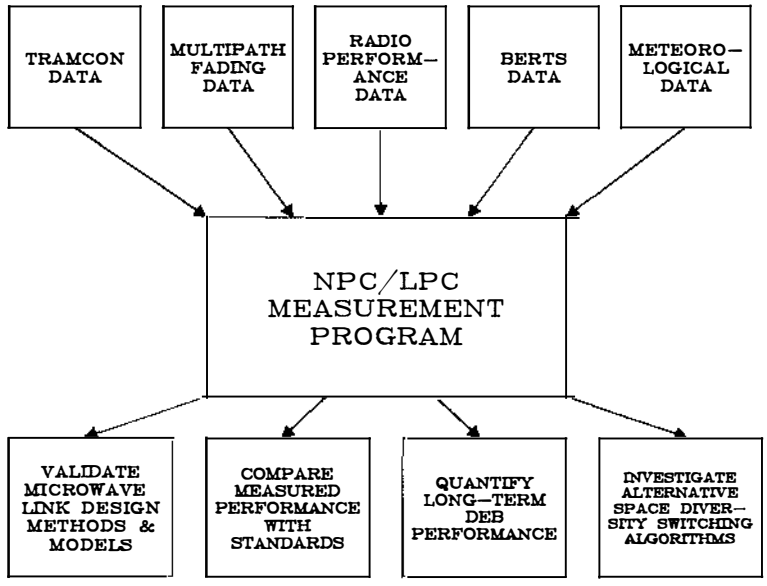
The objectives of this program include validation of microwave link design methods and models, comparison of performance with military and CCIR standards, quantification of long-term (12 months) performance, and an investigation of alternative space diversity switching algorithms. There will be several sources of data for the NPC/LPC measurement program in addition to TRAMCON. Bit error rate test set (BERTS) data, radio performance data, multipath fading data, and meteorological data will be collected as well.

The NPC/LPC project is a large measurement project that will provide valuable data for a variety of national and international standards groups.

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)



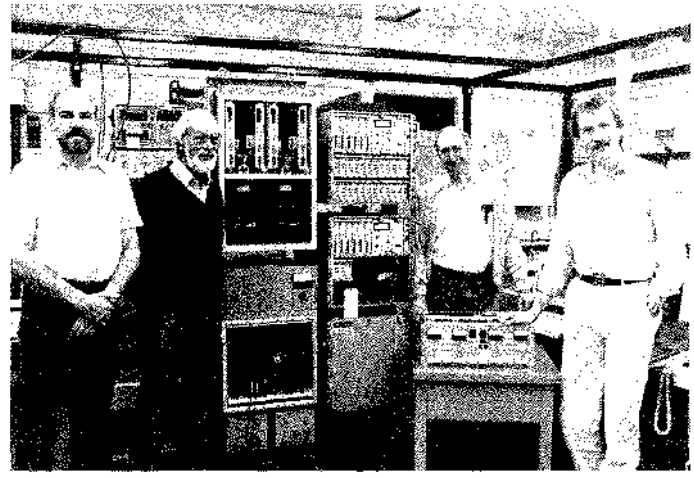
NPC/LPC Measurement Program Objectives

Microwave Communications Link Testing

Outputs

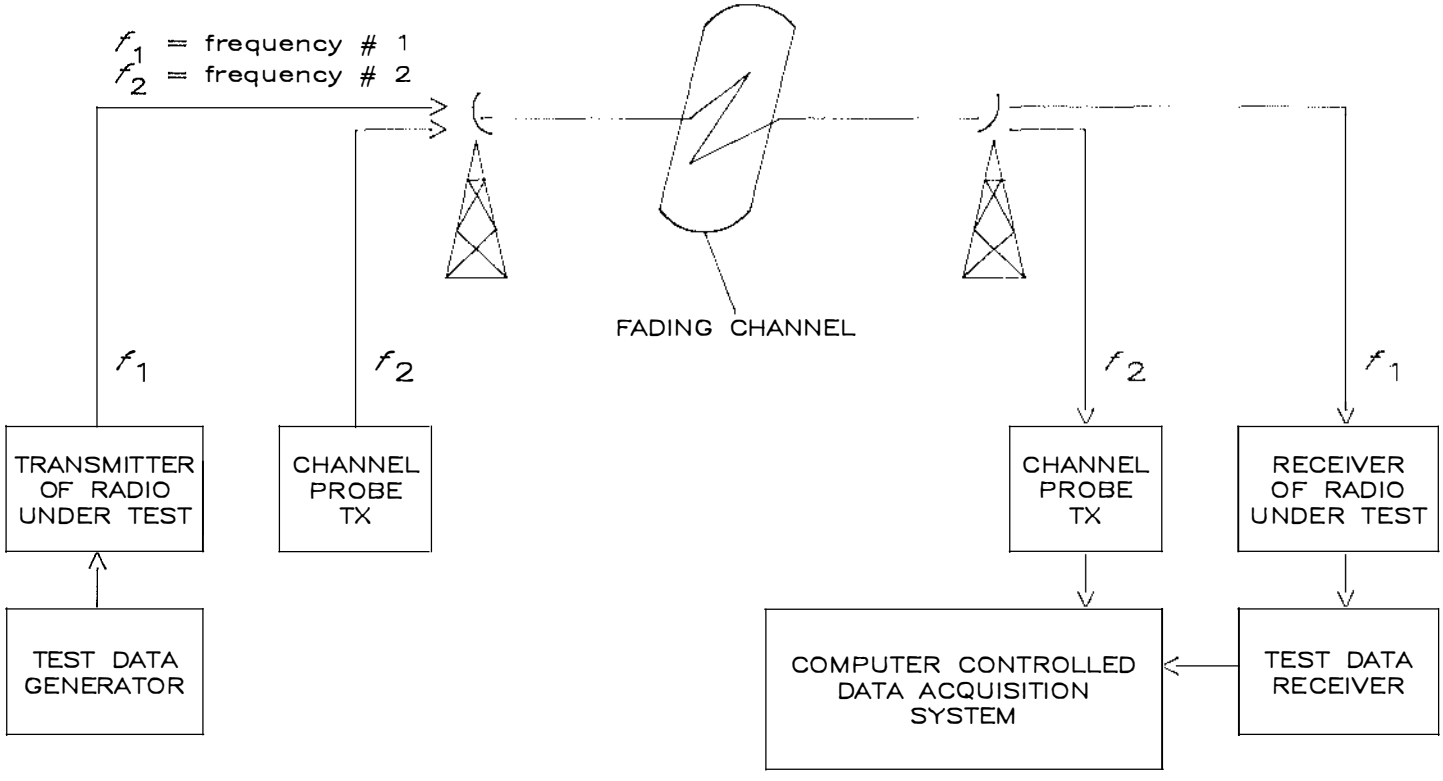
* Channel probe hardware
* Propagation data
* Channel models
* Digital radio performance data

During FY 87, the Institute analyzed test results from one troposcatter link, conducted tests on one line-of-sight (LOS) microwave link, and planned tests to be conducted during FY 88 on another LOS link. Each of these links is part of the Digital European Backbone (DEB) which is a U.S.-owned and -operated network designed to carry both routine administrative traffic and critical command and control traffic. The links tested or analyzed are critical parts of DEB. For example, the Berlin-Bocksberg tropo link, which was tested by ITS during FY 86 and analyzed during FY 87, carries a high percentage of the U.S. military traffic to and from Berlin.



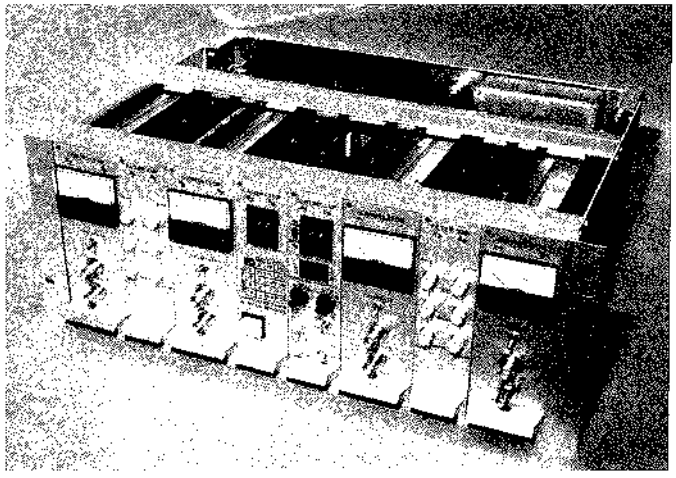
Project personnel (l. to r.) John Lemmon, Bob Hubbard, Lauren Pratt, and Tim Riley

Typical field tests for either LOS or troposcatter links consist of measurements of the error rate of a digital radio under test and measurements of the amount of multipath occurring on the channel at the time errors were observed on the radio. It



Typical Digital Radio Field Test Configuration

is important to have some measure of propagation conditions at the time the radio measurements are being made. Having both sets of data permits one to correlate the level of radio performance with the amount of multipath on the channel.



Tropo Channel Probe Developed by ITS

The Institute has developed two unique instruments for the measurement of multipath on microwave channels--one for use on LOS channels and one for use on troposcatter channels. These instruments provide the channel impulse response by the cross-correlation method. A pseudo-noise sequence is transmitted at one end of the link. At the other end of the link the channel probe does a cross-correlation between the received signal and a replica of the transmitted signal.

