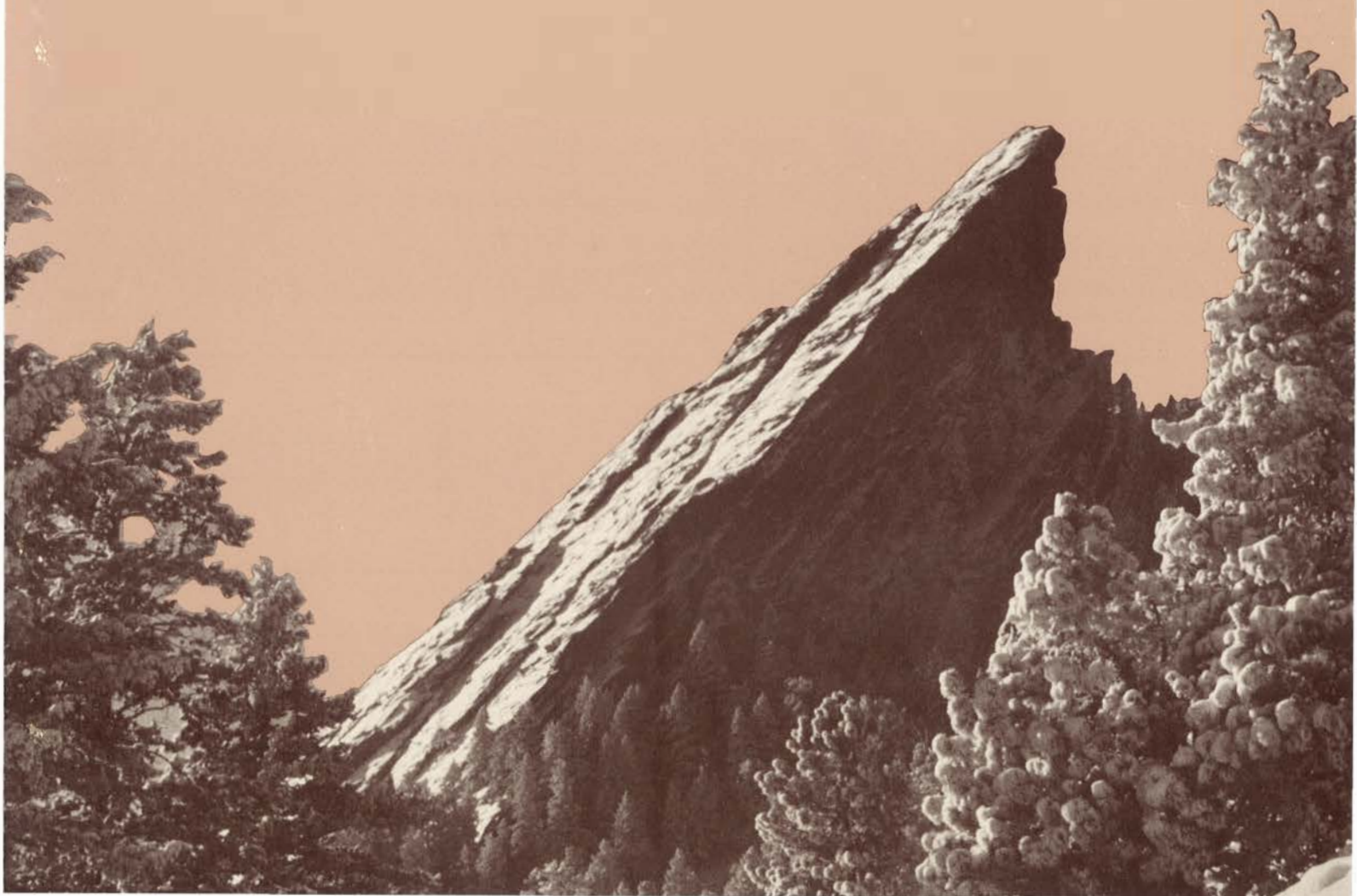
INSTITUTE FOR TELECOMMUNICATION SCIENCES

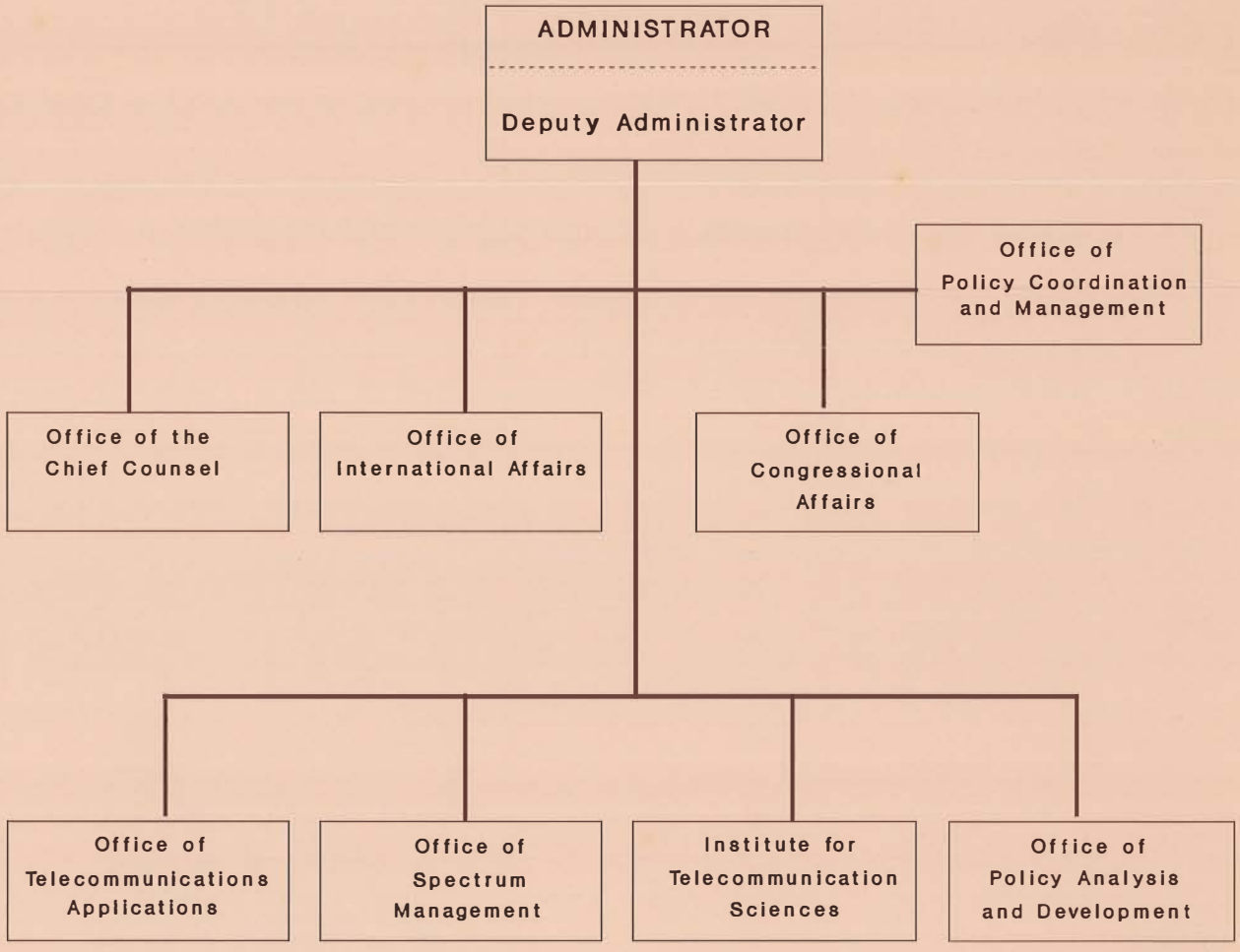
OF THE
NATIONAL TELECOMMUNICATIONS AND
INFORMATION ADMINISTRATION

ANNUAL TECHNICAL PROGRESS REPORT 1990

For the Period October 1, 1989 through September 30, 1990



NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION



Cover Photograph by **Kenneth Spies**

ITS

ANNUAL TECHNICAL PROGRESS REPORT 1990

For the Period
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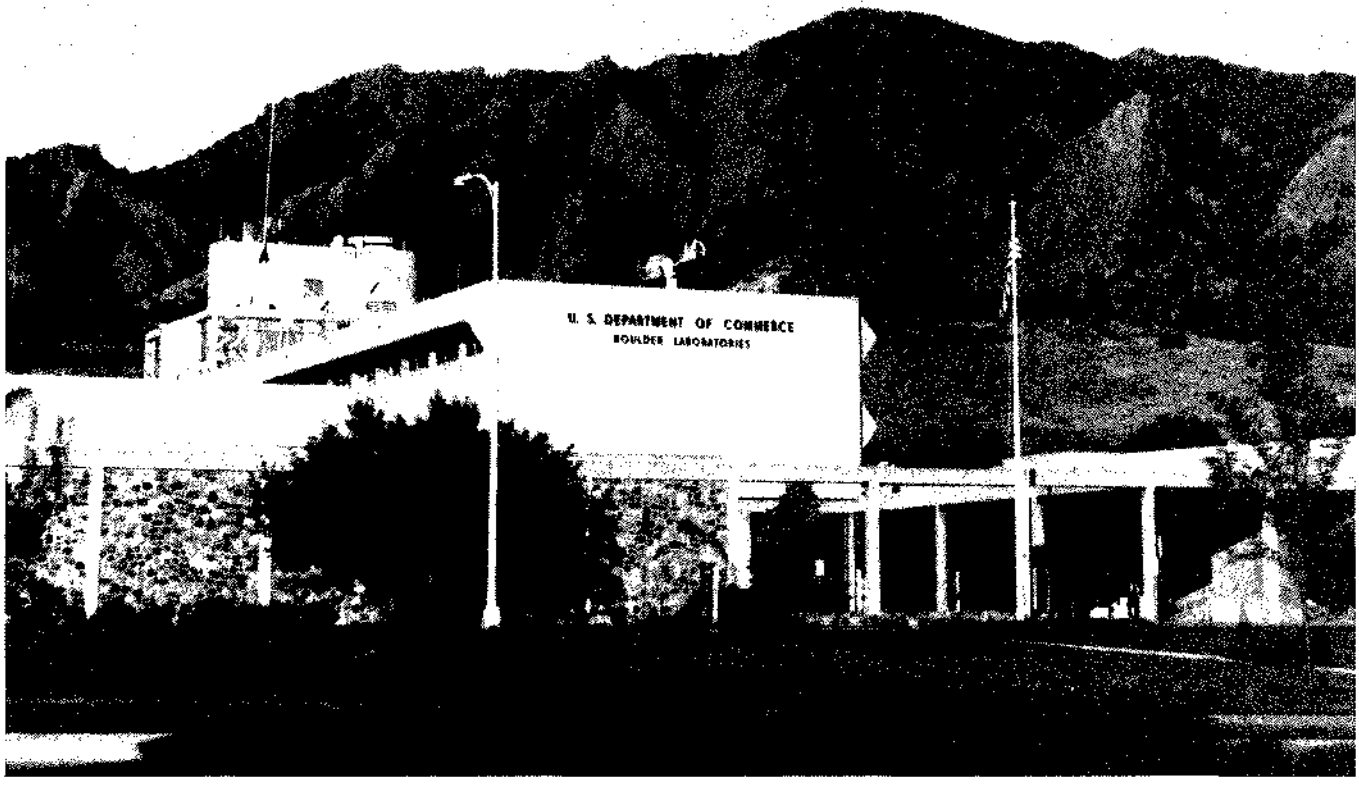
U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

Janice Obuchowski, Assistant Secretary
for Communications and Information

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, 50% of our employees are electronics engineers, 8% are mathematicians, 4% are physicists, 5% are computer scientists, and 4% are computer programers. During FY 1990, ITS support consisted of $3.0 M of direct funding from Commerce and $8.1 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 analyses 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-independent 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.

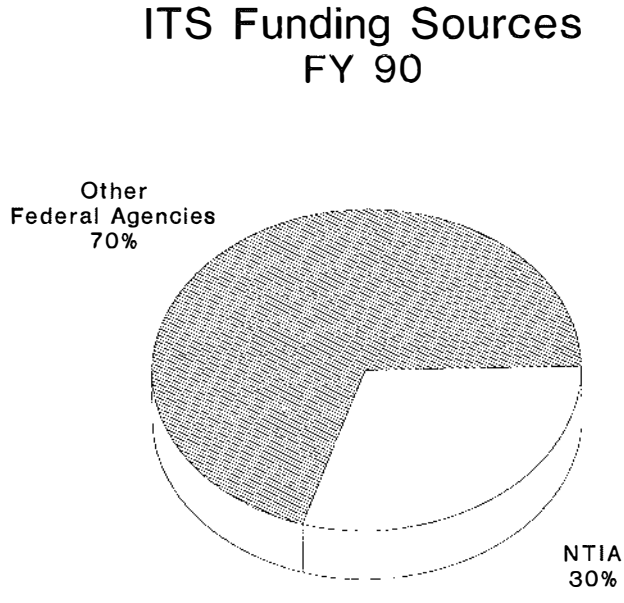
HISTORY

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.

Janice Obuchowski
Assistant Secretary for Communications and Information

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.



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 1990 technical contributions made by ITS that have significance for the public and private sectors.

DISCLAIMER

Certain commercial equipment and software products are identified in this report to adequately describe the design and conduct of the research or experiment. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

Matheson

O'Day

Utlaut

Seitz

Bachinski

Mahoney

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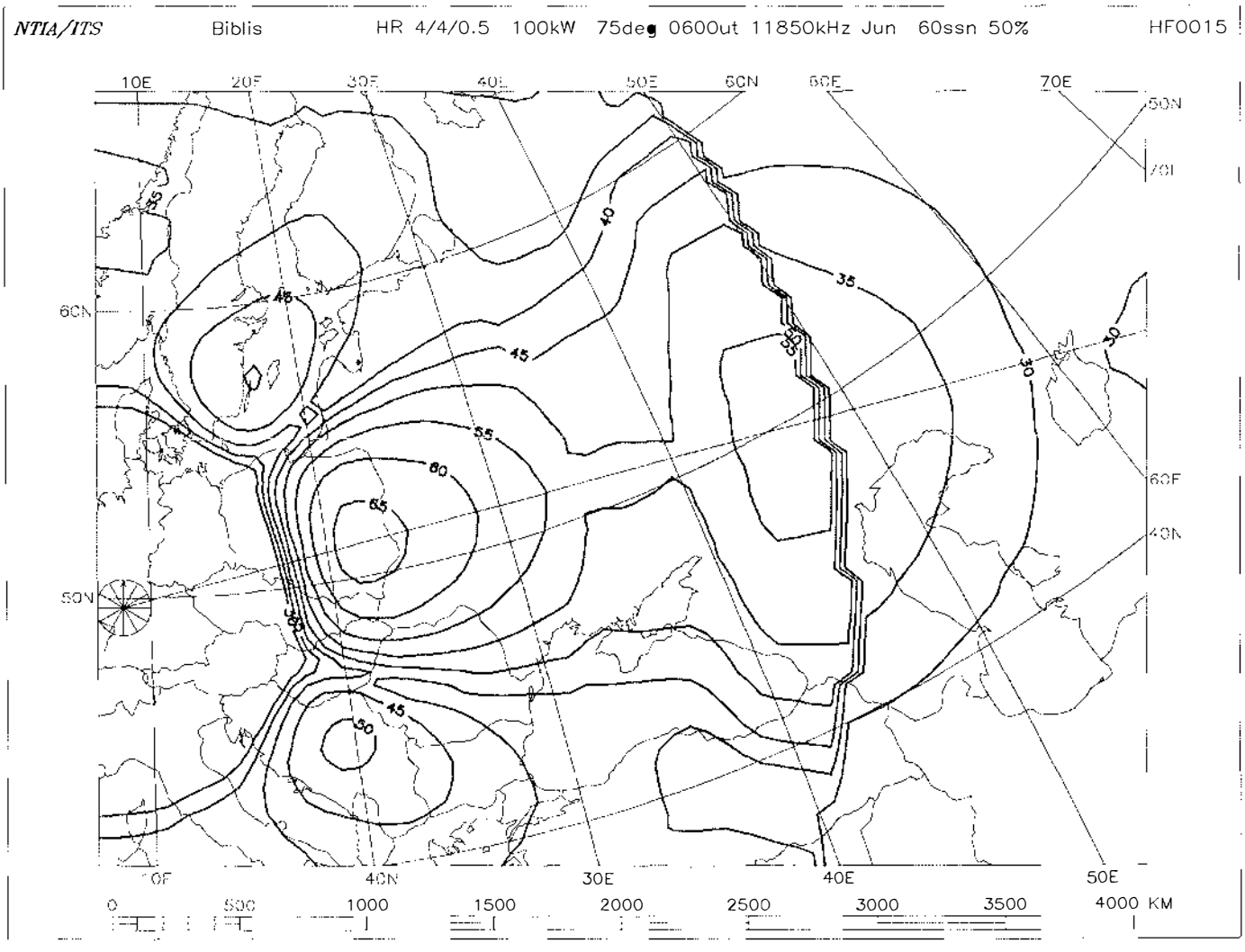


An example of the graphics capability built into the high-frequency spectrum use model (HFSUM): Typical service area contour plot of predicted field strengths (dB (μV/m)).

