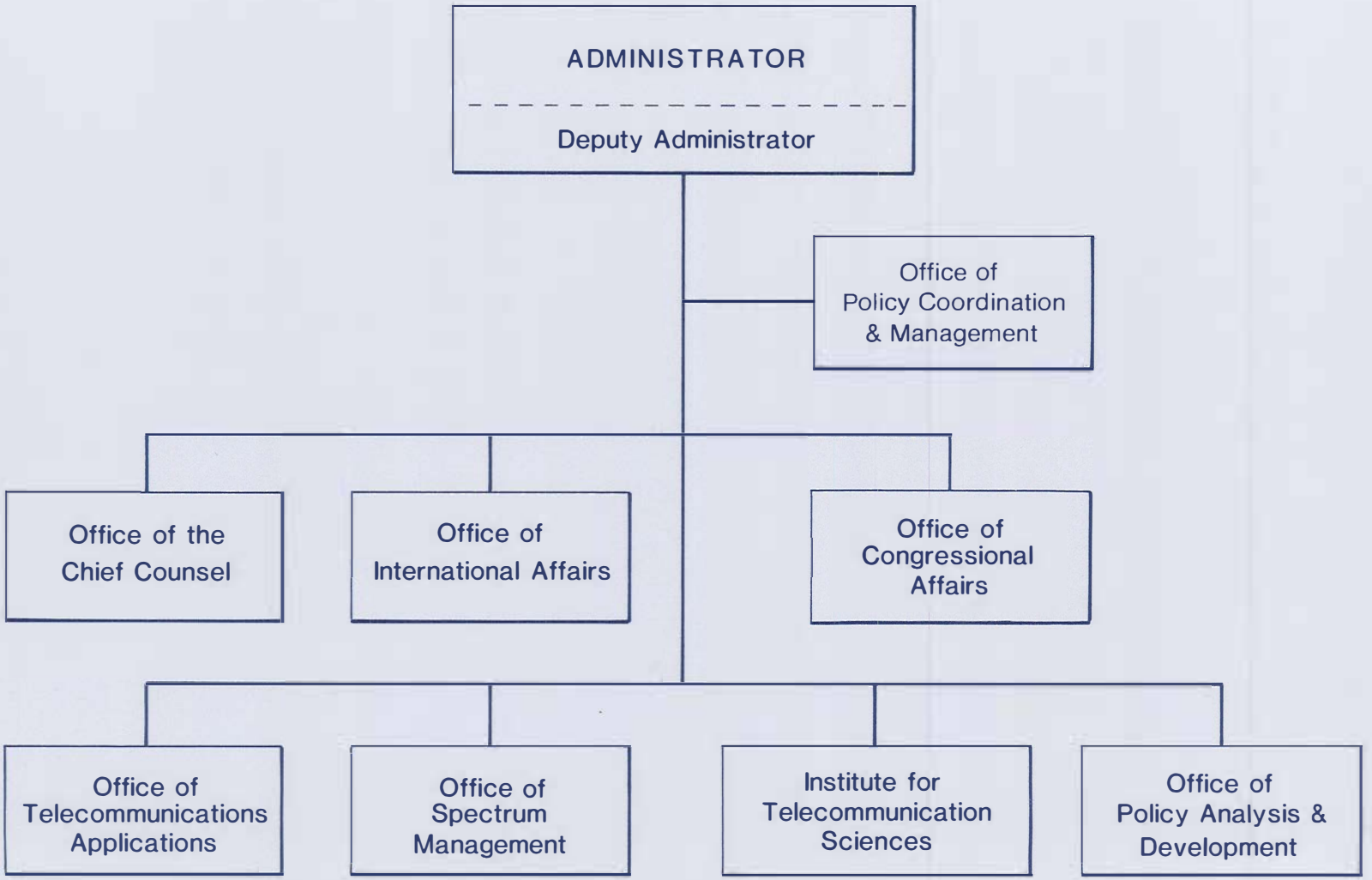
INSTITUTE FOR TELECOMMUNICATION SCIENCES
OF THE
NATIONAL TELECOMMUNICATIONS AND
INFORMATION ADMINISTRATION

ANNUAL TECHNICAL PROGRESS REPORT 1988

For the Period October 1, 1987, through September 30, 1988

U.S. DEPARTMENT OF COMMERCE

National Telecommunications and Information Administration



ITS

ANNUAL TECHNICAL PROGRESS REPORT 1988

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

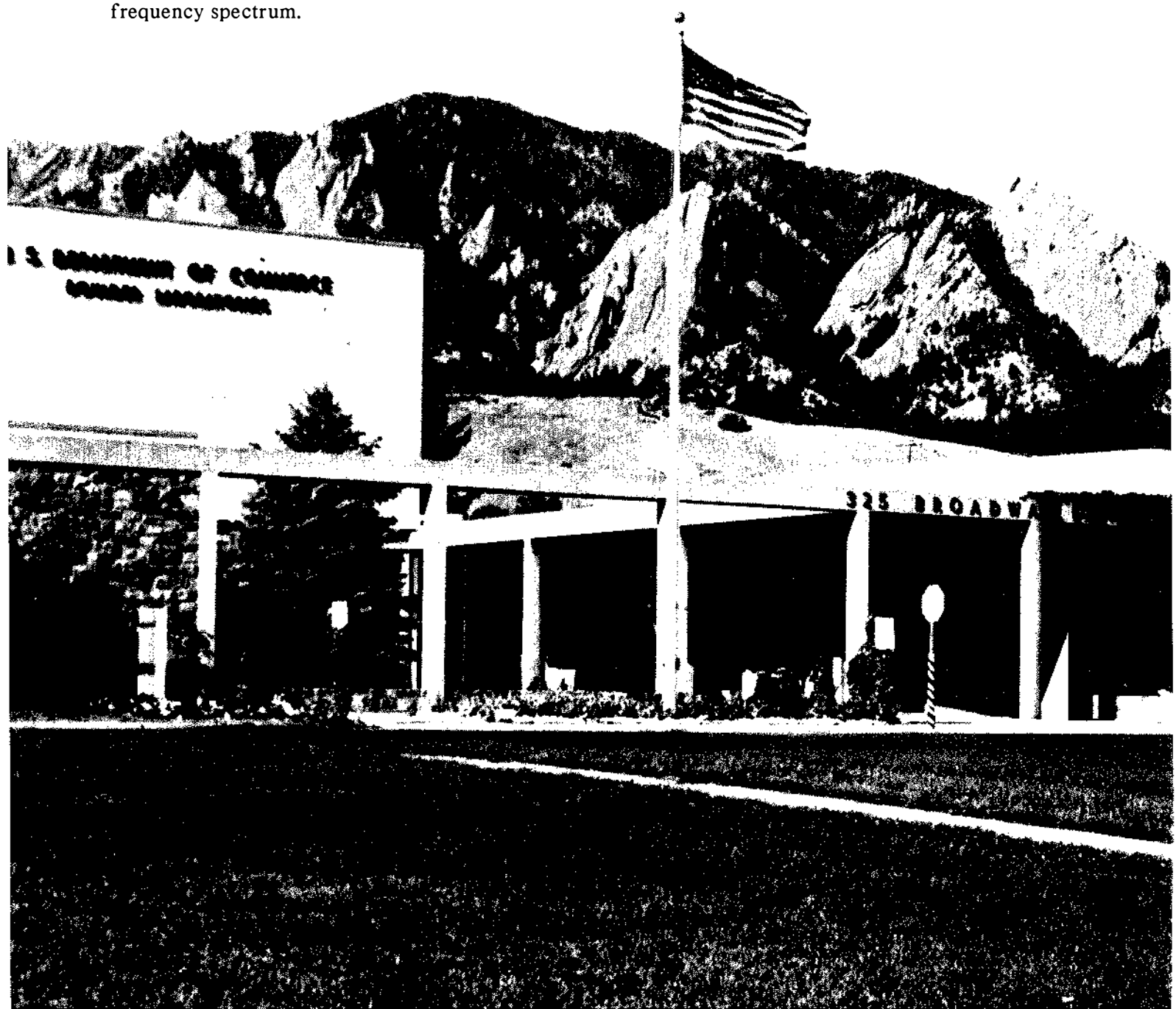
cover photo by Kenneth Spies, ITS

staff photos by Lenora Cahoon, ITS

THE ITS MISSION

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

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



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OVERVIEW

The Institute for Telecommunication Sciences (ITS), located in Boulder, Colorado, is the chief research and engineering arm of the National Telecommunications and Information Administration (NTIA), U.S. Department of Commerce. ITS employs approximately 100 permanent program staff. Many of these employees bring substantial engineering and scientific backgrounds and skills to our technically oriented programs. Indeed, 48% of our employees are electronics engineers, 9% are mathematicians, 4% are physicists, 5% are computer scientists, and 4% are computer programers. During FY 1988, ITS support consisted of $3.2 M of direct funding from Commerce and $5.6 M in work sponsored by other Federal agencies.

ACTIVITIES

In achieving its mission, the Institute performs state-of-the-art telecommunication 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 restoral 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.

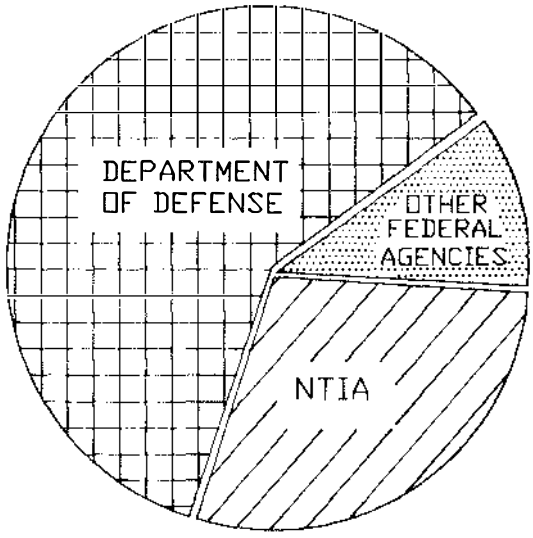
HISTORY

ITS had its organizational beginning during the 1940's as, first, the Interservice Radio Propagation Laboratory and then later as 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 to 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 1988 technical contributions made by ITS that have significance for the public and private sectors.

Alfred C. Sikes, Assistant Secretary for Communications and Information, addresses Boulder Laboratories staff and guests at NTIA TELECOM 2000 presentation.


O'Day


Matheson


Utlaut


Seitz


Salaman


Cahoon


Bachinski

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Budget and Administration
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Technical Publications
Lenora J Cahoon

Propagation Model Development and Application
Dr. A. Donald Spaulding, Chief

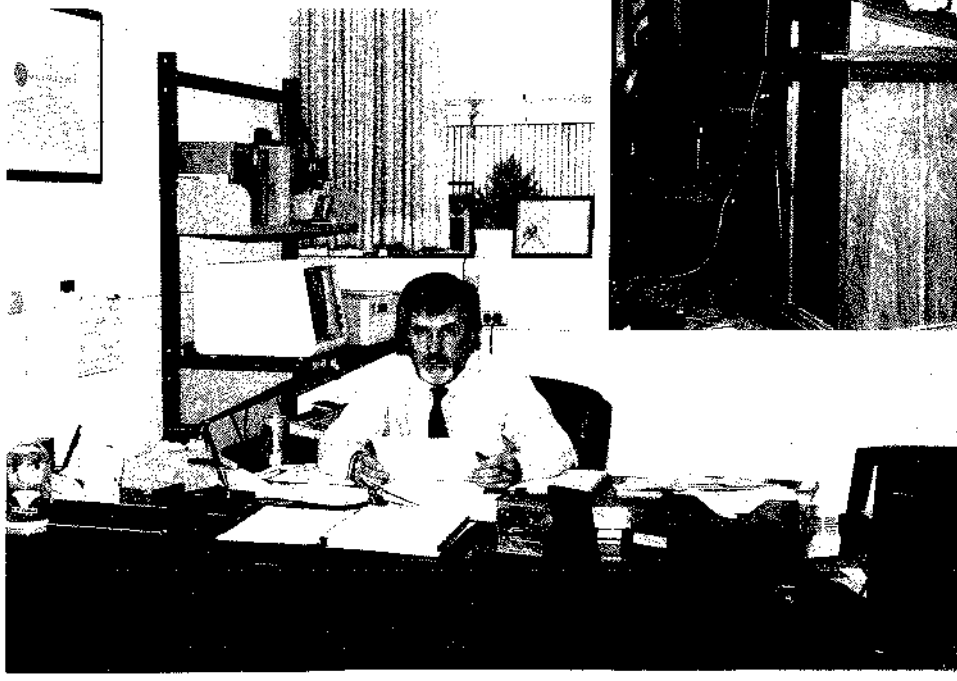
Spectrum Management Analysis and Concept Development
Jean E. Adams, Chief

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
Robert T. Adair, 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

CCIR Activities

Includes projects funded by the National Telecommunications and Information Administration

Domestic Spectrum Analysis

Includes projects funded by the National Telecommunications and Information Administration

Spectrum Usage Measurements

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

Telecommunications Analysis Services

Includes a project funded by reimbursement from subscribers

International Radio Conference Support

Outputs

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

Institute personnel have actively participated in the preparation and defense of U.S. positions at international and regional radio conferences. Institute personnel are continuing to assess the decisions of the Second Session of the High-Frequency Broadcasting Conference. A planning algorithm developed by ITS to predict how these decisions impact U.S. broadcasting objectives guides the United States in its preparations for a third session of the Conference, which is scheduled for the 1992/1994 time frame. The Institute is actively testing these decisions to determine their detailed impact on U.S. broadcasting objectives. The Institute is also working closely with U.S. broadcasters to determine the optimum manner for the United States to submit its broadcasting requirement to the IFRB, who will also be performing detailed tests.

In addition to the technical studies related to planning, the Institute is a primary force in providing data to the IFRB for identifying locations of jammers of western HF broadcasts. These data result from a worldwide data collection effort coordinated by the Institute. These monitoring campaigns are called for in the Final Acts of WARC-HFBC (87).

The Institute has also played a leading role in 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)]. Representatives from ITS participated in both the Joint Interim Working Party meeting [JIWP-ORB(2)] in December 1987 and in the full WARC-ORB(2) between August 29 and October 5, 1988.

ITS personnel actively contributed to the development of an allotment plan for Fixed Satellite Service (FSS) in specific frequency bands, which was one of the conference's primary objectives. To provide a technical basis for producing and verifying this plan, complex computer software has been developed by the United States and provided to the

HFBC Planning Team: Greg Hand and Mary Sowers (standing) and (seated from left) Les Berry, Jim Washburn, and Jeanne Wakefield

International Frequency Registration Board (IFRB). A model was developed for computing the minimum area elliptical beam for the spacecraft antenna created by ITS and utilized by the IFRB.

WARC-ORB(2) Team: (from left) Hiroshi Akima, Darren Smith, and Ray Jennings

ITS also provided leadership in using the ORBIT-II model developed by Japan to perform allotment planning exercises for the benefit of the U.S. Delegation to WARC-ORB(2) and was the only U.S. agency to successfully complete some of the exercises prior to the conference.

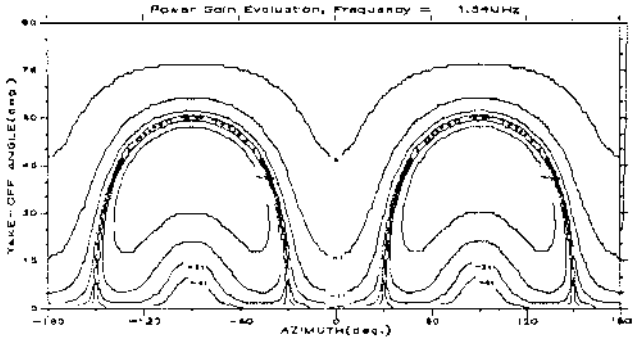
Another model useful for allotment planning is the Geostationary Satellite Orbital Analysis Program

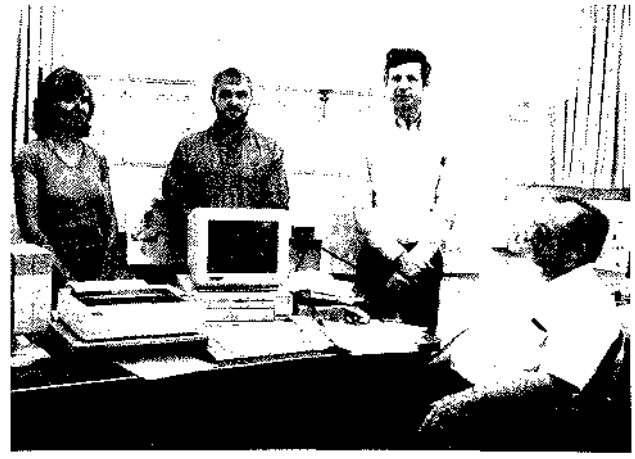
(GSOAP), which analyzes interference between neighboring satellite networks. This program was previously developed by ITS for conference work and has been updated and used to evaluate the solutions provided by ORBIT-II.

To provide a technical basis for producing and verifying this Allotment Plan, complex computer software has been developed by the United States and other ITU member nations and provided to the IFRB. A model for computing the minimum area elliptical beam for the spacecraft antenna is one example of software created by ITS and utilized by the IFRB for this purpose. ITS also contributed to the development and testing of the NASARC and ORBIT-II computer programs in conjunction with other U.S. organizations that participated in conference preparations. Five successive versions of ORBIT-II were installed, tested, and exercised during FY 88, using the ITS Systems and Networks Division's Pyramid 90X super-minicomputer.

In addition to allotment planning, the Institute also addressed the technical issues regarding the reference Earth-station antenna pattern and defined other technical standards and parameters related to WARC-ORB(2) objectives. For example, discontinuities were discovered in the composite Earth-station antenna pattern adopted by the JIWP-ORB(2) Conference. These were corrected through a U.S. Delegation Information Paper, "Recommended Modifications of the Composite Earth-Station Antenna Pattern." Additionally, ITS produced a U.S. Delegation Position Paper entitled "Earth-Station Antenna Characteristics (Reference Pattern) for Allotment Planning" and authored a Department of State letter to the IRFB, responding to the Revised ORB System Report.

ITS is modifying the medium frequency (MF) analysis program that is used by the IFRB to determine the coverage and interference limits of MF broadcast stations. The modifications will allow the use of a new type of antenna being used by the Voice of America for a broadcast station in Belize. The Belize antenna was modeled and a program was coded that calculates antenna gain for use with the IFRB analysis program. The antenna is a rectangular array of evenly spaced horizontally polarized dipole elements. The user must define the number of broadside elements and the number of end-fire elements (rows), the interelement spacing, and electrical phasing. The model then calculates the power gain of the antenna that includes the effects of a curved Earth and the coupling between elements. The Belize antenna consists of two rows of four dipole elements spaced 74 m between rows. The element feeds are spaced 97.54 m apart in each row and are 55 m above ground. The power pattern calculated for this antenna is shown in the figure at the top right.





MF Modification Team: (from left) Jan Geikas, John Godwin, Nick DeMinco, and Jean Adams

Recent ITS Publications

A High-Frequency Spectrum Utilization Model (by Rush, Washburn, and Berry)
Earth Station Antenna Characteristics (Reference Pattern) for Allotment Planning (by Jennings)
The Results of WARC-HFBC(87): Technical Implications (by Rush, Jacobs, and Richards)
Use of Precalculated Data of Minimal Elliptical Beams of Satellite Antennas (by Akima)

CCIR Activities

Outputs

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

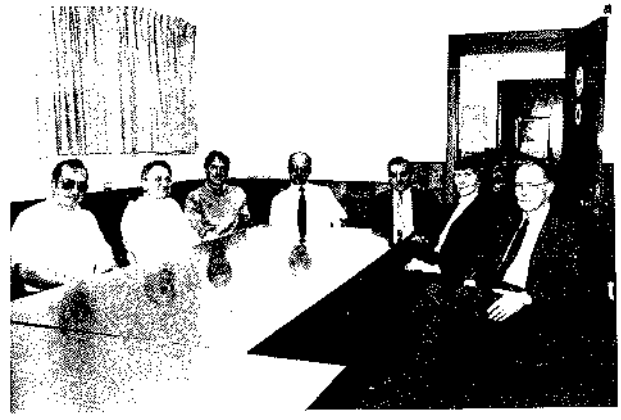
The International Radio Consultative Committee (CCIR) is one of the two consultative committees of the International Telecommunication Union (ITU), the International Telegraph and Telephone Consultative Committee (CCITT) being the other. Both of these committees are permanent organs of the ITU.

All the member countries of the ITU as well as certain private organizations can participate in the work of the CCIR. The work of the CCIR provides the basis for decisions that lead to efficient use of the spectrum for telecommunication applications. The reports and recommendations of the CCIR are used by radio conferences to establish technical criteria that form the basis for spectrum allocation decisions and spectrum use on a global and a 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. It is to this end that much of the CCIR work undertaken by the Institute is directed.

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.

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 until an Interim or Final Meeting. In this instance, the CCIR creates an Interim Working Party (IWP) to address the issue and generate a report or other approved document that is forwarded for consideration 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



Project personnel (from left) Jean Adams, Les Berry, Eldon Haakinson, Don Spaulding, Ray Jennings, Marcie Geissinger, and Bill Utlaut

Study Groups

1 Spectrum Utilization and Monitoring
2 Space Research and Radioastronomy
3 Fixed Service at Frequencies Below About 30 MHz
4 Fixed-Satellite Service
5 Propagation in Non-Ionized Media
6 Propagation in Ionized Media
7 Standard Frequencies and Time-Signal
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

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, 4, 5, and 6. These efforts address issues related to spectrum efficiency and use, satellite fixed-service operations, modification of the texts of Study Groups 5 and 6, and development of methods to improve on the global representation of ionospheric parameters.

Efforts at ITS that are directed to U.S. CCIR concerns in the past year have emphasized participation at the Interim Meeting and the Space WARC. Two Institute engineers were delegates to the Interim Meeting of Study Group 1 in April 1988. One important result of the meeting was a Draft New Report and Study Program concerning criteria for the shared use of the VHF and UHF bands allocated to the broadcasting and land mobile radio services. Another important development was the decision to create a mechanism for establishing priorities and the future direction of the work of the Study Group. An ad hoc committee was formed, and a draft planning document was written. Institute engineers are now beginning preparation for the Final Meeting of Study Group 1 to be held in October of 1989.

Institute activities related to Study Group 3 were directed at establishing the criteria for sharing the expanded AM broadcast band (1605-1705 kHz) between the broadcast service and other services. This work was performed in preparation for the Second Session of the Region 2 Conference on Broadcasting in the Band 1605-1705 kHz.

The emphasis in the Institute's CCIR Study Group 4 work during this past year was directed primarily to issues related to preparation for the Second Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It [WARC-ORB(2)]. Studies were undertaken and reports were written on a broad range of topics including Earth-station antenna radiation pattern characteristics, digital satellite communication systems, conceptual approaches and technical characteristics to be used for allotment planning, and the Joint Interim Working Party (JIWP) Meeting of Study Groups 1, 2, 4, 9, 10, and 11. Contributions from the Institute at the Study Group 4 Interim Meeting and a special meeting of Study Groups 1, 2, 4, 9, 10, and 11 dealing with [WARC-ORB(2)] preparations included papers on Earth-station antenna gain characteristics, the sidelobe levels for reference Earth-station antenna patterns, standardized technical characteristics for allotment planning, and comments on a paper that recommended a methodology for calculating the elliptical beams for satellite antennas as a step in the allotment planning process.

In the area of support to Study Group 5, the Institute concentrated its efforts at the Interim Meeting on the improvement of the CCIR report dealing with millimeter-wave propagation and propagation effects in the land mobile and broadcast bands in the VHF/UHF parts of the spectrum.

The activity undertaken by Institute personnel to support Study Group 6 work is being derived primarily to assure a sound technical basis for U.S. high-frequency broadcasting interests as well as reviewing and updating the texts of Study Group 6 where appropriate. Engineers at ITS also undertook 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.

CCIR Conseiller T. Takasugi and Jean Adams of ITS, International Vice Chairman of SG-3, Conducting a Session at the Interim Meeting of CCIR in Geneva

Domestic Spectrum Analysis

Outputs

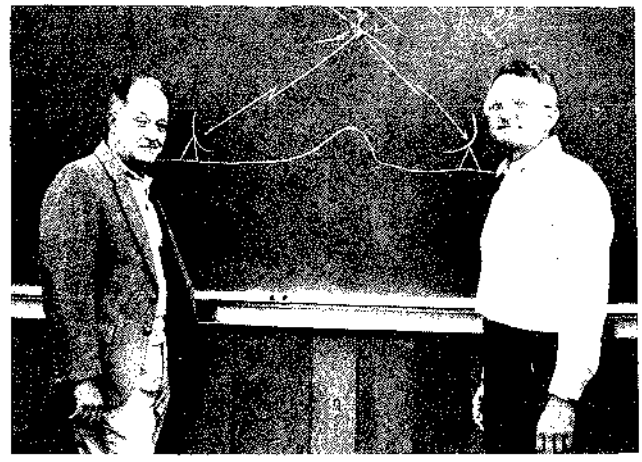
- Spectrum use measure concept development and calculation
- Spectrum resource assessments on high-frequency radio band and meteor-burst systems
- Optimum frequency selection for HDTV scenarios and proposed FAA radars

One of the important developments for NTIA in the area of spectum efficiency was a new and innovative approach to analyzing use of the radio spectrum. The Spectrum Use Measure (SUM) data base, for the first time, joins the technical properties of the radio spectrum to the geographical dimension in a manner that allows for the quantification, measurement, and graphic display of how the Nation's spectrum resource is used.