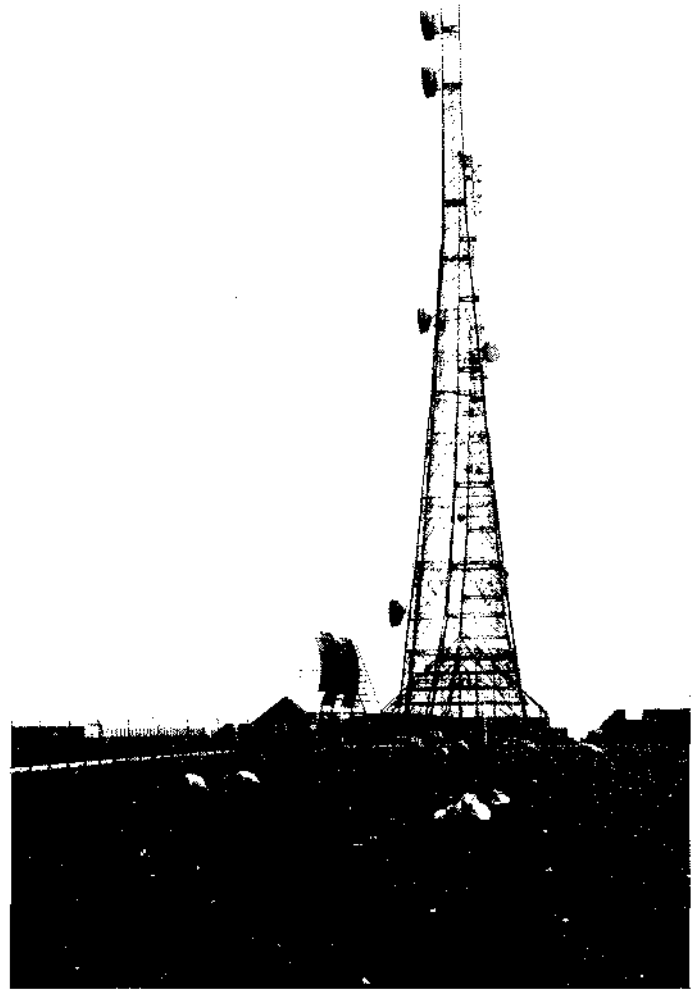
During FY 87, a new channel probe for use on troposcatter links was developed. The new probe has higher resolution than the previous probe. This permits fuller insight into the propagation environment.

The testing and analysis conducted by ITS of the Berlin-Bocksberg link has resulted in new understanding of the effects of troposcatter propagation. In particular, the dynamic nature of this mode of transmission was investigated and found to have a dramatic impact on digital tropo radio performance. This potentially will influence future design of tropo radios.

Measurements on the two LOS links mentioned above are expected to add a vast amount of data relevant to channel modeling, channel simulation, and link design of LOS microwave communication systems. This information is relevant to the private sector (e.g., the common carriers) as well as to the military sector.

Recent ITS Publications

Propagation and Performance Measurements over a Digital Communications Link (by Lemmon)



LOS Microwave Antennas at Swingate, England

Transmission System Modeling

Outputs

* Line-of-sight radio link design program that incorporates a new algorithm for calculating the effects of frequency selective fading on radio link performance
* Wide area propagation software

During the past several years, the Institute has produced interactive programs for the military departments to use in predicting the performance of terrestrial radio transmission systems. Because of the constant updating of standards, evolution of the technology, and the changing communication requirements, the U.S. Army has requested the Institute to enhance the original programs and to develop new ones. Such programs must incorporate the following features:

- o more efficient radio link design
- o design algorithms that are as accurate as possible to assure reliable communications
- o easy-to-use programs, which cut training costs and decrease the chances of operator errors
- o compatibility with wide variety of computers including inexpensive models
- o clear and unambiguous program outputs

Much progress has been made at ITS in achieving these goals. The line-of-site link design program uses multipath fading data for a given path, diversity configuration data, and the characteristics of the bit-error-rate signature of a particular radio. Typical program outputs drawn with this software are shown in the following figures.

Because military personnel change frequently, it was essential that the program be designed so that operators can learn to use it properly, with a minimum of training. Army personnel must use the program to calculate estimations of whether a particular link will perform at an acceptable quality and time availability. The program is documented in a manner that makes it

Project personnel (l. to r.) Ray Thompson and Larry Hause

easily operated, understood, modified, and updated. It covers links operating at carrier frequencies between 1 GHz and 20 GHz. 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.

Current software development efforts by the Institute in the area of microwave link design are focused on producing an integrated set of radio link design and analysis programs with these features:

- o UNIX environment operation
- o convenience of transporting between computer systems
- o incorporation of new and updated algorithms
- o substantially decreased operator time per link design
- o ease of use with less operator training time
- o applicability to all three types of radio links--line-of-sight, marginal line-of-sight, and over-the-horizon links

In a project devoted to wide area propagation model development, a propagation model for NSA was developed that was a refinement of a much more detailed model that required the use of the CDC Cyber 750 computer. The

refined model was designed for a personal computer and incorporates the effects of free-space loss, smooth-earth diffraction, and obstacle diffraction for microwave terrestrial links. This is a classified project.

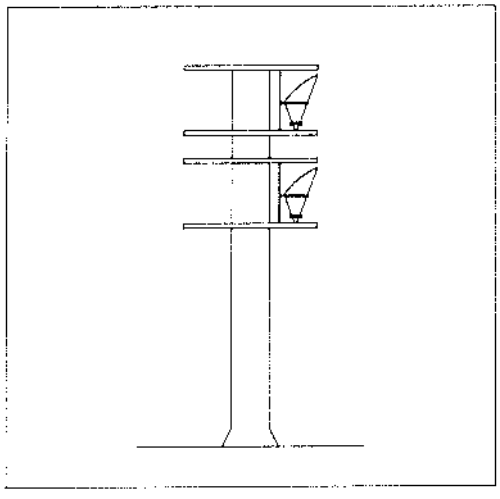
Recent ITS Publications

A Diffraction Model for Wide Area Propagation Analysis (U) (by Dutton and Thompson)

Additional Reflectivity Analysis for the Outer Ring Protection Zone Model (U) (by Dutton and Thompson)

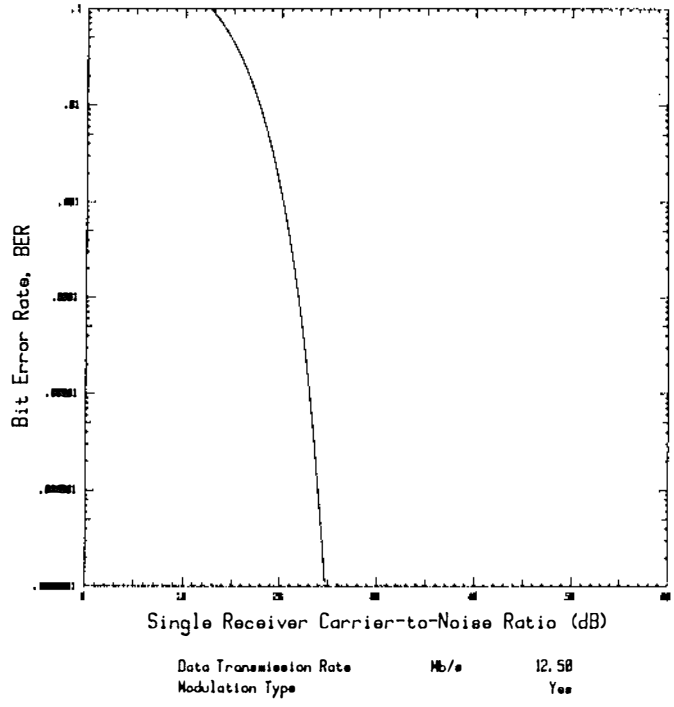
Algorithms Used in ARROWS: Autodesign of Radio Relay Optimum Wideband Systems (by Hause)

Propagation Predictions for Marginal LOS Microwave Paths (by Hause and Farrow)

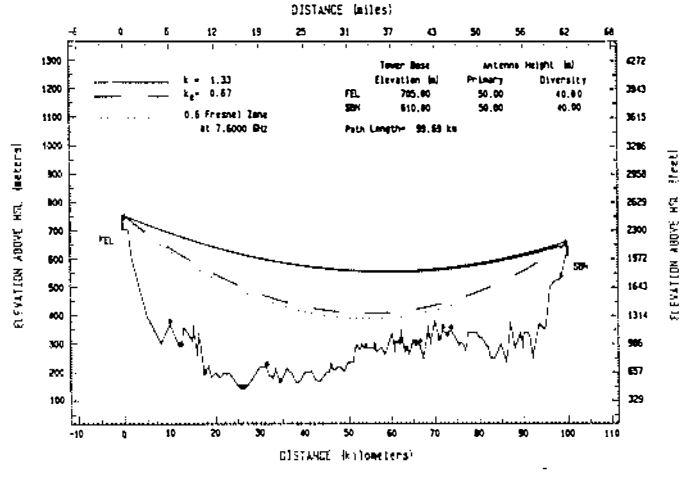


1.	Primary Frequency	GHz	7.4000
2.	Polarization		Vertical
3.	Latitude	d/m/s	49 57' 37.0"N
4.	Longitude	d/m/s	7 38' 17.0"E
5.	Tower Base Elevation Above msl	m	643.00
6.	Beam Azimuth at SKF to MUL	d/m/s	234 49' 09.3"
7.	Beam Magnetic Azimuth at SKF to MUL	d/m/s	239 49' 09.3"
8.	Primary Beam Elev Angle at SKF to MUL	d/m/s	-05' 49.6"
9.	Primary Antenna Vertical Dimension	m	3.00
10.	Diversity Antenna Vertical Dimension	m	3.00
11.	Prim Ant Center Ht Above Tower Base	m	38.50
12.	Diver Ant Center Ht Above Tower Base	m	28.50