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, the U.S. Information Agency, and the Board for International Broadcasting

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 Department of Defense, the National Telecommunications and Information Administration, the National Weather Service, and the U.S. Air Force

Spectrum Surveillance Van Development

Includes projects funded by the U.S. Air Force

Telecommunications Analysis Services

Includes a project funded by reimbursement from subscribers, and funding from the U.S. Department of Transportation

International Radio Conference Support

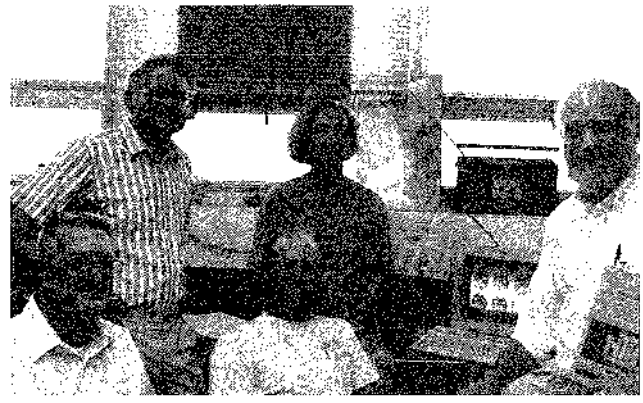
Outputs

- 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 staff have (1) actively participated in the preparation and defense of U.S. positions at world administrative radio conferences (WARC's); and (2) assessed the decisions of the second session of the high-frequency (HF) broadcasting conference held in 1987 (WARC HFBC-87). The United States is guided in its preparations for a limited reallocation conference in 1992 (WARC-92) and a third session of the HF broadcast conference in 1993 (WARC HFBC-93) by using the Institute developed HF spectrum use model (HFSUM) to study issues raised by the decisions of the WARC HFBC-87 and how they impact U.S. broadcasting objectives. The Institute is actively and extensively testing these decisions.

HFSUM determines the effect of a priori planning of HF broadcasting requirements on U.S. broadcasting objectives. This model assures frequency continuity of broadcasts and the division of the HF bands into "planned" and "consulted" portions with all requirements being satisfied. The planned portion of the bands has more cogent protection against interference and noise, and may require some requirements to be transferred to the consulted portions on a least-interfering basis.

The importance of demonstrating the consequences of adopting any planning system is documented by the outcome of WARC HFBC-87. It remains to select a means for demonstrating what the HF broadcasting environment will be like if the improved planning system is adopted by WARC HFBC-93. The colored pie charts prepared by NTIA/ITS for distribution to each administration during WARC HFBC-87 showed how that proposed planning system would have affected their HF broadcasts. This activity was instrumental in the conference's adoption of the U.S. position that the proposed planning system was deficient and unacceptable. A similar activity is planned for the WARC HFBC-93 to demonstrate the results of the IFRB's tests of the improved planning system on an administration by administration basis.



Project personnel (from left) Frank Stewart, Les Berry, Greg Hand, Jeanne Ratzloff, and Jim Washburn

The Institute works closely with U.S. broadcasters to determine their broadcasting needs. For example, ITS recently completed a study assessing the minimum amount of spectrum required for HF broadcasting and the likelihood that this spectrum could be shared with nonbroadcast services on a noninterfering basis.

The study provides a technical basis for the U.S. allocation proposals being developed in preparations for the WARC-92 and WARC HFBC-93. The study applied HFSUM to compute the minimum amount of spectrum required to assure specified levels of broadcast quality (e.g., signal-to-interference ratios of 27, 20, 17 dB) for both the existing double-sideband (DSB) and the proposed compatible single-sideband (SSB) systems. The results obtained in the analysis for all HF broadcasting bands indicate that (1) the existing DSB system needs approximately three to four times as much HF spectrum as that currently allocated to broadcasting; (2) the proposed compatible SSB system needs approximately two to three times the currently allocated spectrum; and (3) there exists a significant likelihood that time-sharing of the HF broadcast bands between broadcast and nonbroadcast services is feasible.

Figure 1 shows summary results of this study of the minimum amounts of spectrum for different radio frequency protection ratios (RFPR's) for a selected broadcasting schedule.

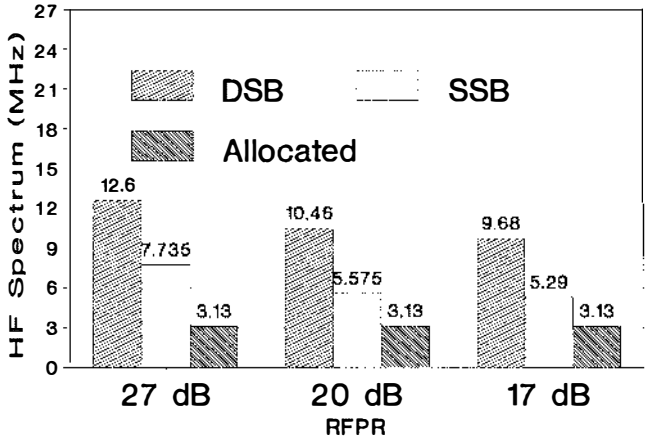


Figure 1. Total amount of HF spectrum by HF broadcast system for operation of seasonal requirements (all bands)

Figure 2 shows the likelihood potential for time-sharing the HF broadcast bands in the Los Angles area for the 9 MHz band under the assumptions used for the study.

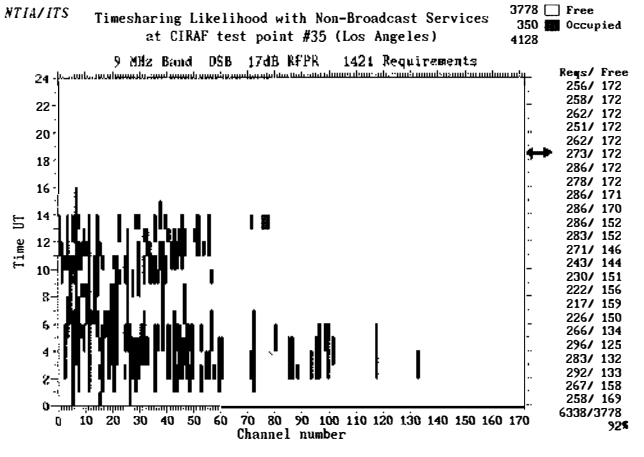


Figure 2. Timesharing likelihood with nonbroadcast services in the Los Angeles area during a typical broadcast season in the 9 MHz band.

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 authorized in the final acts of WARC HFBC-87 and coordinated by the Institute. Although largely curtailed, the potential for misuse of the HF broadcast spectrum through jamming still exists. Flexibility is needed in HF broadcast scheduling to assure minimum effects from any such future misuse.

NTIA/ITS is seeking to continue the development/use of HFSUM on a joint basis among NTIA/ITS, the Board for International Broadcasting (BIB), and the Voice of America (VOA) because of its usefulness as an analytical tool in preparations for WARC-92 and WARC HFBC-93. There is limited time before these conferences are convened and the IFRB's development of the improved planning system will likely continue up to their respective convenings. This continued development will need to be tracked by NTIA/ITS to augment HFSUM. NTIA/ITS, BIB, and VOA need to exercise HFSUM extensively in preparations for both conferences during this development period. NTIA/ITS devised a joint plan to try to secure adequate financial, computer, and staff resources for the improvement, porting, and use of HFSUM in preparation for these important conferences. The joint development plan: (1) defines the nature, scope, and schedule for the upgrading, testing, and use of HFSUM; (2) identifies the computer resources needed to execute HFSUM; and (3) identifies general funding sources from NTIA/ITS, BIB, and VOA to allow budgeting the necessary funds for the timely acquisition of appropriate equipment at both NTIA/ITS and VOA/BIB.

Recent ITS Publications

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

Planning for Frequency Continuity in HF Broadcasting (by Washburn, Hand, Berry, Stewart, Sowers, and Rush)

Monitoring of Harmful Interference to the HF Broadcasting Service: Summary of Monitoring Programs Held Between 1984 and 1989 (by Sowers and Hand)

Spectrum Required for HF Broadcasting (by Washburn, Hand, Berry, and Ratzloff)

For information, contact:
James Washburn (303) 497-3109

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 Telecommunications Union (ITU). The International Telegraph and Telephone Consultative Committee (CCITT) is the other. Both of these committees are permanent organs of the ITU, which is one of the standing committees of the United Nations.

All of 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 are the basis for spectrum allocations decisions and spectrum use on a global and regional basis. Therefore, it is important to the U.S. that CCIR documents accurately reflect the U.S. position, which is one major reason for ITS participation in CCIR work.

Within the U.S. the organization of the work in support of CCIR activities is under the purview of the Department of State (DoS). A National Committee chaired by DoS personnel oversees the U.S. contributions to the CCIR. Because of its preeminent position in the field of telecommunications research and development, members of ITS staff participate very actively in the work of the CCIR at the national and international levels.

The CCIR is organized into Study Groups (SGs). Each SG addresses a specific area of radio system technology. At present there are twelve areas of study; study group 12 on Sharing is a new group that has just been added to consider ways to make more efficient use of the spectrum by allowing different radio services to share the same frequency band. The particular topics treated by each SG should be expected to evolve to meet the needs of the times and to reflect the topics that will be discussed by forthcoming radio conferences. The present CCIR SGs include:

SG1 Frequency management and monitoring
SG4 Fixed satellite service
SG5 Propagation in non-ionized media
SG6 Propagation in ionized media
SG7 Standard frequencies & time signals
SG8 Mobile services
SG9 Fixed service using radio-relay systems
SG10 Broadcasting service (sound)
SG11 Broadcasting service (television)
SG12 Sharing between services

CMTT (joint with CCITT) Transmission of sound broadcasting and television signals over long distances
CMV Vocabulary

The CCIR has a four-year cycle of activity, centered about the Plenary Assembly which meets every four years. Modifications to CCIR document created by the SGs are approved in the Plenary Assembly. In preparation for the Plenary Assembly, the CCIR meets at an Interim Meeting about 2 years before the Plenary Assembly and a Final Meeting for the SGs shortly before a Plenary meeting.

ITS activity in CCIR peaked in late 1989 at the Final Meetings of many SGs, in preparation for the Plenary Assembly held in May 1990 in Duesseldorf, Germany. Institute members served as U.S. chairpersons to SGs 1 and 6; other Institute members have played active roles in SGs 1, 4, 5, and 6.

The Final Meeting of SG 1 (Geneva, December 1989) worked on several topics. These included a question on possible interference from MAC/packet decoders to aeronautical or maritime emergency satellite locator systems. Another topic concerned the establishment of CCIR standards applicable to EM radiation from industrial, scientific, or medical equipment. ITS personnel served as Rapporteur for these sessions and also provided a paper on the U.S. Spectrum Use Measures (SUM) model.

The Final Meeting of SG 4 was held in Geneva, September/October 1989. ITS staff served as a U.S. delegate to this SG and Rapporteur for the SG Plenary sessions. Accomplishments by ITS included a major role in revising a draft of Recommendation 465 on satellite earth station antenna patterns. An ITS representative also participated in a February 1990 meeting of the U.S. SG 4.

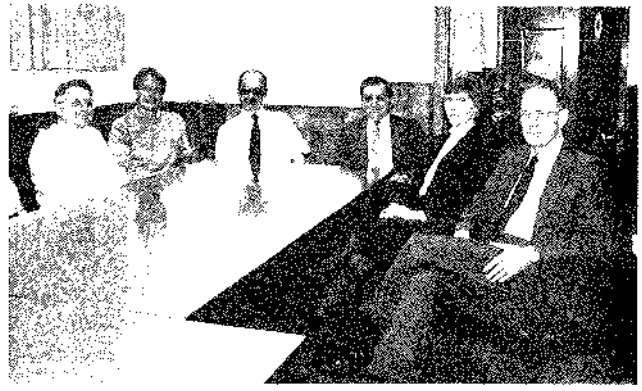
The Final Meeting of SG 5 included ITS contributions to improved CCIR reports on millimeter-wave propagation, and VHF/UHF propagation effects in the mobile and Broadcast bands.

Two ITS personnel served as delegates to the Final Meeting of SG 6 (Geneva, September 1989). One served as Rapporteur for the SG. The ITS delegates were active in Working Groups 6J (Ponospheric Properties), 6M (Natural and Man-made Noise), and 6L (Factors Affecting System Design). The U.S. delegation was led by a former ITS staff member.

At the Plenary Assembly in Duesseldorf, many Recommendations and Reports submitted by the Final Meetings of the SGs were approved. Two broad concerns included the 1992 World Administrative Radio Conference for Reallocation (WARC-92) and a proposed reorganization of the CCIR.

The WARC-92 will be held in Spain in February 1992. This conference will deal with many questions of proposed reallocations to many frequency bands across the entire radio spectrum, establishing the basic frequency bands that various radio services may use. After the frequency bands are established for various services, separate conferences can be set to address the particulars of how radio bands are to be used within a given service. For example, a 1993 WARC is already planned to determine exactly how HF broadcasting assignments are to be made within the bands allocated by WARC-92.

The process of deciding what reallocations the U.S. will propose or support parallels the organization of the US frequency management structure. Federal Government agencies have proposed reallocations through ad hoc 206, a committee of the Interdepartmental Radio Advisory Committee (IRAC). Four subcommittees working under the parent committee have been set up to handle questions in particular frequency ranges. These committees have prepared an IRAC set of proposed reallocations for the WARC-92.



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

The Federal Communications Commission (FCC) solicited comments from industry and private users via a "Notice of Inquiry" (NOI) on the WARC-92. Large numbers of comments and suggestions were received, which were considered as the FCC prepared their recommendations for the WARC. Based on FCC and IRAC documents, a set of US recommendations was produced and sent to the ITU. Corresponding processes were followed in many other countries, which also sent their recommendations to the ITU.