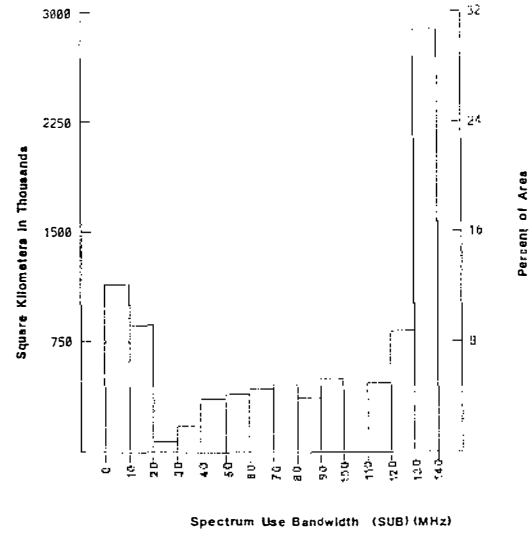
While the physical properties of the invisible spectrum resource are well understood by radio engineers, they are less well appreciated by policy makers and system users. Yet it is important that the management of this critical resource be carried on in such a way as to render understandable and visible the nature of spectrum use. Costs must be assessed, benefits understood, and objective decisions made. An accurate measure of what is available and the geographic costs of a proposed use will better equip us to make balanced decisions. The SUM data base provides this capability.

The SUM model was developed by a team from the Institute and from the Office of Spectrum Management of NTIA. It was applied to the 7750-7900-MHz band and the 1710-1850-MHz band to test its feasibility and to illustrate its benefits. In the future, its capabilities will be expanded to cover more types of radio services and will be used to evaluate the need for and the efficacy of spectrum standards.

The figure shown at the right is an example of output from the SUM data base. It shows the percent of the area of the contiguous United States in which various parts of the 1710-1850-MHz band are used. The horizontal scale shows the amount of bandwidth used in the band, and the right vertical scale shows the percent of area in which that much bandwidth is used. Notice that all of the band (140 MHz) is used in 30 percent of the area of the United States. On the other hand, this band is not used at all in 12 percent of the United States. Another output of the SUM data base is a map showing contours of equal spectrum usage in this band in the United States. Further details are available in the report referenced at the end of this section.



Project personnel Ken Steele (left) and Les Berry



Area and Percent of Area for Various Values of Spectrum Use Bandwidth (SUB) in the 1710-1850-MHz Band

We have also provided information on the availability of spectrum for advanced TV systems. These systems provide higher definition, aspect ratios more favorable for movies, and other desirable features. It is possible that these systems

will require more bandwidth than is provided by the standard 6-MHz TV channel. The FCC formed the Advisory Committee for the Advanced Television Service (ATV) to study the issues and provide guidance in this area. To help this Committee determine the feasibility of providing the necessary bandwidth within the current television bands, we provided them with optimum frequency assignment of supplements for a large number of scenarios in which the supplement bandwidth and required protection ratios were varied. These results were used in the Advisory Committee's report to the FCC.

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 spectrum resource assessment completed in FY 88 was to examine the impact of the expanded use of meteor-burst communication systems on Government VHF spectrum and to identify approaches toward effective spectrum management of this technology. The geometry for meteor burst systems is shown in the figure below.

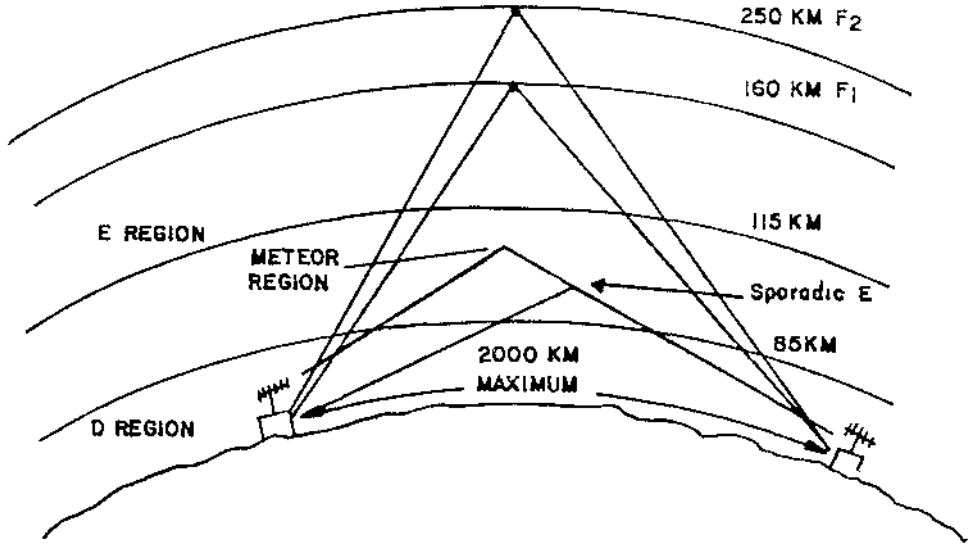
There has been increased interest in meteor-burst systems for long-range VHF beyond-the-line-of-sight communications and telemetry. These systems operate from 40 to 50 MHz. Meteor-burst systems are particularly useful in remote areas of our western states.

The assessment effort has shown that the subbands 39.986-41.015 MHz should be emphasized in order to minimize interference from cordless telephones, and during auroral absorption events subbands 46.6-47.0 and 49.6-50 MHz can be used to advantage. Interference problems may arise from land mobile systems or from adaptive rate meteor-burst systems. Accordingly, the Government should maintain awareness of meteor-burst system usage and technology. Additional study may be needed to identify specific dedicated frequencies for future systems.

There are proposed changes in the rules for the operation of small, unlicensed radiation devices. These changes conceivably may adversely impact Government systems or the reverse. To examine these possiblities, the Institute has developed a technique for determining output spectra, polarization, field strength, and radiation patterns of these devices. This technique will be applied to devices specified by OSM in the next fiscal year.

Recent ITS Publications

The SUM Data Base: A New Measure of Spectrum Use (by Berry and members of OSM).



Meteor Burst System Geometry

Spectrum Usage Measurements

Outputs

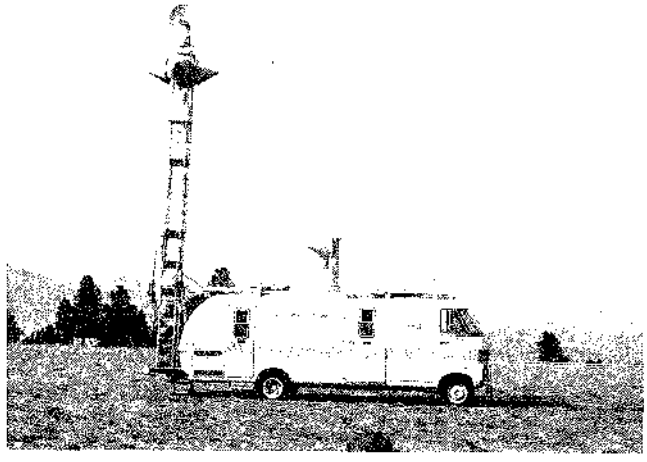
- NTIA spectrum surveys at
  - Atlanta
  - Seattle
- Seismic network interference resolution
- Radar emission spectra
- Air Force site surveys at
  - White Sands Missile Range
  - China Lake Naval Weapons Center
  - Edwards Air Force Base
- Air Force monitoring van design

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 the following:

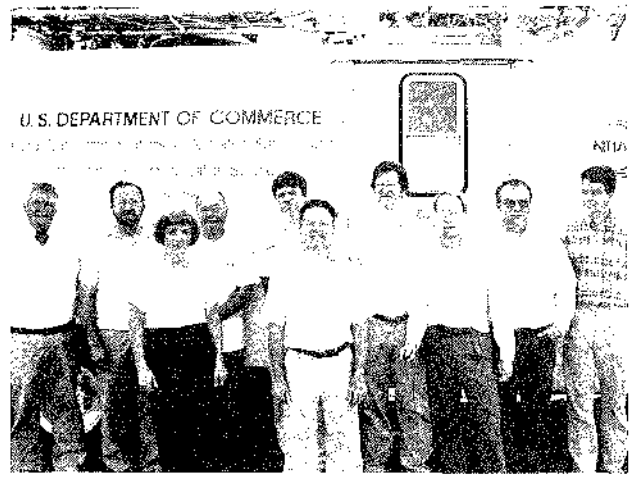
Occupancy measurements to show how much of the time a particular frequency is occupied by radio signals.

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

Compatibility measurements to show whether signals will cause interference to each other.



Radio Spectrum Measurement System Performing a Site Survey



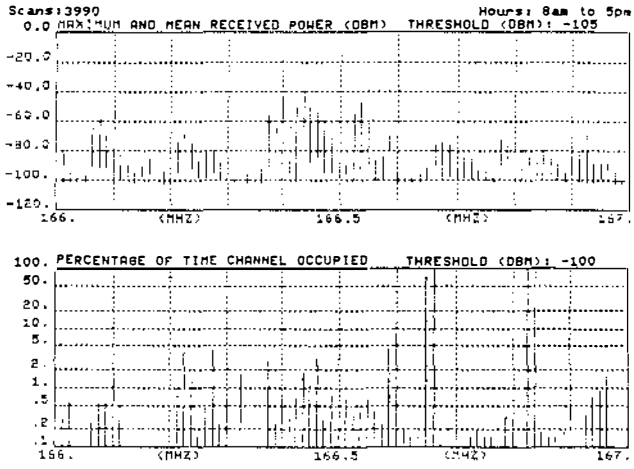
Project personnel (from left) John Smilley, Don Layton, Jane Russell, Gary Gierhart, Bob Achatz, Bob Matheson, Mike Laflin, Frank Sanders, Vince Lawrence, and Brad Ramsey

The main function of these measurements is to 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.

The RSMS contains two independent measurement systems--one optimized for radar measurements and one optimized to measure narrowband voice channels (e.g., land-mobile radio or LMR). Both measurement systems can simultaneously and continuously measure frequency bands selected from a preset schedule. This allows efficient sampling of frequency usage over a period of a week or more, giving good statistical information on signals encountered at each frequency in many frequency bands.

The radar system makes measurements at frequencies up to 18 GHz with bandwidths of up to 30 MHz. Special hardware allows radar pulse train separation, measurements of peak amplitude, automatic direction-finding, and pulse blanking. The recent addition of a digital oscilloscope provides for measurement of radar pulse shape characteristics. The LMR system operates up to 1 GHz using rectangular bandpass filters with bandwidths in the 3-30-kHz range. LMR channel occupancy is measured and analyzed at the rate of 150 channels per second.

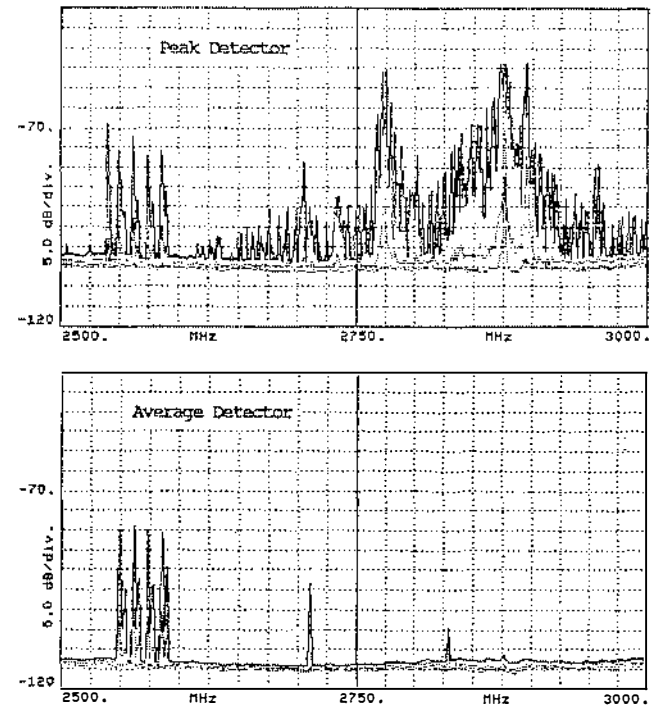
Spectrum usage measurements are made to show which Government frequency bands are crowded and which ones still have some room for new systems. Comparisons between measured signals and assigned signals also serve as a quality check on the accuracy of the frequency assignment listings. During measurements of spectrum usage in large metropolitan areas (Atlanta and Seattle in FY 88), 12 radar bands and 4 LMR bands were measured for a 2-week period at each site. These systematic measurements are used to maintain a library of spectrum usage statistics (like the mobile radio band below) showing which frequency bands are crowded and which are not.



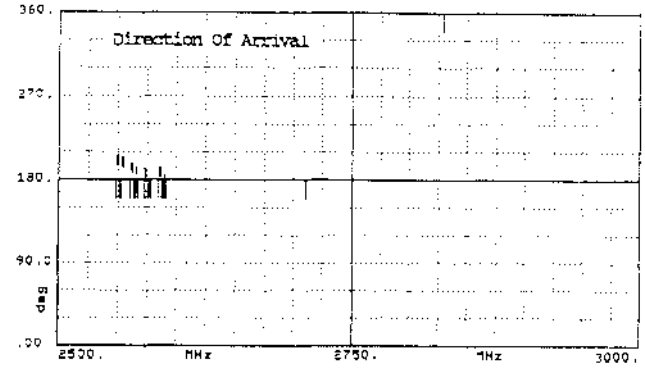
Example of Usage Measurements in a Mobile Radio Band. The upper graph shows the percentage of time that each channel was used; the lower graph shows maximum and average signal levels.

In October 1987, we helped the Department of Interior resolve a serious and elusive interference problem with an extensive seismic warning network in the state of Washington (remember Mt. St. Helens?). We made a series of spectrum measurements across the state using lightweight, battery-operated equipment. These measurements provided the information needed to successfully modify the network to eliminate the problems.

This year the Air Force funded us to use the RSMS for radio site surveys over the 0.15-18-GHz range at three sites proposed for a new Air Force test range facility. We developed new software for the RSMS that measures simultaneously with peak and average detectors, providing good intercept probability for all types of signals. A comparison of the peak and average responses provides clues to the types of signals present at each frequency. In the examples at top right, the radars in the 2650-3000-MHz range are very visible in the "peak" graph, but cannot be seen on the "average" graph. However, the microwave signals around 2550 MHz are seen best on the average detector graph.



The new program also provides approximate information on the direction that signals come from. Measurements are made using antennas pointed in four directions. By knowing the relative signal amplitudes and the antenna pattern, we make a calculation of approximate direction-of-arrival for received signals. The calculated direction of the microwave signals is shown below to be coming from the south (near 180 degrees).



Based on our experience with the RSMS, we are beginning the design of a small range management system for the Air Force Utah Test and Training Range (UTTR). This system will incorporate many of the functions of the RSMS, but in a smaller van using commercially available equipment. The control and calibration software will closely follow techniques developed to give the RSMS many of its automatic capabilities. We are designing the software in such a way that many automated capabilities are easily available to relatively untrained operators.

Telecommunications Analysis Services

Outputs

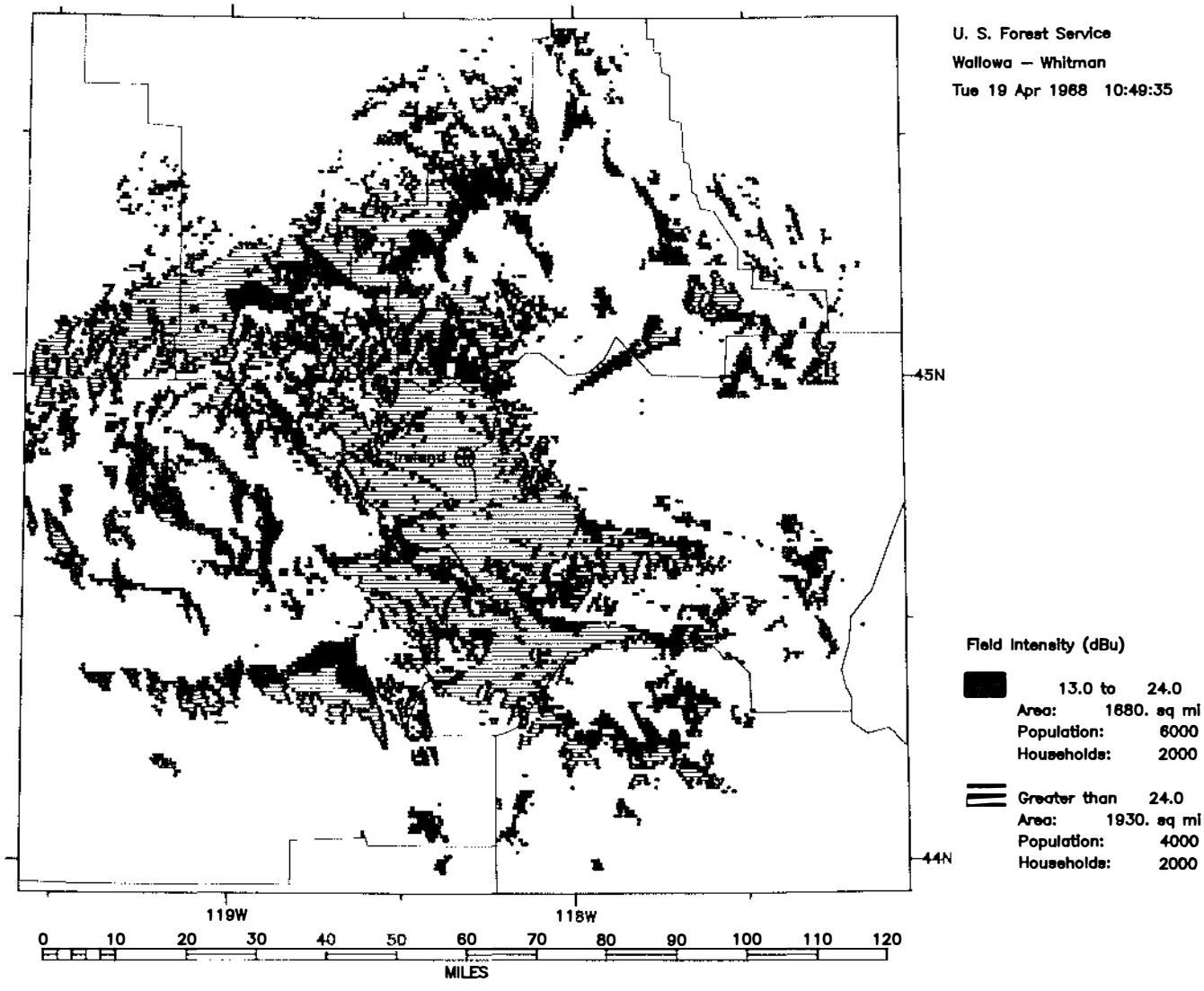
- Easy access for U.S. industry and other Government agencies to the latest in ITS research results and to ITS engineering models and data bases
- Broad applications in telecommunication system design and evaluation of broadcast, mobile, link, and radar systems
- Standard method of system analysis for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

Telecommunications Analysis Services, or TAS, is a group of user-interactive programs that allow other Government agencies, private businesses, and telecommunication consultants the opportunity to use telecommunication analysis tools that have been developed by the Institute. Nearly all of the programs utilize algorithms and data bases that were created to solve a specific engineering problem and have since been modified to be applied to much wider problems. The TAS programs are accessible by dialing and acoustically coupling to a computer at the Institute's Boulder Laboratories. The TAS user pays for the time spent using the programs and for any off-line analyses by those programs. The results of computations that are made off line are sent to the user the next day.

One of the TAS programs is named the Communications System Performance Model (CSPM). To use the model, the user dials the TAS computer, selects CSPM, and answers the program's questions about transmitter location, power, antenna gain, frequency, analysis boundaries, etc. The computations are made off line and produce a plot similar to that in the figure on the opposite page. This particular analysis shows the signal coverage from one of the hilltop transmitters located in the Wallowa-Whitman National Forest in Oregon. The model computes coverage by analyzing the signal attenuation along radials that extend out from the transmitter location. Along each radial, the terrain profile is extracted from the Institute's topographic data base. Based on the terrain, antenna heights, frequency, and analysis parameters, the model computes the attenuation at approximately 1-km intervals along the radial and stores these loss values in memory. Depending upon the distance to the analysis borders, the radials are spaced approximately at 1-deg intervals around the transmitter location.

Project personnel (from left) Mary Luyk, Eldon Haakinson, Yeh Lo, Jan Geikas, and Jean Adams

The user selects the signal level(s) to be plotted; in this case, the field strength level of 13 dBuV/m (and greater) represents the level at which the hilltop transmitter can reliably be heard and the level of 24 dBuV/m is the field strength at which the mobile transmitter can be reliably heard at the hilltop receiver. In the figure, the lightly shaded areas represent those regions in the forest where the mobile can hear and communicate with the hilltop. The solid black areas indicate where the mobile can probably hear the hilltop but cannot reliably return the communications. Finally, the white areas represent the regions of the forest where communication in either direction does not meet the required reliability. The solid lines on the map show state and county boundaries. The legend gives the total area that is within the range of the specified field strengths, e.g., the area on the map that has field strength levels between 13 and 24 dBuV/m is 1680 sq mi. The population and household numbers that are given in the legend are computed from the 1980 U.S. Census data. The Institute's computer can make color plots on large film sheets in the proper scale to overlay on maps. These overlays assist the system designers to determine where coverage is adequate or where additional transmitters will be needed to fill in holes. The CSPM programs can also be used to show coverage from many transmitters or can show interference regions between transmitters.



Sample Output of TAS's Communication System Performance Model

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 that 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

CCITT Activities

Includes projects funded by the National Telecommunications and Information Administration

Digital Network Performance Standards Development

Includes projects funded by the National Telecommunications and Information Administration

Voice Quality Standards Development

Includes projects funded by the Defense Communications Agency and the National Telecommunications and Information Administration

Video Quality Standards Development

Includes projects funded by the National Telecommunications and Information Administration

Radio Systems Interoperability

Includes projects funded by the Defense Communications Agency

Building Telecommunications Architecture and Wiring Standards Development

Includes projects funded by the Defense Communications Agency

CCITT Activities

Outputs

- U.S. CCITT leadership
- Technical contributions
- Proposed CCITT Recommendations

The International Telegraph and Telephone Consultative Committee (CCITT) has become a principal forum for planning future telecommunication services and networks worldwide. CCITT Recommendations strongly impact both the development of telecommunication technology in the United States and the viability of U.S. products in international trade. The Institute contributes to CCITT activities by leading U.S. CCITT preparatory committees, conducting technical studies of CCITT standards issues, and developing proposed new Recommendations on topics of particular interest to U.S. Government and industry organizations.

The Institute provides strong support to the U.S. Department of State in leadership of the U.S. organization for the CCITT. During FY 88, Institute personnel chaired the U.S. CCITT Joint Working Party (JWP) on ISDN, organized and chaired five U.S. CCITT preparatory meetings, served on the U.S. CCITT National Committee, and headed the U.S. Delegations to three major CCITT meetings. This work culminated in the achievement of a major U.S. CCITT objective: Study Group XVIII approval of new Recommendations defining a synchronous digital hierarchy and network node interface for broadband integrated services digital networks (ISDNs). These Recommendations will hasten the worldwide evolution of video communication services and will strongly influence a multibillion dollar market for broadband transmission equipment.

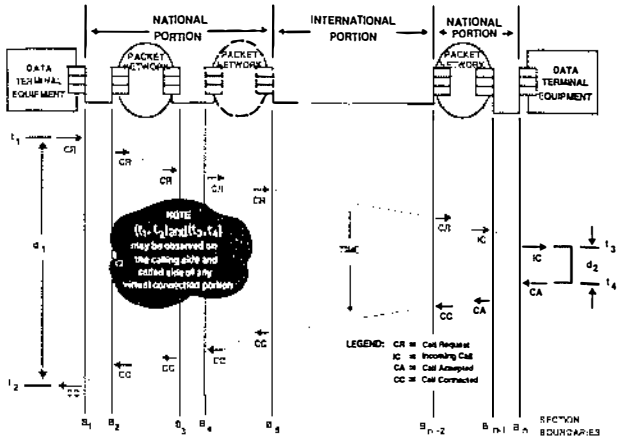
The Institute also provides leadership in CCITT Study Groups and in ANSI-accredited standards committees that contribute to CCITT activities. During FY 88, Institute staff members headed the CCITT Study Group VII Special Rapporteurs Group on Question 29 and two key standards groups within the ANSI-Accredited T1 (Telecommunications) Standards Committee--Subcommittee T1S1 and Working Group T1Q1.3. The Question 29 Rapporteurs Group is responsible for developing CCITT Recommendations on the performance of public data networks. Subcommittee T1S1 develops American National

Project personnel (from left) Bob Kubichek, Dan Tomich, Marcie Geissinger, Bill Utlaut, Kathy Mayeda, Randy Bloomfield, and Neal Seitz

Standards on ISDN services, architectures, and signaling and is the principal source of U.S. inputs to CCITT on these subjects. Working Group T1Q1.3 develops national standards and contributes to CCITT recommendations dealing with the performance of packet-switched networks and ISDNs.