Antenna Sighting Diagram



PCM-TDM Single Receiver Transfer Characteristic for the Link



Path Profile from Feldberg to Schwartzenborn

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

Satellite Studies

Includes projects funded by the National Aeronautics and Space Administration

Planning for Special Communication Environments

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

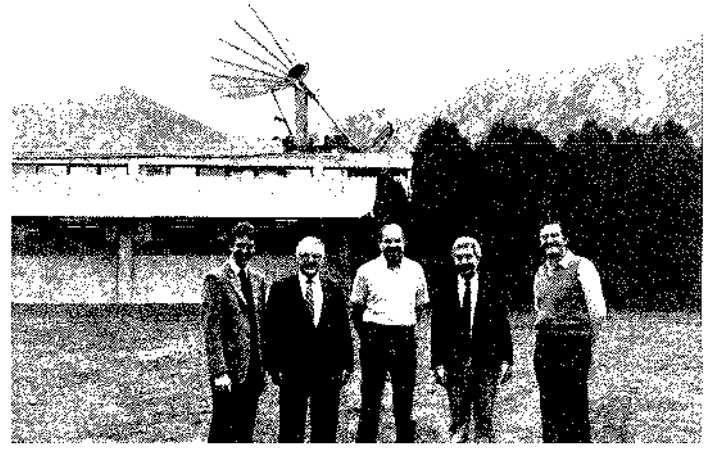
Advanced Systems Planning

Includes projects funded by the Air Force Electronics Systems Division, the Army Information Systems Engineering Support Activity, the Defense Communications Agency, and the Department of State

Satellite Studies

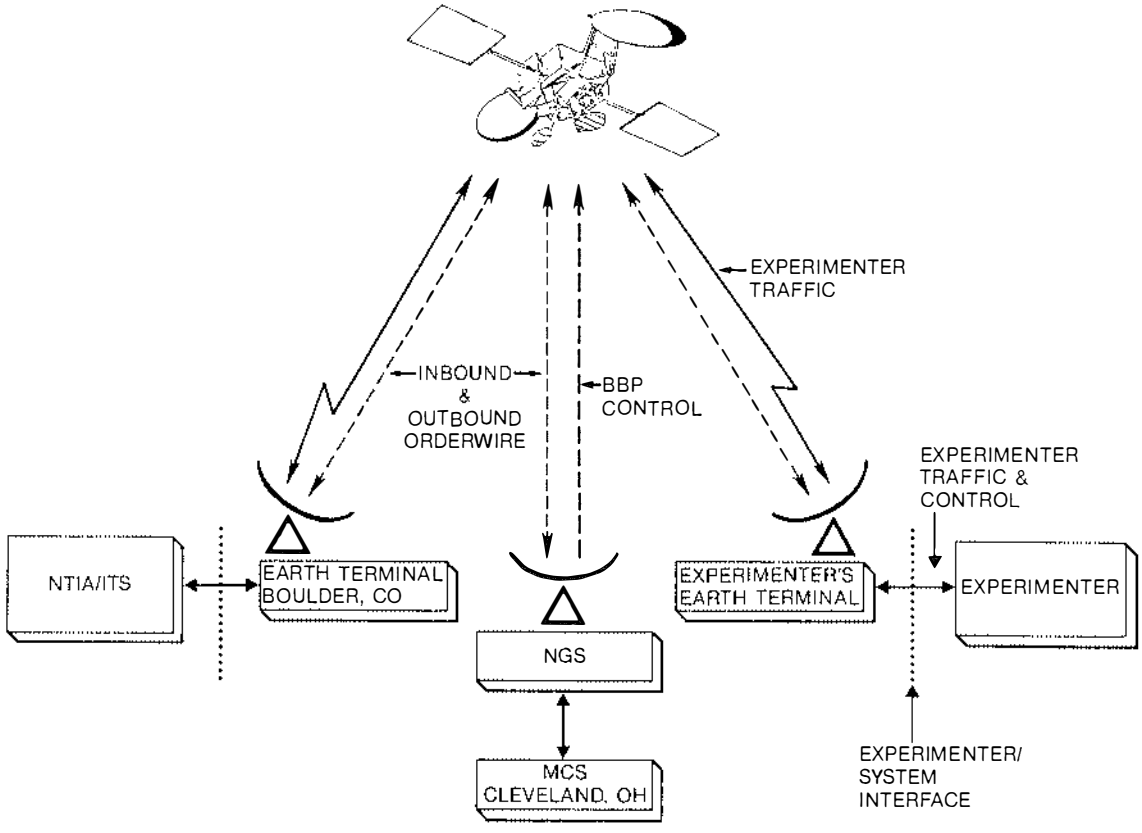
Outputs

* Preparation for World Administrative Radio Conference
* Formation and chairing of a system performance working group with NASA for ACTS
* Contribution to NASA's ACTS Update newsletter detailing the ITS system performance experiments
* Application of ANSI X3.102-1983 to advanced communication systems like ACTS
* Multipath effects on the land mobile
* Advanced satellite communication technology studies



Project personnel (l. to r.) Bob Cass, Earl Eyman, John Lemmon, Bill Kissick, and Martin Nesenbergs

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 will respond to these requirements through the application of onboard digital signal processing and switching techniques unique to communication satellites. These advanced satellites will also incorporate sophisticated hopping spot beam antennas that provide coverage to relatively small geographic locations, as illustrated below. These features will also alleviate orbit and spectrum congestion and, through the



user of 30/20 GHz (Ka-band) frequencies, provide much greater channel capacities.

There is a 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, the Advanced Communications Technology Satellite (ACTS), to be a test bed for these advanced communication satellites. Other Government agencies, universities, and commercial organizations are being invited and encouraged to plan and conduct experiments using ACTS. Though ACTS will not be launched until early 1992, ITS and about 90 other organizations have indicated that they plan to become involved in this experimentation effort.

With a large number of experimenters and a broad range of interests in the experiments that will be planned, it is apparent that substantial coordination will be essential. This concern by both ITS and NASA has led to the formation of a system performance working group that is to be chaired by ITS. This working group will act as a means to provide for coordination of these experiments.

As an experimenter, ITS is planning a unique set of end-to-end system performance measurement experiments using the framework of the recently approved American National Standard, ANSI X3.141-1987, Measurement Methods for User-Oriented Performance Evaluation.

Satellite Multipath Measurements. In the area of propagation studies, ITS is planning a multipath measurement program funded by the National Aeronautics and Space Administration (NASA) as part of NASA's Mobile Satellite Communications Program. The ITS experiment will involve channel probe measurements over earth-satellite paths using signals from the Global Positioning System (GPS) satellites and a suitably modified GPS receiver in a mobile van. The purpose of the measurements is to provide an initial assessment of multipath effects in the land mobile satellite radio channel.

Preparation for World Administrative Radio Conference. Other satellite studies have been conducted in connection with support by the Institute to U.S. preparation for the Second Session of the World Administrative Radio Conference on the Use of the Geostationary Orbit and the Planning of Space Services Utilizing It (WARC-ORB 2). One of the principle objectives of the conference is to produce an Allotment Plan. The ability to produce this plan requires the development and use of very complex computer software. Some of this software has been developed by ITS. A model for computing the minimum area elliptical beam for the spacecraft antenna is a specific example. The spacecraft antenna beam must cover a service area that is defined by a set of polygon points. Such a model, developed originally by ITS for use during the Region 2 Broadcasting-Satellite Conference, was improved and provided to the International Frequency Registration Board (IFRB) and other U.S. organizations that are participating in U.S. preparations for the conference.

A computer program developed several years ago at ITS to compute and plot satellite beam footprints on a map of the Earth (or portion thereof) was reactivated on the ITS User Services Computer (HP-1000). This program is very useful in producing graphic presentations of beam coverage and overlap in determinations of compatibility between networks.

The analysis of measured antenna gain data, obtained from antenna manufacturers and the FCC and reported in last year's report, was used in submitting a report to the U.S. Study Group 4 for the CCIR. The report shows statistically the peak gain of sidelobes in the antenna pattern. This report has been approved by U.S. reviewers and now will be considered at international meetings of the CCIR Study Group 4 and the international Joint Meeting of Study Groups.

Recent ITS Publications

Multipath Measurements for the Land Mobile Satellite Radio Channel Using GPS Signals (by Lemmon)

Planning for Special Communication Environments

Outputs

* A multitier specification for fiber optic long-haul systems to meet NSEP environments
* Several reports and publications resulting from the NSEP/FOC study
* Transfer of information to many relevant industry groups
* Developing classified communication system concepts for U.S. Navy

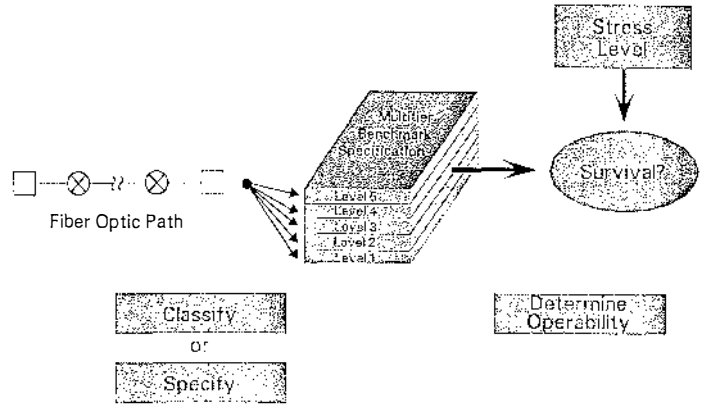
The National Communications System (NCS) has responsibility for defining reasonable enhancements that could be applied to commercial common carrier (or carriers'-carrier) fiber optic systems that will be leased or owned by Government agencies and that may be used for National Security/ Emergency Preparedness (NSEP) purposes.