In June 1990, based on requests from member countries, the ITU announced an agenda for WARC-92. This agenda allows the possibility of many exciting spectrum allocation changes, including allocations for direct broadcast satellite digital sound and HDTV, additional HF broadcast bands, mobile service for aircraft and other uses via satellite (including low orbiting satellites), etc. Since there will be many more proposed allocations than there are frequency bands to accommodate these allocations, and since many countries have different relative priorities which they assign to the uses of the spectrum, there will be many difficult decisions made at WARC-92.

The other major theme of recent CCIR activities concerns a reorganization of the CCIR. Because of the rate of change in the telecommunications industry, it is highly desirable to speed up the rate that the CCIR can make decisions and recommendations. Therefore, the SGs have been given somewhat more authority to make some decisions on their own. The actual technical work has been moved out of the SGs into Working Parties and Task Groups, which will be set up under the SG.

For information, contact:
Robert Matheson (303) 497-3293

Domestic Spectrum Analysis

Outputs

- Measurements of the electromagnetic compatibility characteristics of unlicensed devices
- A paper on the benefits of using optimum frequency assignment algorithms to select specific frequencies for applicants
- Review of replies to NTIA's Notice of Inquiry on the spectrum management process

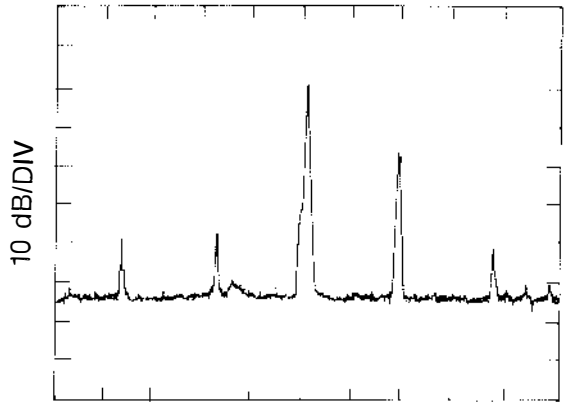
The National Telecommunications and Information Administration (NTIA), in its role as manager of the Federal Government's use of the radio frequency spectrum, undertakes a number of studies each year dealing with spectrum utilization, congested areas of the spectrum, and potential compatibility problems between systems of various departments and agencies. These studies, called Spectrum Resource Assessments (SRAs), provide recommendations for resolving any compatibility conflicts, recommend changes to improve spectrum management procedures, and recommend changes to promote efficient use of the spectrum. This year, we studied the potential interference characteristics of low-power, unlicensed devices with the goal of predicting their impact on licensed spectrum users.

There has been a recent relaxation of the Federal Communications Commission's regulations concerning the use of low power, non-licensed devices covered by Part 15 of the Code of Federal Regulations section for telecommunications. Examples of such devices include cordless telephones, garage door openers, baby monitors, etc. The relaxation would significantly loosen restrictions on frequency, bandwidth, modulation, and usage, thus facilitating development and marketing in the telecommunications industry. NTIA maintains an interest in resultant electromagnetic compatibility issues because of the prospect of potential interference to Government systems.

The Institute added to its existing data base of characteristics of devices that operate below 1 GHz, and initiated an effort to examine new devices that operate well above this frequency, where concerns have been expressed and future development is apt to occur.

For the lower frequency range, the spectrum of a video camera microphone system was examined. The results, shown in the figure below, indicate the presence of four spurious spectral emission peaks, in addition to the main peak at the nominal frequency of the device when no modulation is present.

EMISSION SPECTRUM OF VIDEO CAMERA MICROPHONE SYSTEM



For the higher frequency range, three field disturbance sensors were tested. (Field disturbance sensors are used, for example, to open doors automatically when there is movement in the vicinity of the door.) The sensors tested operated at a nominal frequency of 10.5 GHz, and measurements were made to test for harmonics at 21.0 GHz. The measurements showed that harmonics were found at 14 dB and 28 dB down from the fundamental for the first two units measured. No harmonic could be found for the third unit, even at 67 dB down from the fundamental.

Other devices measured included a cordless telephone, a nursery monitor, an auto security alarm, a video distribution system, and a cordless microphone. The results are incorporated in a report submitted for publication as an NTIA report.

Almost ten years ago, the Institute developed a computer program for assigning specific frequencies to individual users of a frequency band so that the total bandwidth needed by all users is minimized. The program has been used for a number of simulated assignment tasks to study the best frequency assignment strategies, and to determine the amount of spectrum conserved under various equipment standards or characteristics. For example, Table 1 shows the spectrum cost of assigning stations individually, or in small blocks, compared to assigning all stations at once using optimum frequency assignment algorithms.

Table 1. Spectrum cost of small block assignments

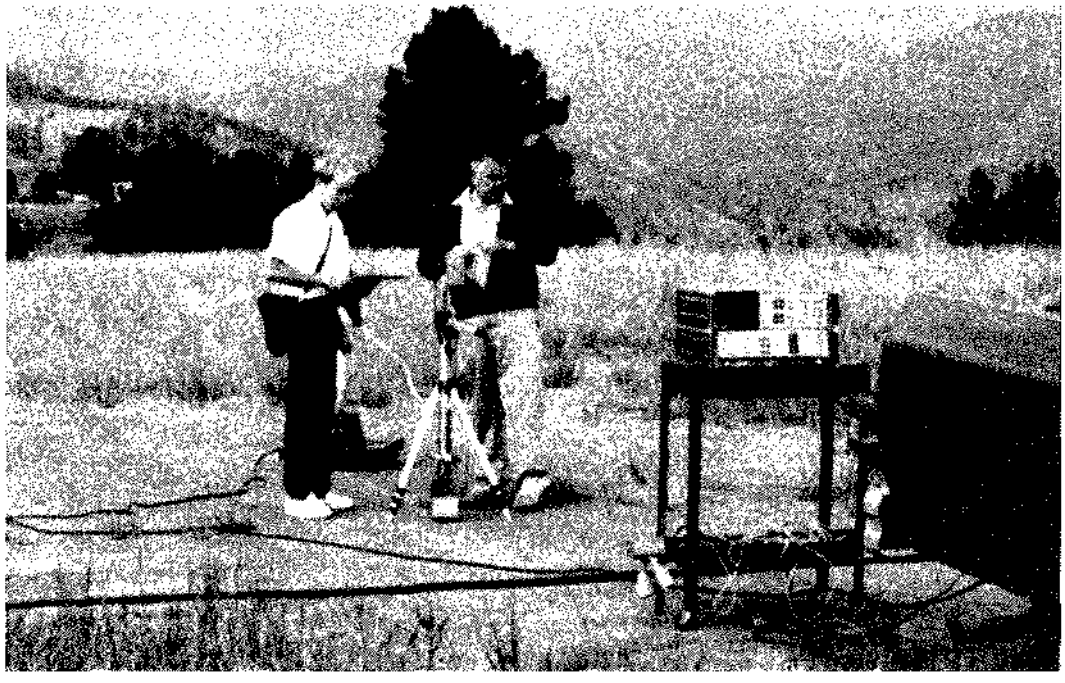
Block size	bandwidth % increase
100	0.0
50	6.2
20	12.1
10	14.3
1	21.2

The table shows that assigning 100 stations one-at-a-time takes more than 20% more total bandwidth than assigning them all at once, under the conditions of the study. Other studies have shown that commonly-used methods of assigning stations one-at-a-time use can use another 20 % more spectrum than the optimum one-at-a-time method used to compute the table.

These results, and others were discussed in a talk delivered at the special session on Spectrum Issues in the 21st Century at the 1990 IEEE International Symposium on Electromagnetic Compatibility. In that paper, it was noted that even though optimum frequency assignment computer programs have been available for nearly ten years, they are not generally used. In light of the spectrum conservation that is possible, it is recommended that optimum methods be used in the future.

In this fiscal year, NTIA issued a formal Notice of Inquiry (NOI) and request for comments on a Comprehensive Policy Review of the Use and Management of the Radio Frequency Spectrum. The main leadership of this review is in the Office of Policy Analysis and Development and in the Office of Spectrum Management, but the Institute is reviewing the comments, especially in the area of alternative methods of allocating and assigning the spectrum. Examples of alternative methods might include market systems, with auctions of spectrum rights. Over 3000 pages of comments were received and are being reviewed. NTIA will issue its findings later this year.

For information, contact:
Les Berry (303) 497-5474



Frank Sanders (left) and John Smilley making measurements of FCC Part 15 devices, west of Boulder on Green Mountain Mesa

Spectrum Usage Measurements

Outputs

- New modular measurement system (CRSMS)
- Interference elimination for DoD on Guam
- Acceptance measurements on TV Marti
- Site surveys for DoD at Guam, Washington, D.C., Alaska, and Maine
- NTIA measurements on wind profiler radars in Colorado
- NTIA site survey at Chicago

NTIA manages Federal Government use of the radio spectrum, a function similar to the FCC's responsibility for the use of radio frequencies for non-government purposes. In support of the NTIA mission, ITS operates several measurement systems, including the Radio Spectrum Measurement System (RSMS), the Compact Radio Spectrum Measurement system (CRSMS, also known as the "suitcase system"), and a low frequency measurement system. The CRSMS and the low frequency system were both developed this year. These measurement systems provide the following:

Occupancy measurements to show actual amount and type of usage in the radio spectrum;

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, and to provide information for solving existing and potential interference problems.

Development: The RSMS has been fully described in previous technical progress reports. This year it was joined by two new ITS measurement systems, the CRSMS and the low frequency signal and noise measurement system (described on page 49). All three systems have been used for measurements this year.

The Compact Radio Spectrum Measurement System, also called the suitcase measurement system, is a modular, computer-controlled measurement system which performs many of the same measurements as the RSMS. Like the RSMS, it operates from 20 kHz to 18 GHz. Its calibration, data acquisition, data corrections, and data storage have all been automated.

The CRSMS can be used for site surveys as well as measurements on emitters of special interest. So far this year, for example, the CRSMS has made versatile measurements on several radars, has performed site surveys through satellite receiver systems, and has made measurements on a balloon-borne television transmitter.

The CRSMS was developed in response to the need for a system which could be more easily and cheaply transported to remote or inaccessible measurement locations (e.g., Guam, the Aleutians, and rooftops), and which would produce data which are compatible with widely used PC technology. Toward these ends, the system is operated with a portable 80386-based computer, and is arranged in a modular fashion in which no measurement equipment in any system box depends upon another box for its operation. This modular system design makes it possible to deploy the CRSMS to each measurement location in a configuration tailored to the required measurements. This in turn reduces the system's weight and bulk, making it practical to transport as baggage on commercial airliners.

Measurements: The RSMS was used for two measurement tasks this year, one for NTIA and the other for the National Weather Service (NWS). The NTIA task was a radar and land mobile radio site survey in the Chicago, IL area. The survey was part of a NTIA program to characterize actual spectrum usage in major metropolitan areas, as a check against spectrum loading studies based on paper assignments which may incorrectly indicate that large parts of the radio spectrum cannot accommodate additional users.

The second RSMS task was performed for NWS, and involved the measurement of the extended emission spectrum of the new NEXRAD weather radar. The RSMS measurements showed that the radar met the newest and most restrictive Radar Spectrum Engineering Criteria (RSEC), and that NEXRAD had little potential for interference with other systems in its operational band. These measurements assisted in an effort to sell the radar internationally; the RSMS measurements put to rest an objection raised by potential buyers that the radar would pose too much of an interference potential in its band.

The CRSMS was used for several measurement tasks, mostly for other government agencies, this year. The first job required an overseas deployment to the island of Guam, where an ongoing interference problem existed between a radar and a DoD system. ITS was requested to evaluate the interference and recommend a way to resolve it. ITS measurements with the CRSMS showed that, although the spectrum of the suspect radar met the applicable RSEC, the interference could be resolved only by installing filters on the radar. ITS personnel then located spare filters in a government warehouse in Oklahoma, shipped the filters to Guam for in the radar. The interference problem, which had existed for several years, was resolved.

The CRSMS was also used in Florida for a project with the U.S. Information Agency (USIA). A television transmitter was to be lofted to a high altitude as part of the well-known TV Marti project, and, as a transmitter at that height would have a large line-of-sight coverage area, it was feared that operation of TV Marti would interfere with existing television service in southern Florida. ITS personnel were in place and making measurements when TV Marti first went on the air. With a measurement sensitivity more than 45 dB in excess of a television set's sensitivity, measurements with the CRSMS showed that there was little or no potential for interference between TV Marti and television sets in southern Florida.

The CRSMS has been deployed at several locations, including the Aleutian Islands, Washington, DC, and Maine, for the purpose of performing site surveys through DoD antenna systems. These surveys have been highly successful, and more are planned.

The CRSMS has been used for measurements at two radar sites in Colorado in support of an NTIA project. Wind profiler radars, such as two units currently operating at Platteville and Longmont, pose an interference potential to some receivers on earth satellites. As part of the effort to resolve this problem, extensive measurements have been made on the emission spectra and antenna patterns of the wind profiler radars. The results have been used in the NTIA report on the problem and its likely resolution.