During FY 88, the Institute's technical contributions to CCITT were focused on network performance specification. The Q29 group completed four new Recommendations on the performance of international packet-switched services. Recommendation X.134 defines apportionment boundaries and packet layer reference events that provide a basis for performance description. The boundaries are physical interfaces at which CCITT Recommendation X.25 or X.75 procedures are used, and the events are corresponding interface state transitions. Recommendations X.135, X.136, and X.137 define specific packet-switched service performance parameters and associated values. The parameters are measures of packet-switched service speed, accuracy, dependability, and availability applicable to end-to-end virtual connections and their component sections. The values are worst-case performance limits for the national and international portions of an international virtual connection. It is anticipated that these performance parameters and values will be widely used in the planning and operation of international packet-switched services.

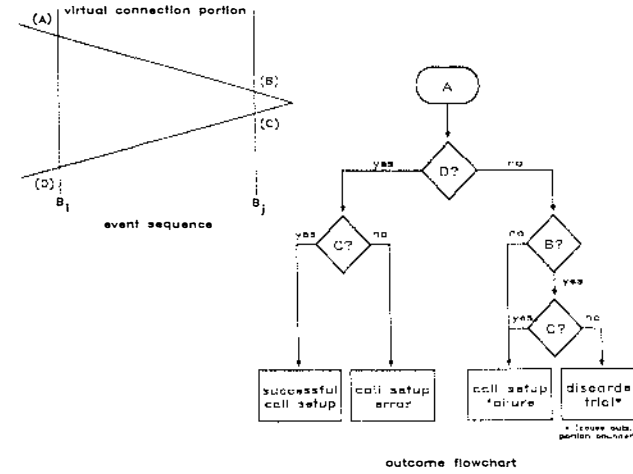
The figure below illustrates the definition of one particular speed of service parameter, call setup delay. That delay is defined first at a single section boundary (B_i), and then between a pair of section boundaries (B_i, B_j). The call setup delay at a single section boundary is the time difference between two packet layer reference events: the transmission of a call request packet, and receipt of the corresponding call accepted packet. The call setup delay between a pair of section boundaries is simply the difference between the call setup delay at the first boundary and the call setup delay at the second.



Call Setup Delay Defining Events

Call setup delay can be specified and measured at any section boundary (or between any pair of section boundaries) within an end-to-end virtual connection. This generality facilitates the combination of performance values for concatenated sections. The other packet-switched service performance parameters have a similar general applicability.

The figure to the right illustrates the decision criteria used in defining call setup error and call setup failure probability parameters in Recommendation X.136. The reference events used in defining these parameters are the same as those used in defining call setup delay, but in this case the focus is on which events actually occurred. The four events are identified sequentially, A to D. A call setup attempt is an occurrence of event A. On any particular call setup attempt, call setup error is defined to occur when event D occurs but C does not; it is the packet switching equivalent of a "wrong number." Call setup failure is defined to occur if either event B does not occur or event C occurs but event D does not; it is the packet equivalent of a "blocked call."



Call Setup Outcome Definition

A similar enumeration of performance outcomes is used in defining the other packet-switched service parameters in the X.130-Series Recommendations.

Institute staff members also contributed strongly to CCITT Study Group XVIII work aimed at developing performance parameters for ISDNs. Two pilot Recommendations on ISDN performance were completed during FY 88. Recommendation I.350 defines a general framework for ISDN performance description. Recommendation I.352 defines layer 3 message transfer events and connection processing delay parameters. The I.350/I.352 Recommendations establish a general approach to ISDN performance description compatible with that successfully used in developing the X.130-Series Recommendations.

Digital Network Performance Standards Development

Outputs

- Standard performance parameters and software measurement tools
- Performance measurement results
- Assistance to users and providers in competitive procurements

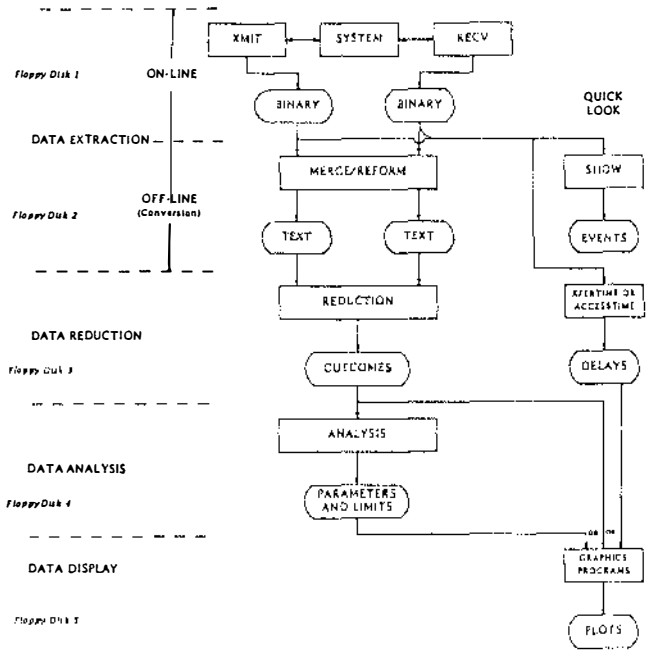
The Institute's Digital Network Performance program has three major goals. The first is to develop standard performance parameters and measurement methods to be used in specifying, assessing, and comparing the performance of digital communication networks. The second is to verify, optimize, and demonstrate the standard parameters and measurement methods by implementing them in representative performance assessment situations. The third is to assist users and providers in applying these tools in competitive telecommunication procurements. During FY 88, Institute staff members completed documentation of standard performance measurement software, published a comprehensive NTIA report describing the results of pilot performance measurements on several packet-switched public data networks, and provided technical assistance to users and providers in a major Federal procurement of packet-switched services. Initial steps were taken to enhance the ITS-developed performance measurement tools for application to Integrated Services Digital Networks (ISDNs), and an ISDN Performance Measurement Laboratory was established.

Standard Performance Measurement Software. The structure of the ITS-developed performance measurement software is illustrated in the figure on the right. The software consists of a four-part system that automates the measurement of data communication performance in accordance with American National Standards X3.102 and X3.141. These standards, developed under ITS leadership, specify user-oriented, technology-independent performance parameters and measurement methods for data communication services. The four major software modules are Data Extraction, Data Reduction, Data Analysis, and Data Display. The data extraction software generates and records the on-line test events and prepares the recorded data for reduction and analysis. The data reduction software processes the recorded test data to determine the results of individual

Project personnel (from left) Marty Miles, Ken Spies, Ned Crow, Randy Bloomfield, Earl Eyman, D.J. Atkinson, and Dave Wortendyke

performance trials (e.g., access, block transfer, and disengagement attempts). The data analysis software calculates performance parameter estimates and associated confidence limits from the outcomes observed in an individual test or related group of tests. The data analysis software also provides guidelines for pretest sample size selection. The data display software presents the measurement results in a variety of graphical forms. The reduction and analysis programs are written in FORTRAN 77 and all the other programs are written in C language. Extensive use of shell scripts in both AT&T Bourne Shell and Berkeley C Shell have been used to integrate the latter three software modules into a completely automatic process that can be executed, with no operator intervention, on one CPU. This ITS-developed measurement software system is available to the public and is currently being implemented by telecommunications users and providers.

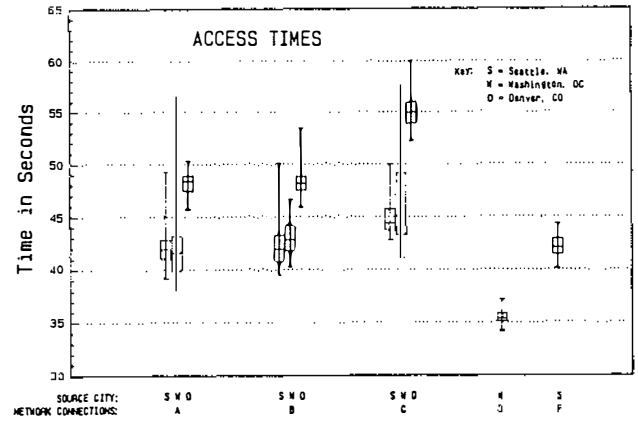
Performance Measurement Results. During FY 88, the Institute published a comprehensive report summarizing the results of X3.102/X3.141 performance measurements. These measurements provided a framework for developing the performance measurement software and ultimately demonstrated its practicality and utility. A summary of measurement results for one particular



Software System for Connection-Oriented Services

parameter--access time--is shown at the right. The results are presented in the form of "box plots" that are produced by the data display software. Each plot summarizes the distribution of access time values measured in a related group of tests in terms of five percentiles: the 25th and 75th percentiles (upper and lower edges of the box), the 50th percentile (horizontal line within the box), and the 50/n and 100-50/n percentiles for sample size n (the ends of the whiskers extending above and below the box). The plots show access time values observed on connections established between three source cities (Seattle; Washington, DC; and Denver) and Boulder, CO, via three public data networks (labeled A-C). Selected access times for voice and data connections established via the dial telephone network (D) and the Federal Telecommunications System (F) are also presented.

Procurement Assistance. The American National Standard X3.102 parameters were used to specify performance requirements in several major data communication procurements during FY 88. The Institute reviewed the technical specifications prepared in one such procurement in which the Veterans Administration (VA) is acquiring a packet-switched service to interconnect over 700 facilities nationwide. The VA representatives asked that ITS focus its review in three particular areas: (1) application of the generic X3.102 parameters to the particular user/network interfaces defined in the VA specification, (2) selection of numerical performance objectives, and (3) acceptance testing and operational performance measurement. Institute staff members provided the VA with precise definitions and worst-case values for packet network equivalents to each of the ANS X3.102 parameters (drawn directly from draft CCITT Recommendations on packet-switched service performance developed under NTIA/ITS leadership in CCITT Study Group VII) and with access to the X3.141 performance measurement software system. The recommended parameter definitions and values and a prominent reference to the measurement software have been included in the final text of the VA specification. The Institute also advised the Department of Justice in the development of a request for proposal for the Justice Telecommunications Network.



Access Time Box Plot

During FY 88, the Institute began a major effort to enhance its performance measurement capabilities for application to ISDNs. Required test equipment (including a computer-based test system implementing the ISDN access protocols and an ISDN network simulator) were procured, and an ISDN Performance Measurement Laboratory was established. This laboratory will enable ITS to (1) contribute strongly to the development of ISDN performance standards in national and international forums, (2) develop ISDN performance measurement tools consistent with these standards for transfer to private industry, and (3) assist other Federal agencies in applying ISDN technology to meet their telecommunication needs. The laboratory will provide the capability to instrument and assess both simulated and real ISDN services.

Recent ITS Publications

User-Oriented Performance Evaluation of Data Communication Services: Measurement Design, Conduct, and Results (by Spies, Wortendyke, Crow, Miles, Quincy, and Seitz)

Voice Quality Standards Development

Outputs

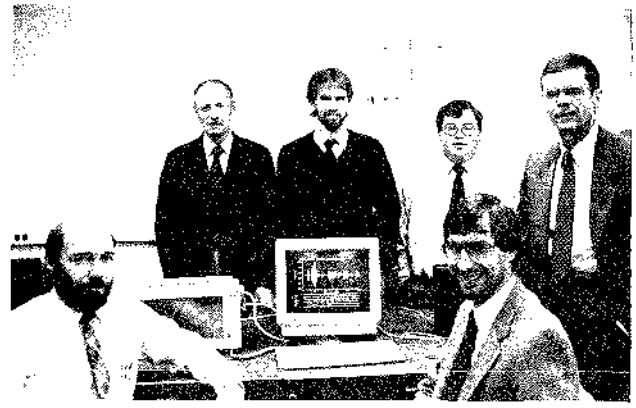
- Contributions to standards committees
- Pattern recognition software
- Expert system development

Telecommunication providers and users have an increasing need for precise, technology-independent measures of voice transmission quality. Providers need such measures to design individual speech processing and transmission systems and to ensure interoperability among systems that may be interconnected. Users need such measures to compare performance among equipment and service alternatives. Human listener panels can be used in voice quality assessment, but that is a slow, costly, and unreliable process. The Institute is supporting the national and international standards committees addressing this problem by developing new voice quality parameters based on statistical pattern recognition and expert systems techniques. The Institute plans to implement the parameters ultimately selected in a microcomputer-based voice quality measurement system.

The figure on the lower right summarizes the development steps being employed in evaluating candidate parameters and developing the prototype measurement system. The first block, Data Base Development, refers to the requirement for a representative set of distorted speech data, along with listener panel quality scores. This information is used to "train" the system. The Institute has received several speech data bases from cooperating industry organizations.

The second block consists of parameter measurement and evaluation. The goal is to identify voice parameters that demonstrate good correlation with human quality scores. Currently, nearly 250 voice parameters are measured and are being analyzed to find a small, effective parameter subset.

The third block consists of two parts. The Pattern Recognition Design element represents a statistical pattern recognition module that returns voice quality predictions based on parameter statistics. The second element, Expert System Design, is used to incorporate additional data that allows the system to handle distortions such as delay and echo, as well as user bias due to such factors as hearing impairment or nationality.



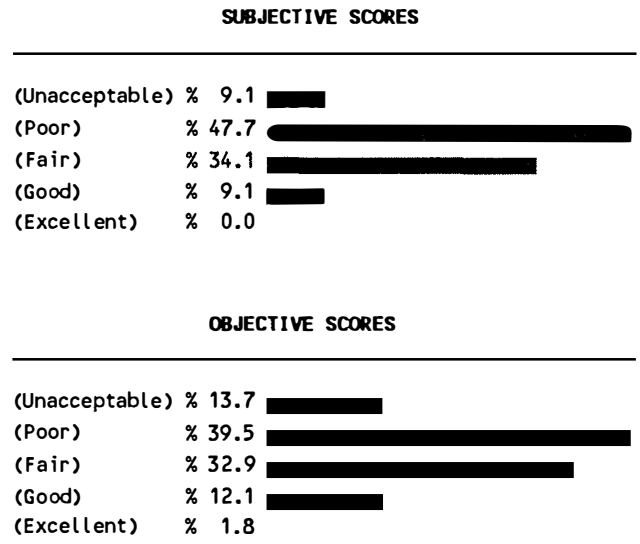
Project personnel (standing from left) Duane Hyovalti, Kevin Kiser, D.J. Atkinson, Ed Quincy, and (seated from left) Bob Kubichek and Dan Tomich

In FY 88, ITS completed software development of all elements except the expert system. When the entire system is completed, it will be validated to prove its effectiveness over a broad range of conditions. The Institute intends to make the prototype system consistent with Federal, national, and international voice quality standards. To this end, ITS staff members have participated actively in T1 and FTSC standards development and plan to begin work supporting similar activities in CCITT.

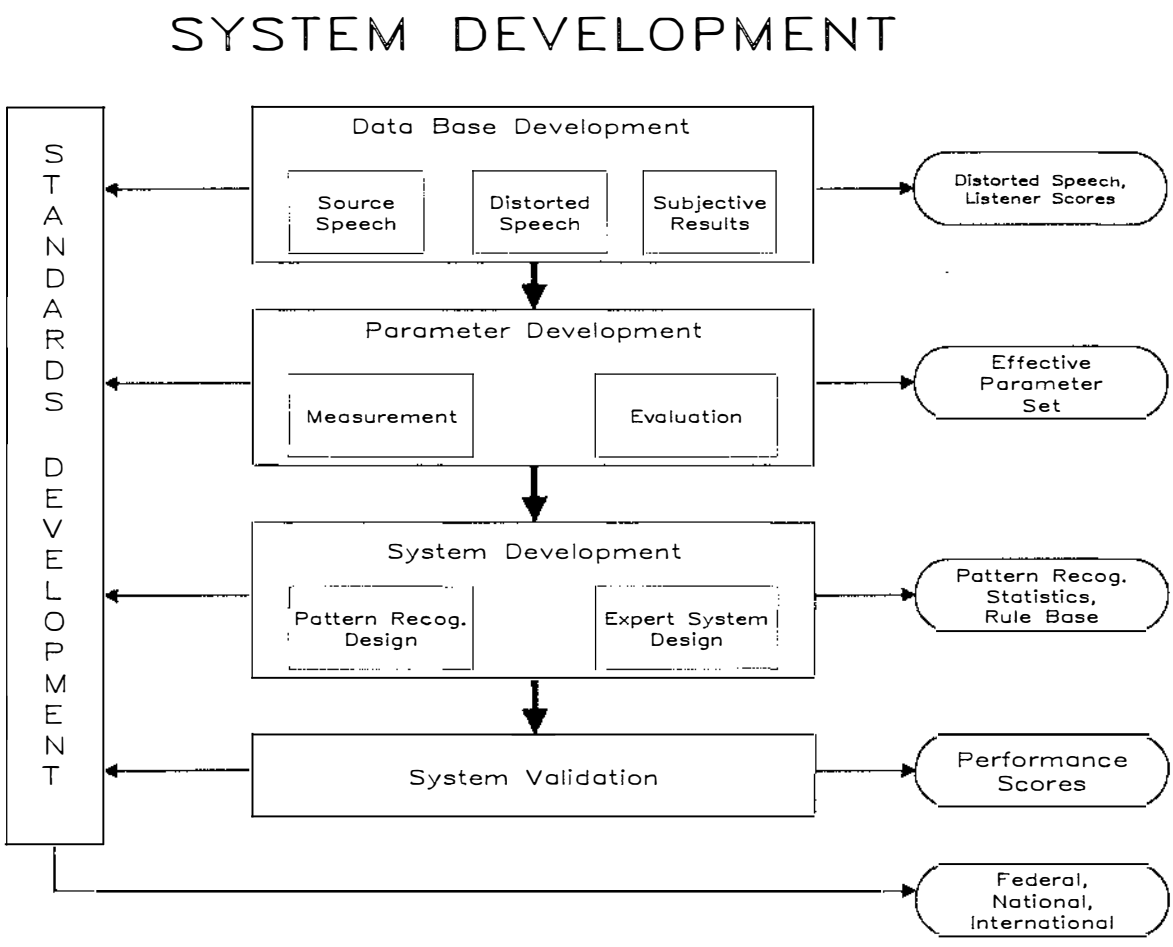
The figure on the upper right demonstrates output from the pattern recognition module for the case of speech contaminated with noise. In typical operation, voice parameters are measured from distorted speech of unknown quality. The parameter's statistics are compared against those in the training data base, and the results are used to predict the unknown quality. In the diagram, the upper histogram (Subjective) portrays actual listener panel scores in terms of percent voting for each of five quality levels. The lower histogram (Objective) is the pattern recognition system's quality estimate. Close agreement between the two histograms indicates good performance of the system, at least for this simple test case.

Standards Contributions

- Automatic Speech Segmentation for Improved Voice Quality Classification (by Kubichek, Quincy, and Tomich)
- Nonlinear Selection of Objective Voice Quality Parameters (by Kubichek, Quincy, and Tomich)
- Status of Voice Quality Assessment with an Expert Pattern Recognition System (by Quincy, Kubichek, and Tomich)
- Study Project Proposal: Technology-Independent, User-Oriented, Objective Classification of Voice Transmission Quality (by Quincy and Kubichek)



Listener Panel Scores (above) and Automatic Assessment (below) Showing Close Agreement



Development and Validation of Expert System for Voice Quality Classification

Video Quality Standards Development

Outputs

- Contributions to standards committees
- Pattern recognition and image processing software
- Expert system development

The Institute is developing a method for objective measurement of video 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 video and image transmission system performance.

Objective measures of video transmission quality are urgently needed by increasing numbers of potential end users. For instance, providers and procurers of high-definition TV (HDTV) and video teleconferencing systems require video quality measures to gauge the performance of these 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.

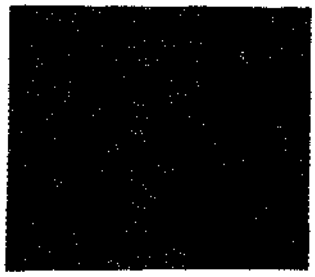
Traditional techniques for estimating video quality are based on analog measures of the transmission signal. Such measures include waveform tests and chrominance/luminance gain factors. These parameters are not adequate in assessing video quality when images are impaired by the many new types of distortions introduced by modern digital transmission systems. In such cases, viewing panels are required to subjectively evaluate distortion effects on video quality. Unfortunately, this approach is time consuming and expensive. Also, special care must be taken to prevent wide variation between tests.

The ITS computer-based approach uses statistical techniques to remove this unwanted human variability from the quality estimate. Pattern recognition is used to classify video transmissions into levels of quality ranging from unacceptable to excellent with minimum probability of error. Quality estimates are based on parameters that are measured directly from video images.

Project personnel (standing from left) Ed Quincy, Dan Tomich, D.J. Atkinson, and (seated from left) Dara Parsavand and Steve Wolf

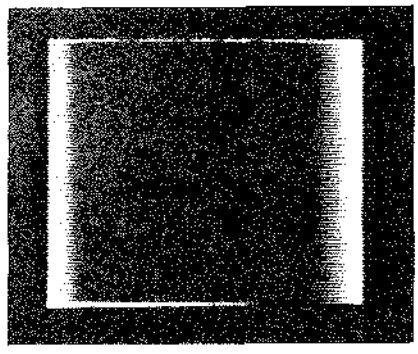
An urgent need by providers and procurers is to objectively assess the quality of video teleconferencing transmissions containing motion. One of the major effects of motion is to distort edges and other such boundary regions of an image. The distortion primarily consists of a blurring effect of edges not parallel to the direction of motion. Quantifying motion distortion can be accomplished by forming difference images. A difference image is created by subtracting an undistorted image from its distorted version. If no differences exist (an all black image) then there was no distortion. In the resultant image, distortions appear as gray levels rather than black. Analyzing an intensity histogram of the difference image yields a quantitative measure of image quality.

Figures at the right illustrate this process. The top figure is an image of a black square on a white background and is used as the test image. To its right, the same image during fast horizontal motion is displayed. It is clear that the edges of the square perpendicular to the motion have been distorted. This distortion is illustrated by the figure in the center of the page, the difference image of the distorted and undistorted image. The experiment was repeated for an image undergoing a slower motion. A single measure of quality can be defined by using the root-mean-square (rms) value of the

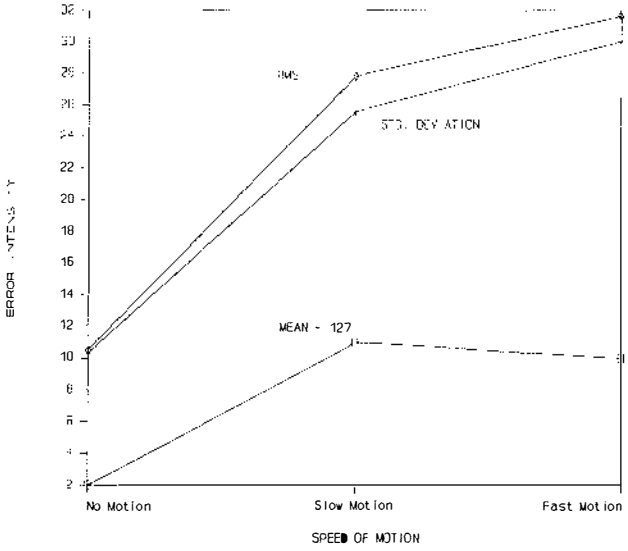


Undistorted Test Image

Image Distorted by Fast Motion



Difference Image of Distorted and Undistorted Images



Video Motion Quality Measurement Results

value of the mean and standard deviation of the difference image histogram. This measure, along with the mean and standard deviation, for the above experiment are shown in the bottom figure. The rms measure is sensitive to and reliably characterizes motion error. Some errors occur for the no-motion case due to inaccurate image alignment.

Unfortunately, PR results applied to measures such as described are insufficient in assessing overall video quality. Test conditions, the type of transmission used, and user and application characteristics contribute to the outcome of the quality assessment. An expert system guides the operation of the pattern recognition module to improve the statistical assessment by integrating this knowledge that is not easily incorporated by the pattern recognition module. A knowledge based expert system combines this additional knowledge and applies knowledge about human perception of quality to refine the PR results.

Publications and Standards Contributions

Expert Pattern Recognition Method for Technology-Independent Classification of Video Transmission Quality (by Quincy, Kubichek, and Tomich)

Expert Pattern Recognition Methodology for Technology Independent, User Oriented Classification of Video Transmission Quality (by Quincy, Tomich, and Kubichek)

Report on Applications of Expert Pattern Recognition Methodology for Assessing Video Quality (by Quincy, Tomich, and Kubichek)

Statistical Measures of Video Motion Distortion (by Quincy, Parsavand, Kirlin, and Tomich)

Radio Systems Interoperability

Outputs

- Leadership in Federal telecommunication standards organizations
- Proposed Federal telecommunication standards
- Technological and economic impact assessments

The Institute provides extensive engineering services to the National Communications System (NCS) in the development of Federal standards for radio system interoperability. The NCS mission, in part, is to develop technical standards to ensure that functionally similar Government communication networks can "rapidly and automatically interchange traffic in support of national security leadership requirements." The Institute contributes to this goal by providing leadership in Federal telecommunication standards development organizations, by preparing and coordinating proposed Federal standards, and by conducting technological and economic impact assessments to ensure that Federal standards are promulgated with due consideration to product availability.