In support of the NCS mission, ITS has prepared a multitier specification identifying prudent measures that could be incorporated in to the design of commercial, intercity, fiber optic transmission systems to make them more responsive to NSEP requirements in exchange for rights-of-way concessions by the Government. The specification has been structured in such a way that it can also be used as a "report card type" instrument for assessing the degree to which present and future, intercity, fiber optic systems not using Federally controlled rights-of-way measure up from an NSEP standpoint. The array of situations that the fiber optic systems must cope with from an NSEP standpoint include natural disasters (e.g., floods, earthquakes, fire); local acts of sabotage; and nuclear attacks (i.e., nuclear radiation and electromagnetic pulse effects). The design parameters addressed by the specification are those that tend to minimize interruptions of service in the face of these hazards by proper attention to features that facilitate quick restoral of operation or bridging around damaged terminals or repeaters.

Project personnel (l. to r.) Joe Hull, Bill Ingram, Bob Adair, Bill Pomper, John Harman, Martin Nesenbergs, and Dave Peach

The Multitier Specification (shown conceptually in the accompanying figure) concentrates on the engineering and installation aspects of optical communication, common-carrier-type-systems and recommends those additional practices or alternatives that result in higher probability of survival or restoral in a broad range of NSEP environments. The rating approach is a five-level, multitier, rank-ordered specification.

The Institute applied this Multitier Specification to a commercial fiber optic link and identified several enhancements required to upgrade this link to Level 4,



as defined in the Multitier Specification. Estimates of the cost of incorporating these enhancements in the subject commercial link were made.

One of the analysis tools developed by ITS to support the use of the Multitier Specification is FIBRAM. FIBRAM is a computer-generated model that predicts the bit error ratio of an optical fiber link that is exposed to gamma radiation from fallout. This radiation can cause a darkening of the fiber, thus reducing the received light level. Additional degradation of the received light signal can be caused by radiation damage at the photodiode detector. FIBRAM is designed to run on a personal computer.

The NOSC communications consulting project involved providing communications systems engineering support to the Naval Ocean Systems Center in the areas of signals intelligence (SIGINT) and surveillance. Essentially, the work consisted of the development of concepts and designs for several classified, special-purpose communication systems to aid in the collection and dissemination of intelligence data.

Recent ITS Publications

A Program Description of FIBRAM: A Radiation Attenuation Model for Optical Fibers (by Ingram)

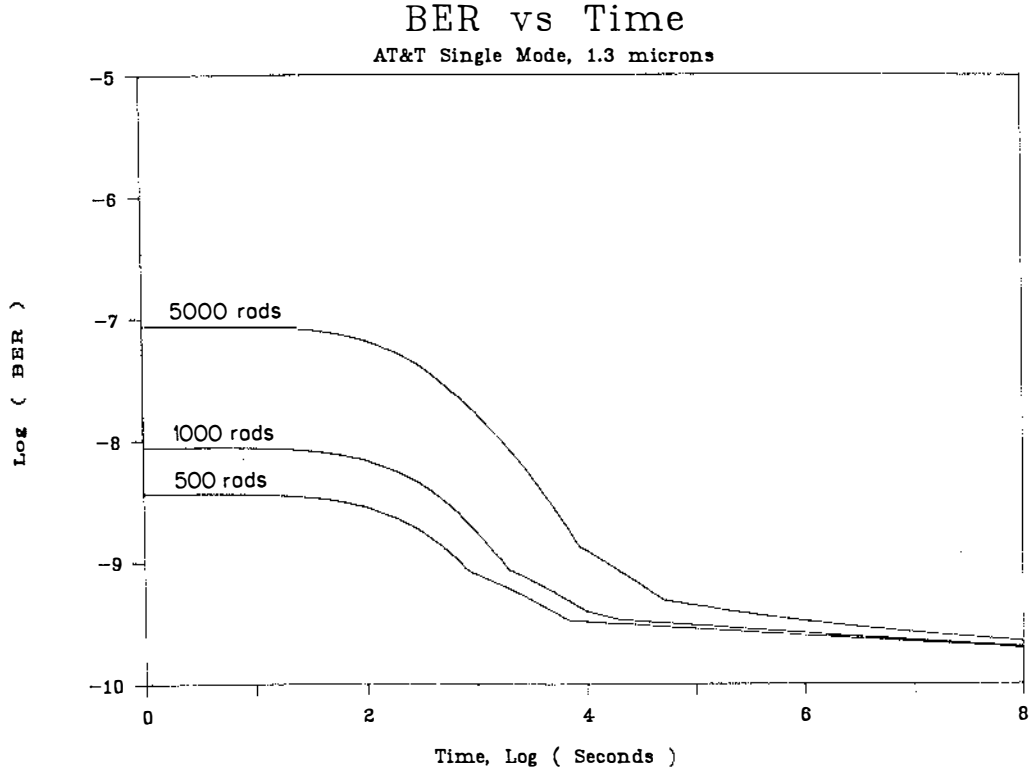
Effects of Radiation Damage in Optical Fibers--A Tutorial (by Englert)

Fiber Optic Networks and Their Service Survival (by Nesenbergs)

Multitier Specification for NSEP Enhancement of Fiber Optic Long-Distance Telecommunication Networks: Volume I: The Multitier Specification -- An Executive Summary and Volume II: Multitier Specification Background and Technical Support Information (by Peach)

NSEP Fiber Optics System Study Background Report: Nuclear Effects on Fiber Optic Transmission Systems (by Hull)

Some Practical Ideas for Increasing Fiber Optic Telecommunication System Stamina (by Peach)



Fiber Optic System Performance Versus Time after Gamma Radiation

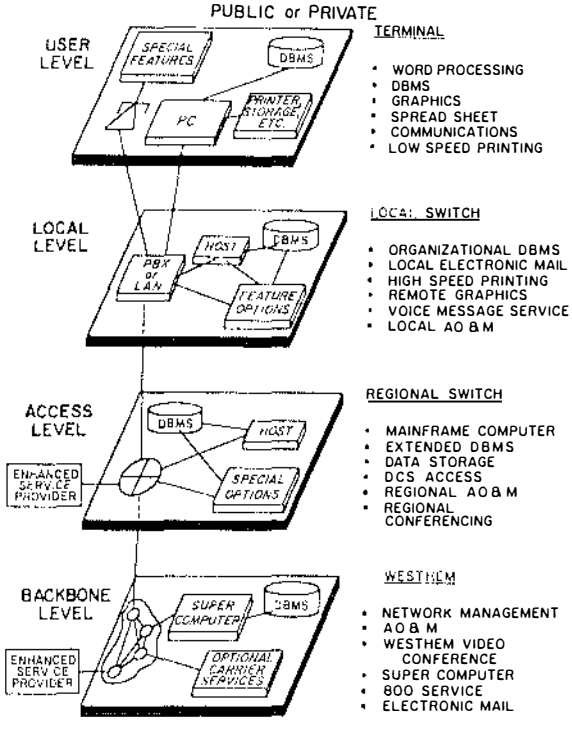
Advanced Systems Planning

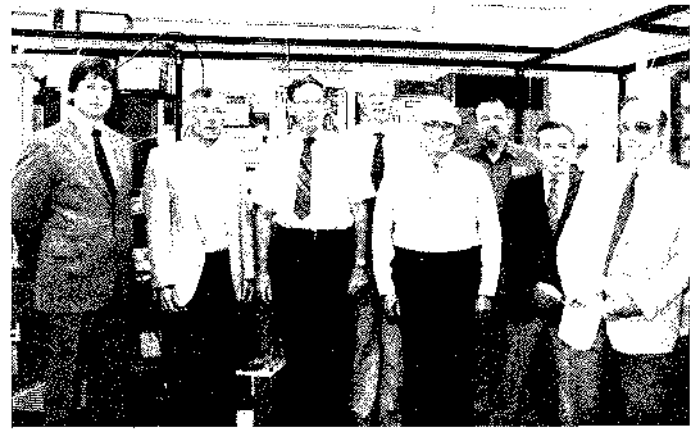
Outputs

* Logistic information systems
* Nodal architectures
* Information policy support
* Local area network planning
* Meteor-burst system concepts
* Telecommunication assessments in South America

The Institute provides planning and consulting services to other Government agencies as well as technical support to other groups in NTIA who are engaged in developing policy. Specific programs are described below.

Architectural Development Support. This project, supported by the Defense Communications Agency, is concerned with developing architectures for the western hemisphere portion of the Defense Switched Network for the 1990's. The objective is to develop alternative network configurations with emphasis on the access nodes. A multilevel network structure is being used to assess functional, logical, and physical architectural concepts and to explore





Project personnel (l. to r.) Randy Bloomfield, Bill Pomper, Roger Salaman, Bob Linfield, Ernie Morrison, Joe Farrow, Ray Jennings, and Jean Adams

issues. An example of this multilevel structure showing the functional levels that exist is shown at left. Network intelligence may be distributed between the different structural levels inherent in the network.

U.S. Air Force Network Consulting. The Battle Staff Management System Network will interconnect eight Air Force logistic centers and provide a logistic information system for crisis conditions. The system will comprise initially 3 host computers and about 90 terminals spread over the continental United States, each one of which will be able to communicate with any other. Much of the traffic to be carried will be sensitive so that information will be carried in encrypted form. ITS is acting as a communication consultant on the interbase circuits and is installing two-terminal LANs at Logistic Command sites.

Information Technology Policy. In support of NTIA's responsibility to develop and present telecommunication and information policy, ITS has assisted in evaluating issues to expand the offerings of both the telephone operating companies and the providers of enhanced services. This evaluation has centered on the provision of equitable access to the local telephone distribution system. ITS has also proposed

updating the 1968 review of telecommunication policy as required to meet the needs of the 21st century.