For information, contact:
Frank Sanders (303) 497-5727

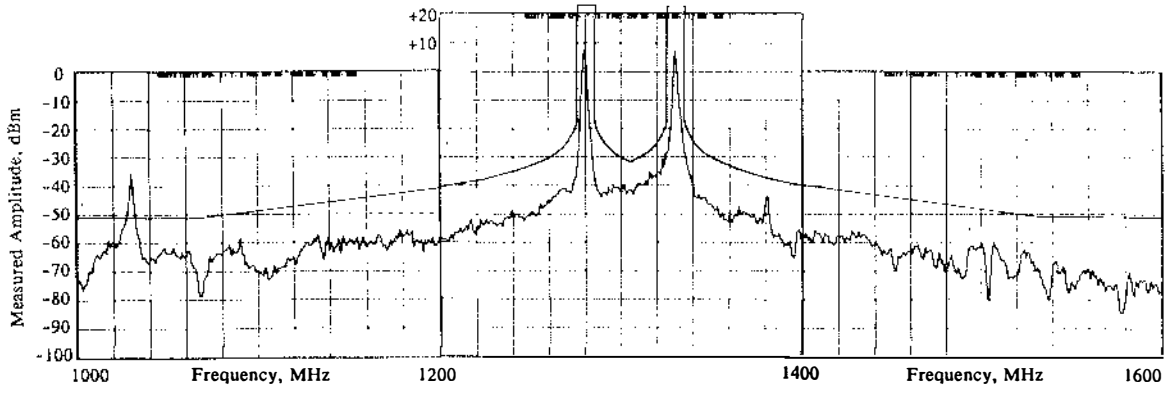


Figure 1. Guam radar spectrum before ITS interference study

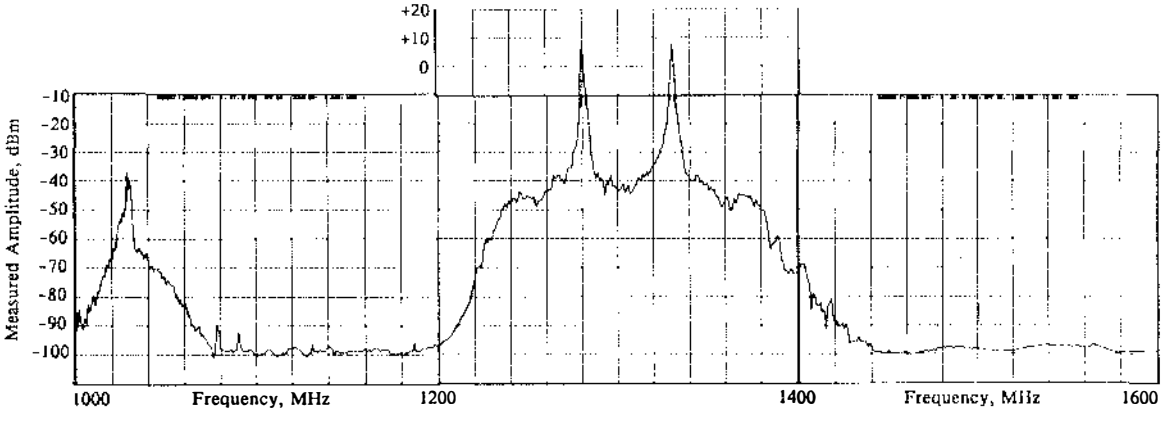


Figure 2. Guam radar spectrum after ITS interference suppression implemented

Spectrum Surveillance Van Development

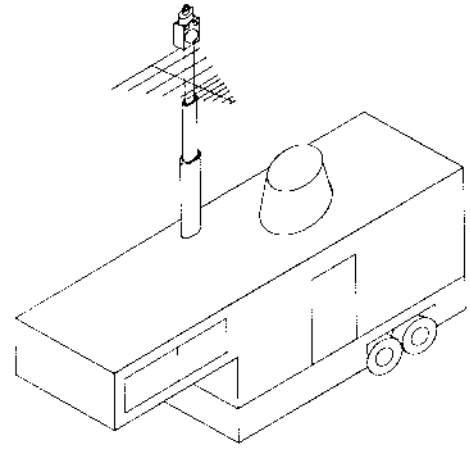
Outputs

- USAF frequency management
- Spectrum surveillance
- Testing verification
- Adaptable software
- High-speed pulse data

Final delivery of two specialized measurement systems for the Air Force was a major achievement of the Spectrum Use Group in FY 90. With a one-ton four-wheel-drive van as the enclosure, these vehicles are the range frequency management systems for the Utah Test and Training Range for Hill Air Force Base. Designated the Frequency Control and Analysis (FCA) systems, these vans are providing an agile mobile frequency management capability. While monitoring frequency usage on the test range the Air Force will also be watching for extraneous transmitted energy that could potentially jeopardize device testing or other operations on the range.

A third system called the GEMS, for Ground Emitter Monitoring System, scheduled for a December, '90, delivery, will become the test monitor system in support of weapons testing at the Dugway, UT, facility. A companion remote antenna trailer will provide close-in support for weapons testing by allowing unmanned operation in the danger zone and Air Force personnel to reliably observe operations of radars and devices under test at a safe distance.

ITS electronic engineers (from left) Brent Bedford, Jeff Wepman, and Bob Achatz working on the Air Force antenna system



Hill AFB GEMS vehicle

The GEMS was the reason for an extensive development effort on a pulse measurement system with the capability of rapidly measuring and storing data on up to 20,000 pulses-per-second (pulse descriptor words) to a read/write optical disk. Until now this capability was elusive with many unsuccessful schemes.

These systems were the reason for an extensive software development effort resulting in a user-friendly and adaptable measurement system including many of the measurement techniques of the RSMS measurement system (see page 8). It is intended that this development effort will help to overcome the stigma of computer controlled measurement and bring expanded capability to the military environs as well as other agencies.

Direct application of the Air Force development has been seen in the modular measurement system which is presently augmenting the operations of the RSMS. This facility will be extremely valuable in allowing quick response to measurements anywhere in the country or in the world.

Other government agencies have already discovered the utility of such a flexible and friendly measurement system wherever there is a signal interference problem or site survey to avoid such problems.

For information, contact:
Don Layton (303) 497-3291

Hill AFB FCA Monitoring Van

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 comparison between competing designs or proposed telecommunication services

Telecommunications Analysis Service (TAS) is a service provided by the Institute to all of the telecommunications community that allows industry, and Government agencies access to the latest Institute research and engineering on a cost basis. It is built around a series of computer programs that have been designed to be user-friendly and intelligent, so that the user can access the required information and data with a minimum of computer expertise or in-depth knowledge of radio propagation. These programs and data bases are updated as new data and methodologies are developed at the Institute's Boulder Laboratories in its many engineering and research programs.

The following is a brief description of the current programs in the TAS that do the calculations that the user requests on-line, and immediately send the output to the user's terminal.

INFO - This gives an up-to-date listing of the services available, and any new or changed operating procedures.

MORE-INFO - This program gives more general system news, programs to be made available in the near future, etc.

PATH PARAMTRS - This program calculates the great circle distances and bearings between the user specified locations, and also provides "delta H" and average terrain heights for those locations.

RAPIT - This program gives the user on-line access to the latest in VHF/UHF propagation models. It can calculate basic transmission loss and other engineering information such as received signal levels over irregular terrain for the design or analysis of broadcast and mobile radio systems. The program has a broad range of options that allows the user to easily look at the affects on the received signal from changes in the input parameters such as antenna height.

FMFIND - This program lists the user selected FM station engineering parameters from the Federal Communications Commission (FCC) assignment data base according to user specified search parameters of location and search distance.

TVFIND, AMFIND, TOWERFIND, and LMFIND - are similar to FMFIND in that they return the parameters for the respective TV, AM, Tower, or Land Mobile station assignments/data according to the user specified search locations and distances.

RAIN - This program calculates the increased attenuation of microwave and millimeter wave signals due to the precipitation along the path. It is used in the design and analysis of point-to-point telecommunication systems.

BURST - This program calculates the waiting times for a message to be successfully received over a meteor burst communication system or network.. The user specifies the locations and engineering characteristics of the equipments, and the program determines the probabilities of successful communications for the transmission of various length messages that are propagated from reflections of ionized meteor trails.

LFMF - This program uses the latest Institute methodology for propagation of surface wave signals. It calculates the user's system performance or basic propagation path loss for systems that use the ground wave between 10 KHz and 30 MHz as the primary means of propagation, and it also calculates the skywave for MF systems if requested.

The following set of programs do the calculations that the user requests, and sends the response either immediately to the user's terminal, or else the calculations are completed off-line and the output mailed or expressed overnight to the user.

INMOD - This is a comprehensive intermodulation calculation program that calculates and lists to the user intermodulation products in the user's specified receiver bandpass from up to 40 transmitters, 40 receivers, up to seventh order, and with up to 5 concurrently operating transmitters.

PROFILE - The Institute maintains a digitized topographic data base of elevations of the terrain in various parts of the world. A sample of the topography around the San Francisco Bay area is shown in the figure below. The data varies in density from 3 to 30 second increments, but is generally derived from 1:250,000 scale maps of the Defense Mapping Agency. Using this program the path profiles are extracted according to user specified input parameters of location, bearing, etc. The data are extracted and then either the individual elevations along the profile are sent to the user's terminal or optionally they are averaged and the average sent to the user's terminal. Another option allows the user to have the Institute plot the profiles adjusted for various K factors depending upon the intended use of the path. For microwave links, Fresnel zone clearance can be easily determined from the plots so that poor paths can be eliminated from a planned circuit or network.

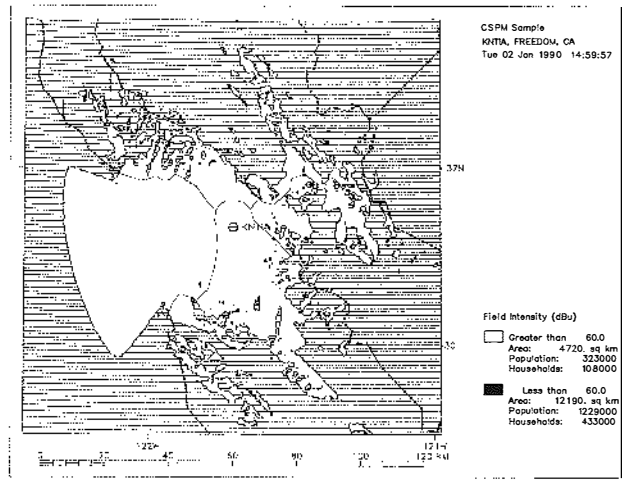
In the following programs, the user inputs the required system details on-line, then the calculations are performed off-line, and the output tables and/or plots are either mailed to the user the following day (usually) or sent by overnight express.

HORIZON - This program plots the radio horizon around a specified location in the United States using the digitized topographic data. It is generally used for siting of satellite terminals and radars so that the terrain shielding effects can be determined as well as the limits on the elevations visible from the site.

SHADOW - This program plots the radio line-of-sight regions around a specified location in the United States using the digitized topographic data. It shows clear areas that are line-of-sight to the base of the antenna, grey to areas that are line-of-sight to the top of the antenna, and black to areas that are beyond line-of-sight to the antenna.

COVERAGE - This program calculates the receive signal levels along radials that are spaced at 15° increments of bearing around the transmitter. It plots the contours of signal coverage of the transmitter, and then includes the population coverage estimates based on the latest census data. The user can specify that either the FCC Broadcast rules or the Institute's irregular terrain propagation model be used in the calculations.

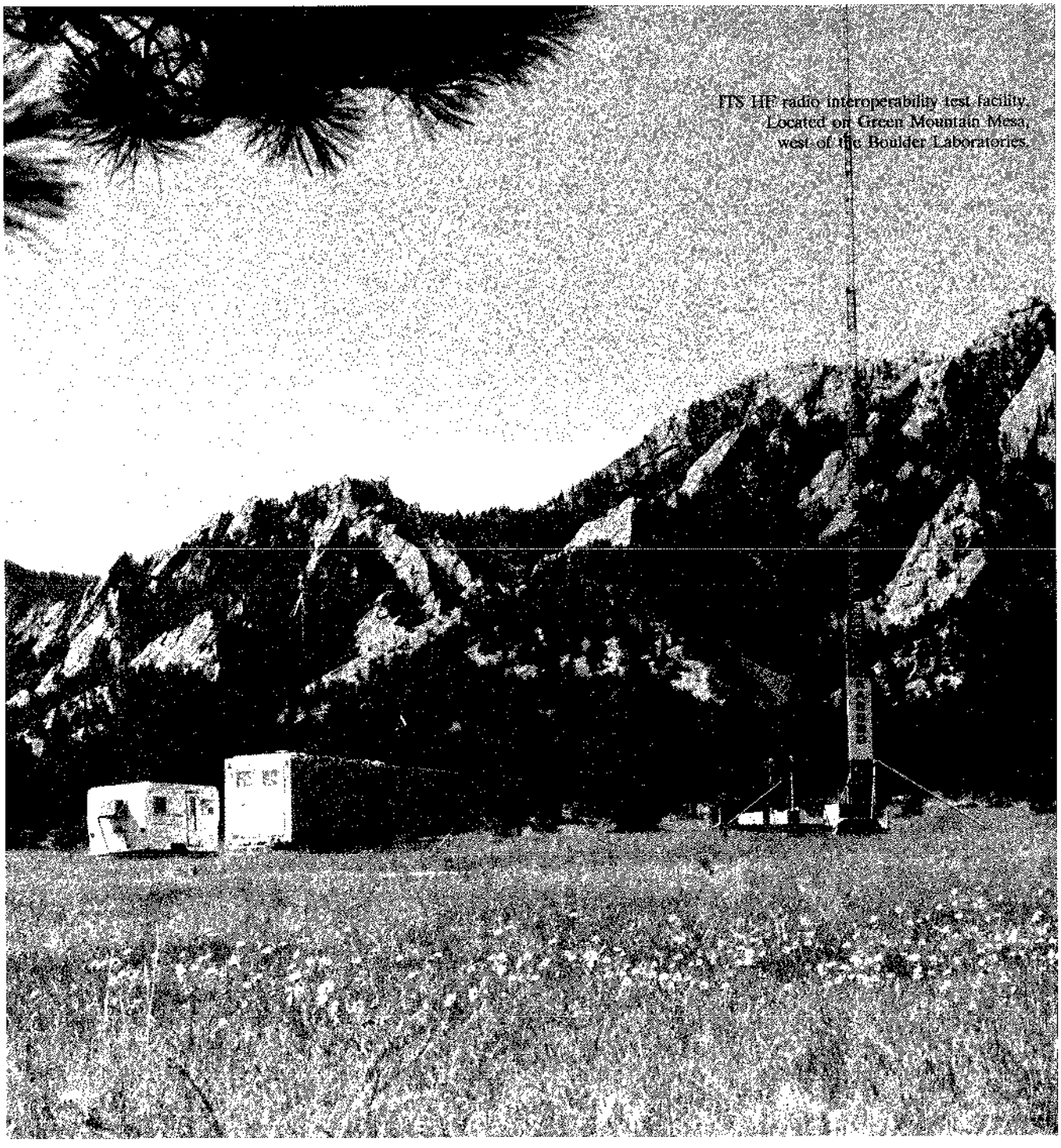
CSPM - Communication System Performance Model is a program that determines the system performance of mobile and broadcast systems in detailed output plots of signal intensity as shown in the following figure. This program has an option that allows the user to have the output plotted on clear plastic to a specified scale, and in brilliant colors for overlaying on top of widely available geopolitical maps. This program is the most detailed of the signal calculation programs available, and uses the Institute's irregular terrain model in point-to-point mode. It is capable of combining coverage from several transmitters to show the coverage from several transmitters to show the coverage from a network of stations. Another option allows the plotting of interference regions to determine potential interference from a user specified transmitter within the area of interest. It shows the population, households, and areas covered within each of the user defined signal ranges. The most ambitious use of CSPM to date involved plotting the coverage by all of the educational TV stations in the United States and determining the population covered by at least one of these stations.



Example of TV station coverage calculated using CSPM

SKYWAVE - This program provides predictions of the performance of radio systems that use the frequencies ranging from 3 to 30 MHz and that propagate over ionospheric paths. It uses the Institute's ionospheric prediction program IONCAP and provides table of reliability or other user requested performance measures.

For information, contact:
Eldon Haakinson (303-497-5304)



ITS HF radio interoperability test facility. Located on Green Mountain Mesa, west of the Boulder Laboratories.

TELECOMMUNICATION STANDARDS DEVELOPMENT

Much effort within ITS is focused on the development and application of national and international telecommunication standards. These standards promote interoperability and facilitate competition in the provision of enhanced telecommunication products and services and promote trade opportunities for U.S. telecommunications providers.

The Institute's national standards 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 spearheaded the development of technical standards for specifying and measuring performance of data communication systems and services as seen by end users. Major end products are Federal and American National Standards.

The Institute's international standards effort addresses the need for technically strong, broadly-based U.S. contributions to international telecommunication standards organizations. Institute staff members lead and contribute to several international standards 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 developed by these organizations significantly influence U.S. trade in telecommunication products and services. During FY 90, special emphasis was placed on the development of technical standards for Integrated Services Digital Networks (ISDNs). The Institute has provided strong leadership and support to ISDN standards development activities in both domestic and international forums.