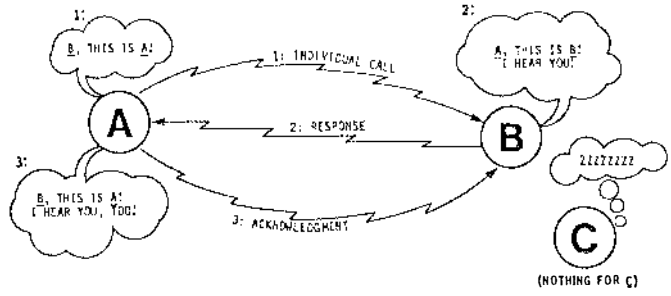
The Institute's current work is focused on developing two families of standards: one addressing HF radio systems and one addressing land mobile radio systems. When fully implemented, these standards will substantially improve radio communications interoperability within and among civilian Federal agencies, emergency preparedness organizations, and the U.S. military departments. They will also enhance competition and promote new product development in the U.S. telecommunications industry.

During FY 88, development of HF automated radio standards was initiated by the Federal Telecommunication Standards Committee's HF Radio Subcommittee, which is chaired by an ITS staff member. The Institute contributed strongly to the formulation and development of Proposed Federal Standard 1045 (pFS 1045), the first in the family of HF automated radio standards. This standard will provide the foundation for developing the entire family of HF radio standards. The illustration to the right shows a simplified view of the HF automatic link establishment functions being standardized. Proposed FS 1045 provides the technical guidance for emission of the call, response, and acknowledgment signals. The emission waveform contains address information that will selectively alert a station and will invoke a response from that station if the station is not mute.

Project personnel (from left) Bill Ingram, Tom Jones, Joe Hull, and Dave Peach

The standard specifies the required protocols and timing but leaves implementation to the creativity of the radio designer.

The Institute staff coordinated the development of a new standards development process that has proven to be very successful in the preparation of pFS 1045. The process has now been adopted by other standards development groups and will be used to formulate and prove the technical content of the other standards in the HF radio standards family. This process is illustrated at the right. The key to the success of the process has been the specification and performance of structured tests to prove the concepts proposed in the Statement of Requirements (SOR). An iterative process to prove, and improve, the technical approach before embedding it in a standard ensures that the published standard will be practical and implementable. In the case of pFS 1045, the structured tests involved both laboratory



Automatic Link Establishment (ALE)

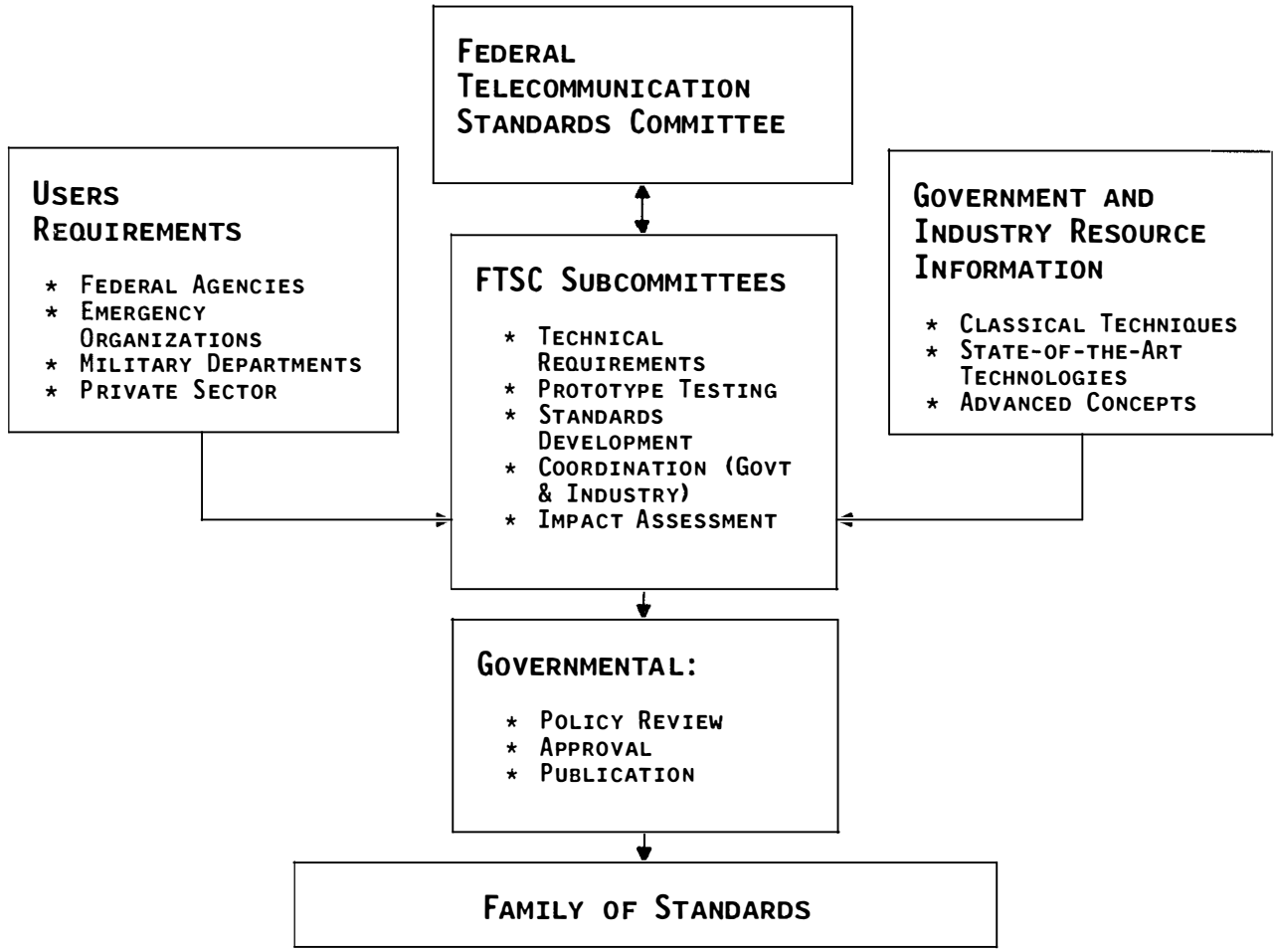
simulations and on-the-air measurements. Institute staff members reviewed and approved the draft test results and coordinated their submission to the FTSC as a final step in the standards development process.

To ensure adequate coordination of the HF radio interoperability standards, ITS presented frequent briefings to FTSC, the SHARES (SHared RESources) Committee, the Joint Steering Committee (JSC), the Army Information Systems Command/Federal Emergency Management Agency Working Groups, and other organizations including affected private sector equipment and service vendors. These activities have expedited the development of the pFS 1045 standards family. During FY 88, Institute personnel coordinated several beneficial new relationships among the participants in the HF Radio Subcommittee involving the sharing of research and development information, personnel, hardware, test facilities, and test methods.

In a related project, ITS serves as Secretariat and provides technical support to the FTSC Land Mobile Radio Subcommittee. This subcommittee is pursuing standards in a number of areas, including encrypted digital voice for 25-kHz channels, narrowband encrypted digital voice, and trunked radio systems. In support of this work, ITS participates in the Evaluation Task Group for Working Group III of Telecommunications Industry Association (TIA) TR-45.3. This group will determine the criteria to be used in rating narrowband digital system proposals for the next generation cellular radio system. The knowledge gained in TIA-TR-45.3 has assisted ITS in taking a leading role in investigating the requirements and the technological advancements relevant to a narrowband, encrypted, digital voice standard.

Recent ITS Publications

Impact Assessment of Proposed Federal Standard 1023 (by Jones)
Impact Assessment of Proposed Federal Standard 1045 (by Ingram)
Proposed Federal Standard 1045 - High Frequency Radio Automatic Link Establishment (by Peach and Adair)



Federal Standards Development Process

Building Telecommunications Architecture and Wiring Standards Development

Outputs

- Building grounding specifications for an industry telecommunication standard
- Multimode optical fiber specifications for an industry telecommunication standard
- Leadership in development of standard telecommunication terminology

The Institute represents Federal user interests in the development of voluntary industry standards with the goal of adopting such standards as Federal standards. Within Telecommunications Industry Association (TIA) Working Group TR-41.8.3 (Telecommunications Architecture for Commercial and Industrial Buildings), ITS has contributed strongly to the specification of telecommunication building grounding systems. Current building codes generally address only the safety aspects of grounding and do not assure that signal grounding is satisfactorily achieved. Building architects and contractors must consider the incorporation of more sophisticated grounding subsystems in buildings where tenants may utilize sensitive electronic/computer equipment or where equipment must respond to emergency needs following a natural or man-made disaster.

Equipment protection has become much more important in the implementation of building grounding systems because of the introduction of highly sensitive (and highly vulnerable) electronic systems, such as networks of computer terminals, in most buildings. This new equipment requires special grounding and protection considerations to prevent operational upset or burnout from transient induced voltages and currents and to eliminate the pickup of significant electrical noise.

The primary source of external transient voltages and currents that may cause catastrophic failure of telecommunication equipment is lightning. Lightning causes large electrical currents to flow in conducting media that may penetrate a building. It may also cause extremely high currents and voltages to be induced when a direct strike occurs on a building. Lightning strikes also produce electromagnetic pulses that radiate into a building and interact with wiring and equipment in the building.

Project personnel Joe Hull (left) and Glenn Hanson

The telecommunication building grounding system of interest to the building architect or designer is made up of the following subsystems, each of which is addressed in the proposed standard: earth electrode subsystem, lightning protection subsystem, fault protection subsystem, signal ground subsystem, and transient protection subsystem.

Another area of concentrated ITS effort is the specification of multimode optical fiber for on-premises applications. Initial work in this area was summarized in the 1987 ITS Annual Report. This effort, motivated by earlier deliberations in the ITS-chaired Fiber Optics Task Group of the Federal Telecommunications Standards Committee, has been carried out under the auspices of TIA Working Group TR-41.8.1 (Wiring for Commercial and Industrial Buildings). The resultant document, a Detail Specification, was in the final ballot process as an ANSI/EIA standard (under the aegis of TIA) at the end of FY 88. When approved, the standard will be the principal technical specification used in the procurement of optical fibers for building applications in the United States. A compatible Federal standard is planned, and a related international standards project has been proposed.

The proposed ANSI/EIA standard specifies a 62.5/125-μm core/cladding diameter multimode optical fiber. This specification is the first such

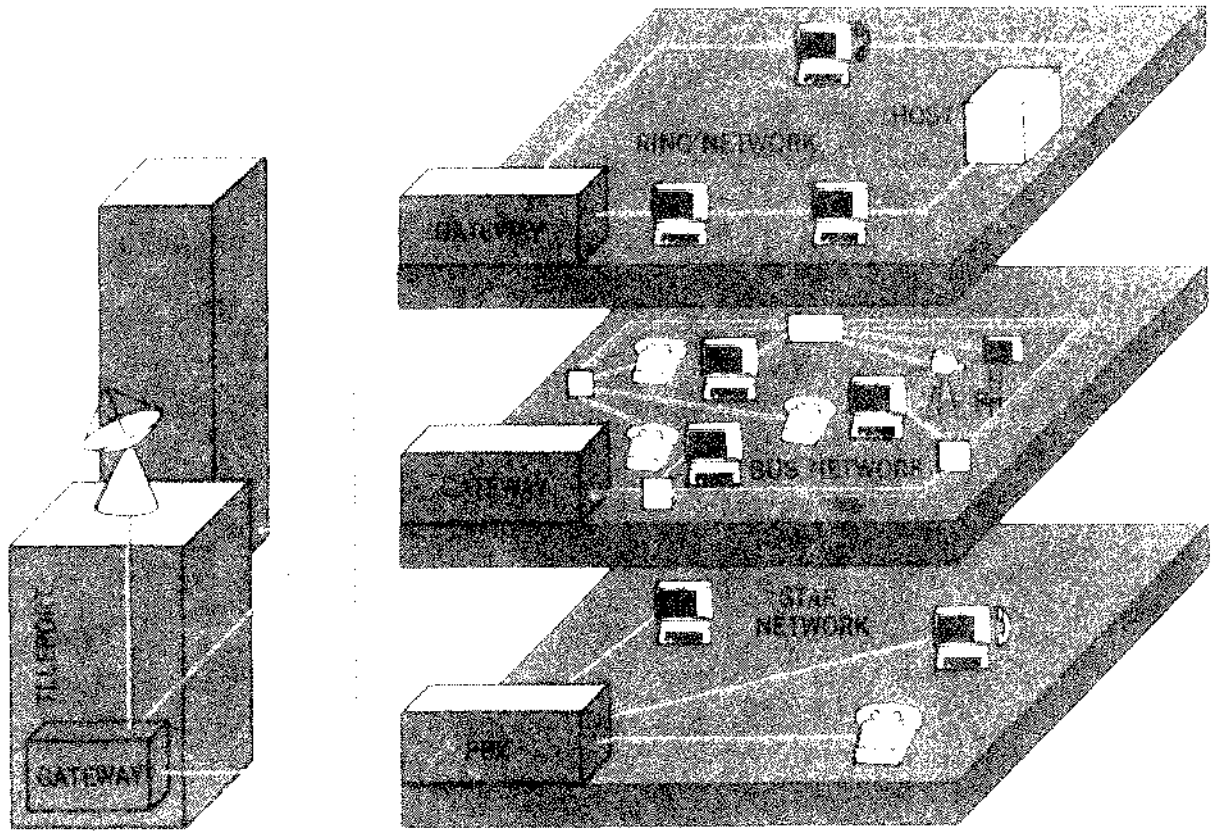
standard written in the optical fiber field and therefore has received considerable attention and intensive reviews during several industry ballots. Private-sector reactions indicate that the standardization of this fiber will benefit manufacturers as well as the user community.

The success of this effort will pave the way for standardization of optical fiber cables. A new EIA standards effort has been initiated in this area as a follow-on to the fiber specification work. A family of nine cable Detail Specifications will be written and coordinated by ITS within a newly formed Fiber Optics Division Task Group.

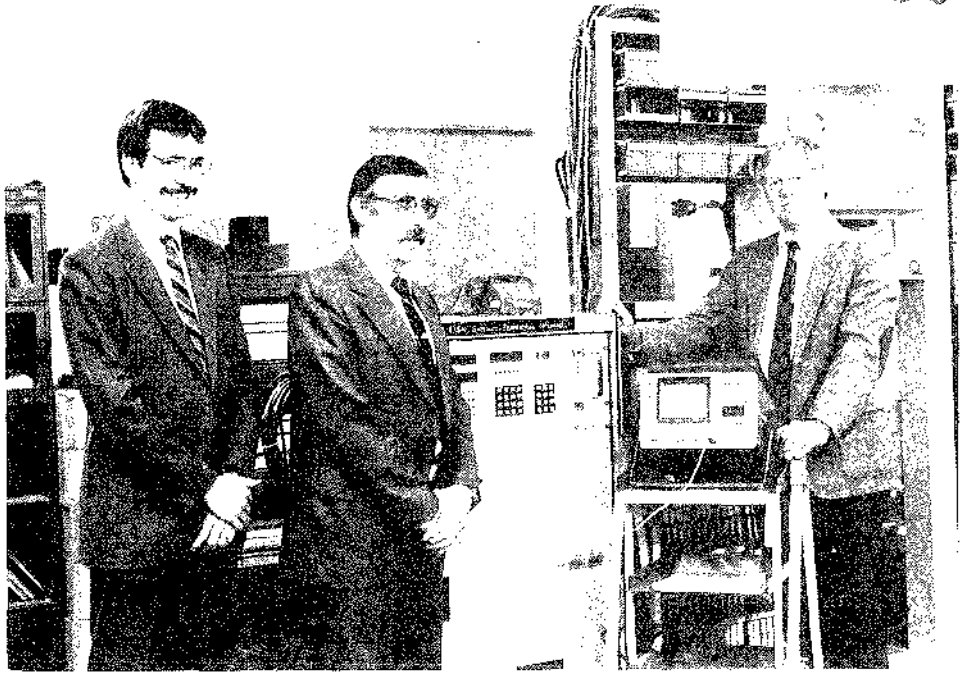
The Institute has also been involved in the creation of several telecommunication terminology standards. The current effort is focused on terms and definitions for building telecommunications architecture. The end product will be published both by TIA and by the Canadian Standards Association (CSA). An ITS staff member cochairs the terminology Working Group and contributes to the definition of terms. The terminology standard, in penultimate draft form at the end of FY 88, represents a successful resolution of numerous semantic and technological distinctions in U.S. and Canadian terminology usages.

Recent ITS Publications

Development of Proposed Federal Standard 1070: 62.5/125-μm Graded-Index, Multimode Optical Fiber Waveguides for On-Premises Applications (by Hanson and Hull)



On-Premises Distribution System



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

High Definition Television Evaluation

Includes projects funded by the National Telecommunications and Information Administration

Computer Aided Design and Video Teleconferencing Network Development

Includes projects funded by Naval Sea Systems Command

HF Systems Assessment

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

Transmission System Performance Measurement, Monitoring, Evaluation, and Control

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

Microwave Communications Link Testing

Includes projects funded by the Air Force Electronic Systems Division and the Naval Air Test Center

Transmission System Modeling

Includes projects funded by the Army Information Systems Engineering Center and the Department of Defense

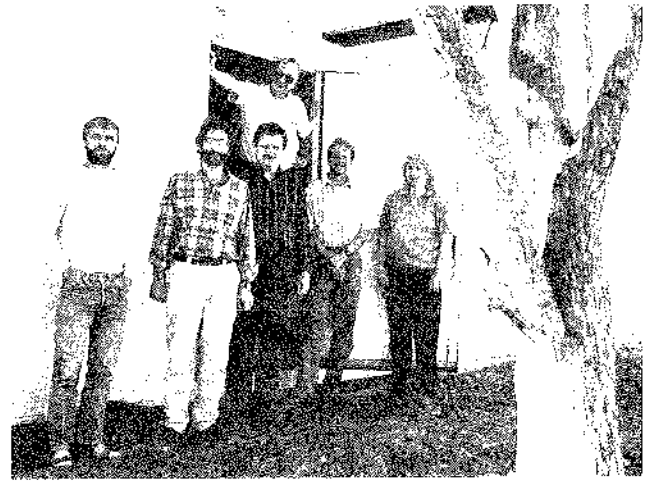
High Definition Television Evaluation

Outputs

- Analysis of HDTV interference on current TV signals
- Analysis of propagation effects on split-band HDTV signals

With the potential of being a $50 billion industry, High Definition Television (HDTV) requires a careful analysis to ensure that it can be introduced without technical limitations to its own goals and without causing interference to the present TV service. The Institute has been studying those aspects of propagation that can affect HDTV. Because many HDTV systems require more bandwidth than present TV, each transmitter could transmit the additional signal in the spectrum that is contiguous with its present spectrum. Although this would be the preferred way of increasing the bandwidth, many transmitters would be unable to expand in this manner because of the adjacent channel interference each would cause to neighboring transmitters. One potential scheme of introducing HDTV would have part of the signal transmitted in the VHF TV band and part in the UHF TV band. However, the terrain attenuates the UHF signal more than the VHF signal. Also there can be a difference in the phase of the signals between the VHF and UHF bands at the receiver. The Institute has been conducting studies to estimate the attenuation and phase differences. In one instance the UHF coverage area was only 60 percent of the VHF coverage area.

The FCC has formed an Advisory Committee for the Advanced Television Service. One of its demonstration exercises was to attempt to assign HDTV supplementary frequencies to existing transmitters, which would allow the transmitters to provide HDTV service. In order to make these hypothetical assignments, the committee had to relax the current restrictions on the placement of transmitters operating at frequencies that might interfere with neighboring transmitters. Each step of the relaxation process allowed more supplementary HDTV assignments to be made. The Institute has analyzed the interference to four transmitters in the committee's assignment exercise to determine how much additional interference had been introduced by the HDTV supplementary assignments. The four transmitters all operate on Channel 68 within 200 mi of the committee reference location, New York City.

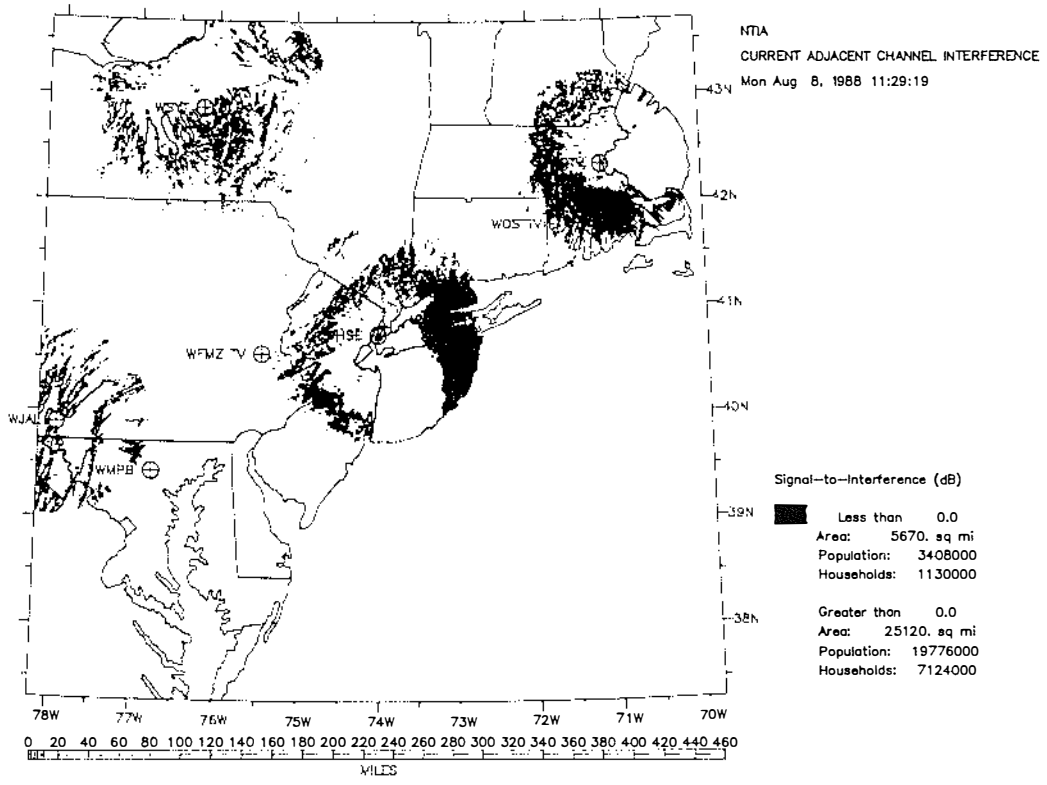


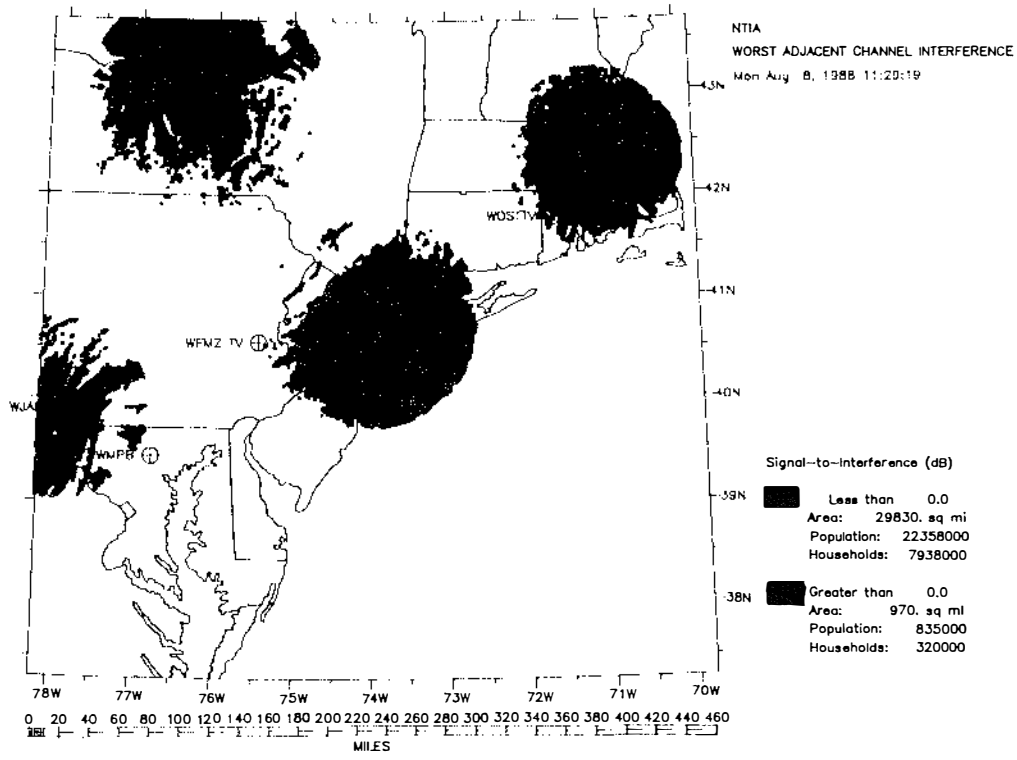
Project personnel (front row from left) John Godwin, Jeff Wepman, Brent Bedford, Eldon Haakinson, Nancy Kuester, and (center back) Jean Adams

As an example of one of the analyses, the figure at top right shows the signal coverage from the four transmitters by the shaded areas surrounding each transmitter. The shaded areas show where the signal exceeds the FCC's Grade B level. Although the detail does not show up in this reduced, black and white plot, regions where adjacent channel interference exceeds the FCC's allowed limits are also plotted. The legend gives the land area, the population, and the number of households that fall into the various levels of signal-to-interference ratios. In those regions where the signal is above the Grade B level and the signal-to-adjacent channel interference exceeds 0 dB, a typical receiver is assumed to have satisfactory service. In those regions where the signal-to-interference is less than 0 dB, the received signal is assumed to be degraded to an intolerable level by the adjacent channel interference.