Technical Assessment of Telecommunications in Chile and Peru. The U.S. Trade and Development Program (T.D.P.) of the International Development Cooperation Agency sponsored a definitional mission to Chile and Peru to evaluate requests for T.D.P. financing of feasibility studies concerning improvements to the telecommunication capabilities and services in these countries. Two technical members of the ITS staff visited Chile and Peru to conduct a preliminary assessment of the proposed projects, to clarify each countries' views on future needs, and to review current telecommunication capabilities and services. Based on these missions, a number of conclusions were reached concerning the technical validity of contemplated cellular radio and satellite projects. An informal document was prepared for use by NTIA in their report to the sponsor.

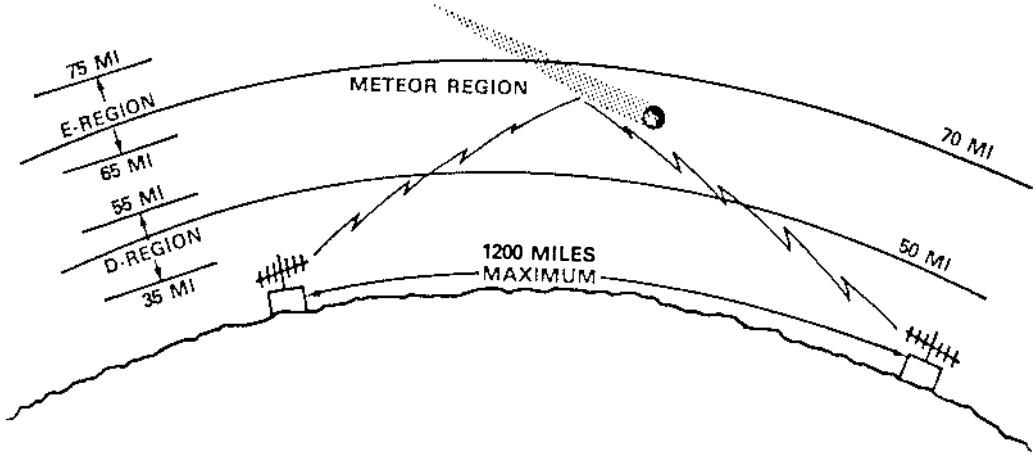
DCA Meteor Burst. The purpose of this ongoing project is to provide technical support to DCA in the development of interoperability standards for meteor-burst communications. See figure below. The ITS work in FY 1987 was primarily to define the communications security (COMSEC) portion of the initial meteor burst interoperability standard. Accomplishing this task involved analyzing meteor burst network security requirements, developing approaches to meeting these requirements, and examining COMSEC equipment for its potential application to the meteor burst environment. The end products for this year included writing the COMSEC portion of the initial interoperability standard and developing and documenting a recommended COMSEC design that meets requirements specified in this standard.

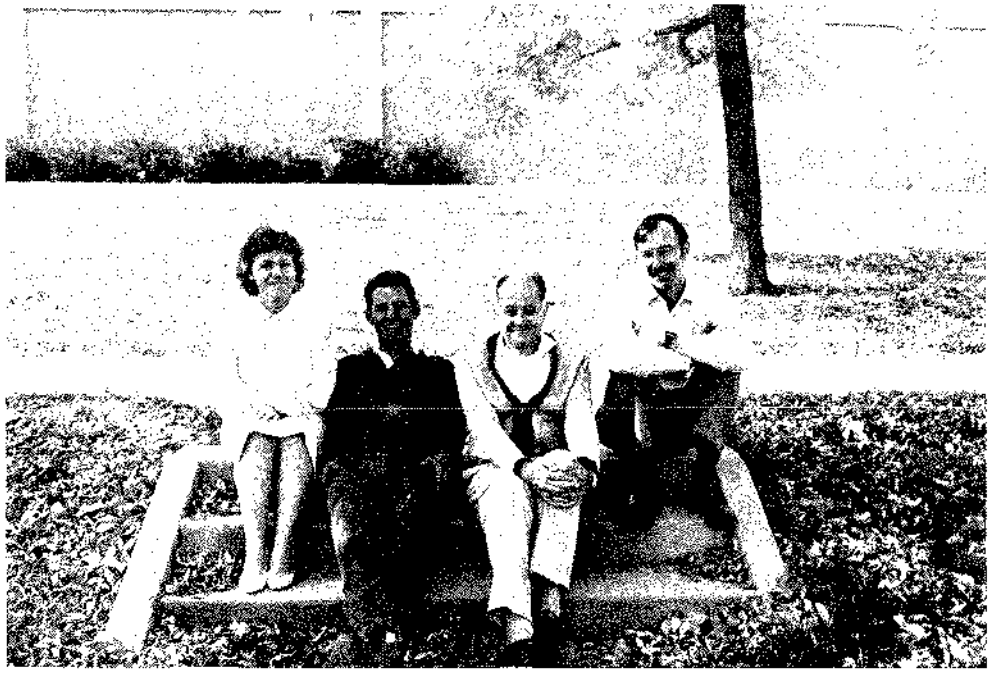
Battlefield Functional Area and C^3I Performance and Effectiveness Analysis. This is a coordinated effort being conducted by ITS, the U.S. Army, and Army contractors. The ITS participation in FY 87 included developing simulation facility specifications, supporting Army TRADOC in structuring operational scenarios, developing communication and combat system performance models, defining combat environment parametrics and linkage to performance models, and developing data analysis procedures. Ultimately a complete operational scenario and engagement model will be implemented on VAX and CRAY computers. Subsequent refinements in FY 88 will exploit parallel processing technologies possibly using HYPERCUBE machines to improve time scaling.

Recent ITS Publications

Development of DCS/DSN WESTHEM Access Node Architectures for the Post-1995 Era (by Bloomfield and Linfield)

Open Network Architectures and the Defense Switched Network (by Linfield)





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 Army Communications Electronics Command, the Army Intelligence and Security Command, the Army Missile Command, the Army Research Office, the National Telecommunications and Information Administration, and the Naval Ocean Systems Center

Signal Processing Studies

Includes projects funded by the Department of Defense, the U.S. Air Force, and the Naval Research Laboratory

Radio Environment Simulators

Includes projects funded by the Air Force Electronic Systems Division, the Army Information Systems Engineering Support Activity, the Joint Tactical Command, Control, and Communications Agency, and Rome Air Development Center

Millimeter-Wave Studies

Outputs

* Millimeter-wave telecommunication system design software
* Models of atmospheric propagation effects
* Measurements of propagation up to 96 GHz

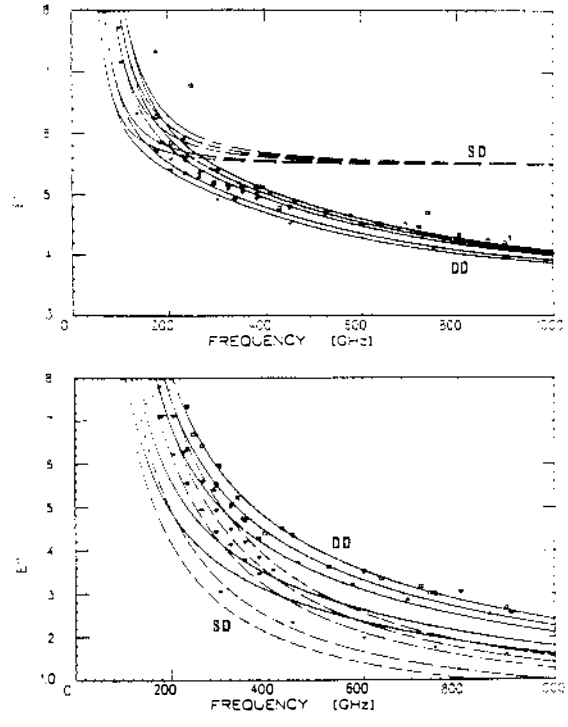
The millimeter-wave program at ITS is a comprehensive program for telecommunication applications. As such, it provides a central focus within the Government for millimeter-wave propagation studies. The program involves laboratory measurements, field measurements, and model development. Practical application models in the form of computer programs are also produced to serve as design tools for other government agencies and private industry.

The propagation of millimeter waves is affected by many atmospheric phenomena 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 in signal power and interference. Water vapor and oxygen in the atmosphere attenuate millimeter waves by absorption. The turbulent 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 receiver. Echoes can also result from the reflection of the millimeter waves from terrain features. In urban and suburban environments, reflections have a major impact on the characteristics of the received signal.

Significant advancement in the knowledge of millimeter-wave propagation was achieved in FY 1987 in several areas. The most fundamental was the development of a new model for the complex permittivity of liquid water at millimeter-wave frequencies. The permittivity determines the propagation velocity and attenuation rate of millimeter

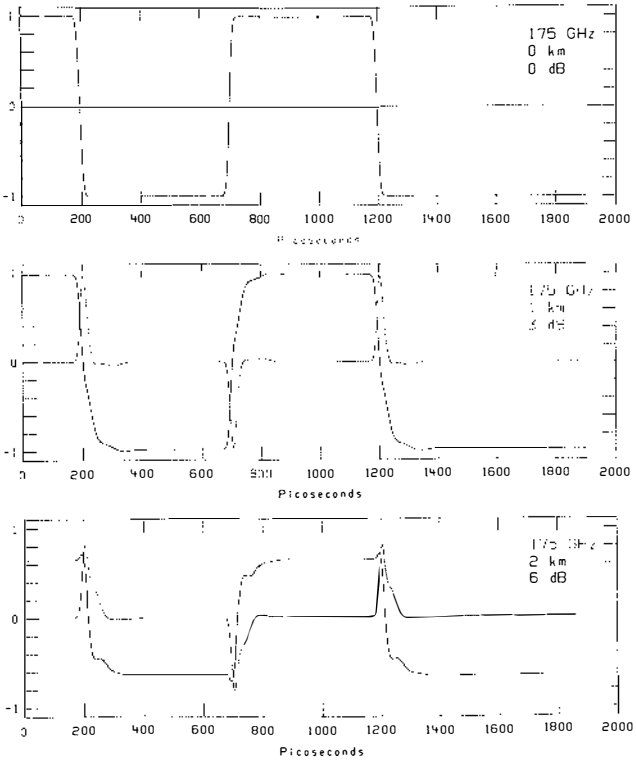
Project personnel (standing l. to r.) Ken Allen, Takeshi Manabe, Hans Liebe, George Hufford, Evan Dutton, Dave Jones, Keith Beasley, and (kneeling) Bob Nemeth, Scott Hector, Chad Carr, and Andy Katz

waves in water. It has a direct influence on the attenuation rate of millimeter waves in rain, fog, clouds, and haze. The new model uses a double Debye term and matches existing data much better than the single Debye model for frequencies above 100 GHz. See the figure below.