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 National Communications System and the National Telecommunications and Information Administration

Video Quality Standards Development
Includes projects funded by the National Telecommunications and Information Administration, the National Institute of Standards and Technology, and the Defense Communications Agency

Radio System Interoperability Standards Development
Includes projects funded by the National Communications System, the Defense Communications Agency, and the U.S. Army

Building Cabling and Telecommunication Terminology Standards Development
Includes projects funded by the National Communications System, and the Defense Communications Agency

CCITT ACTIVITIES

Outputs

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

The long-range planning of public telecommunication services has been internationalized and increasingly, is focused in one forum: the International Telegraph and Telephone Consultative Committee (CCITT). The technical standards ("Recommendations") developed by the CCITT have a substantial impact on both the evolution of the U.S. telecommunications infrastructure and the competitiveness of U.S. telecommunications products and services in international trade. The Institute supports U.S. participation in CCITT activities by leading U.S. CCITT preparatory committees, preparing technical contributions on selected CCITT standards development issues, and drafting proposed CCITT Recommendations on topics of particular importance to U.S. interests and goals.

The Institute provides strong support to the U.S. Department of State in leadership of the U.S. Organization for the CCITT. During FY 90, Institute personnel served on the U.S. CCITT National Committee, which guides overall U.S. participation in CCITT activities; continued chairmanship of U.S. CCITT Study Group B, which coordinates and approves U.S. Contributions to CCITT on ISDN issues; headed the U.S. Delegations to two meetings of CCITT Study Group XVIII (ISDN); and contributed to an interregional standards conference to improve the coordination of regional telecommunication standards activities with those of the CCITT. U.S. Study Group B and its accredited U.S. Delegations contributed strongly to the achievement of a major international standards objective during FY 90: Study Group XVIII approval of a set of 13 new Recommendations which provide a baseline for the coordinated development of Broadband ISDNs. These rapidly-evolving, ultra-high-speed networks will ultimately provide fully-integrated voice, data, and video communication services through the shared use of transmission and switching facilities employing the Asynchronous Transfer Mode (ATM), an innovative cell switching technology. The CCITT's B-ISDN Recommendations are expected to influence hundreds of billions of dollars in worldwide telecommunications investments over the next decade.

The Institute also provides leadership in CCITT Study Groups and ANSI-accredited standards committees that contribute to CCITT activities. During FY 90, the Institute continued to lead the CCITT Study Group XVIII Special Rapporteurs Group on Question 5 and two key standards groups within the ANSI-accredited T1 (Telecommunications) Standards Committee: Subcommittee T1S1 and Working Group T1Q1.3. The Question 5 Rapporteurs Group is responsible for developing the general technical approach to be used in ISDN performance description within CCITT. Subcommittee T1S1 has overall responsibility for developing American National Standards on ISDN services, architectures, and signalling, and is the principal source of U.S. contributions to CCITT on these subjects. Working Group T1Q1.3 develops American National Standards and contributes to CCITT Recommendations dealing with the performance of packet-switched public data networks and ISDNs.

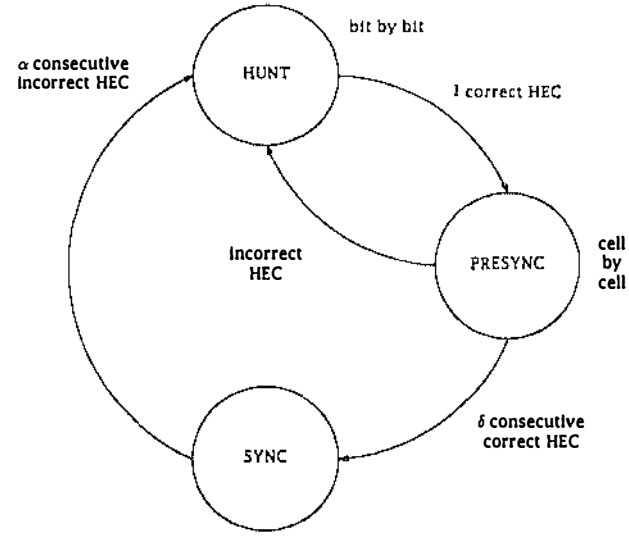
FY 90 was a particularly productive period in the work of Subcommittee T1S1. This group has grown consistently since its formation in 1988 and is currently one of the most influential regional standards committees. Its five yearly meetings are typically attended by over 300 participants and involve concurrent sessions of up to 10 subordinate groups. During FY 90, Subcommittee T1S1 processed over 1200 technical contributions from member organizations; developed 159 formal U.S. Contributions to international standards committees, including CCITT Study Groups XVIII, XI, XVII, and I; and completed 12 American National Standards which are expected to have a major impact on the evolution of U.S. ISDNs. The group's activities involve 21 separate T1 standards development projects and encompass a wide range of topics including ISDN architecture and services, switching and signalling protocols, numbering, and the technology and service capabilities of Broadband ISDNs.

The Institute's FY 90 technical contributions to CCITT were focused on the development of ISDN performance Recommendations within CCITT Study Group XVIII. In cooperation with other

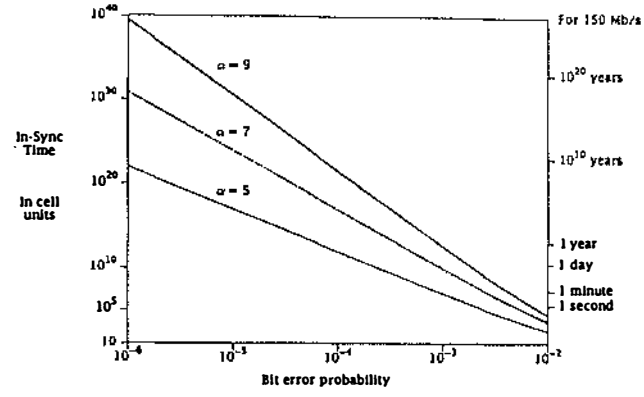
participants, Institute staff members developed the essential content for three new draft CCITT Recommendations during FY 90. Recommendation I.351R defines the overall structure for a related set of CCITT Recommendations that collectively provide a comprehensive basis for the specification and apportionment of performance in ISDNs. Recommendation "I.35E" identifies the set of protocol-specific reference events which will be used in defining the ISDN performance parameters. Recommendation "I.35B" defines speed, accuracy, and dependability performance parameters for the ATM layer of a Broadband ISDN. Institute staff members also developed ISDN connection apportionment definitions to be included in an existing Recommendation (I.325), contributed to a preliminary draft Recommendation on ISDN availability ("I.35A"), and conducted a mathematical study to estimate the mean in-synchronization and synchronization acquisition times for a B-ISDN ATM cell stream.

The latter study was undertaken to assist CCITT in selecting values for two parameters, α and δ, which will determine the performance of the ATM cell synchronization (or "delineation") algorithm specified in new draft Recommendation I.432. The specified cell delineation algorithm will be used to identify the beginning of each successive cell in a stream of ATM cells received at the B-ISDN user-network interface. Delineation is accomplished using the correlation between an 8-bit header error control (HEC) field and the 32 cell header bits the field protects. The algorithm proceeds through three successive states. In the HUNT state, the algorithm searches the incoming data stream bit by bit to identify the first correct HEC (i.e., syndrome equals zero). In the PRESYNC state, the algorithm compares cell header bits with the HEC field on a cell by cell basis until either an HEC violation occurs or the encoding law is confirmed δ times consecutively. In the SYNC state, the algorithm continues the cell by cell comparison to detect synchronization loss (HEC violated α times consecutively).

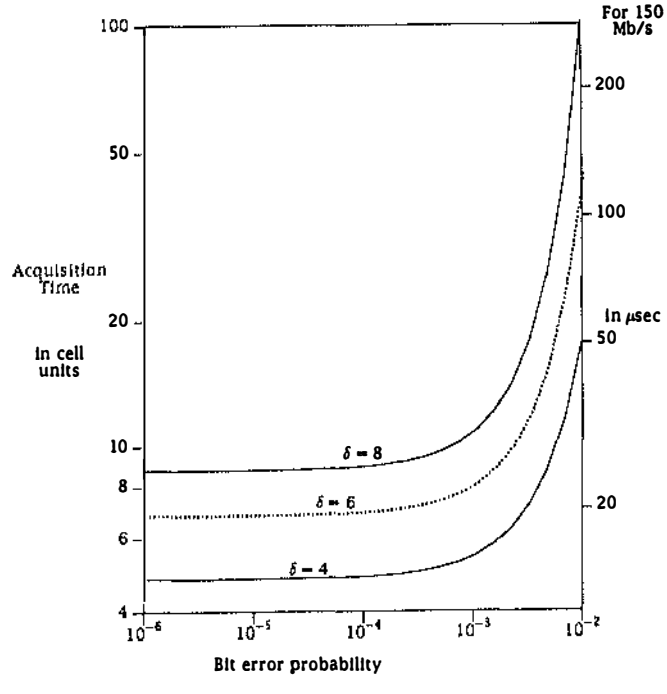
Values for the parameters α and δ must be chosen to make the cell delineation process as robust as possible while meeting the applicable performance requirements. The Institute's contribution presented results of a probability analysis in which the mean in-synchronization time and the mean synchronization acquisition time for an ATM cell stream were estimated as a function of the channel bit error probability for several representative values of α and δ. The results were used to confirm a tentative selection of cell delineation parameters and were included in an Annex to the new CCITT Recommendation.



Delineation state diagram



In-sync time versus bit error probability



Acquisition time versus bit error probability

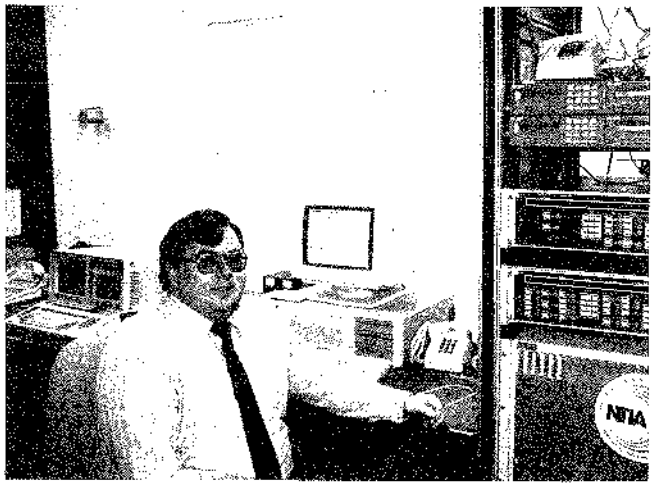
For information, contact:
Neal Seitz (303) 497-3106

Digital Network Performance Standards Development

Outputs

- ISDN laboratory capabilities
- Performance measurement software and results
- Standard performance parameters and measurement methods

For a number of years, the Institute has been involved in the development of digital network performance standards. In prior work, the staff of the Institute has defined comprehensive methods of specifying and measuring the performance of data communication systems and services from an end user perspective; coordinated the adoption of these methods in national and international standards; implemented the specified measurement methods in prototype microcomputer-based test equipment; and demonstrated application of the prototype test equipment in assessing the performance of private and competing public data communication networks. The ITS-developed performance specification and measurement standards are now widely used in the procurement of data communication systems and services. The Institute has assisted several other agencies in the application of the performance measurement and specification standards to their data communications procurements. In FY 90, the Institute expanded the capability of the test facility to better serve the interests of NTIA, Commerce, other federal agencies, and standards bodies.



David Atkinson in the ISDN Laboratory

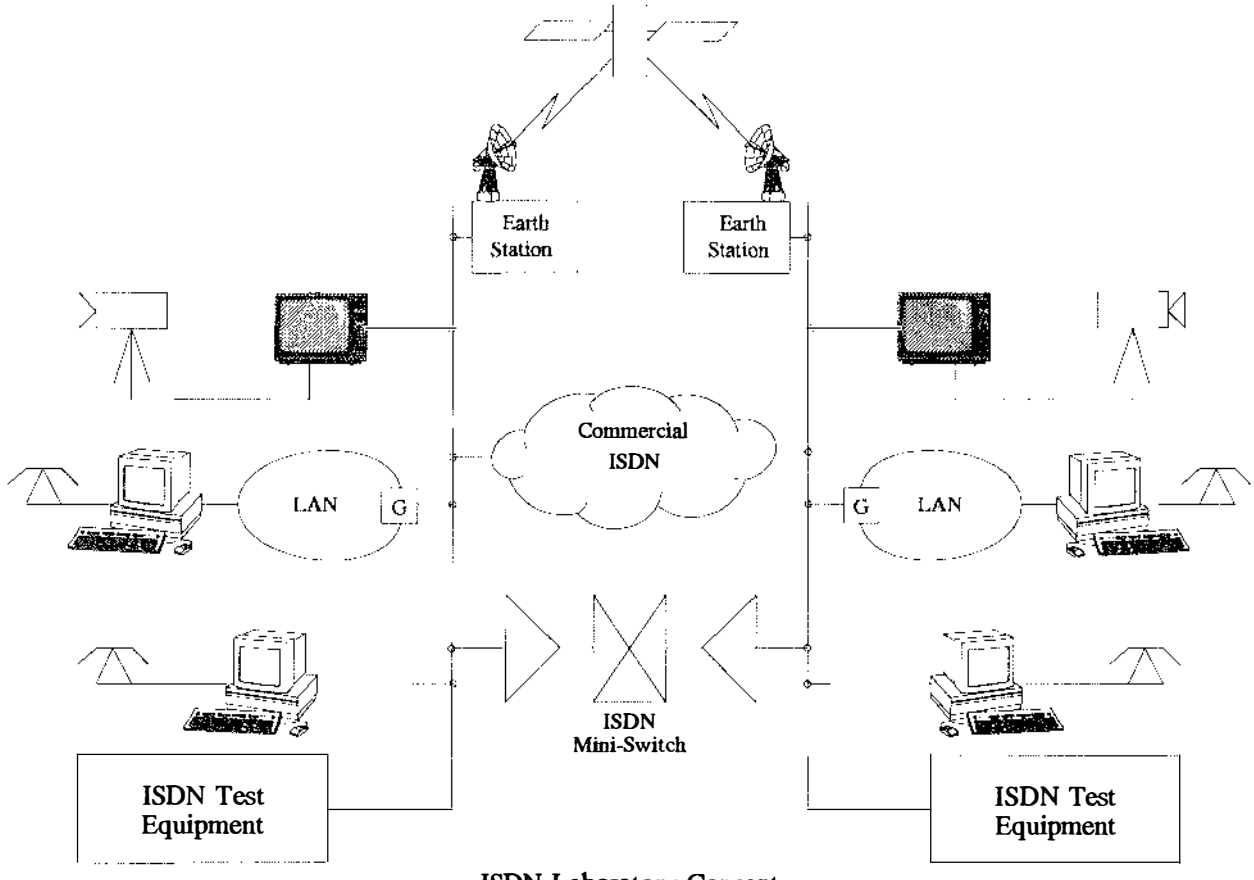
ISDN Performance Measurement Laboratory. A major objective of the Institute's digital network performance program is the development and demonstration of practical methods of measuring the performance of Integrated Services Digital Networks (ISDNs). This work provides an experimental foundation for NTIA's contributions to the development of ISDN performance standards in CCITT and ANSI. Toward this goal, Institute personnel specified, procured and installed laboratory equipment capable of conducting initial ISDN service demonstrations and performance measurement experiments. The ISDN performance laboratory concept is illustrated in the figure on the facing page. Desk-top computers equipped with special ISDN interface cards function as ISDN Terminal Equipment (TE), and provide ISDN telephone connectivity. Commercial ISDN test equipment monitors the ISDN "D" and "B" channels and provides a record of performance-significant events. An ISDN mini-switch, ordered and installed in FY 90, provides a stand-alone ISDN network simulation capability. The mini-switch can be supplemented by operational ISDN network capabilities, including one or more commercial ISDN services and a satellite-based ISDN transmission and switching facility. The ISDN terminal and measurement equipment will be supplemented by equipment specified and ordered in FY 90 to include video teleconferencing services. Future enhancements will include local area network interfaces with the ultimate goal being to fully support Broadband ISDN features and functions.