The figure at top right shows the current adjacent channel interference conditions that are computed for the four Channel 68 transmitters. The figure at bottom right shows the additional interference that would be introduced with the additional hypothetical HDTV supplementary assignments as made by the Advisory Committee. Note from the legends next to the plots the number of households and population receiving the unsatisfactory service increases by 656 percent for this particular scenario.

The Institute will continue the analytical studies to determine propagation effects on HDTV. In addition, the Institute will begin field measurements to determine typical values of parameters such as delay spread with the wide bandwidth HDTV signals.



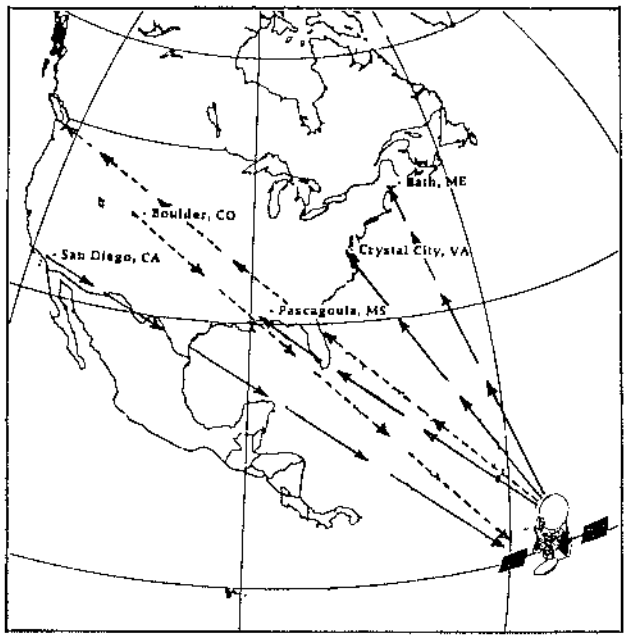


Computer Aided Design and Video Teleconferencing Network Development

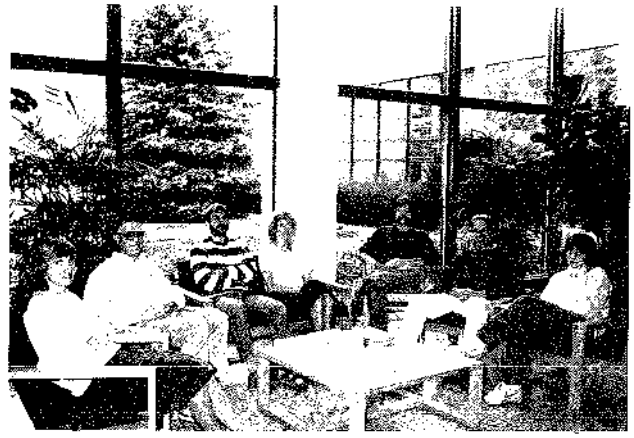
Outputs

- Enhanced standard performance measurement software for LAN and WAN applications
- Measured performance of LANs and WANs
- Multivendor Ethernet with multivendor workstations
- Multisite network and application requirements

Integration of Services on Networks. The Institute is developing a prototype network to demonstrate the integration of a variety of services and methods for fulfilling Navy requirements. Network development at the Boulder laboratories is primarily in support of shipbuilding. Computer Aided Design (CAD) is one of the fundamental activities to be supported on the network. For example, workstations at a shipyard in Mississippi could access files from a fileserver in Virginia as illustrated in the figure below. Video Teleconferencing (VTC) is another major activity to be supported, potentially including both conference room settings and the desk-top environment at a workstation. Other services to be incorporated are transfer of Computer Aided Logistics Support (CALS) files for contracting and high-resolution graphics for interactive document or image editing. Integration of these services is over an interconnected set of Local Area Networks (LANs), Metropolitan Area Networks (MANs), and Wide Area Networks (WANs).

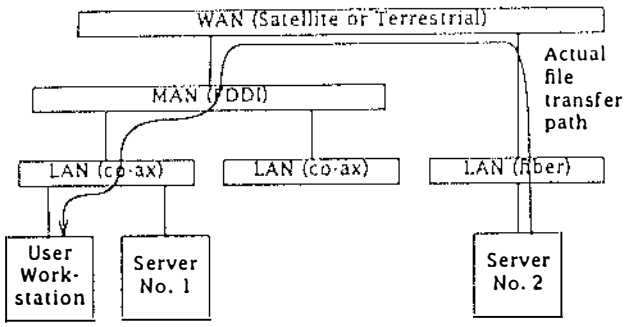


Wide Area Networking with Simultaneous One-Half T1 Channels



Project personnel (from left) Martin Nesenbergs, Dave Wortendyke, D.J. Atkinson, Margarete Ralston, and Ed Quincy

Application of Data Communication Standards to Other-Agency Network Performance Assessment. One major goal of the Navy work is to measure the performance of prototype integrated networks by applying user-oriented performance measurement software developed at ITS over the last several years. Previously, only connection-oriented services such as Public Data Networks (PDNs) had been measured. This work represents a new challenge because the applications involve high-speed networks and several types of services. The physical connections may be LANs, MANs, or WANs, as well as the traditional PDN. The performance measurement technique has been thoroughly demonstrated on PDNs with ITS software. A WAN was direct dial tested at 9600 bps representing a connection-oriented service without contention. Software implementation was straightforward, but required test sets with much higher performance than previously had been used.



Navy Network Test Scenario

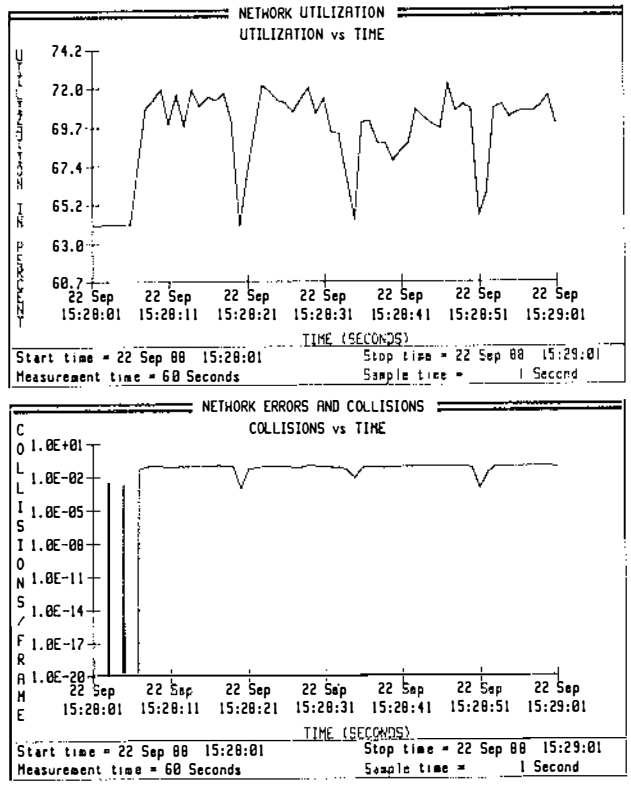
The newest challenge is performance testing on the Ethernet LAN. The connectionless environment typically found between workstations and servers requires a substantially different approach to performance assessment. This work represents the first application of the NTIA-developed data communication performance standards and measurement software to connectionless services and to LANs. (See figure above.)

Network Development. ITS is implementing LANs with coaxial and optical fiber cables as 10 Mbps IEEE 802.3 Ethernets. These are primarily intended for connection of CAD workstations but may also support desk-top VTC and high-resolution graphics. Preliminary characterization tests were conducted on LANs with various background loadings while transferring typical 1-1.5-Mbyte CAD files. These results show dependence of network utilization on occurrence of collisions (see figure to the right). The MAN will provide a base-wide backbone to interconnect LANs and provide a gateway to WANs. The MAN will be implemented with optical fiber as an Ethernet and migrated to a 100 Mbps FDDI network as components become available.

The WANs will connect geographically dispersed shipyards, bases, and headquarters. The WAN implementation is evolving as a Ku-band satellite network with terrestrial alternates. ITS is installing a 14/12 GHz transmit and receive Earth station at the Boulder laboratories to aid in network testing and investigations. It will use a 3.7-meter dish and operate up to 1.544 Mbps (T1) with a 10^{-6} bit error ratio. Current applications are intended to use a 1/2 T1 channel.

Major network issues under investigation are

- interoperation of multivendor equipment and software within and between networks
- bandwidth/data rate requirements to support multiple services
- optimum communication protocols for error-free transmission of CAD/CALS and high-resolution graphics files
- throughput and error rates for file transfers
- effects of satellite link delay and degradations on performance and protocol optimization
- video quality dependence on codec data rate



Ethernet Collision Dependence on Utilization
(65% Background Traffic, 1.3 Mbyte File)

HF Systems Assessment

Outputs

- Improved techniques to predict HF system performance
- Analytical techniques for Government agencies' HF operational use
- Interactive HF sky-wave models

The Institute for Telecommunication Sciences has provided support to other Government agencies in various areas pertaining to high-frequency (HF) propagation system performance. Many of the efforts undertaken involve the Ionospheric Communication Analysis and Prediction Program (IONCAP). The IONCAP program is an integrated system of models designed to predict HF, sky-wave system performance and analyze ionospheric parameters.

One study undertaken by the Institute consisted of the incorporation of an alternate set of antennas to be used with the IONCAP program. The antenna set referred to as the HFMUFES antennas was incorporated in a PC desk-top computer version of IONCAP. This implementation allows the user to have access to an expanded set of antennas for the generation of propagation predictions that utilize the IONCAP program.

Another study involved the development of an interactive input processor called IONPUT that can be used to generate input for the IONCAP program. This processor allows the user to generate input for IONCAP by (1) specifying free-form input that is then translated to the standard IONCAP input, (2) answering questions from the input processor corresponding to the specific analysis to be performed, or (3) a combination of these where the user specifies the input card image name and then responds to questions from the input processor. This input processor has been implemented on mainframe and PC computers and is now intended for future release for public distribution.

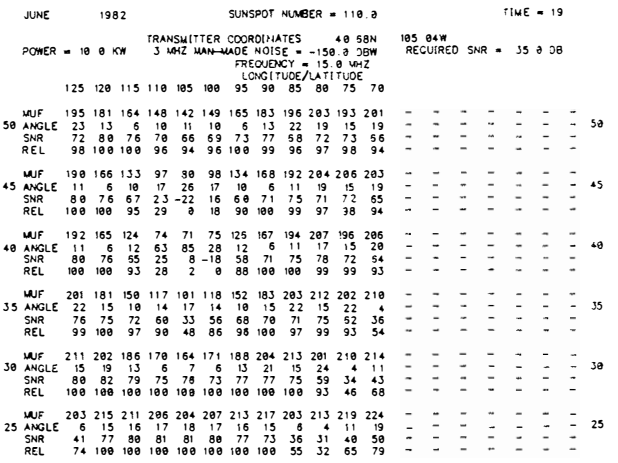
It is often useful to have ionospheric propagation predictions presented in a form that can assist in the estimation of geographic coverage of a given frequency at a given time and with a specific antenna. Predictions such as the MUF (maximum usable frequency), circuit reliability, signal-to-noise ratio, and median field strength could aid HF broadcasters and others if presented in a geographic latitude-longitude display or a distance-azimuth

Project personnel (fromleft) Janet Geikas, Frank Stewart, John Godwin, Jeanne Wakefield, Larry Teters, Eldon Haakinson, and Susan Rothschild

display for specified areas of the world. A procedure has been developed to generate a geographic area coverage representation of ionospheric characteristics for a specified area. The area is identified by specification of the latitude and longitude boundaries of the area or by specifying distances from the transmitter location and a set of azimuths. The ionospheric predictions are computed at the boundary locations of the grid and at incremental locations within the grid. The area coverage representation consists of the predictions represented on a matrix grid for each frequency and each hour the user requests and for each specified month and antenna. The area coverage representation therefore consists of the propagation predictions of several point-to-point communication paths that characterize the grid specified by the user.

The figure shown to the right is a representative output of the area coverage model QUILT to predict the coverage of WWV located at Ft. Collins, CO, over the continental United States. This output represents the maximum usable frequency, take-off angle, signal-to-noise ratio, and circuit reliability dependent of latitude and longitude.

The implementation allows the flexibility to identify the construction of the geographic grid where (1) a specific transmitter location is used to communicate with each receiver location in the grid and (2) each location on the grid is considered a transmitter and is used to communicate with a specified receiver location.



JUNE 1982 SUNSPOT NUMBER = 110.0 TIME = 19

TRANSMITTER COORDINATES 40 58N 105 04W
POWER = 10 0 KW 3 MHZ MAN-MADE NOISE = -150.0 DBW REQUIRED SNR = 35 0 DB
FREQUENCY = 15.0 MHZ
LONGITUDE/LATITUDE

		125	120	115	110	105	100	95	90	85	80	75	70							
	MUF	195	181	164	148	142	149	165	183	196	203	193	201	-	-	-	-	-	-	-
50	ANGLE	23	13	6	10	11	10	6	13	22	19	15	19	-	-	-	-	-	-	-	50
	SNR	72	80	76	70	66	69	73	77	68	72	73	56	-	-	-	-	-	-	-	
	REL	98	100	100	96	94	96	100	99	96	97	98	94	-	-	-	-	-	-	-	
	MUF	190	166	133	97	80	98	134	168	192	204	206	203	-	-	-	-	-	-	-	
45	ANGLE	11	6	10	17	26	17	10	6	11	19	15	19	-	-	-	-	-	-	-	45
	SNR	80	76	67	23	-22	16	60	71	75	71	72	65	-	-	-	-	-	-	-	
	REL	100	100	95	29	0	18	90	100	99	97	98	94	-	-	-	-	-	-	-	
	MUF	192	165	124	74	71	75	125	167	194	207	196	206	-	-	-	-	-	-	-	
40	ANGLE	11	6	12	63	85	28	12	6	11	17	15	20	-	-	-	-	-	-	-	40
	SNR	80	76	55	25	8	-18	58	71	75	78	72	54	-	-	-	-	-	-	-	
	REL	100	100	93	28	2	0	88	100	100	99	99	93	-	-	-	-	-	-	-	
	MUF	201	181	150	117	101	118	152	183	203	212	202	210	-	-	-	-	-	-	-	
35	ANGLE	22	15	10	14	17	14	10	15	22	15	22	4	-	-	-	-	-	-	-	35
	SNR	76	75	72	60	33	56	68	78	71	75	52	36	-	-	-	-	-	-	-	
	REL	99	100	97	90	48	86	98	100	97	99	93	54	-	-	-	-	-	-	-	
	MUF	211	202	186	170	164	171	188	204	213	201	210	214	-	-	-	-	-	-	-	
30	ANGLE	15	19	13	6	7	6	13	21	15	24	4	11	-	-	-	-	-	-	-	30
	SNR	80	82	79	75	78	73	77	77	75	59	34	43	-	-	-	-	-	-	-	
	REL	100	100	100	100	100	100	100	100	100	93	46	68	-	-	-	-	-	-	-	
	MUF	203	215	211	206	204	207	213	217	203	213	219	224	-	-	-	-	-	-	-	
25	ANGLE	6	15	16	17	18	17	16	15	8	4	11	19	-	-	-	-	-	-	-	25
	SNR	41	77	80	81	81	80	77	73	36	31	40	50	-	-	-	-	-	-	-	
	REL	74	100	100	100	100	100	100	100	55	32	65	79	-	-	-	-	-	-	-	

Daytime Area Coverage Representation at 15 MHz for WWV Example

The Ionospheric Communications Analysis and Prediction Program (IONCAP) is used to generate the propagation predictions presented in the area coverage representation. The procedure consists of an input processor that generates the input to the IONCAP program based on the user-specified area coverage requirements. The input generated by this processor consists of the many point-to-point communication paths that represent the area to be covered. The second step in the area coverage procedure consists of the interface to the IONCAP program and the generation of the propagation predictions. The final step in this procedure is the geographic representation of the propagation predictions. This representation is currently in the form of a numerical representation, but this could be modified to constitute a graphical representation of the predictions. This graphical representation would allow, for instance, coverage maps to be produced that display the predicted field strength in a given service area. This area coverage model has been implemented on large mainframe computers and also personal computers. The area coverage model developed has been given the name QUILT.

A specific application of the propagation predications generated by the IONCAP program consists of a series of programs that have been developed by ITS that assist the Voice of America (VOA) to plan and operate HF broadcast stations. The VOA has specific antenna bands available for use and has particular reception areas to cover. Because of the long distances between the broadcast transmitter and the reception areas, the primary mode of communication is via HF sky wave. Two conditions preclude the use of a single, fixed antenna at the facility: (1) The ionospheric propagation path undergoes diurnal, seasonal, and sunspot cycle changes and (2) the reception area changes throughout the day depending on the broadcast schedule.

Before the system planner can validate an HF broadcast antenna design, the planner must define a location for the transmitter site, define a region (or regions) to receive the broadcast, define a broadcast schedule, and finally define a candidate antenna design that is to accomplish the tasks. A processor has been developed called VALDPR to create data bases from the output of IONCAP that are utilized in another processor called VALSUM that allows the user to select predetermined variables from the IONCAP program and display these in user-selected table formats. These formats allow the user to select specific broadcast situations and to summarize the antenna performance based upon the criteria set by VOA. The VOA has defined the requirements for the design of validation programs in VOA Engineering Standard 16775.01. The summary programs will indicate whether the proposed antenna is adequate for the reception regions to be covered and the ionospheric conditions selected.

The IONCAP program is also being restructured to allow IONCAP to evolve into the "next generation" propagation model. Consideration has been given to the restructured version that should allow the program to become the center of an IONCAP system, which would include the existing analysis capabilities and other new models and capabilities. The new IONCAP system could become an integrated procedure that is highly interactive and user friendly, but also allows batch processing capability and ease of transport from one computer to another.

Transmission System Performance Measurement, Monitoring, Evaluation, and Control

Outputs

- Digital network performance measurement hardware and software
- Network performance analysis software
- Transmission monitor and control software
- Consultative services on transmission network management

The U.S. Department of Defense is in the process of installing a microwave communications network in Europe. This network, known as the Digital European Backbone (DEB), is now partially operational. The Institute has played a major role in the successful design, development, and testing of this network over the last several years. Two ongoing programs in which the Institute is contributing to this critical communications network are the Transmission Monitor and Control (TRAMCON) software development program and the Network/Link Performance Characterization program.

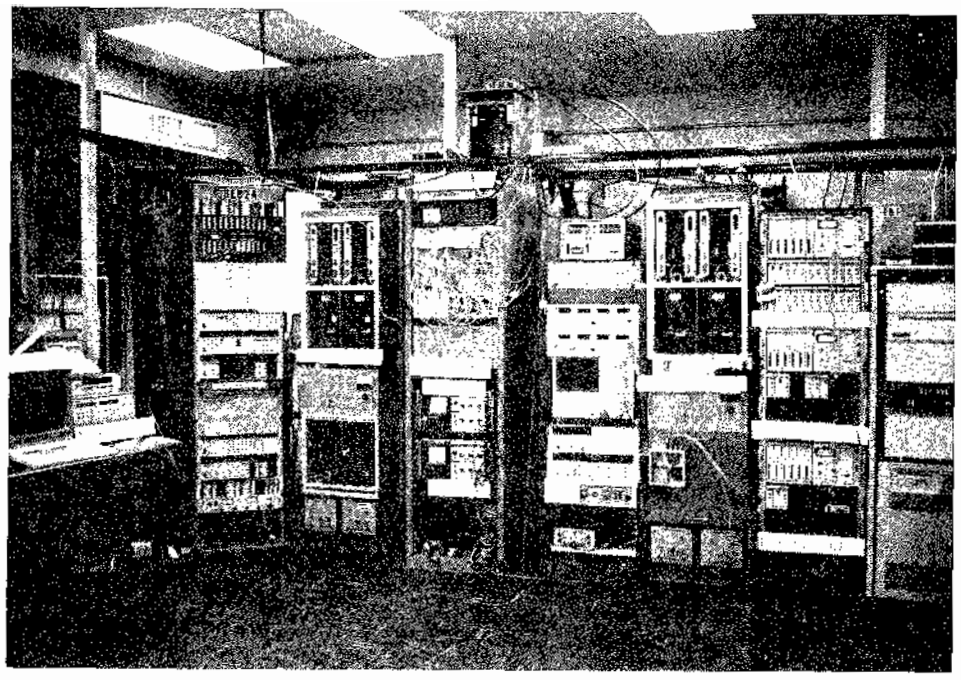
The Institute has the primary responsibility for design, development, and installation of the TRAMCON system. This system continuously monitors the status of DEB transmission equipment and provides means for remotely controlling the system configuration and activating backup equipment in the event of failure. The TRAMCON system will eventually consist of 20 minicomputers that monitor DEB equipment at over 250 communication sites in Europe.

During FY 88, the Institute completed a new version of the TRAMCON software, worked closely with the Air Force organization that will assume responsibilities for software maintenance, and developed a software simulator that will be used in testing changes to the TRAMCON system. The simulator will also be used in formal training of TRAMCON system operators.

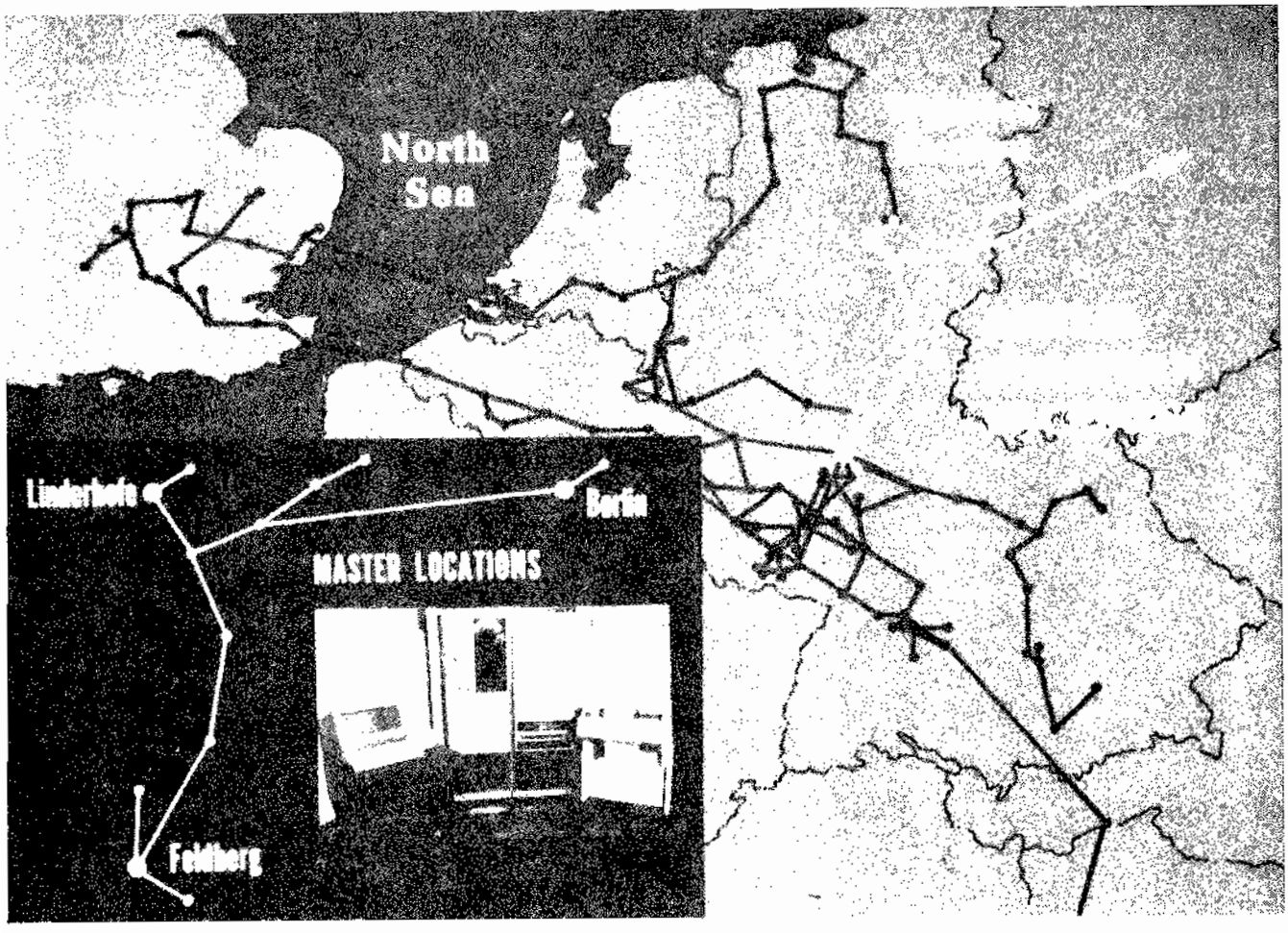
The TRAMCON system has significantly reduced the number of Air Force and Army personnel required to operate and maintain the Digital European Backbone. This has resulted in significant cost savings to the Government.