At some frequencies, the double Debye model results in attenuation rates that are twice (in dB) those of the single Debye model. An analysis of the distortion of pulses by

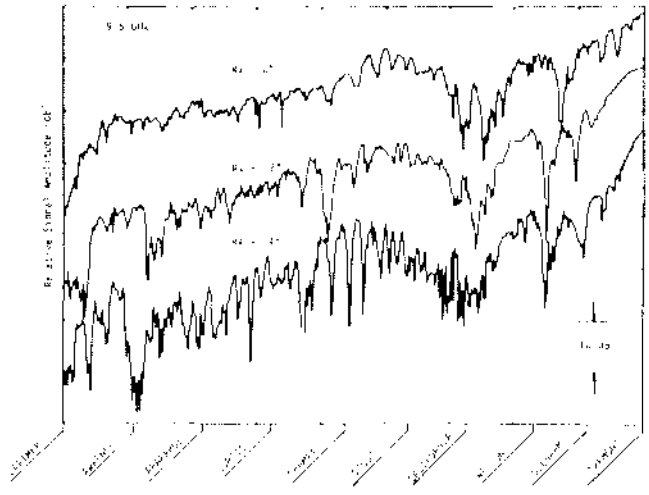
the clear atmosphere (oxygen and water vapor) verified that extremely wide bandwidths are available in the millimeter-wave spectrum. An example of pulse distortion is shown below.



Rain poses the most significant limitation on millimeter-wave telecommunications. Rain rates of 1 inch per hour are capable of attenuation rates as high as 15 dB/km at 96 GHz. In previous years, ITS showed that the rate of attenuation in rain is highly dependent on location and season. Newer measurements conducted in FY 1987 have moved beyond mere attenuation to the polarization dependent effects of rain on phase.

Polarization dependent phase delay is particularly important for polarimetric radars that seek to derive as much information as possible about the target from the radar return. Measurements were made in Alabama at 96 GHz using circular polarization. A relative phase shift between right- and left-hand components was observed in rain on a 1 km path.

A major study of the propagation of millimeter waves in urban and suburban environments was completed in FY 1987. A report describing several years of measurements and modeling effort has been prepared. The results are relevant to the growing local area network communication requirements of computers. The figure following shows an example of the variation of signal amplitude with distance.



During FY 1987, the millimeter-wave telecommunication system design software known as ETSEM (EHF Telecommunication System Engineering Model) was extended to cover not only terrestrial but also Earth-space communication paths. The capability to predict performance for many types of digital modulations and time-division-multiplexed voice channels was also added. This computer program runs on compatible personal computers and is available through NTIA. The ITS model predicts link outage time from propagation losses due to rain, multipath, and clear-air absorption for frequencies from 1 to 300 GHz. It is user friendly and enables the convenient evaluation of the effect of design changes on system availability.

Recent ITS Publications

An EHF Telecommunication System Engineering Model (by Allen)

Complex Permittivity of Water between 0 and 30 THz (by Manabe, Liebe, and Hufford)

Millimeter-Wave Pulse Distortion by a Single Absorption Line Simulating the Terrestrial Atmosphere (by Hufford)

Observed Phase Delay through Rain at 96 GHz (by Allen)

Observations of the Specific Attenuation of Millimeter Waves by Rain (by Allen)

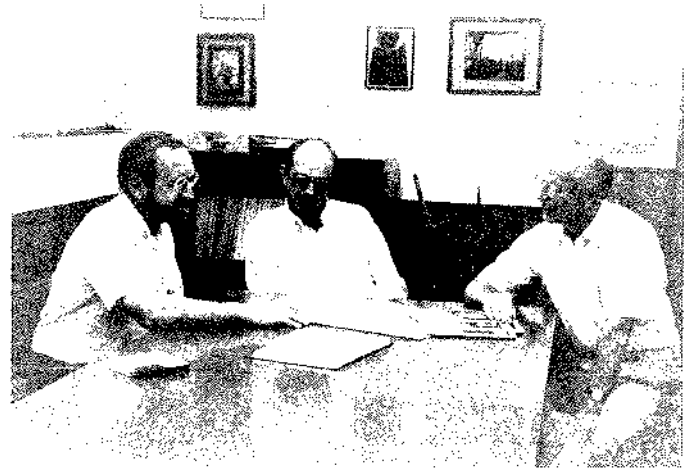
Signal Processing Studies

Outputs

* Statistical-physical models of non-uniform, quasi-static EM signals and non-Gaussian noise fields
* Measurements of non-Gaussian interference processes
* Locally optimum, appropriate suboptimum, and robust nonparametric signal detection and extraction software algorithms
* An Extended Single-Error-State model for bit error statistics

It has long been recognized that in most communication situations, the additive interference is not Gaussian in character, even though most existing systems are basically those known to be optimum in Gaussian noise (when such optimality can be determined, as in the case of simple digital systems). Correspondingly, there has been substantial effort to determine the performance, both by theoretical calculations and by measurement, of such systems. Also, since Gaussian noise is the worst kind of interference in terms of minimizing channel capacity, very large improvements in the performance of systems usually 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 receivers can be realized. These receivers generally take the form of current receivers (based on Gaussian noise), preceded by one or more particular adaptive nonlinearities. Such receiving systems approach true optimality for small signal levels and often perform substantially better than current receivers at all signal levels. Such a receiving system can be 20, 30, or more decibels better than the normal receivers because a signal-to-noise ratio of 20 or more decibels less than currently required will produce the

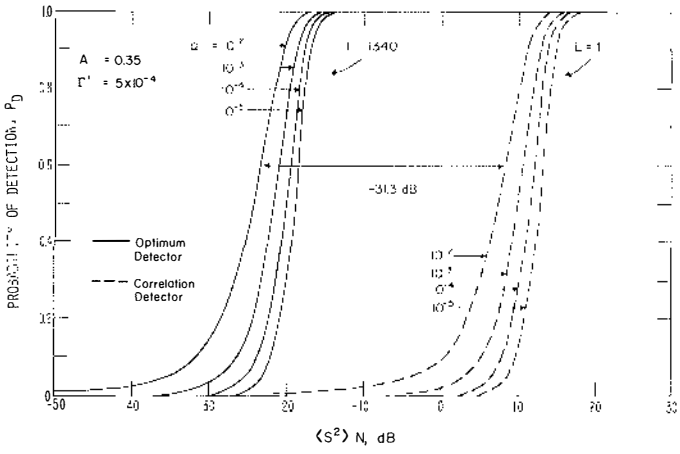


Project personnel (l. to r.) Don Layton, Don Spaulding, and Lew Vogler

than currently required will produce the same performance. Or, correspondingly, a 20 or more decibel smaller signal can be detected.

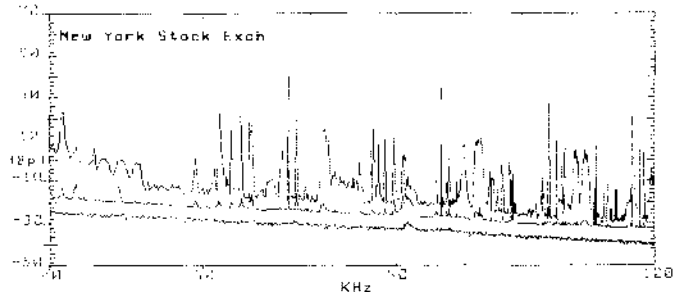
Unfortunately, such gains are achievable only if the number of independent received waveform samples is large for each detection interval. This can reduce information throughput. One way to overcome the requirement for a large number of samples is to use both spatial and time sampling rather than time waveform sampling alone. This has required the development of detection and extraction algorithms appropriate for interference fields and the expansion of the earlier, physical-statistical, non-Gaussian interference models to vector/tensor nonuniform electromagnetic signal and interference field models. Canonical models of non-Gaussian, space-time fields have been developed, based on both scaler and vector Poisson and quasi-Poisson processes. These models play the central role in the structure of optimum threshold detection, extraction, and estimation algorithms. Both optimum and "good" suboptimum processing algorithms have been obtained and their performance evaluated in the general weak-signal regimes, both theoretically and via Monte Carlo computer simulations. The figure following shows an example of the performance improvement

achievable for one sample of narrowband (collection of interfering signals) non-Gaussian interference, giving the probability of detection for various false alarm probabilities.



One aspect of our problem of extracting weak signals from highly non-Gaussian environments is situations where there is significant noise arising from local electromagnetic emissions. This has required the extension of the interference-field models to near field situations. The figure below shows a sample measurement of maximum, minimum, and root mean squared average magnetic field strength in an office environment. These areas typically include computer systems of all types, power and telephone lines, local power sources, and other measurement equipment.