Advanced Telecommunications Standards Development. The National Communications System (NCS) has tasked the Institute to assist it in the development of telecommunication standardization strategies based on emerging ISDN technologies. Current technical support includes enhancing existing Institute data communication performance measurement tools to include ISDN measurement capabilities that will facilitate the establishment of American National Standards, Federal Standards, and CCITT Recommendations on ISDN performance. The enhanced measurement system will be compatible with ISDN performance standards being developed in Subcommittee T1Q1 and CCITT XVIII.

This will be ensured by Institute personnel taking an active role in the development of those standards. These measurement capabilities will allow ITS to work with U.S. ISDN service providers to validate, demonstrate, and optimize the developing standards, and to provide initial ISDN performance data to NCS and other Government users. The Institute also provides NCS with technology summaries and strategy briefings related to ISDN performance standards efforts around the world.

Digital Network Performance Software Documentation. Among the major results of the Institute's digital network performance program are three American National Standards, ANS X3.102 and ANS X3.141, which define user-oriented performance parameters and measurement methods for data communication services, and ANS T1.504, which defines a set of performance parameters which specifically applies to the technology of packet switching while remaining consistent with X3.102 and X3.141. In prior work, Institute staff members have developed a software system which provides an efficient, automated means of measuring data communication performance in accordance with these standards. The software system can be implemented on a wide variety of microcomputers commonly used in portable test equipment, and is available to other Federal agencies and the public. During FY 90, Institute personnel developed a six-volume report which describes the X3.102/X3.141 measurement software system in detail and provides step-by-step instructions on its installation and use. The 6 volumes include a general overview of the software system and a separate volume describing each of its five component programs: Experiment Design, Data Extraction, Data Reduction, Data Analysis, and Data Display. These six volumes will be published in early FY 91.

For information, contact:
David Atkinson (303) 497-5281



ISDN Laboratory Concept

Voice Quality Standards Development

Outputs

- Contributions to standards organizations
- Operational voice quality assessment software
- Techniques for analyzing voice parameters

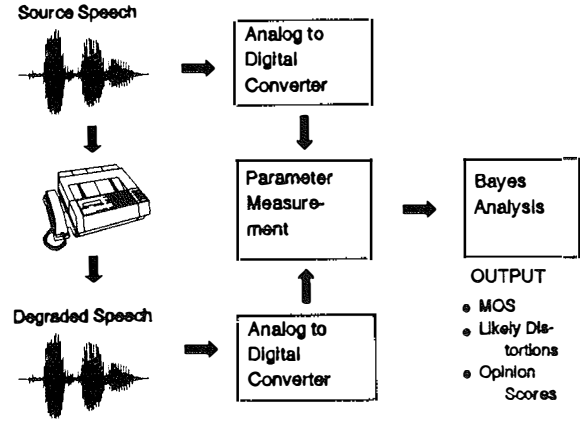
Gauging the performance of voice communication services and equipment is an important element of the design and operation of modern telecommunication systems. Accurate measurement of speech transmission quality provides a key measure of performance that directly relates to end-user satisfaction. Development of a new digital radio, for example, requires an engineer to adjust design parameters that may affect voice quality. Typically, the parameters are chosen to produce what, in the engineer's opinion, is the best voice quality. Unfortunately, such informal assessments of quality are unreliable and may be quite misleading. Obtaining more accurate information requires a panel of listeners to provide a rigorous statistical assessment of "subjective" quality.

Although human listeners provide the most dependable ground truth assessment, the time and dollar costs of listener panels often make them prohibitive. A tool for automatic, or "objective", assessment of voice quality has therefore been sought for many years. Such a system offers many advantages: it would provide near real-time estimates of voice quality, compared with days or weeks required for listener panel results. Computer-based quality assessments would be consistent and repeatable, while human listener scores vary with time, geographical location, and from panel to panel. Finally, a computer based system would be relatively inexpensive, requiring only a personal computer and simple analog to digital conversion equipment. The low cost of an automated system makes it accessible to a wide spectrum of users, including many who could not afford extensive listener scoring of their speech data.

The Institute has developed a computerized system for objective voice quality assessment based on "Bayes" pattern recognition techniques. The method uses measurements of the input and output voice signal that correlate with subjective listener scores. A significant portion of ITS research involves the development of a set of voice measurements, or "parameters", that provide accurate prediction of subjective listener panel scores for a broad range of impairments. Nearly 250 parameters have been implemented and studied for use in the system. Identification of an effective set of parameters has been a formidable task considering the massive number of possible parameter combinations to be evaluated.

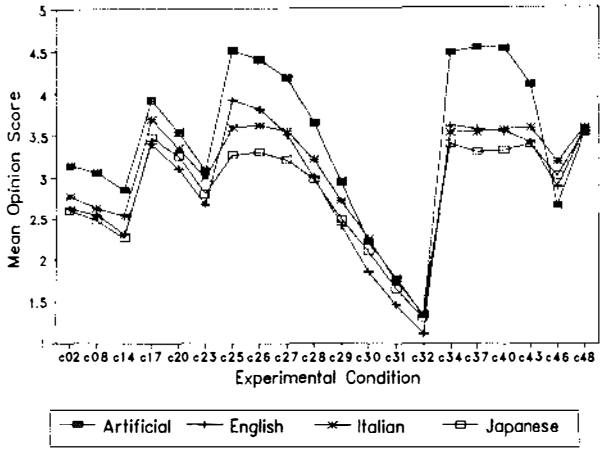
Once an effective set of objective voice parameters has been selected, the system is "trained" using a database of speech records that have been subjected to relevant types of degradations and subjectively tested. Training consists of estimating statistics of objective parameters for each type of degradation in the database.

After training, the system is ready to be used as an assessment tool. As shown in the figure below, the input and output speech are digitized and processed by computer to measure the selected objective parameters. Finally, Bayes estimation techniques compare the objective parameter values measured from the test speech with the training data statistics to produce an objective quality score.



Output of the system includes an estimate of mean opinion score (MOS), which ranges between 1 and 5 where 1 is "unacceptable", 2 is "poor", 3 is "fair", 4 is "good", and 5 is "excellent". Additional information includes estimated opinion score probabilities, and types of degradation likely to be present in the speech.

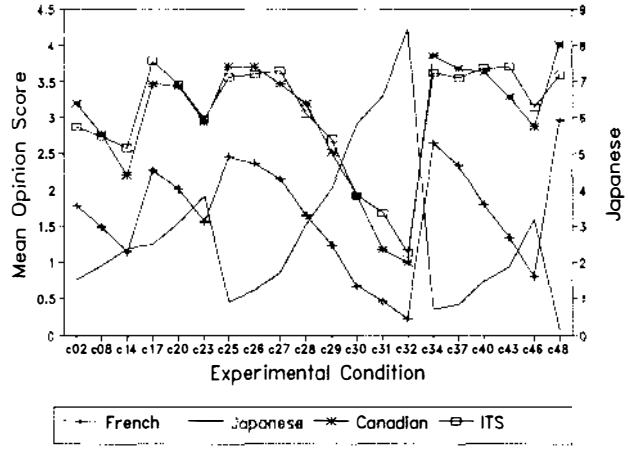
In addition to conducting research in objective assessment techniques, the Institute is strongly promoting national and international standards development in this area. During FY 90, Institute personnel continued to lead a Study Project, within the ANSI accredited T1Y1 Technical Subcommittee, to determine the feasibility of a national standard objective assessment technique. On the international level, ITS is participating in a CCITT SG XV subjective and objective test of 16 kbit/s speech coding techniques. Included in the codec test is an evaluation of four objective quality assessment methods being considered by CCITT. Techniques include the ITS pattern recognition based system, as well as submissions from France, Japan, and Canada. Results of the test will determine future CCITT goals regarding establishment of an international standard assessment method.



As one of the host laboratories participating in the international test, ITS has implemented all four objective assessment techniques and has applied them to the speech database developed by CCITT. The database consists of over 1.2 Gbytes of speech data representing numerous types of codec-related distortions. Included languages are North American English, Italian, Japanese, and artificial voice, with both male and female talkers. Example results of the test are shown in the second figure. Here, averaged estimates of mean opinion score derived from the ITS system are shown for each language and impairment. Condition numbers on the horizontal axis refer to different impairment conditions used in the test. It is interesting to note the disparity of objective scores between languages.

For information, contact:
Robert Kubichek (303) 497-3594

The final figure compares assessments of all four objective techniques for an Italian male talker. With the exception of the Japanese technique, the methods are all well correlated. The Japanese technique produces a measure of distortion so that larger values relate to lower opinion scores. Subjective listener scores are not currently available to permit evaluation of assessment accuracy. However, the objective scores are generally consistent with the level of distortion within each experimental condition.



The Institute is providing leadership in the development of national standards for related areas of voice telecommunications. Bob Kubichek, leader of the ITS voice quality project, chairs the ANSI accredited Specialized Voice and Data Processing Working Group, T1Y1.2. This group has developed several ANSI standards including T1.302 defining 32 kbit/s ADPCM voice coding, and T1.306 for wide-band speech coding. Their current projects include digital circuit multiplication equipment (DCME), packetized voice, embedded 32 kbit/s ADPCM, packetized circuit multiplication equipment (PCME), 16 kbit/s and less than 16 kbit/s speech coding algorithms, and objective voice quality.

Recent Contributions

Status Report on Objective Voice Quality Assessment system (by Kubichek)

Preliminary Results on Segmentation, Principal Component Analysis, and Parameter Modifications (by Kubichek)

Draft Technical Report: Technology-Independent, User-Oriented, Objective Classification of Voice Transmission Quality (by Kubichek, Atkinson, and Webster)

Preliminary Results of Objective Assessment Tests (by Kubichek, Atkinson, and Webster)

Objective Voice Quality Assessment using Bayes Pattern Recognition Techniques (by Kubichek)

Video Quality Standards Development

Outputs

- Automated video quality measurement techniques and software
- Contributions to standards committees
- Video expertise provided to NTIA, Department of Commerce, and Defense Communications Agency for establishing U.S. policy on advanced video technologies
- Technical support for Law Enforcement Standards Laboratory

Video Quality Standards. As the world prepares to enter the age of compressed and digitally transmitted video services such as video teleconferencing/video telephony (VTC/VT), digital television, broadband ISDN, high resolution graphics transmission, and high definition television (HDTV), new quality assessment techniques are needed. Traditional techniques for estimating video quality are based on analog measures of the transmission signal. Such measures include waveform tests and chrominance/luminance gain and phase factors. These parameters are not adequate in assessing video quality when images are impaired by the many new types of distortions introduced by the modern digital transmission systems given above. In such cases, the video transmission quality is often a function of the type of imagery being transmitted (line drawings, natural scenes, etc.). Since the information has been compressed, small transmission errors can have large effects on the received video quality. As a result, viewing panels have been used to subjectively evaluate these modern distortion effects on video quality. Unfortunately, this approach is time consuming, expensive, and requires special care to prevent wide variations between tests.

New, objective measures of video transmission quality are urgently needed by standards organizations, end users, and providers of advanced video services. ITS is developing a method for objective measurement of video quality based on parameter extraction from sampled video imagery and pattern recognition techniques. The ITS computer-based approach extracts objective video quality measurements directly from the captured video images. Video quality parameters extracted from the sampled imagery are sensitive to user applications and the effects of modern transmission channel impairments. The objectively measured parameters can then be interpreted and mapped to an overall quality rating using pattern recognition techniques. The ITS approach removes unwanted human variability while implementing the essentials of user orientated subjective evaluation. The ITS approach will allow users to obtain impartial, reliable, repeatable, and cost effective measures of video and image transmission system performance. Other benefits include increased competition among providers as well as better capability of procurers and standards organizations to specify and evaluate new systems.

The American National Standards Institute, Committee T1Q1.5 is drafting interface performance specifications for VTC/VT, and advanced television (ATV). ITS has participated actively in the development of a catalogue of motion artifacts associated with the digital coding and transmission process and has developed measurement techniques and parameters for the different artifacts. One of the most prevalent artifacts in VTC/VT and ATV systems is blurring of the received video imagery when motion is present. This artifact normally results when the information content of the video signal exceeds the transmission system bandwidth. Since the resolution of the human visual system depends upon the amount of motion that is present, it is desirable to quantify independently the blurring of the still and motion parts of the image. Figures 1 to 3 describe an ITS developed method for separating the motion part of an image. In Figure 1, an initial estimate of the motion is obtained by taking the absolute difference of two input video images that are centered about the time of interest. To separate the true motion from random fluctuations in the still background, the image in Figure 1 is thresholded and filtered, resulting in Figure 2. Region growing techniques are then applied to the image in Figure 2. The end result in Figure 3 is a mask that gives the motion part of the image. This motion mask may now be used to separate the motion part of the image from the still part of the image. Any of the ITS developed parameters may now be applied to just the motion part of the image. This is demonstrated in Figures 4 through 9 for the ITS developed edge sharpness parameter. In Figures 4 through 6, the motion separation algorithm has been applied to the original input image. In Figures 7 through 9, the motion separation algorithm has been applied to a degraded VTC/VT image. Note the

blurring of the edges in the VTC/VT output image (Figure 9) when compared with the edges in the original image (Figure 6). In this case, the motion part of the VTC/VT image is much more blurred than the still part of the VTC/VT image.

Video Teleconferencing Quality Assessment Standards. This program is synergistic with the video quality standards program. Emphasis is placed on performance assessment of video teleconferencing systems over ISDN networks. The video quality measurement software and hardware are being used in conjunction with the ISDN laboratory to perform automated on-line testing of video teleconferencing performance.

Video Surveillance Equipment Requirements. The Law Enforcement Standards Laboratory of the National Institute of Standards and Technology has tasked the Institute to develop a Guide for the procurement of video surveillance equipment. The Guide will assist state and local law enforcement agencies in making intelligent decisions concerning the capabilities and costs of video surveillance equipment. There are four tasks in the development of the guide. First is to determine the requirements of the personnel who will be using the video surveillance equipment. Second is to determine what products are available to law enforcement agencies. Third is to determine how the specifications of the products researched in Task 2 map into the user requirements from Task 1. The final task is to turn the information from Task 3 into a guide which will be understandable and useful to state and local law enforcement agencies.

Task 1 was completed with the use of a questionnaire. Thanks go to the Boulder County Sheriff's Department and the Fort Worth Police Training Academy for their assistance in the development of the questionnaire. Task 2 was completed with the assistance of many manufacturers and vendors who shared their product literature in the interest of the project. Task 3 and Task 4 will be completed in the next fiscal year, and will involve comprehensive laboratory testing of surveillance equipment to determine how various manufacturers' products satisfy the established user requirements. Extensive documentation will record all testing methodology and results.