Project personnel (standing from left) Jim Hoffmeyer, Chris Behm, Evie Gray, Joe Farrow, Dick Skerjanec, Larry Hause, and (seated from left) Suzy Bernal and Rick Statz

Another major effort in support of the DEB during FY 88 was the development of an extensive performance evaluation system for use in the Network/Link Performance Characterization Project. This system will provide end-to-end user performance data on 64-kb/s channels as well as digital radio performance information on one long (98-km) line-of-sight link. The objectives of this program include comparison of performance with military, CCIR, and CCITT standards; validation of microwave link design methods and models; quantification of long-term performance; and an investigation of alternative space diversity switching algorithms. Bit error ratio (BER) data, radio performance data, multipath fading data, and meteorological data are currently being collected.



Network/Link Performance Characterization Hardware



TRAMCON Application to Digital European Backbone

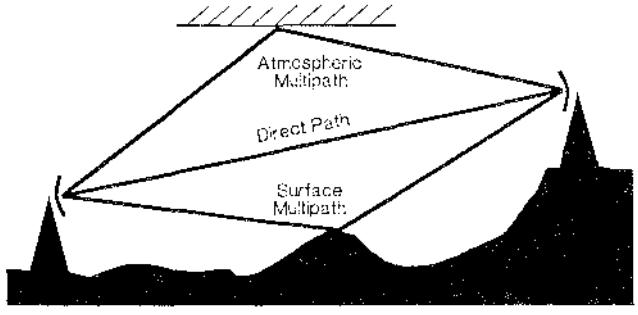
Microwave Communications Link Testing

Outputs

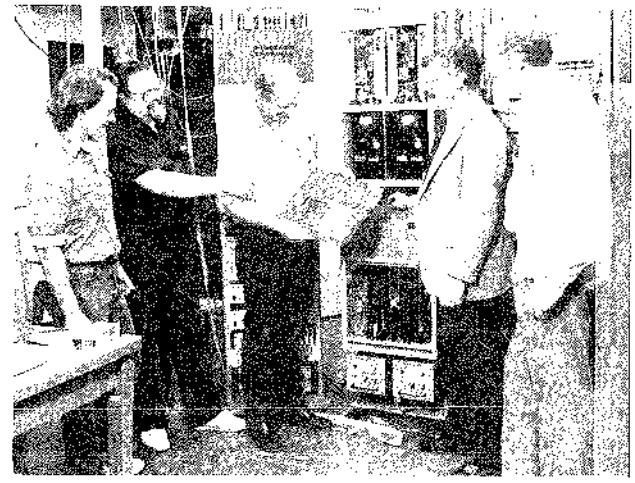
- Digital link performance measurement hardware and software
- Link performance analysis software
- Consultative services on digital microwave link engineering

The Institute has a long history in field testing microwave radios, both line-of-sight (LOS) and troposcatter. The purpose of this testing is to evaluate the radio performance in a fading environment. Typically, the test includes the acquisition of three types of data: (1) radio performance, (2) channel propagation, and (3) meteorological conditions. The latter two types of data are useful in assessing the causes of radio performance impairments.

The principal radio performance measure is bit error ratio (BER). The channel propagation data consist of either spectral distortion data or multipath data. The multipath data are acquired from a unique instrument developed by the Institute, known as a channel probe. Separate channel probes have been developed for LOS and troposcatter links. Meteorological data are typically obtained from the nearest atmospheric sounding station. These data are useful for understanding multipath signals. Fading on line-of-sight transmission channels can be caused by two types of multipath signals: atmospheric multipath and surface multipath as shown below.



Line-of-Sight Transmission



Project personnel (from left) Chris Behm, Joe Farrow, Dick Skerjanec, Jim Hoffmeyer, and Lauren Pratt

During FY 88, the Institute developed a specialized hardware/software system to be used in assessing a long (98-km) link from Schwarzenborn to Feldberg, Germany. This link is part of the Digital European Backbone--the principal U.S. military communication system in Europe. Measurements are being made over a 12-month period. The measurements include radio performance measurements, multipath measurements using both the channel probe and a spectral distortion measurement system, and automated meteorological measurements. The purposes of these measurements are to investigate the long-term performance of the digital radio used in the DEB and to investigate alternative space diversity switching algorithms.

Error performance standards specified by both CCITT and military standards organizations typically allow only a few hundred errored seconds per year. The measurements being conducted in Europe will be useful both in investigating the performance of the particular radio being used in DEB and in resolving questions regarding the realizability of the standards themselves.

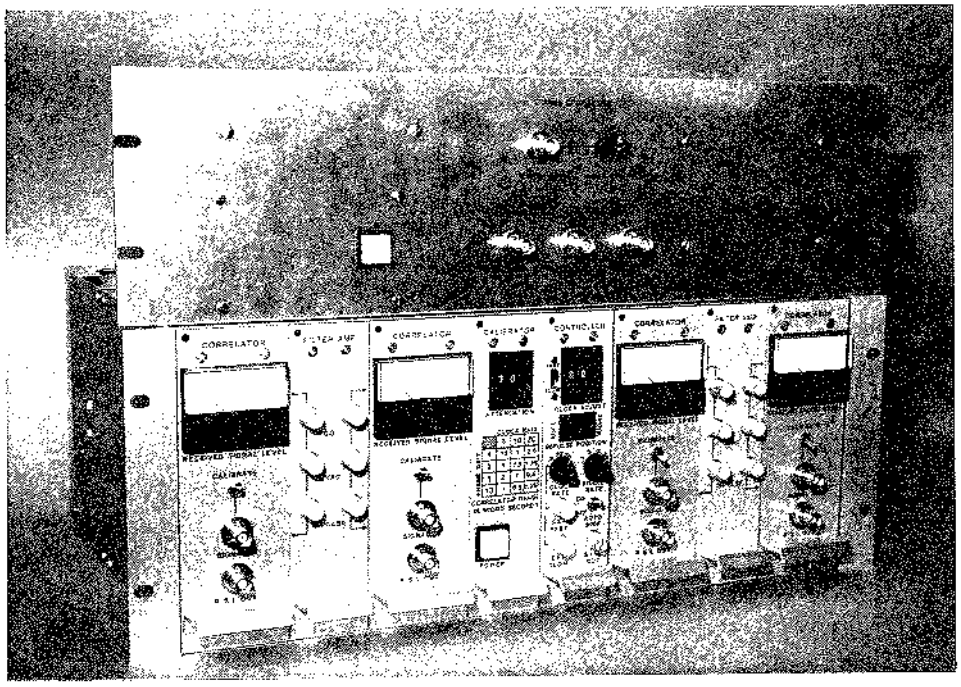
During FY 88, the Institute also provided support to the U.S. Air Force in making performance measurements on a long (88-km) LOS link over the English Channel. The

climatic conditions on this link create a very difficult propagation environment. This program involved the same types of measurements as those made on Schwarzenborn-Feldberg link in Germany.

In a related project, the Institute has provided consulting services for the Charleston Tactical Air Crew Training System (TACTS) as the Navy installed upgraded communication facilities for a major offshore air warfare training center. This work included assistance with testing the ocean tower-to-shore microwave systems and assistance with the land link system to bring the air warfare simulation information to the control center at Beaufort, SC.

Recent ITS Publications

Propagation and Performance Measurements Over the Berlin-Bocksberg Digital Troposcatter Communications Link (by Lemmon and Riley)



Troposcatter Channel Probe Constructed at ITS

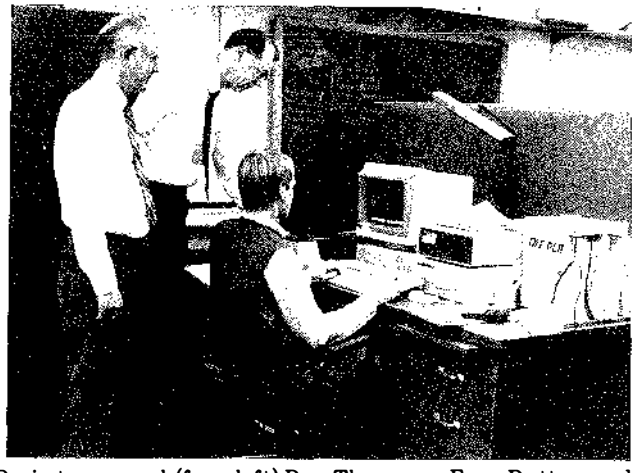
Transmission System Modeling

Outputs

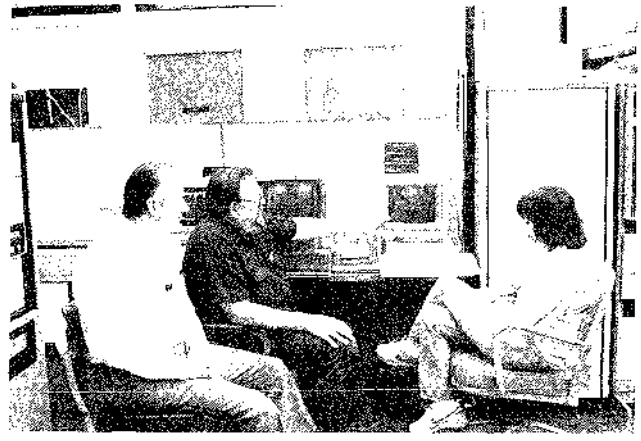
- Digital link performance prediction software
- Wide area propagation performance prediction software
- Link performance prediction consulting

Line-of-Sight Radio Link Design Program. The proliferation of desk-top computers throughout the military departments has created new opportunities for interactive design of radio links at many user locations as well as at engineering centers. ITS has been involved with the preparation of radio system design software. During the last few years the Institute has developed a number of sophisticated design packages used to predict the performance of terrestrial radio transmission systems. Current efforts include translating previously developed line-of-sight radio link design software for use on a personal computer. This software has been put to use by the U.S. Army Information Systems Engineering Command at Ft. Huachuca.

To meet the military's need for a highly interactive program that would analyze radio link performance in terms of Military Standard requirements, ITS is developing the Digital Line-of-Sight or DLOS program set to provide estimates of link performance. This program set will utilize the Defense Communications Agency technique of analyzing the performance of a digital microwave radio over a typical line-of-sight path. One of the primary reasons for the development of the DLOS program was to provide a "quick look" tool for link and system designers.



Project personnel (from left) Ray Thompson, Evan Dutton, and Mike Province



Project personnel (from left) Larry Hause, Joe Farrow, and Susan Rothschild

The DLOS design can proceed using approximate information for many of the link parameters that influence performance. This provides a first approximation of expected link performance. If the agency performing the link design decides to pursue the design in greater detail or with greater precision, the DLOS programs allow the input data to be updated to provide a more precise estimation of link performance. In addition, the DLOS parameters can be changed so easily and the recalculations performed so quickly that iterative link design is possible to arrive at a final design that meets the military standard performance availability requirements. An example output of the DLOS software is shown in the link profile plot. This plot provides a visual indication of the clearance of the line-of-sight signal above the ground.

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:

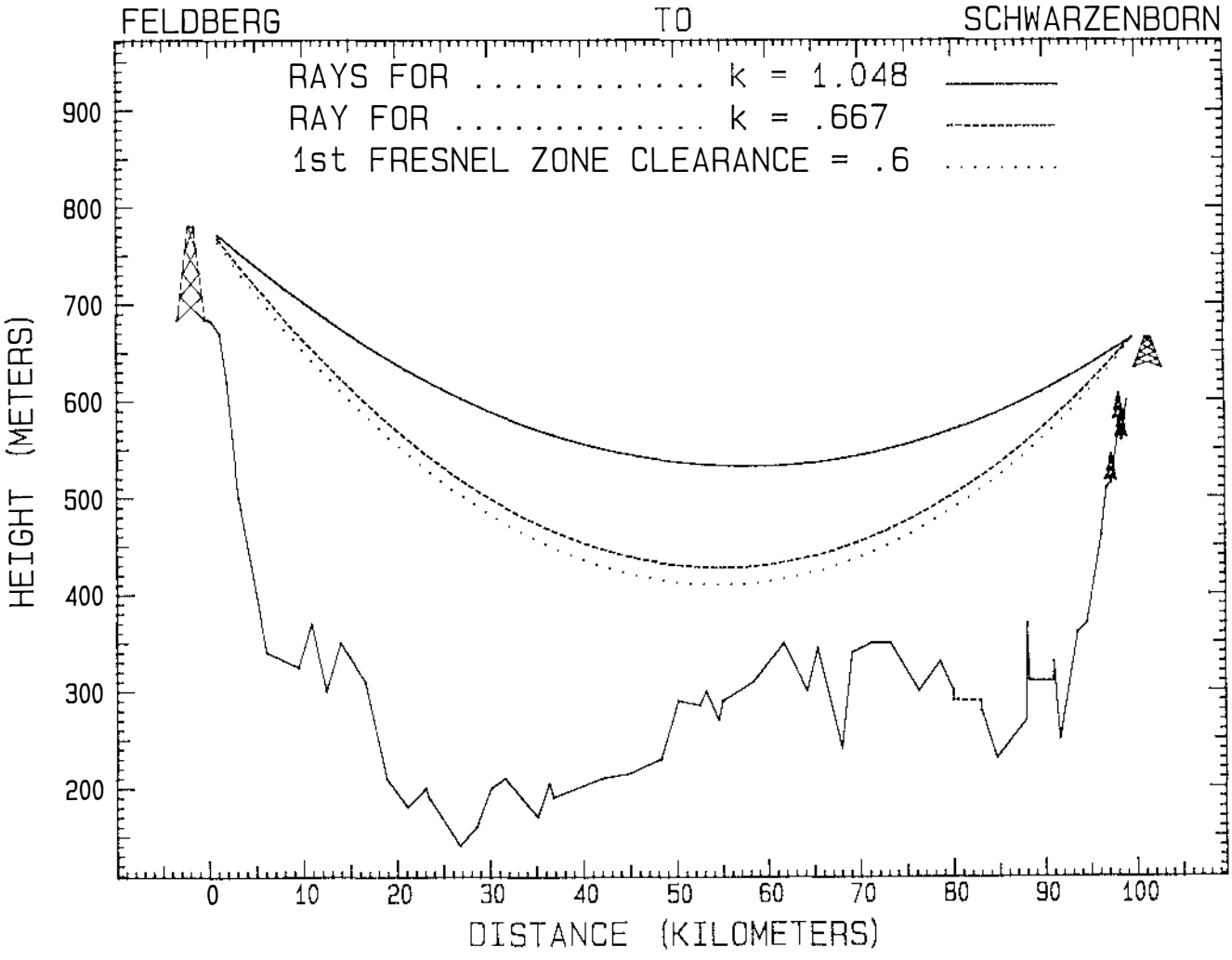
- UNIX™ environment operation
- convenience of conversion between computer systems
- incorporation of new and updated algorithms
- substantially decreased operator time per link design
- ease of use with less operator training time

- applicability to all three types of radio links: line-of-sight, marginal line-of-sight, and over-the-horizon links

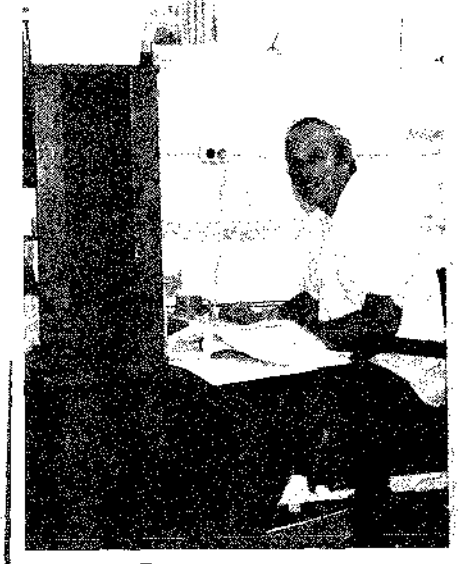
Wide Area Propagation Software. Three of the most commonly used digital modulation techniques for point-to-point terrestrial applications at microwave/millimeter-wave frequencies are 8-PSK, 16-QAM, and 64-QAM. These modulation techniques become increasingly sensitive to multipath with increases in the signal constellation density. Of the three, 64-QAM is the most sensitive to multipath. In the Wide Area Propagation Modeling effort, ITS is developing models to ascertain the bit error rates of received signals that employ these digital modulation techniques. Terrain multipath is modeled as two-ray multipath and treated as a form of interference in order to investigate its effects on bit error rate under various propagation conditions. There are several applications (e.g., mobile communications and military battlefield environments) where LOS propagation over terrain that causes terrain multipath is a distinct possibility. The effects of terrain multipath on digitally modulated systems can be severe because of the large spectral requirements of these high-data-rate systems.

Recent ITS Publications

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



On-Screen Profile Plot



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 and the National Telecommunications and Information Administration

Planning for Special Communication Environments

Includes projects funded by the Army Signal Center, the Defense Communications Agency, and the National Bureau of Standards

Advanced Systems Planning

Includes projects funded by the Air Force Electronic Systems Division, the Defense Communications Agency, the National Telecommunications and Information Administration, and the U.S. Department of Agriculture/Forest Service

Satellite Studies

Outputs

- Advanced satellite communication technology studies
- Technical guidance on the PEACESAT Network
- Analysis of multipath effects on land mobile radio systems

Advanced Satellite Communication Technology Studies. The evolution of communication satellites is being driven by the need for increased service capacity, lower service costs, and integration with advancing communication system technologies such as optical fiber transmission and Integrated Services Digital Networks (ISDNs). A new generation of advanced, "smart," communication satellite systems will respond to these requirements through the application of on-board switching and digital signal processing techniques. These advanced satellites will also incorporate sophisticated, hopping, spot-beam antennas that facilitate the instantaneous establishment of high-volume circuits on demand. These features will also help alleviate orbit and spectrum congestion and, through the use of 30/20 GHz (Ka-band) frequencies, will 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. The National Aeronautics and Space Administration (NASA) is developing and will launch in 1992 an experimental satellite, the Advanced Communications Technology Satellite (ACTS), as a test bed for these advanced satellite studies. Government agencies, universities, and commercial organizations are being invited and encouraged to plan and conduct experiments using ACTS.

The Institute is planning a unique set of end-to-end system performance experiments using the framework of an NTIA-developed American National Standard (ANS), X3.141-1987, "Measurement Methods for User-oriented Performance Evaluation." During FY 88, the Institute prepared an NTIA report that defines user-oriented performance parameters suitable for describing the end-to-end system performance of advanced communication satellite systems.

PEACESAT. ITS is providing consultative support to the Pan-Pacific Education and Communication Experiment by Satellite (PEACESAT) program, a University of Hawaii effort that recently received

Project personnel (from left) Ray Jennings, John Lemmon, Karen Henderson, Rob Cass, and Darren Smith

a Public Telecommunication Facilities Program grant. The original PEACESAT Network was established in the early 1970s as an educational, cultural, and emergency medical communication satellite network using NASA's Application Technology Satellite 1 (ATS-1). In 1985 ATS-1 ran out of station-keeping fuel and started to drift, resulting in the abandonment of the network. In 1988 Congress funded a grant to reestablish the network.

The challenge in finding a suitable replacement satellite system for ATS-1 is identifying systems that are cost effective, yet provide the service required with a level of earth terminal technology appropriate for use in the developing countries and microstates of the Pacific. The original PEACESAT Network operated in the VHF band with inexpensive, homemade earth terminals. However, many of the candidate replacement systems operate at higher frequencies, requiring sophisticated, hence expensive, earth terminal equipment.

ITS' consultative role in the PEACESAT program includes providing technical guidance for the identification and evaluation of suitable ATS-1 replacement candidates and associated earth terminal equipment.

Satellite Multipath Measurements. During FY 88 the Institute completed initial planning for a multipath measurement experiment to be conducted in support of NASA's Mobile Satellite

Communication Program (MSAT-X). 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 land mobile satellite radio channels.

ITS completed a report to NASA discussing the various alternatives for development of a modified GPS receiver. In addition, the technical specifications for the procurement of the modified receiver were developed. This latter effort resulted in a paper presented at the Mobile Satellite Conference in Pasadena, CA, in May 1988.

Related Programs: Millimeter-Wave Propagation Studies. In a related propagation studies program, ITS is conducting a series of measurements on a slant path from coast line to mountain top in Hawaii. This joint NASA/NTIA program will assess the impact of clouds and rain on EHF transmission systems for advanced communication satellite applications. A broader discussion of this program is given in the **Applied Research, Propagation Measurements**, section of this report.

Recent ITS Publications

Multipath Measurements for Land Mobile Satellite Service Using Global Positioning System Signals (by Lemmon)
Quantifying ACTS Communication System Performance (by Cass)
Suitability of ANSI Standards for Quantifying Communication Satellite System Performance (by Cass)

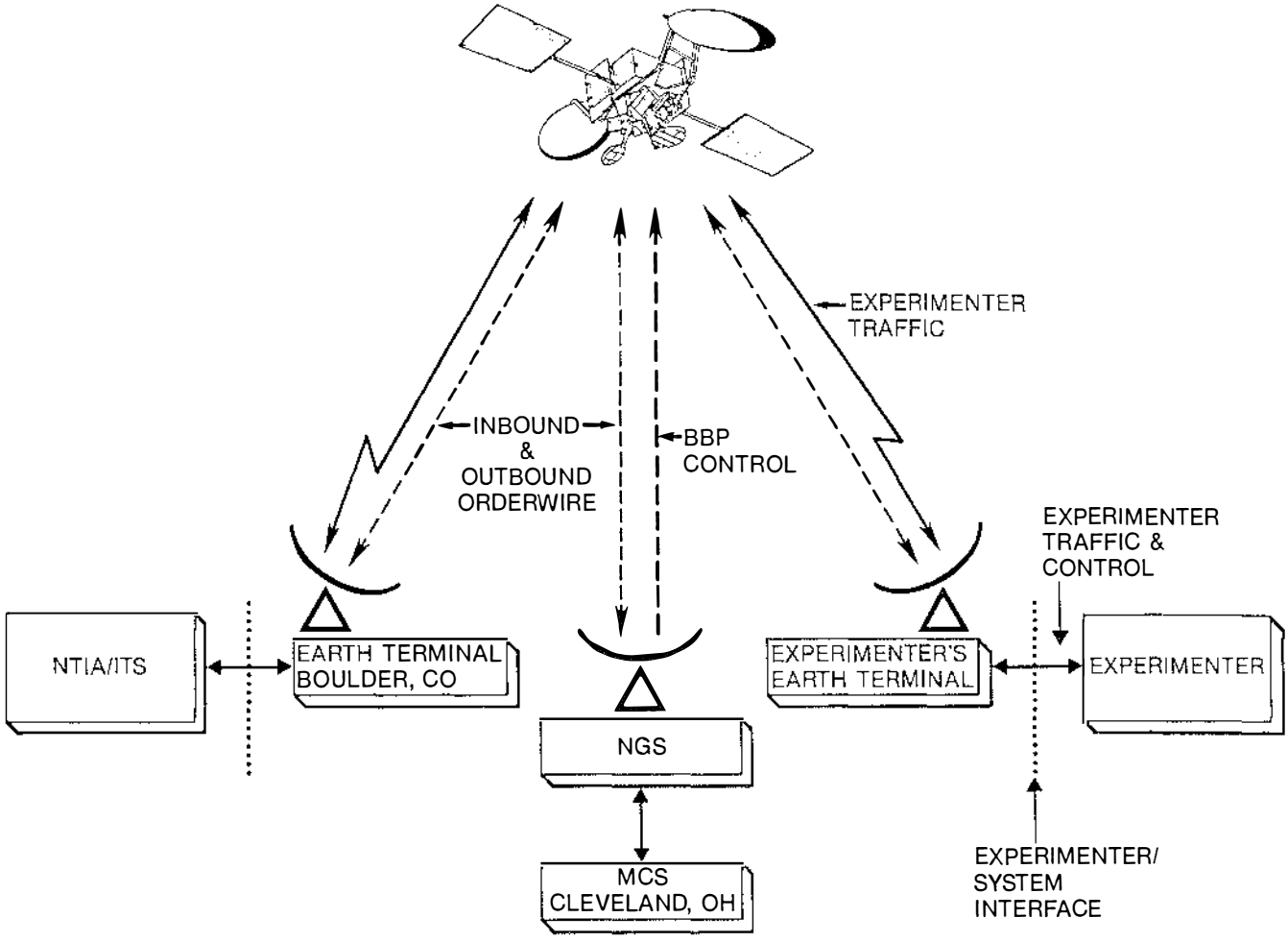


Diagram for ACTS Update Article on Satellite System Performance

Planning for Special Communication Environments

Outputs

- Multitier specification for improving the hardness of fiber optic long-haul systems
- Application of the multitier specification to an installed fiber optic link
- Analysis of trunked radio systems

The Institute provides support to the National Communications System (NCS) in its responsibility for assisting industry and Government in improving the survivability of National Security Emergency Preparedness (NSEP) telecommunication systems. During FY 88, this work moved from the development of basic tools for improving hardness to applying these tools in specifying upgrades for an actual installed system.