Over a dozen different parameters have been used in describing the transmission accuracy of digital communication systems. Some of the more common ones are bit error rate, block error rate, burst rate, error-free seconds, errored seconds, severely errored seconds, and degraded minutes. Other, more specialized parameters include burst length, burst weight, error-free gap length, burst gap length, and the probability of m or more errors in a block of length n. Some of these are general parameters with many specializations or variants. The Institute has developed a bit error statistics model that provides relationship among the performance parameters of a digital communication channel. The model, called the Extended Single-Error-State model, is applicable to channels characterized not only by independent bit errors, but also to those containing error bursts. Applications of the model to switched network T1 systems and to high-speed fiber optic links are currently being investigated. The model is implemented in a computer program that calculates performance statistics for use in system evaluations and error control procedures.



Recent ITS Publications

A Method of Translating Values Among Error Parameters (by Vogler and Seitz)

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

Effects of Noise and Interference on System Performance (by Spaulding)

First-Order Non-Gaussian Class C Interference Models and Their Associated Threshold Detection Algorithms (by Middleton)

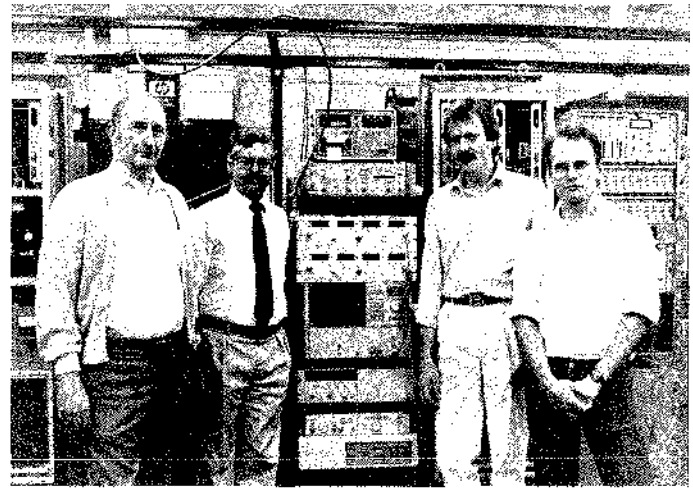
Radio Environment Simulators

Outputs

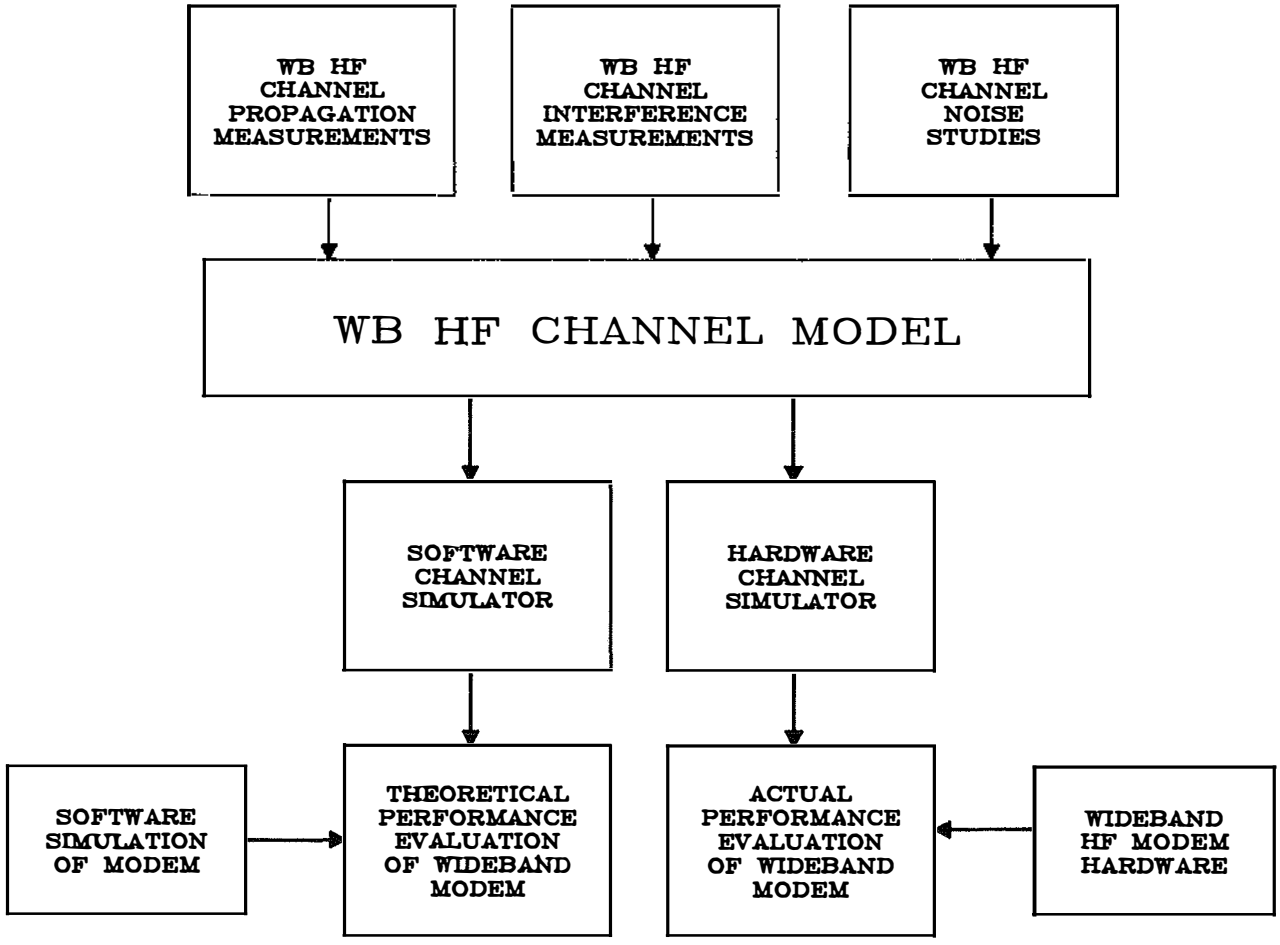
* LOS channel simulator hardware and software
* Wideband HF model

The Institute has played a leading role in channel modeling and simulation for many years. For example, the pioneering work of C. Watterson in narrowband high frequency (HF) channel simulation has been adopted by international standards bodies. This work is currently being extended for wideband HF (greater than 1-MHz) applications.

The figure below depicts necessary steps in the development and application of a wideband HF channel simulator. The Institute has begun this process through a research program whose objective is the



Project personnel (l. to r.) Lauren Pratt, Jim Hoffmeyer, Tim Riley, and Chris Behm



Wideband HF Channel Measurements, Modeling, and Simulation

development of a wideband HF channel model. A model of any propagation channel must be based on empirical data obtained through propagation measurements on the channel. The Institute has initiated a cooperative program with other Government agencies to obtain the required data.

During FY 87 the development of a wideband HF channel model was initiated. The model will be completed during FY 88. As indicated in the figure, a model that has been validated by propagation, interference, noise measurements, and studies can be implemented in either a software or a hardware channel simulator. Software simulation of both the channel and the modem is useful during the initial design phase of transmission equipment. Hardware simulation of a propagation channel is useful in the performance evaluation of transmission equipment after the hardware has been developed.

Channel simulators have been found to be a cost effective means for the performance evaluation of various types of radio equipment. They have the further advantage of permitting a comparative evaluation of radios from several vendors under identical test conditions. The line-of-sight (LOS) channel simulator developed by ITS for testing microwave radios has demonstrated these advantages.

The LOS channel simulator development effort was initiated during the 2 previous fiscal years. During FY 87, a second channel simulator was developed which permits testing of space diversity radios. The simulator was used to test a digital radio being used in the Defense Communications System. Different space diversity switching algorithms were tested using the simulator.

A picture of the simulator hardware developed at ITS is shown below. The simulator is unique because the channel model was implemented at rf and because the simulator and the entire test process is fully automated through microprocessor control.

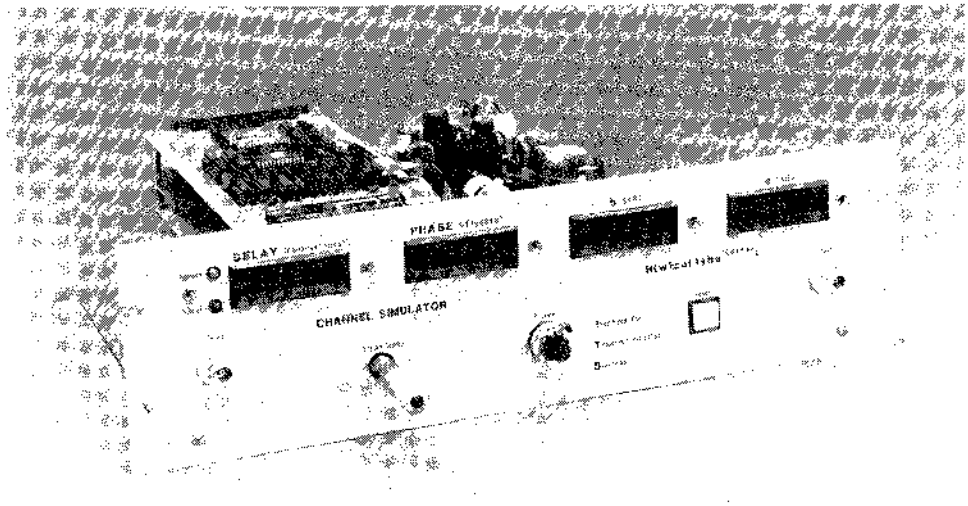
Recent ITS Publications

Measurement, Modeling, and Simulation of Line-of-Sight Microwave Channels (by Hoffmeyer and Vogler)

Modeling of Wideband HF Channels (by Nesenbergs)

Performance Evaluation of LOS Microwave Radios (by Hoffmeyer, Pratt, and Riley)

Wideband HF Modeling and Simulation (by Hoffmeyer and Nesenbergs)



LOS Microwave Channel 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) and Troposcatter Channel Probes - ITS has developed a unique capability for measuring the amount of multipath on either line-of-sight or troposcatter communication links. Multipath is the result of atmospheric refraction of the signal as it propagates from the transmitter to the receiver. Multipath causes a deterioration of radio performance. Channel probes are used to measure the amount of the dynamically changing multipath during the period in which radio performance is being measured. This permits a correlation of the amount of multipath with the performance level of the radio.