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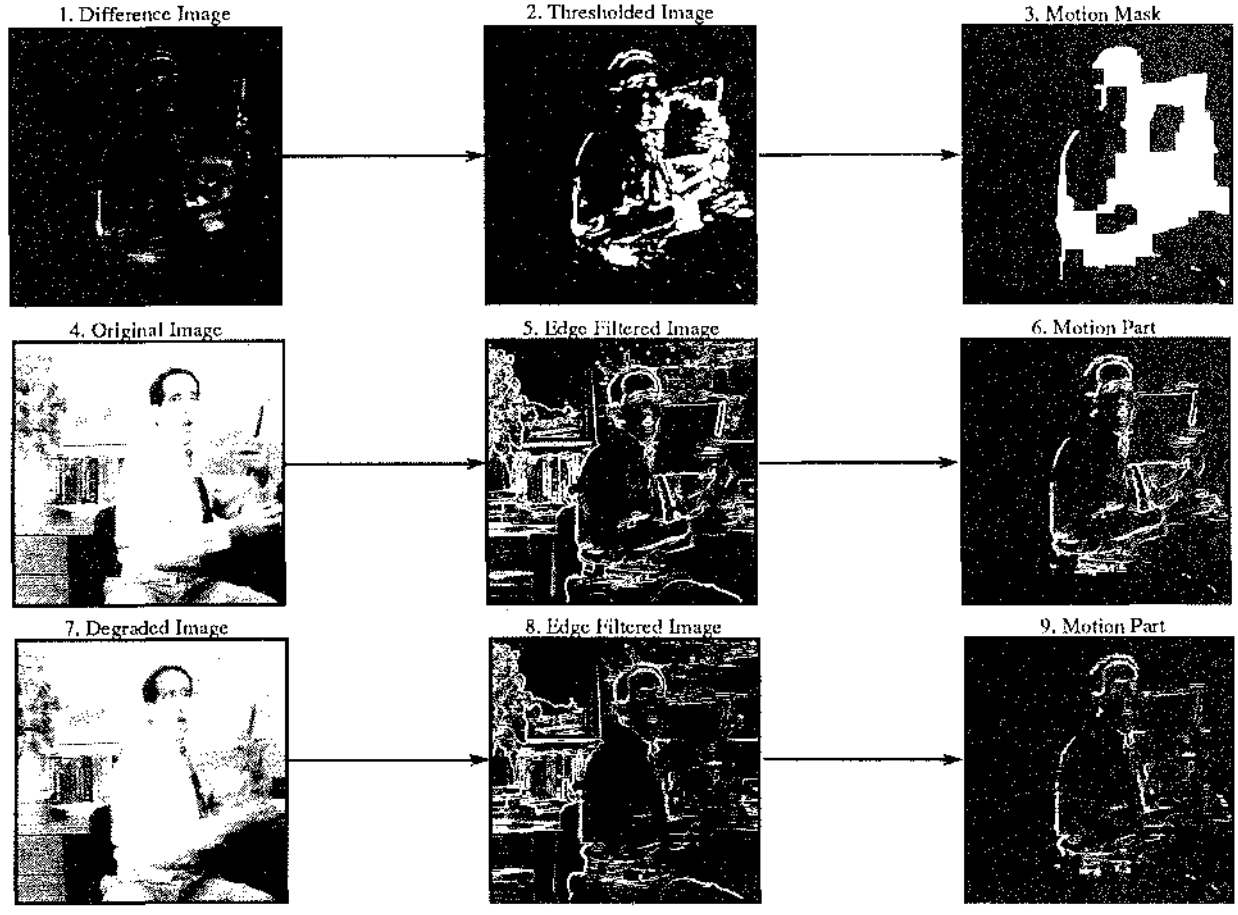


Radio Systems Interoperability Standards Development

Outputs

- FTSC subcommittee leadership and technical support
- Federal interoperability standards for radio systems
- Military planning standard for adaptive HF radio
- Standards impact assessments
- Radio systems interoperability evaluations
- Adaptive HF radio proof-of-concept testing for developing technology

By Presidential directives, the Federal Government is required to use interoperability as a prime criterion for the acquisition of new radio equipment. Specifically in the areas of national defense and emergency preparedness, disaster recovery, drug interdiction, and law enforcement, the various governmental agencies must interact and interoperate with each other. The Federal Telecommunications Standards Committee (FTSC) has responsibility for development of Federal interoperability standards for radio systems, including high-frequency (HF), land mobile (primarily law enforcement), and meteor burst radio equipment. The Institute supports FTSC radio standards activities through leadership of technical subcommittees and through a variety of standards development, implementation, and evaluation projects. The Department of Defense (DOD) through the U.S. Army Information Systems Engineering Command (USAISEC), is developing the new field of interoperable adaptive HF radio systems. The Institute supports the USAISEC mission through the development of Military Standard (MIL-STD) 187-721, "Planning and Guidance Standard for Automated Control Applique for HF Radio." The Institute also performs critical reviews of draft standards for both the Federal Standard and the Military Standard programs.

Development of Advanced HF Radio Systems Standards. The FTSC, under the direction of the National Communications System (NCS), has assigned its HF Radio Subcommittee the responsibility for developing a family of HF radio interoperability standards: Federal Standards (FED-STD) 1045 through 1054. The HF Radio Subcommittee is chaired by an ITS staff member. The secretary is also from ITS. FED-STDs 1045 through 1049 provide interoperability for automated and adaptive HF radio systems. FED-STD-1045 (HF Radio Automatic Link Establishment) was published in January 1990. FED-STD-1046 (HF Radio Automatic Networking) and FED-STD-1049, Section 1 (Automatic HF Radio Operation in Stressed Environments, Link Protection) are currently under development. The features of these two developing standards are the subject of the proof-of-concept testing. These HF radio standards are being written in a progression that conforms to the Open Systems Interconnection (OSI) architecture. MIL-STD-187-721 is being developed in parallel with the Federal standards. Generally, the same personnel support the features development for both communities. This results in a considerable savings in time, money, and technical development efforts. The end result will be complete interoperability between the military and the Federal communities. The only differences will be the addition of military unique features. The process is to first develop the requirements, primarily in Government/Industry technical working groups. Secondly, the features are written in draft standards. The third step is to test prototype hardware embodying these newly developed features. If the tests demonstrate that the new features are implementable and fulfill the stated requirements, a coordination draft standard is prepared along with the prototype test results and forwarded to both Government (including the military community) and industry for comment and approval. Upon receipt of all comments, any problems or conflicts are resolved and a final manuscript is prepared for the General Services Administration for publication.

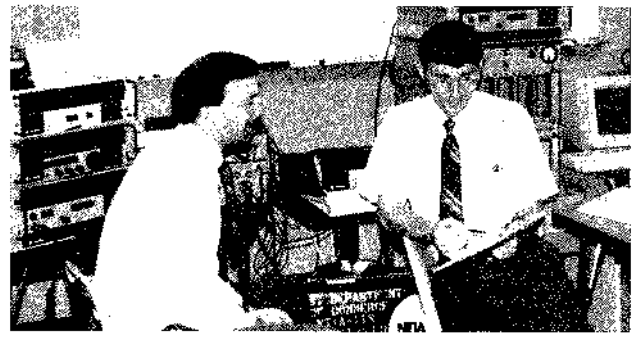
High Frequency Radio Interoperability Test Facility (ITF). The ITF has been established as an independent, unbiased testing facility. Its primary purpose is the measurement of performance and the assessment of interoperability of automatic and adaptive HF radio systems for Government agencies and military departments. It also assists these agencies and departments in making planning decisions relating to the procurement of adaptive HF radio systems. The ITF is also actively involved in the development process for the family of the new Federal standards pertaining to the advanced features of adaptive HF radio. The core of the ITF assessment capabilities are three ionospheric propagation channel simulators. These simulators, based on the work of former ITS staff member Clark Watterson, are modern, solid state, light weight devices which can be

easily transported in a suitcase along with the other supporting test equipment. This suitcase capability allows the ITF test engineers to conduct full interoperability testing "off-site". The ITF maintains an HF radio transmitting and receiving station on a mesa overlooking the Institute's Boulder facility for over-the-air testing as well as having a mobile test capability. The facility has been expanded in FY 90 through continuation of funding by the National Communications System (NCS). The initial ITF testing mission was a short duration, high impact vendor interoperability assessment of all commercially available HF radio systems complying with the new FED-STD-1045. The tests, both laboratory and over-the-air, were done for the Counter-Drug Telecommunication Integration Office of the Defense Communication Agency. Six vendors were tested using the traveling simulators at their facilities as well as over-the-air, with the other vendors and the Boulder mesa station. These tests have led to increased competition in the HF radio marketplace and to a greater confidence among Federal agencies when procuring equipment which meets FED-STD-1045.

Land Mobile Radio Interoperability Standards. ITS serves as the Secretariat and provides strong technical support to the FTSC Land Mobile Radio Subcommittee. FED-STD-1024 (Interoperability Requirements for Narrowband Encrypted Digitized Voice Radios) and FED-STD-1044 (Interoperability Requirements for Trunked LMR Systems Operating with Analog and Digital 25 kHz Channel Radio) are currently under development. ITS has provided support to this subcommittee in waveform analysis, critical technical review of the proposed standards, assistance in preparation of the official replies to formal comments letters, and the economic analysis for each of the proposed standards.

Interoperability Standards for Meteor Burst Communications. The Institute is providing technical support to the National Communications System (NCS) in the development of two Federal interoperability standards related to Meteor Burst Communications (MBC). Proposed FED-STD-1055 defines the basic interoperability requirements and technical characteristics for MBC terminals. A companion document, proposed FED-STD-1056, defines standard methods of encryption for sensitive or classified data transported via MBC. The Institute has written both standards and is revising the initial drafts based upon comments received to date. ITS is engaged in the planning of tests required to validate the parameters in both of these standards, and will be responsible for any required validation testing. ITS also serves as the Secretariat to the MBC Subcommittee.

Standards Impact Assessments. The Institute performs a detailed survey of potential users and vendors of proposed radio systems, detailed in the emerging radio standards. The results of these surveys are evaluated, combined and tabulated, and form the basis for a Technological and Economic Impact Assessment document. These documents assess the willingness of vendors to develop a product to meet a proposed standard and the user's need for the specified radio system.



ITS engineers Chris Redding (left) and Dave Wortendyke conducting C-D TIO interoperability test at Rochester, NY.

Recent Publications

Federal Standard 1045, Telecommunications: HF Radio Automatic Link Establishment (by Peach and Adair)

Proposed Federal Standard 1055, Meteor Burst Communications (by Pomper)

Proposed Federal Standard 1056, Encryption for Meteor Burst Communications (by Pomper)

Other Related Issuances

Link Protection Technical Report (by Johnson)

Connectivity Technical Report (by Brewster)

First Working Group Draft Military Standard 187-721 (by McMillian)

Draft Economic and Technological Impact Analysis for Proposed Federal Standard 1044 (by Ingram)

Cost Analysis for Group 3, STANAG 5000 and MIL-STD-188-161A Type Facsimile Machines (by Ingram, Peach, Adair, Pomper)

Economic and Technological Impact Analysis for Proposed Federal Standard 1016, Telecommunications: Analog to Digital Conversion of Radio Voice by 4,800 Bit/Second Code Excited Linear Prediction (CELP) (by Ingram)

Federal Standard 1045, Performance and Interoperability Assessment (by Smith, Wortendyke, Redding, and Ingram)

Proceedings of the Adaptive HF Radio Forum for Industry (by McMillian)

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Telecommunications Engineering for NCS/DCA

Outputs

- FTSC standards development support
- Telecommunication wiring standards for commercial and residential buildings
- Survivability criteria for long-haul fiber optic systems
- Telecommunication terminology definitions
- Network management standards evaluation

The Federal Telecommunication Standards Committee (FTSC) is responsible for establishing Federal standards to promote the end-to-end interoperability and survivability of telecommunication systems owned or leased by the Federal Government. Institute staff members support the FTSC in fulfilling this responsibility by contributing to private-sector standards committees, where Federal and industry standardization objectives coincide, and by leading or staffing FTSC Technical Subcommittees where Federal-unique standardization requirements exist. During FY 90, the Institute contributed to Federal and industry standardization efforts focused on telecommunication wiring for commercial and residential buildings, survivability of long-haul fiber optic systems, and telecommunication terminology; further, ITS began a study of evolving industry standards for network management. This work involved participation in standardization activities of the Electronic Industries Association and Telecommunications Industry Association (EIA/TIA), the FTSC, and the ANSI-accredited T1 standards committee.

Telecommunication Wiring Standards. Institute staff members have contributed strongly to EIA/TIA TR-41.8 Working Groups in standardizing technical specifications for telecommunications wiring in commercial and residential buildings. Several proposed industry standards (and compatible Federal Standards) have been developed. The first of these, ANSI/EIA/TIA-568, defines a general architecture for commercial building telecommunication wiring including recommended media, topologies, and span lengths. Institute participants played a key role in the EIA/TIA decision to recommend that a single optical fiber size (62.5 micron core, 125 micron cladding) be used in all intra-building fiber installations, and spearheaded the development of a companion standard, ANSI/EIA/TIA-492AAAA, which provides a detailed specification of technical characteristics for such fibers. The architecture standard is currently in the EIA/TIA ballot process and will ultimately be adopted as Federal Standard 1090; the detail specification was approved by EIA/TIA in FY 89 and is currently being processed for adoption as a Federal Information Processing Standards Publication (FIPS-PUB). The 62.5/125 micron fiber size has already become the de facto standard for premises applications in the U.S. and has been proposed for international standardization in the International Electrotechnical Commission (IEC).

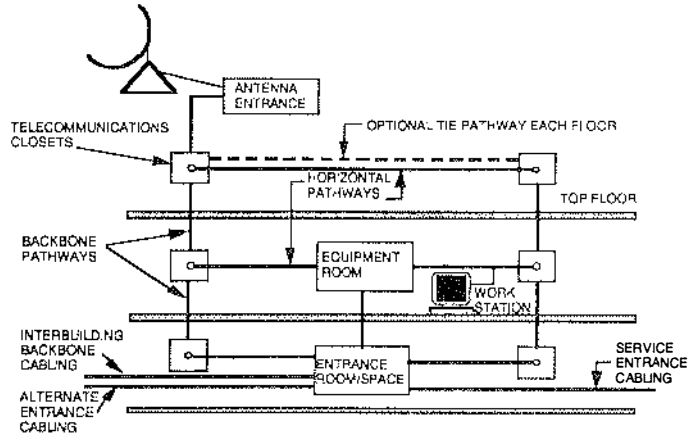
In subsequent work, Institute staff members contributed to the development and coordination of two related building wiring standards: ANSI/EIA/TIA-569, which specifies dimensions, fire protection requirements, and other technical characteristics for telecommunications pathways and spaces in commercial buildings (see figure at the upper right); and ANSI/EIA/TIA-570, which specifies telecommunication wiring standards for residential and light commercial buildings. Both standards are currently in the EIA/TIA ballot process and will ultimately be adopted as Federal Standards (1091 and 1092, respectively). The TR-41.8 group developed the ANSI/EIA/TIA-569 document in close cooperation with a counterpart committee in the Canadian Standards Association, and an adaptation of that document has been proposed as a Canadian National Standard. In more recent follow-on work, an Institute staff member organized a cooperative industry/Government standards effort to define grounding and bonding requirements for telecommunications installations in commercial buildings (see figure at the lower right).