During FY 87, ITS developed a multitier specification to be used as a guideline in determining the hardness of a fiber optic long-haul installation. The specification is written such that it can be used to either classify the hardness of an existing installation or to specify the hardness of a link being designed. The multitier specification is expected to be used in the future by civilian and military Government agencies to specify the hardness of fiber optic installations that support critical Government services.

During FY 88, ITS conducted a follow-on study in which the multitier specification was applied to an existing NSEP-significant fiber optic link. This study had two objectives: to evaluate the hardness of the link as installed, and to evaluate the cost of enhancing the link's hardness, both by upgrading the existing facilities and (hypothetically) by implementing the same upgrades during the original link installation. A link installed by Mountain Bell (now US West Direct) was selected for the evaluation.

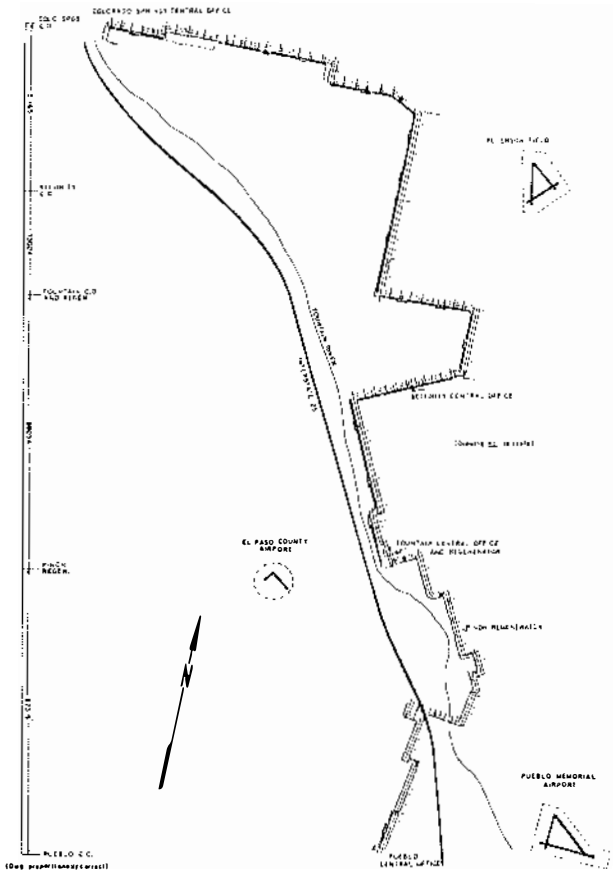
The figure at the top of the facing page shows the route of the selected link and indicates various geographical features in the vicinity that could increase its vulnerability. Examples are the link's close proximity to an airport and its location within the basin of a river. The ITS study demonstrated, in a practical way, the value of the multitier specification in identifying and mitigating such risks.

Project personnel (from left) Joe Hull, Bob Adair, and Dave Peach

The upgrade study was initiated by determining the hardness of each major component of the system as installed. A rating scale (1 to 10 with 10 being the hardest) was used to indicate the level of protection provided. Various upgrades were proposed, and the resultant improvements in level of protection were determined. These ratings are shown in the table for each major stress category.

The cost analysis conducted in conjunction with this application demonstrated that the hardness of a long-haul fiber optic link can be substantially improved at little additional cost if appropriate enhancements are included in the original installation. The cost of adding the same hardness enhancements to an installed link is substantially higher. The hardness enhancements described in the multitier specification appear to be cost effective, particularly in cases where an installed link is likely to support critical traffic.

During FY 88, the Institute also provided assistance to the National Institute of Standards and Technology's Law Enforcement Standards Laboratory (LESL) in a project entitled Performance and Applications of Trunked Land Mobile Radio Systems. In this project, ITS investigated various aspects of trunked radio systems as they relate to requirements of public safety radio users. This work included computer evaluation of various trunked radio systems



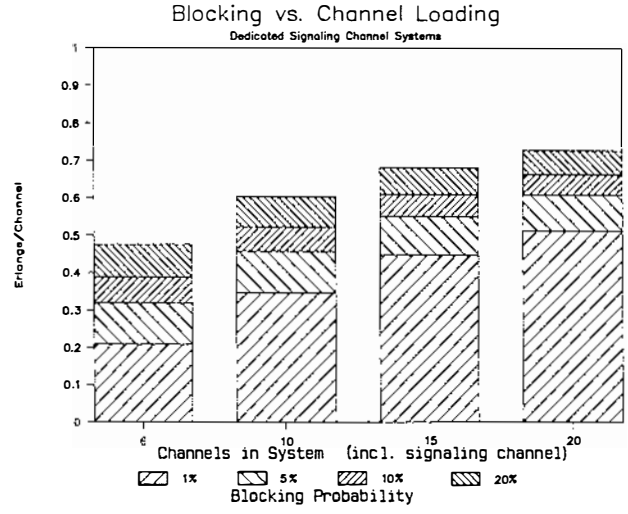
Fiber Optic Link Physical Layout

Stress Parameter	Levels of Protection: Before Upgrade	Levels of Protection: After Upgrade to (Level 4)
1. Natural Events		
Ice	10	10
Snow	10	10
Rain	10	10
Wet Conditions	10	9
Dry Conditions	10	10
Flood	10	8
Water Erosions	10	10
Deep Frost	10	10
Wind	8	10
Earthquake	8	9
Lightning	10	10
Accidents on ROW	9	10
2. Extreme Hot/Cold	10	10
3. Blast from Explosion	6	10
4. Nuclear Blast Overpressure		
2 psi (Level 1)	10	10
10 psi (Level 4)	2	10
5. Gamma Radiation		
5000 rads	1	10
30000 rads	1	10
6. HEMP		
5000 V/m field strength	1	10
50000 V/m field strength	1	10
7. Sabotage Damage	7	10
Overall Protection Level	1	10

Stress Protection - Before and After Upgrade

under different traffic loads. The ITS staff is investigating methods of measuring performance of trunked radio systems. ITS also served as a consultant to the sponsor on techniques for measuring the performance of Amplitude Companded Sideband (ACSB) transceivers in this project.

The figure below shows the results of some of the computer evaluations. The figure shows that for a given blocking probability, larger trunked systems can handle more traffic per channel or conversely, for the same traffic per channel a larger trunked system will experience a lower blocking probability. The figure shows that a 20-channel system can be over 50 percent loaded (0.5 Erlangs/channel) and still experience only 1 percent blocking. The figure also indicates the importance of considering loading percentage in addition to blocking probability when designing public safety trunked radio systems. For example, if a 20-channel system under routine traffic loading experienced 1 percent blocking (50 percent loading) it could be grossly overloaded in a major emergency when traffic may increase by a factor of three to four times. Public safety systems must be designed considering traffic loading requirements of emergency situations.



Recent ITS Publications

EMP Protection Attained Through Use of a Multitier, Stress-Hardening Specification (by Peach)

Multitier Specification Applied to Modify the Hardness of an Essential NSEP Fiber Optic Link (by Peach and Adair)

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

Advanced Systems Planning

Outputs

- National telecommunications policy recommendations
- Advanced system concepts, specifications, and standards

The Institute contributes to the planning of advanced telecommunications and information systems in two ways: first, by providing technical support to other NTIA offices involved in developing telecommunications and information policies, and second, by providing system requirements analysis and planning services to other Federal agencies. Examples of specific FY 88 activities follow.

NTIA Policy Support. The Institute made technical contributions to several NTIA policy development activities during FY 88. Institute staff members served on a project team that undertook (and completed) a major, long-range study of U.S. telecommunications and information policy--**NTIA Telecom 2000: Charting the Course for a New Century.** The study report assesses telecommunications and information technology trends, proposes new applications for these technologies in the 21st century, and suggests ways in which the Government can assist U.S. industry organizations in realizing their benefits. Institute staff members surveyed key technologies such as fiber optics, advanced satellites, computers, and integrated services networks and contributed to several technical sections of the study report. A key recommendation of the report is the adoption of new Government policies that will hasten and ensure public access to "universal information service"--a synthesis of innovative new voice, data, and video information processing, transmission, and storage capabilities that will enrich our economy and society in the 21st century.

In a related study, ITS examined the convergence of telecommunications and information industries and the possible evolution of a "knowledge society" in the 21st century. This study concludes that present Government regulations and policies and incentives for industry fragmentation are inhibiting the development of integrated services needed to meet emerging information demands.

Project personnel (standing from left) Roger Salaman, Bill Pomper, Joe Farrow, Val Pietrasiewicz, and (seated from left) Randy Bloomfield and Bob Linfield

DCS Integrated Node Architecture. This project, supported by the Center for Command and Control, and Communications Systems of the Defense Communications Agency, provides development assistance to the DCA for the design and procurement of the next-generation Defense Communications System (DCS). Based on ITS analysis of current and future DCS requirements, and technology and regulatory trends, the project is developing preferred access node architectures for the post-1995 DCS. Because of the complexity of the network design problem, which involves technical, economic, regulatory, policy, and organizational issues, new approaches for developing alternative candidate architectures have been established. As illustrated, a functional architecture paradigm is being used to assess architectural concepts and to explore issues. Preliminary conclusions indicate that Integrated Services Digital Networks will provide the underlying access architecture of the DCS in the 1990s, and that broadband ISDN will become the predominant attribute of DCS in the early 21st century.

DCA Meteor Burst Communications. In this project, the Institute provided technical support to DCA in the development of interoperability standards for meteor-burst communications (MBC). The ITS work was focused on defining the communications security (COMSEC) portion of the proposed meteor-burst interoperability standard. Accomplishing this task involved

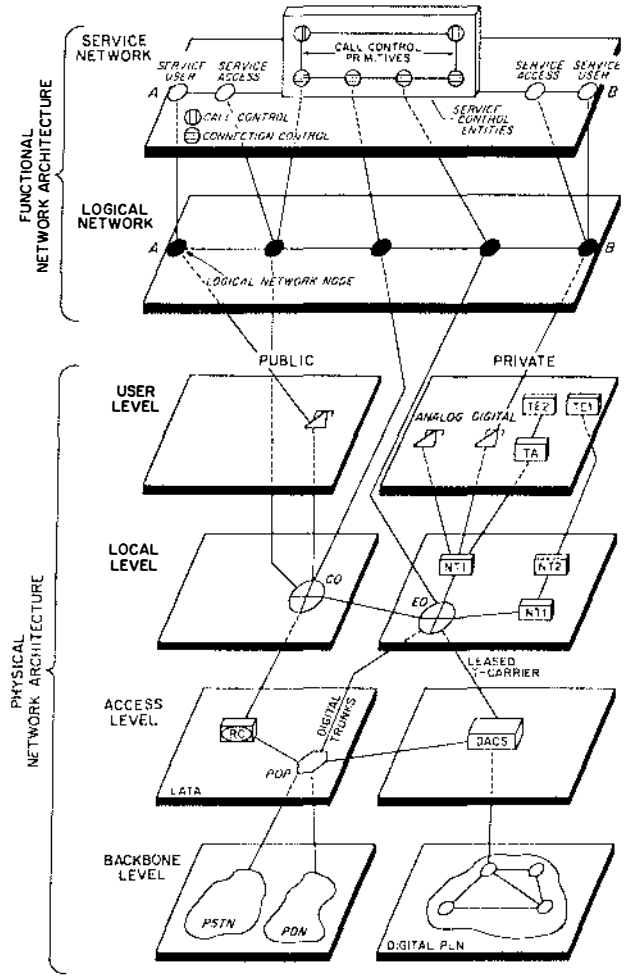
analyzing meteor-burst network security requirements, developing approaches to meeting these requirements, and examining COMSEC equipment for its potential application to the meteor-burst environment. The end products included writing the COMSEC portion of the proposed interoperability standard and developing and documenting a recommended COMSEC design that meets requirements specified in this standard. ITS participated in the MIL-STD-188-135 Working Group. The Institute also conducted a study of the feasibility of developing an advanced MBC interoperability standard in the near future and recommended the direction of future standardization efforts in this area. Other areas of work involved MBC protocols, protocol verification test methods, and embedded COMSEC.

USAF Local Area Network Consulting. The Battle Staff Management System network connects the eight major Air Force Logistics Command bases. The system at present comprises 3 host computers and 91 remote terminals distributed throughout the United States. The traffic carried by the system is classified and is transmitted in encrypted form. ITS has acted as a communications consultant for the interbase circuits and has provided assistance to the using agency in initiating and maintaining system operation.

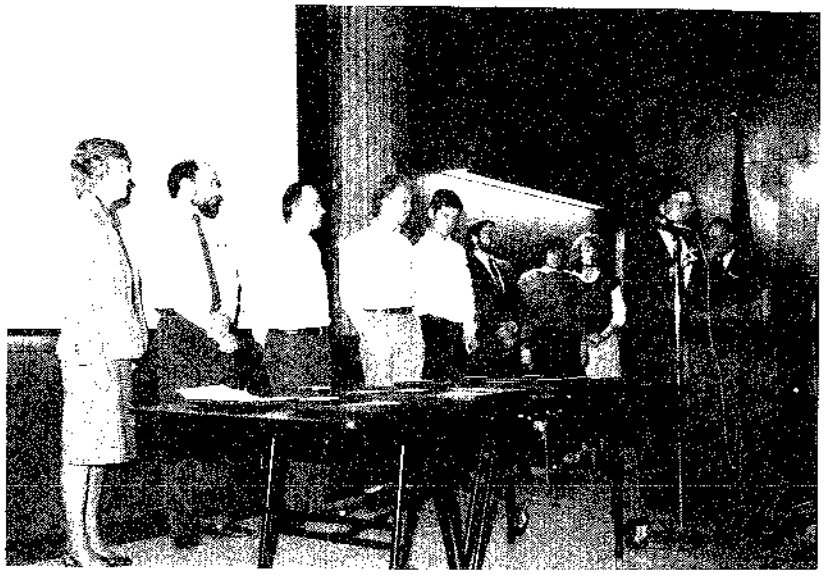
Forest Service Telecommunications Planning. Sponsored by the Wallowa-Whitman National Forest, this project began in FY 88 and will conclude in FY 89. The end product of the project will be a long-range telecommunication plan for the Forest. This plan will present a comprehensive architecture for a Forest-wide telecommunication network that will integrate radio, voice telephone, and data communications to meet the Forest's technical requirements in an economical manner. During FY 88, ITS developed two reports for the USFS. The first report dealt with requirements definition. It included a review of existing systems, identification of primary and peripheral needs, technical and other applicable constraints to the design process, and establishment of the degrees of service integration to be considered. The second report developed and evaluated a series of architectural alternatives for mobile communication systems. Future work will include the planning and engineering design leading to the final telecommunication plan and a detailed cost estimate for the recommended system.

Recent ITS Publications

Architectural Considerations for Accessing the Post-1995 CONUS DCS/DSN: Target MILDEP Local Information Transfer Networks (by Bloomfield)



Levels of the Functional Architecture Approach



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 Propagation Modeling

Includes projects funded by the Army Intelligence and Security Command, the Army Missile Command, the Department of Defense, and the Naval Ocean Systems Center

Propagation Measurements

Includes projects funded by the Army Communications-Electronics Command, the Department of Defense, the National Aeronautics and Space Administration, and the National Telecommunications and Information Administration

Radio Environment Simulation

Includes projects funded by the Air Force Electronic Systems Division, the Army Information Systems Engineering Center, and Rome Air Development Center

Millimeter-Wave Propagation Modeling

Outputs

- Updated MPM model
- User's manual for ETSEM
- Software for predicting millimeter-wave system performance in various scenarios
- Model of propagation in the mesosphere

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. The field measurements are discussed in the following section entitled "Propagation Measurements." Practical application models in the form of computer programs are also produced to serve as analysis tools for other Governmental agencies and private industry.

Two major modeling efforts were undertaken in FY 88. One was the development of software for analyzing and predicting the performance of systems, as limited by propagation effects, for frequencies from 1 to 1000 GHz in a variety of operational scenarios.

ETSEM (EHF Telecommunication System Engineering Model) was developed in previous years to predict the performance of terrestrial links. It was written specifically to be an aid to engineers in the determination of cost-effective design trade-offs while maintaining required link availability. ETSEM was later extended to include ground-to-satellite and ground-to-aircraft links.

The new software for Analysis of Millimeter-wave Operational Scenarios (AMOS) is structured in a different manner to serve as an aid in evaluating performance for a variety of scenarios. The new software is much more flexible in its capabilities, and because it is highly structured, new capabilities can easily be added.

The components of AMOS are a user-created catalog of equipment, ground stations, aircraft, and satellites and the software for creating and maintaining the catalog; a climatological data base for the world; a library of propagation subroutines; and the analysis software. The types of scenarios that can be analyzed are ground-to-ground, ground-to-satellite, ground-to-aircraft, and aircraft-to-satellite. For each type of scenario, a number of analyses are available.

Project personnel (from left) George Hufford, Ken Allen, and Hans Liebe

Typically, a user would pick the scenario type that best fits the situation in which he is interested. He then defines the scenario for the software. For example, for a ground-to-aircraft scenario, he would specify the ground station, the aircraft platform, and the flight path of the aircraft. The ground station and aircraft platform are contained in the user-created equipment data base, which also contains the specifications of the transmitter, antennas, and other equipment that are used at the ground station and aircraft platform.

After defining the scenario, which is also stored in the user-defined data base, the user chooses from the list of analyses that are available for each scenario type. For example, the user may choose to compute the carrier-to-noise ratio as a function of aircraft position on the flight path. Afterwards the user can choose another analysis or modify the scenario, including any equipment specification such as antenna gain or frequency, and rerun the analysis.

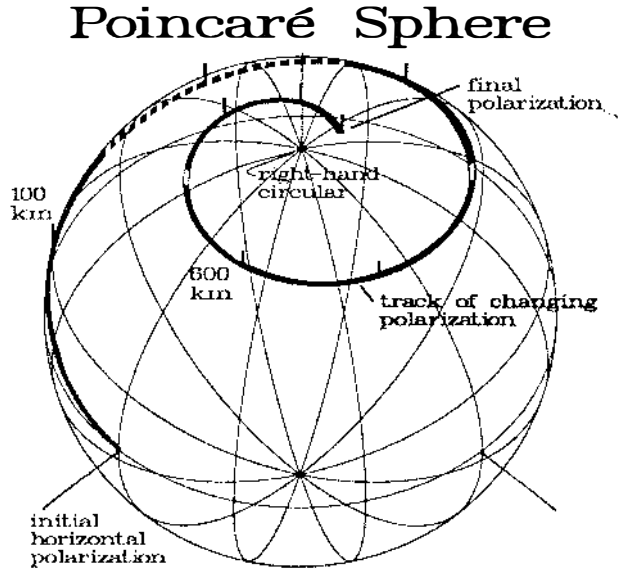
As can be seen from the above example, the new software was written to analyze various scenarios or situations instead of to serve as a design tool for a system engineer. However, because the new software is so versatile, it also should be useful for many problems, including link design.

The other major modeling effort was focused on propagation in the mesosphere at frequencies near the oxygen lines in the complex from 50 to 70 GHz and at 118 GHz. Because of the low pressure in the mesosphere, the geomagnetic field has a Zeeman effect on the oxygen lines. As a result, the line is split or spread over a few megahertz, and the effect of the line depends on the direction of propagation with respect to the Earth's magnetic field.

An anisotropic refractive index is modeled in three dimensions as a function of frequency about each oxygen line. For a given propagation direction with respect to the geomagnetic field, a 2x2 matrix is derived. The eigenvectors of this matrix define characteristic waves (polarizations). The corresponding eigenvalues define the phase delay and attenuation rate for each characteristic wave.

When a wave is propagating, its polarization approaches the polarization of the characteristic wave with the lower attenuation rate. The polarizations of the characteristic waves are linear when the propagation direction is perpendicular to the magnetic field lines and circular when the direction is parallel to the field lines.

The Poincare sphere below shows the change in polarization of a 59.592-GHz wave propagating 1000 km at a height of 80 km and at an angle of 27.5 degrees with respect to a magnetic field of 31 microtesla. The wave is initially horizontally polarized and it approaches right-hand circular polarization.



Of course, when a wave propagates through the mesosphere, variations in pressure, the direction of propagation with respect to the geomagnetic field, and the strength of the geomagnetic field are changing continuously. Software to account for all of these factors has been written in order to compute the effects on a wave as it propagates on an arbitrary path through the mesosphere. A model of the geomagnetic field and a model profile of the atmospheric parameters are included in the software.

Additional accomplishments in FY 88 include the completion of a user's manual for ETSEM and the updating of the MPM model--a physical model of propagation in the troposphere for frequencies from 1 to 1000 GHz.

Also, an instrumentation design study was completed for measurements of millimeter-wave transmission and scattering characteristics for combat related transient events. Typical events include fuel fires, fire storms, large surface and near surface chemical detonations, low altitude and surface tactical nuclear detonations, chaff fields, and obscurant clouds.

Recent ITS Publications

Atmospheric Attenuation and Delay Rates Between 1 GHz and 1 THz (by Liebe)

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

Mesospheric Radio-wave Propagation in the 60 GHz Band Affected by Zeeman-split Oxygen Lines (by Liebe, Hufford, and Katz)

Millimeter-Wave Attenuation and Delay Rates Due to Fog/Cloud Conditions (by Liebe, Manabe, and Hufford)

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

Propagation Measurements

Outputs

- Fully automated meteor-burst propagation measurement system
- New, fully polarimetric millimeter-wave instrumentation
- Measurements of millimeter-wave system performance on an AT&T path
- Final report on urban/suburban millimeter-wave propagation measurements
- Short-path millimeter-wave attenuation measurements in a tropical environment
- Measurements of millimeter-wave propagation through conifer forests

Field measurements constitute a major emphasis of the ITS propagation program. They help identify areas where further modeling work is needed and are the ultimate test of the validity of models. Last year, propagation measurements included work in VHF/UHF meteor-burst paths and at millimeter wave frequencies.

In FY 88, new instrumentation was designed and built for millimeter-wave measurements. The new instrumentation adds the ability to measure phase delay as well as attenuation, and it adds this ability in a fully polarimetric sense. Because any coherent, fully polarized wave can be separated into two orthogonally polarized components, such as horizontal and vertical, or left- and right-hand circular, the effect of a propagation medium or path on the wave can be described by a 2x2 transmission matrix. That is, the coherent, fully polarized portion of the wave remaining after propagation can be found by multiplying the vector representing the transmitted wave by a matrix representing the effects of the propagation. This matrix fully characterizes the effects of the medium upon the coherent wave. It contains the phase delay and attenuation information of each co- and cross-polarized component. Thus, in order to completely describe the effects of the medium, it is necessary to measure the phase delay and gain (attenuation) of all four of the elements of the transmission matrix.

The most common technique for measuring the elements of the transmission matrix is to switch between combinations of polarizations at the transmitter and receiver. However, with such a method, the measurements are not simultaneous and are limited in time resolution by the time required for switching and settling. The technique used in the ITS instrumentation is to transmit one polarization

Project personnel (standing from left) Jeff Wepman, Brent Bedford, and Bob Achatz and (kneeling from left) Dave Haupt, Dave Jones, and Rob DeBolt

at 28.8 GHz and the other at 28.815 GHz. A dual polarization receiver is used in which each received polarization results in two intermediate frequencies (IFs), one for the copolarized wave and one for the cross-polarized wave. All signals are coherently received, and the relative phase and absolute amplitude of each component are measured. Thus, all the elements of the transmission matrix are measured simultaneously, and the time resolution of the measurements is limited only by the IF bandwidth and system noise. The same technique is used simultaneously at 96.1 and 96.15 GHz.

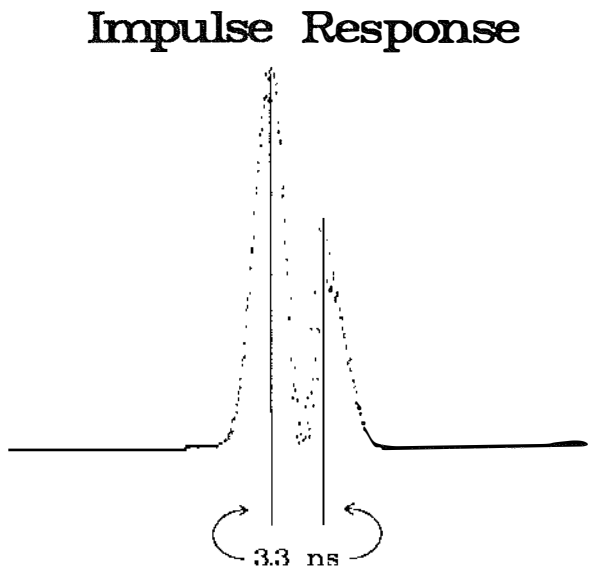
The new system has been installed on a slant path of 5 degrees from 13,800 ft to sea level in Hawaii to measure the effects of the lower atmosphere on a simulated Earth-space path. We are particularly interested in depolarization effects in rain.