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 communication 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.

Propagation Measurement Van - ITS uses this mobile facility to measure the performance of radio systems throughout the spectrum. The receiver is placed on a mobile van and the system makes continuous measurements of the received signal level as the van moves along a planned measurement path. The measurement system is capable of taking samples at many different wavelengths. ITS makes measurements using this facility to improve and validate computer models that provide system designers and users with performance prediction capabilities.

ITS Projects for Fiscal Year 1987 Organized by Department and Agency

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 - William A. Kissick (497-3723) - Develop measures of system performance applicable to the class of advanced satellite communication systems that uses a baseband processor (switch) in the spacecraft.

AM Broadcasting Studies - Eldon J. Haakinson (497-5304) - Provide support to NTIA's Office of Policy Analysis and Development for AM broadcasting studies.

Analysis Services (TASERVICES) - Jean E. Adams (497-5301) - Make available to the public, through user-friendly computer programs, a large menu of engineering models, scientific and informative data bases, and other useful communication tools.

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 Standards/Technical International Conference - Edmund A. Quincy (497-5472) - Provide leadership and technical support to U.S. industry and Government organizations participating in the development of Integrated Services Digital Network (ISDN) standards.

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.

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.

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

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

Spectrum Engineering Models - Leslie A. Berry (497-5474) - Develop and implement spectrum engineering models necessary to effectively manage the Government's use of the radio spectrum.

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.

Thailand Radio Frequency Allocation and Usage - Robert J. Matheson (497-3293) - Advise the government of Thailand on how to set up a modern radio frequency management system.

National Bureau of Standards (NBS)

1206 Test Procedures - John D. Smilley (497-5218) - Develop an updated test procedure to evaluate the performance of the ARMY SG-1206 signal generator.

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 land-mobile communications for law enforcement needs.

Cumulative Gain and Range Plots for Mobile VHF/UHF Antennas - William A. Kissick (497-3723) - Develop cumulative distributions of a set of mobile antenna patterns, and with certain assumptions, develop cumulative distributions of range for the same family of antenna patterns.

National Oceanic and Atmospheric Administration (NOAA)

NOAA Wind Profiler Data Communications - William B. Grant (497-3729) - Assist ERL in the implementation of the data communication system for the Wind Profiler Demonstration project.

National Weather Service

NWS Radar Measurements - John D. Smilley (497-5218) - Measure the emission characteristics of the WRS-74S weather radar at Portland, Maine.

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.

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 Diffraction Model - Ray E. Thompson (497-3352) - Add the capability of special point-to-point propagation analysis to the wide area propagation model.

Air Force (USAF)

MOTES-R Support - Donald H. Layton (497-3741) - Assist the USAF in resolving problems and improving the operation of the MObile Test and Evaluation System-Radar (MOTES-R) receiver system and upgrading the system hardware to accommodate improvements in technology.

Air Force--Electronic Systems Division (ESD)

Feldberg-Schwarzenborn Performance Measurements - James A. Hoffmeyer (497-3140) - Conduct measurement program on the Feldberg-Schwarzenborn link of the Digital European Backbone.

Swingate-Houtem LOS Channel Measurements - James A. Hoffmeyer (497-3140) - Perform measurements on the Swingate-Houtem link of the Digital European Backbone using the LOS channel probe.

TRAMCON 87 - Richard E. Skerjanec (497-3157) - Development, testing, and support for the TRAnsmission Monitor and CONtrol program (TRAMCON) which is being developed to monitor and control the digital transmisison system for the Defense Communication System in Europe.

TRAMCON 87 Software - Richard N. Statz (497-3389) - Continued development, testing, and support for the TRAnsmission Monitor and CONtrol program (TRAMCON).

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.

Wideband HF Channel Modeling and Simulation Study - James A. Hoffmeyer (497-3140) - Study the wideband HF medium leading to its characterization and modeling.

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.

RSMS AF Radar Measurements - John D. Smilley (497-5218) - Make peak effective radiated power measurement on 19 selected AF radar transmitters at a site near Belle Fourche, SD.

Rome Air Development Center (RADC)

Wideband HF Study - James A. Hoffmeyer (497-3140) - Study the wideband HF medium leading to its characterization and modeling.

Army Communications--Electronics Command (CENCOMS)

MMW Studies of Propagation through Conifer Vegetation - Kenneth C. Allen (497-3412) - Measure centimeter and millimeter wave propagation through and around conifer vegetation.

Army Electronics Proving Ground (EPG)

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.

Army Information Systems Engineering Integration Center (ISEIC)

Integrated Radio Systems Analysis - Laurance G. Hause (497-3945) - Update and enhance the interactive computer programs developed to predict the performance of three major types of terrestrial radio transmission 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. orrison (497-5888) - Develop traffic profiles and basic communication model configuration to evaluate the DoD combat support communication 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 communication facilities.

LOS Channel Simulator - Second Channel - James A. Hoffmeyer (497-3140) - Construct a second channel for the line-of-sight (LOS) channel simulators that were developed for the test and evaluation of digital radios that are being procured by the U.S. military.

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 telecommunication 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.

HFMUFS Antennas - Frank G. Stewart (497-3336) - Develop and implement a version of HFMUFS antennas for use on an IBM PC/AT and provide consulting and assistance in implementing and using the antenna package.

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.

Army Training and Doctrine (USA/TRADOC)

C^3I MOE Methodology - Ernest L. Morrison (497-5888) - Define a generic methodology for structuring C^3I MOE hierarchies, and detail the ES rule sets and data support requirements to minimize effectiveness plane ambiguities.

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.

DCA Meteor Burst - William J. Pomper (497-3730) - Assist the DCA in the development of interoperability standards for meteor-burst communications particularly in the area of communication security.

DCS Integrated Node Architecture - Randall S. Bloomfield - (497-5489) - Develop a DCS/DSN integrated access node architecture for the 1995 time frame.

DEB Performance Measurement - James A. Hoffmeyer (497-3140) - Obtain long-term (12 month) user-to-user performance data on a 64 kb/s channel.

NCS Voice Quality - Robert F. Kubichek (497-3594) - Develop an expert pattern recognition system and specify Federal Standards for technology-independent assessment of voice transmission quality.

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.

NSEP/FOCS - David Peach (497-5309) - Apply the multitier hardening specification to a selected fiber optic link in accordance with NSEP goals.

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.

Navy (USN)

NAVY CAD/CAM/CAE Telecommunications - Edmund A. Quincy (497-5472) - Consult on FAN/CAD/CAM/CAE intragateway communications performance specifications.

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 communication system.

NOSC Spacecom Engineering - William J. Pomper (497-3730) - Provide engineering consulting services in support of the development of a classified naval space communication 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.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

ACTS Experiments Coordination - William A. Kissick (497-3723) - Apply the data communication performance standards to experiments and demonstrations and assist NASA in developing an "Experimenter's Handbook," which will describe the format of raw performance data as well as provide a concise ACTS system specification for all experimenters.

Multipath Measurements in the Land Mobile Satellite Radio Channel - John J. Lemmon (497-3485) - Measure and analyze multipath propagation in the land mobile satellite radio channel.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)

Build Refractometer - Kenneth C. Allen (497-3412) - Build a refractometer with only an analog output that has a low-pass filter roll off about 50 Hz.

STATE, DEPARTMENT OF (DoS)

Chilean and Peruvian Assessment - Jean E. Adams (497-5301) - Discuss with government of Chile feasibility studies of rural and urban applications of cellular radio/telephone technology and an expansion of a Chilean satellite system. Also, confer with Peruvian officials concerning Peru's telecommunication capabilities and assess technical merits of a proposal for studying some telecommunication improvements.

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.

U.S. INFORMATION AGENCY (USIA)

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 - Charles M. Rush (497-3821) - 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.

ITS Publications for Fiscal Year 1987

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Allen, K. C. (1987), Overview of the ITS mm-wave program, Proc. NAPEX XI, Virginia Polytechnic Institute and State University, Blacksburg, VA, June 19, pp. 20-23

Bedford, B. L. (1987), A comparison of measured and predicted, 800 MHz, land mobile radio signals, Proc. 37th IEEE Vehicular Tech. Conf., Tampa, FL, June 1-3, pp. 137-144

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Hoffmeyer, J. A., and L. E. Pratt (1987), Evaluation of DRAMA radio performance in a simulated fading environment, NTIA Technical Memorandum 87-120, January, 52 pp.

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Hopponen, J. D., and H. J. Liebe (1986), A computational model for the simulation of millimeter-wave propagation through the clear atmosphere, NTIA Report 86-204, October, 30 pp. (NTIS Order No. PB 87-131173/AS)

Hufford, G. A. (1987), A general model for signal level variability, IEEE J. Selected Areas Commun. SAC-5, No. 2, February, pp. 299-301

Hufford, G. A. (1987), A general theory of radio propagation through a stratified atmosphere, NTIA Report 87-219, July, 40 pp. (NTIS Order No. PB 87-226197/AS)

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