Previous measurements on a short path to characterize the rain in Hawaii (and more generally in a tropical climate) were completed at the bottom end of the slant path (Hilo, Hawaii). Rain rate and attenuation (vertical polarization) at 9.6, 28.8, 57.6, and 96.1 GHz on a 1-km path were measured from February through September 1988. These data add to the ITS data base of other short-path measurements made in California, Colorado, and Alabama. These data form the largest data base on the climatic and geographical variability of millimeter-wave attenuation rates in rain.

In order to study the performance of millimeter waves under multipath conditions, measurements were made on an AT&T operational path (Salton to Brawley) known to suffer almost every day from multipath fading. This gave the opportunity to compare the relative performance of links at 4 and

6 GHz to links at 11.4, 28.8, and 30.3 GHz, where the use of narrower beam antennas might result in improved performance under multipath conditions.

Preliminary analysis of the data shows that there was no significant difference in multipath attenuation between the millimeter-wave and commercial links. In addition, although Bell Laboratories inferred multipath delay times up to 1.5 ns from frequency domain measurements, the ITS 500-Mb/s, pseudo-random noise, channel impulse probe at 30.3 GHz twice measured a strong multipath component at a delay greater than 3 ns as shown below.



Impulse Response Measured at 30.3 GHz on March 30, 1988, During Multipath Fading on the 60 km Salton-Brawley Path

Over a period of several years, ITS has made measurements of millimeter-wave propagation in urban and suburban environments. Measurements of diffraction around buildings, propagation through and into buildings constructed of various materials, and reflection from various building and pavement surfaces were included. In addition, measurements of signal level and impulse response as a function of various path parameters such as transmitter and receiver separation, antenna pointing, height, and beamwidth were made in an urban environment (downtown Denver). A "ray" model for propagation in urban environments was developed that agrees well with the measurements. A final report containing all of the results was prepared in FY 88 and should be published soon.

In addition to urban propagation measurements, ITS has measured millimeter-wave propagation through various vegetation over several years. Measurements have been made through deciduous trees with and without leaves. This year measurements were made in a conifer forest in Washington. A report on these measurements will be published next fiscal year.

The advantages of meteor-burst communication, which includes its resistance to jamming and its low probability of being intercepted, along with current capability of high data transmission rates, are creating a resurgence of interest in this type of communication. The primary goal of the meteor-burst propagation measurement experiment is to measure, analyze, and compute statistics of meteor-burst duration and waiting times (between meteor bursts) and to compare these statistics with existing model predictions. Additionally, transmission loss over the meteor-burst path is to be investigated. Time and amplitude data are collected from transmissions on four fixed frequencies spaced between 30 and 105 MHz. The signal is transmitted on each frequency alternating between a vertical and a horizontal polarized antenna. Yagi antennas are used for all configurations. The system will soon be deployed on a 700-km link between Israel and Greece.

The transmitter system is designed for fully automated operation. A dual-tone baseband signal is transmitted using narrowband FM transmission. The computer controls the FM modulator and switches between the four rf frequencies on a fixed hourly time schedule. The computer also controls the coaxial switch and connects the rf signal to the vertically or horizontally polarized antenna.

A dual-tone multiple frequency (DTMF) decoder detects the desired signal at the receiver. The amplitude of the desired signal is sampled and recorded under computer control. The sampling rate is fast enough to capture the quick under-dense bursts and determine their longevity. The receiver system is fully automated and designed to recover from anticipated field hazards.

Empirical statistics are being developed for comparison with the ITS Meteor Burst Communication Model. The results of the comparison will provide insight into the performance of the model as well as our understanding of this phenomenon.

Recent ITS Publications

Millimeter-Wave Propagation Characteristics and Channel Performance for Urban-Suburban Environments (by Violette, Espeland, and Allen)
Millimeter-Wave Studies (by Allen)
Overview of the ITS MM-Wave Program (by Allen)
Observed Phase Delay Through Rain at 96 GHz (by Allen)
Polarimetric Measurements Through Atmospheric Obscurants at 96.1 GHz (by Jones, Allen, DeBolt, and Violette)

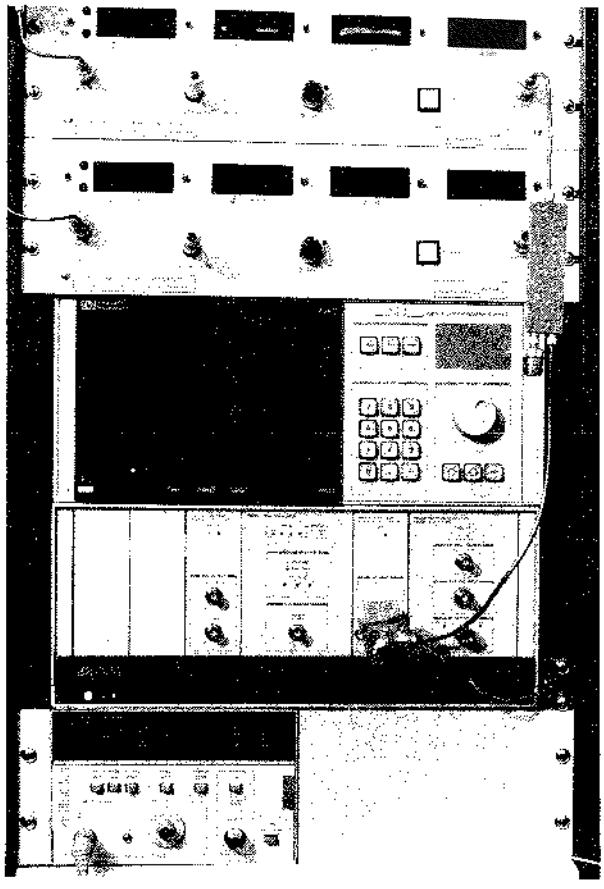
Radio Environment Simulation

Outputs

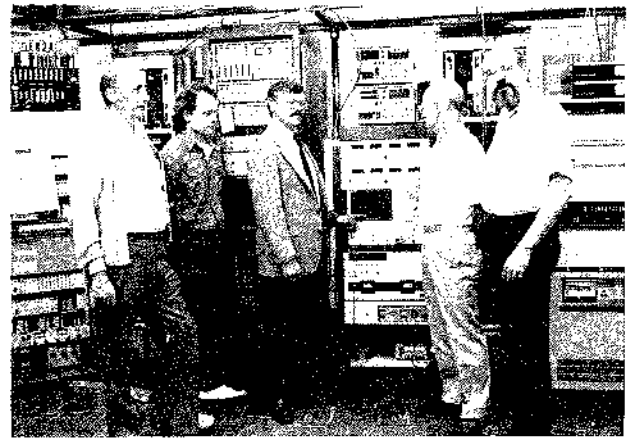
- New HF channel transfer function model
- Wideband HF noise/interference model
- Comparative performance evaluation of LOS microwave digital radios

Channel simulators are a cost-effective means of assessing and comparing the performance of two or more radio systems under controlled conditions. The advantages of channel simulators include repeatability, accuracy, comprehensiveness, and reduced testing cost. Institute staff members have developed a computer-controlled hardware simulator for line-of-sight (LOS) microwave channels and are currently developing mathematical models that will be implemented in a new simulator for high-frequency (HF) channels.

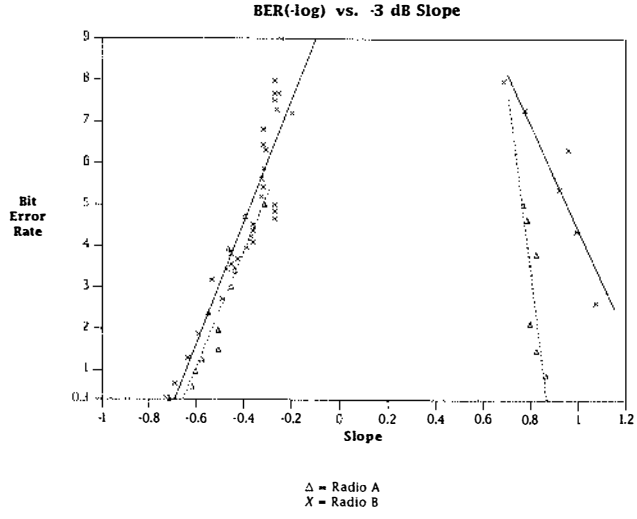
The Institute's LOS channel simulator (shown below) provides a unique capability for testing microwave radio systems. The simulator can be connected directly between a radio transmitter and receiver and will accurately reproduce multipath fading and other signal impairments observed in actual channels over the full range of microwave transmission frequencies. During FY 88, the LOS channel simulator was used to evaluate the performance of two digital microwave radios under simulated fading conditions. These experiments provided experience and preliminary results that will be applied in a more comprehensive evaluation of digital radios to be used in the worldwide Defense Communications System (DCS). Evaluation results are shown in the figure below.



LOS Channel Simulator



Project personnel (from left) Lauren Pratt, Chris Behm, Jim Hoffmeyer, Lew Vogler, and John Lemmon



Radio A Versus Radio B

Interest in high-frequency communication systems has grown substantially in recent years as a result of their robustness and relatively low cost, but the HF spectrum is severely congested. New technology such as spread spectrum is being developed to improve the performance of HF systems, but its optimization will require extensive testing. Such testing is not possible with currently available HF channel simulators because of their bandwidth limitations. During FY 88, the Institute made substantial progress in the development of mathematical models for a new HF simulator that will overcome these limitations.

The principal FY 88 product was a deterministic model that produces wideband ionograms that closely match ionograms produced from empirical measurements. These comparisons are shown below.

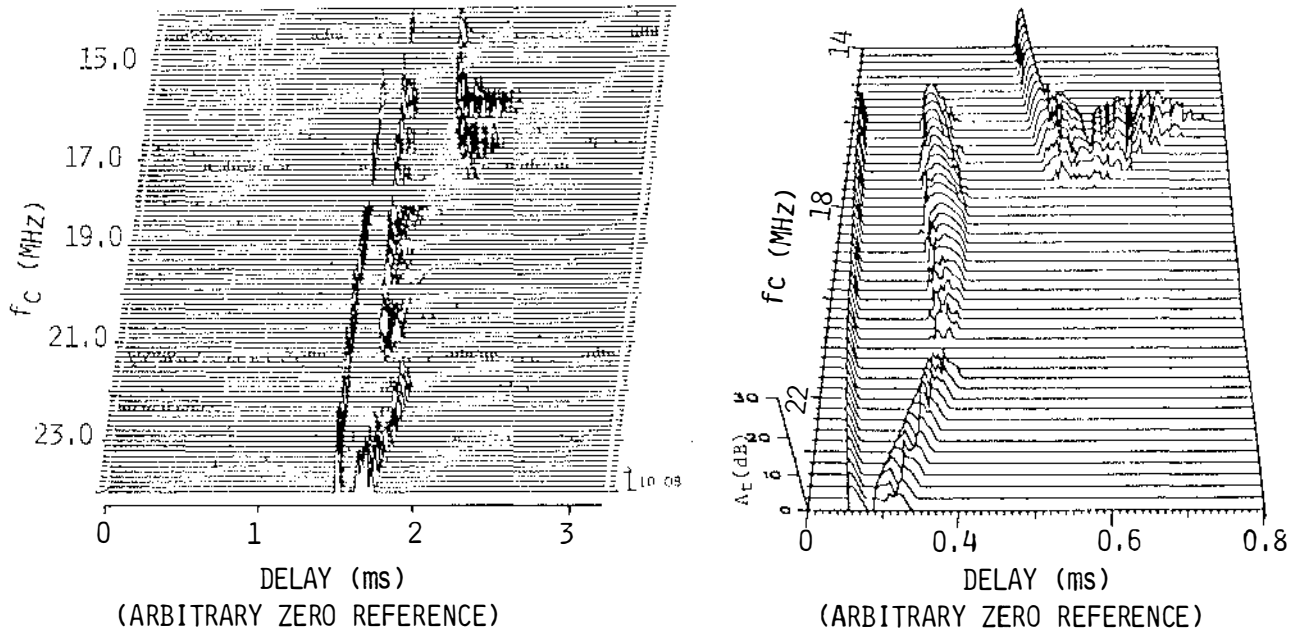
A new noise/interference model was also developed. During FY 89, these models will be enhanced to enable them to represent channel variations over time. The channel transfer function and noise/interference models will then be implemented in channel simulation hardware.

Recent ITS Publications

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

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

Progress and Remaining Issues in the Development of a Wideband HF Channel Model and Simulator (by Vogler, Hoffmeyer, Lemmon, and Nesenbergs)



a) IONOGRAM FROM NRL CHANNEL PROBE

b) IONOGRAM FROM MODEL

2600-km MIDLATITUDE PATH, WINTER MORNING

Comparison of Measured and Model Ionograms

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.

ISDN Laboratory • To support ITS leadership in developing national and international telecommunication performance standards and to facilitate the transfer of telecommunications technology to industry and Government, the Institute has recently established an Integrated Services Digital Network Performance Laboratory. In FY 88, the Systems and Networks Division focused on establishing in-house capabilities for testing prototype ISDN services. The equipment includes personal computer ISDN coprocessor boards, ISDN network emulation software, and a sophisticated ISDN protocol test system. Functionally, the equipment allows ISDN basic rate (2B+D) bearer service to be emulated and the protocols monitored between two ISDN workstations. ISDN performance measurement software developed by ITS is used to send voice, video, and data information between the workstations to measure the performance parameters under study.

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 and 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.

Local Area Network Laboratory • The ITS Network Laboratory is used to develop and study a variety of networks for interoperability and performance under many conditions. This facility can be used to simulate Local Area Networks, Metropolitan Area Networks, and Wide Area Networks. Specific objectives include the development of user-oriented performance measures for applications involving CAD, CAM, and both video and high-resolution graphics teleconferencing.

Equipment available for this laboratory is quite varied. Two micro-minicomputers with high-resolution displays and two 80386-based computers are available as workstations. These units are connected together by an IEEE 802.3 coaxial Ethernet (10 Mbps). Test equipment consists of two Ethernet analyzers and one 64-Kbps protocol analyzer. ITS plans to add six 80386-based workstations, an additional protocol analyzer, an optical fiber Ethernet, a Fiber Distributed Data Interface (FDDI)

network, a 14/12-GHz transmit/receive earth station (Ku Band), and a video teleconferencing system.

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 Department of Defense; 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 determining the performance of potential communication paths. Each terminal (transmit and receive) can be fixed or mounted on a van, which provides 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 (such as rain attenuation, multipath phase interference, antenna beam decoupling, and ray defocusing) as well as channel distortion across a 1.5-GHz bandwidth. Instrumentation to measure meteorological parameters such as rain rate, refractive index, and water vapor content is also available for simultaneous observation. 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.

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 vehicle, complete with an electrically raised antenna tower and a mobile telephone system.

The Table Mountain Radio Quiet Zone • This is a unique facility (one of only two in the Nation), that 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 (i.e., garage door openers, computers, citizen band radios, arc welders, and appliances) 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 saturated by background noise (interference). This facility is available for use by private parties on a reimbursable basis.

Video Quality Laboratory • The ITS Video Quality Laboratory is used to develop automated techniques for assessing the quality of video and image data. This computer-based system will allow users to obtain reliable, repeatable, and cost-effective measures of video and image transmission system performance. The system also provides a means of implementing a large set of video and image parameters and evaluating their usefulness in quality assessment.

Laboratory hardware consists of an 80386 computer-based image-processing workstation and peripheral image store/capture equipment. The workstation is capable of capturing

512 x 512 color images from video cameras, video tape recorders, or broadcast television signals. Once captured, images are digitized and stored and may be analyzed and processed using standard and ITS-developed methods. Other equipment includes an electronic-shutter, solid-state color camera and a still-frame VHS video cassette recorder.

Voice Quality Laboratory • This laboratory is used to study the effects of transmission impairments on perceived voice quality. ITS is using the facility to develop a method for automatically assessing voice quality as perceived by human listeners without the need for costly subjective scoring. The system will satisfy an urgent need of providers, users, and standards organizations for fast, inexpensive, accurate, and reliable quality-assessment methods. The laboratory consists of high-fidelity audio equipment attached to a computer workstation used to process and analyze the speech data. Two extensive data bases of distorted speech are also available. These represent a wide variety of real-world impairments and have been tested by human listeners.

ITS Projects for Fiscal Year 1988 Organized by Department and Agency

AGRICULTURE, DEPARTMENT OF

Forest Service

Wallowa-Whitman Telecommunications Plan • Val J. Pietrasiewicz (497-5132) • Develop a long-range telecommunications plan for the Wallowa-Whitman National Forest

BOARD OF INTERNATIONAL BROADCASTING (BIB)

BIB Analysis Standards • Gregory R. Hand (497-5258) • Develop HF broadcasting analysis software to be used by Radio Free Europe and Radio Liberty

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 • Robert D. Cass (497-5478) • Develop end-to-end system performance experiments applicable to the class of advanced communication satellite systems that use a baseband processor (switch) in the space craft. Investigate the various roles these advanced communication satellites should play in ISDNs

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

Broadcasting and Related Propagation Studies • Eldon J. Haakinson (497-5304) • Provide support to NTIA's Office of Policy Analysis and Development for high-definition television studies

Digital Network Performance • Randall S. Bloomfield (497-5489) • Promulgate and demonstrate compatible Federal and American National Standards for specifying and measuring data communication performance, and provide emphasis on application of these standards to, or integration with, voice and video performance in ISDNs

HF Broadcasting WARC Planning • James S. Washburn (497-3109) • Provide the United States with the capability to assess the impact of decisions taken at WARC-HFBC(2) on U.S. high-frequency broadcasting interests and provide the United States with the technical leadership necessary to successfully defend U.S. positions

International Standards • Edmund A. Quincy (497-5472) • Provide leadership to T1 and U.S. CCITT preparatory committees and lead and contribute technically to international efforts for development of functionally oriented, implementation-independent performance standards for packet-switched public data networks and ISDNs

ISDN Standards Technical International Conference • Daniel J. Tomich (497-3606) • Develop video quality assessment techniques and standards contributions in support of ISDN standards within T1 and CCITT, focusing on applications in high-resolution video work stations and high-definition television

ISDN Technical • Robert F. Kubichek (497-3594) • Develop voice quality assessment techniques and standards contributions in support of ISDN standards within CCITT

Millimeter-Wave Modeling • 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

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

PEACESAT • Raymond D. Jennings (497-3233) • Provide technical support to identify a satellite replacement system for the ATS-1 satellite and develop the technical specifications to acquire a space segment to replace ATS-1

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) • Develop the general principles for efficient use and management of the spectrum, and resolve specific current issues related to spectrum efficiency.

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 • Leslie A. Berry (497-5474) • Assess the impact that expanded use of meteor-burst communication systems will have on the Government-allocated VHF spectrum and identify approaches toward effective spectrum management of this technology

National Bureau of Standards

Performance and Application of Trunked Land Mobile Radio Systems • L. Thomas Jones (497-5953) • Assess the usefulness of trunked radio systems and their enhancements to law enforcement radio licensees, and identify the important performance aspects of a trunked radio system and make measurements to assess the performance of available systems

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

LF Signal and Noise Measurement • Donald H. Layton (497-5496) • Study the signal and noise environment in the 0- to 10-kHz range in a typical office/business environment

Millimeter-Wave Mesospheric Propagation Model • Hans J. Liebe (497-3310) • Develop a computer model running on the IBM PC and compatibles that describes the propagation effects in the mesosphere for arbitrary polarization

Millimeter-Wave Prediction Model for Tactical Scenarios • Kenneth C. Allen (497-3412) • Develop a highly structured computer model to predict the performance of millimeter-wave systems in a wide variety of tactical scenarios

Technology Transfer Methodology Implementation • Ernest L. Morrison (497-5888) • Provide guidance to selected Federal agencies in the application of strategic defense initiative organization developed telecommunications, AI/ES, and supercomputer technologies

VHF Experiment • Jean E. Adams (497-5301) • Design, install, and conduct a VHF propagation experiment to determine ducting occurrences in the Mediterranean and ionospheric scatter in Europe

Wide Area Propagation Model • Evan J. Dutton (497-3646) • Add the capability of special point-to-point propagation analysis to the wide area propagation model

Air Force (USAF)

AF Site Surveys • John D. Smilley (497-5218) • Perform radio-frequency site surveys over a 0.15- to 18-GHz frequency range at White Sands Missile Range and at China Lake

Hill AFB FCA Van • Donald H. Layton (497-5496) • Design, procure, and integrate a radio-frequency control and analysis van for Hill Air Force Base

MOTES-R Support • Donald H. Layton (497-5496) • 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)

European TRAMCON Support • Robert A. McLean (497-3262) • Support the TRAMCON operation in Europe for a period of 18 months including problem isolation, training, testing support, and configuration management

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) • Develop, test, and support the TRAnsmission Monitor and CONtrol program (TRAMCON), which is being developed to monitor and control the digital transmission system for the Defense Communication System in Europe

TRAMCON 87 Software • Richard E. Skerjanec (497-3157) • Continue development, testing, and support for the TRAnsmission Monitor and CONtrol program (TRAMCON)

USAF Local Area Network Consulting • Joseph E. Farrow (497-3607) • Provide ESD with assistance in its 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

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 • David L. Jones (497-6295) • Modify the wideband millimeter-wave propagation measurement system for future measurements and complete the conifer measurement report, including the recent 96-GHz measurements

Army Information Systems Engineering Center (ISEC)

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

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

Radio Link Integrated Performance Predictions • Joseph E. Farrow (497-3607) • Update and enhance the interactive computer programs developed to predict the performance of line-of-sight, marginal line-of-sight, and beyond-the-horizon radio links

Army Intelligence and Security Command (INSCOM)

ETSEM/PC • Robert O. DeBolt (497-5324) • Enhance and upgrade the ETSEM program, which is used as a tool for the system design of line-of-sight terrestrial communication links

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 Media Instrumentation Design Study • Ernest L. Morrison (497-5888) • Design and prepare implementation plan for instrumentation to measure propagation characteristics for millimeter-wave signals in representative battlefield environments

Army Signal Center

Spectrum Management Analysis • Ernest L. Morrison (497-5888) • Evaluate the spectrum conservation potential for three implementation levels in a segment of an Army tactical network supporting a moderate and high-stress dynamic operation

Defense Communications Agency (DCA)

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 (for FY 88) • David F. Peach (497-5309) • Apply the multitier hardening specification to a selected fiber optic link in accordance with NSEP goals

NSEP/FOCS (for FY 88 and FY 89) • David F. Peach (497-5309) • Make available to system designers and users the knowledge necessary to understand what is required to protect a fiber optic system from stress

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

Naval Air Test Center

Navy Air Systems Command Consulting • Joseph E. Farrow (497-3607) • Provide consulting services to assist with the activation of the Charleston Tactical Aircrew Combat Training System communication links

Naval Ocean Systems Center (NOSC)

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

Naval Sea Systems Command

Aegis CAD/VTC Satellite Networks • Edmund A. Quincy (497-5472) • Design, develop, and demonstrate a prototype wideband high-data-rate satellite telecommunication network optimized to transfer computer Aided Design and Computer Aided Logistics system data and also transport video teleconferencing between the Navy's principal shipbuilders and weapons manufacturers and headquarters

Navy CAD/CAM Telecommunications • Edmund A. Quincy (497-5472) • Provide technical assistance in establishing intergateway telecommunication system and services including developing user requirements between gateways of CAD/CAM FANS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

ACTS Experiments Coordination • Robert D. Cass (497-5478) • 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

Millimeter-Wave Slant-Path Measurements • Kenneth C. Allen (497-3412) • Conduct measurements on a slant path of propagation effects at millimeter-wave frequencies to provide information needed for satellite telecommunication application

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

U.S. INFORMATION AGENCY (USIA)

IFRB MF Modification • Jean E. Adams (497-5301) • Provide Voice of America with an MF analysis capability that allows the use of VOA-generated antenna patterns

VOA Predictions • Eldon J. Haakinson (497-5304) • Provide Voice of America with ionospheric predictions that are used in frequency planning and coordination

VOA Studies and Support • Eldon J. Haakinson • Provide Voice of America with the capability to continue to effectively upgrade its broadcast facilities

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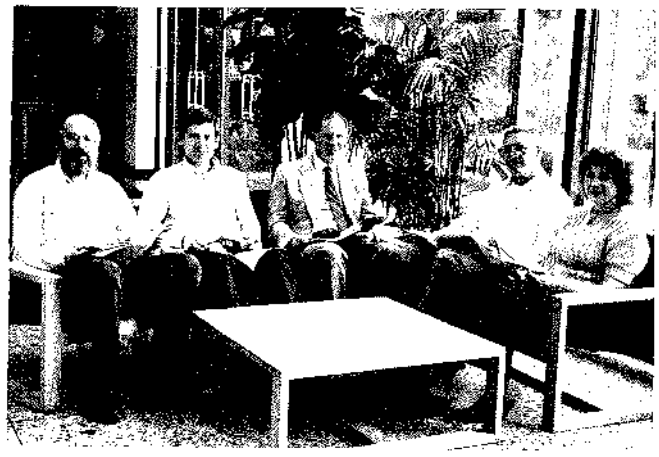

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