Fiber Optic System Survivability Criteria. In prior work, the Institute developed a multi-tier specification which defines installation practices designed to improve the survivability of long-haul fiber optic systems. During FY 90, the Institute assisted the National Communications System (NCS) in proposing and outlining an industry (T1Y1) standards project in which similar installation practices would be specified in one or more American National Standards. Preliminary T1Y1 discussion suggested the development of three standards dealing separately with

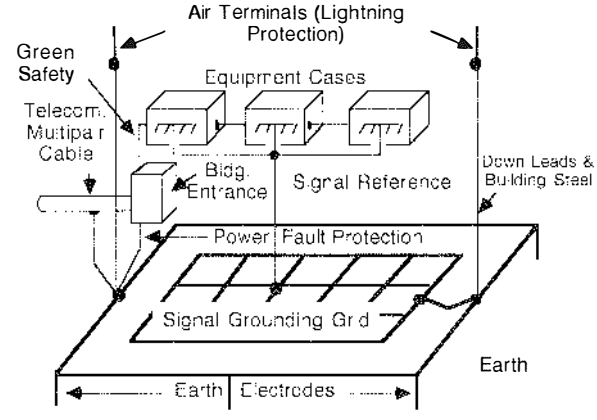
electrical protection, physical protection, and hardening against nuclear effects.

Telecommunication Terminology Definition. Approved Federal telecommunication standards are reviewed at 5-year intervals to ensure that they remain relevant as technologies evolve. In prior work, the Institute contributed to the initial development and first revision of FED-STD 1037, a widely-used glossary of telecommunication terms. During FY 90, the Institute led an FTSC technical subcommittee in conducting a second major revision of this standard. Institute staff members chaired 10 meetings of the technical subcommittee and contributed to the development of new definitions in areas such as ISDN, HF radio, optical fiber communication, automated data processing, secure communications, and data transmission. All existing definitions were reviewed to identify state-of-the-art usage. The subcommittee produced a 400-page coordination draft, which was very widely distributed. A final approval draft of the revised standard, proposed Federal Standard 1037B, which incorporates several hundred review comments resulting from the coordination draft, will be completed during the first quarter of FY 91.

Network Management Standards Evaluation. During FY 90, the Institute initiated a comprehensive study of telecommunication network management standards under development by national and international standards bodies such as T1M1, ISO, and CCITT. The purpose of this study is to assist Federal communications managers in understanding, evaluating, and procuring network management systems. Preliminary results were presented in a tutorial seminar entitled "Basic Concepts of Digital Transmission Leading to Network Management Systems."



Intrabuilding Elements as Defined in EIA/TIA-569 Standard



Building Grounding Subsystems Defined in EIA/TIA PN-2327

Recent ITS Publications

Building Grounding for Telecommunications Infrastructure (by Hull and Meister)

Digital Performance Estimates for 24 AWG Unshielded Twisted Pair Transmission Line (by Sutherland and Hull)

Grounding Systems for Telecommunications in Buildings (by Hull)

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ITS Engineer, Lauren Basel, raises the antenna tower on the HDTV propagation measurement van.

TELECOMMUNICATION SYSTEMS PERFORMANCE

The Institute conducts a variety of programs in which the results of more basic studies are applied in improving the performance of particular telecommunication systems. The Institute develops practical methods of predicting and evaluating telecommunication system performance; applies these methods in system design; and conducts laboratory and field measurements to optimize the performance of recommended systems and their components.

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 the U.S. Naval Sea Systems Command

HF Systems Assessment

Includes projects funded by the Army Communications-Electronic Command, the Army Information Systems Engineering Command, the Department of Defense, and the U.S. Information Agency

Transmission System Performance, Monitoring, Evaluation, and Control

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

Measurements, Modeling, and Simulation of LOS Microwave Links

Includes projects funded by the Air Force Electronic Systems Division, the Defense Communications Agency, and the Naval Air Test Center

Wide Area Prediction Model

Includes projects funded by the Department of Defense

Terrestrial Link Engineering Design Software

Includes a project funded by the Army Information Systems Engineering Command

High Definition Television Evaluation

Outputs

- Statistics of multipath distortion of 4.2 MHz video channels in various environments for VHF and UHF frequencies
- Data used to set parameters of multipath simulator for ATTC tests
- Feasibility of ghost cancellation system for NTSC and HDTV using PN sequence training signal

ITS has been tasked to perform measurements of multipath distortion to support the development of the HDTV (high definition television) broadcast standard for the United States. This data will be used to design tests for the competing HDTV systems being evaluated by the Advanced Television Test Committee (ATTC) and to aid in the design of ghost cancellation systems for HDTV and NTSC broadcast. Previous measurements have been limited in scope and some have had problems that invalidated their results. Although much experience has been gained over many years with standard NTSC television, the candidate HDTV systems use different modulation, encoding, and data compression techniques that will be affected very differently by multipath. Standard television produces ghosts when multipath is present while the digital transmission techniques used by some HDTV systems would experience inter-symbol interference that would degrade the received picture in other ways. Most of the candidate HDTV systems employ some type of ghost/echo cancellation to ensure that high quality video is maintained.

After determining that additional measurements were necessary, ITS personnel designed and implemented a system that was quickly fielded to supply the necessary data to ATTC and manufacturers of proposed HDTV systems. Existing TV transmitters were used to avoid previous problems with limited range. Most of the necessary equipment was available from standard industry sources and modified to meet our needs.

A pseudo-noise (PN) sequence was inserted on an unused line in the vertical blanking interval (VBI) using a Tektronix 1910 Digital Test Generator modified to transmit the designed PN sequence. The VBI is a set of scan lines above the normal picture that is used to transmit various test signals, teletext, and closed captioning information. Most stations have several of these lines available for use. Two transmitters, KMGH-TV channel 7 and KDVR-TV channel 31 were used in the Denver area providing 316 kW and 5 MW of effective radiated power respectively. This allows coverage of an area up to 100 miles from the transmitters. Figure 1 shows the PN sequence waveform used. Two 127 bit PN sequences at a chip rate of 8/5 of the color burst frequency (5.73 Mbits/sec) were utilized. This allowed detection of reflections from -5 microseconds before the main signal up to +15 microseconds after the main signal. Since each television line is approximately 50 microseconds long, ghosts having a length up to 60% of the width of the television screen can be detected.

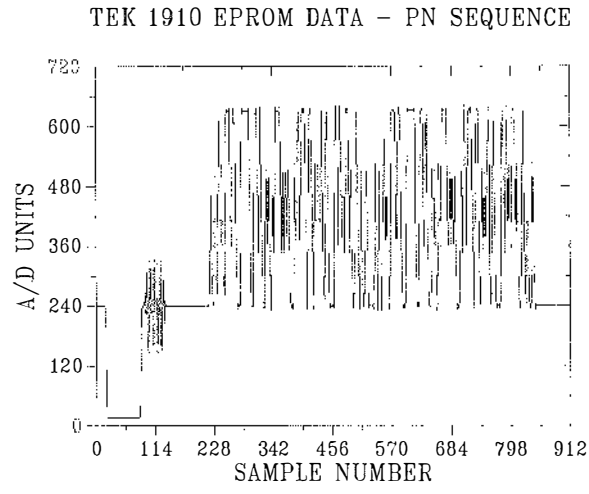


Figure 1. Pseudo-noise test signal

The receiving system includes a log periodic directional antenna and two omni-directional antennas (one for each band) that feed two commercial television demodulators (TEK 1450) that provide in-phase and quadrature outputs for each of the two channels (both in-phase and quadrature phase responses are necessary to completely characterize a channel).

A line monitor (TEK 1480) provides synchronization with the VBI line containing the PN sequence. A video processing amplifier that provides an output phase-locked to the transmitted color burst sub-carrier which is multiplied by four with a phase-locked oscillator to provide a clock for two analog to digital convertors operated by a microcomputer that collects and stores 32 sweeps of the VBI line that contains the PN sequence. Figure 2 is a simplified block diagram of the receiving system. The equipment is installed in a standard size van with a 9 meter pneumatic mast for the antennas.

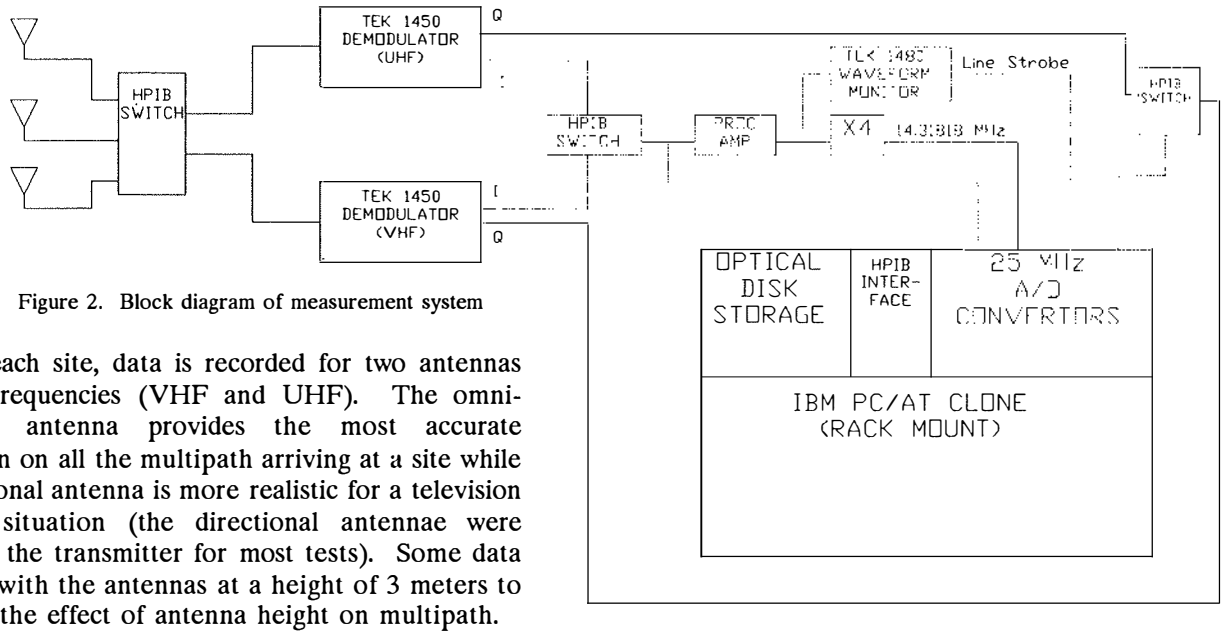


Figure 2. Block diagram of measurement system

At each site, data is recorded for two antennas and two frequencies (VHF and UHF). The omni-directional antenna provides the most accurate information on all the multipath arriving at a site while the directional antenna is more realistic for a television reception situation (the directional antennae were pointed at the transmitter for most tests). Some data was taken with the antennas at a height of 3 meters to determine the effect of antenna height on multipath.

The raw A/D data is processed by correlating the digitized received data with the original PN sequence and combining the in-phase and quadrature phase channels to obtain the magnitude of the impulse response for the television channel. Figure 3 shows the received in-phase (upper) and quadrature (lower) data.

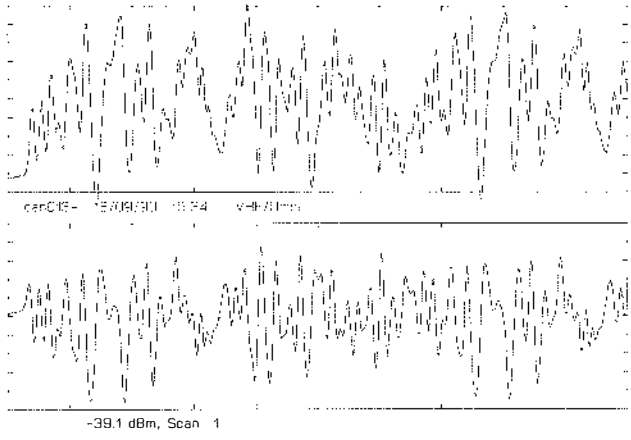


Figure 3. Received signal on in-phase and quadrature channels

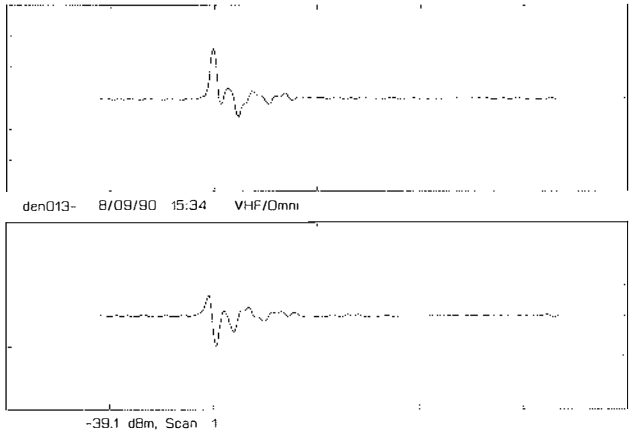


Figure 4. Correlated signals on in-phase and quadrature channels

Figure 4 shows the respective results of the correlation and Figure 5 is the magnitude of the impulse response. Various statistics of the approximately 200 sites measured in the Denver-Boulder area will be calculated to provide data on the distribution of the relative time and magnitude of reflections for different types of areas (e.g., urban/suburban/rural, residential/industrial/high-rise, lightly/heavily wooded, etc.). Pictures were taken to aid in the classification of sites into these categories.

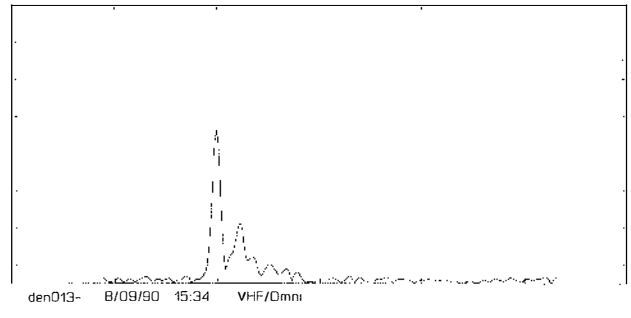


Figure 5. Real part of multipath response

In fiscal year 1991, additional measurements will be taken at two other cities to broaden the statistical base by including more types of terrain and environments. Similar data collected by the Canadian Research Centre may be incorporated. Additional measurements may be taken to characterize cross-polarization effects.

For information, contact:
John Godwin (303) 497-5191

Computer Aided Design and Video Teleconferencing Network Performance

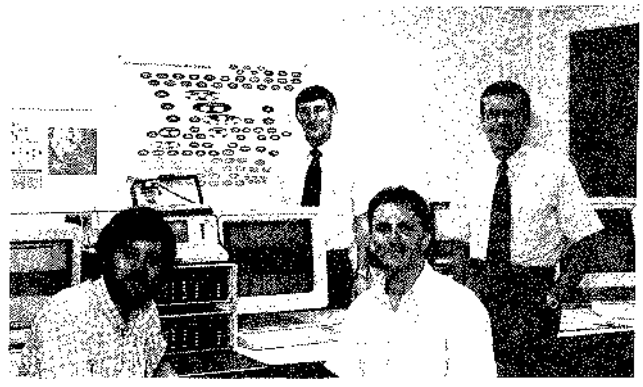
Outputs

- Optimized objective gradient measures of VTC quality
- Objective video quality measurements of desktop, conference room, and graphics scenes at NTSC, 1.536 Mbps, 768 kbps, and 384 kbps rates
- Network performance measurements between work stations and file servers over 10 Mbps LANs and a simulated WAN
- Technical standards contributions

The Institute has developed a series of interconnected, prototype networks in support of the U. S. Navy AEGIS shipbuilding program. These networks serve as a test-bed to demonstrate and evaluate the integration of Computer Aided Design (CAD), Computer Aided Logistics Support (CALS), Video Teleconferencing (VTC), and Interactive High Resolution Graphics Teleconferencing (IHRGT). The major focus has been on network performance evaluation for compressed VTC and CAD/CALS file transfers.

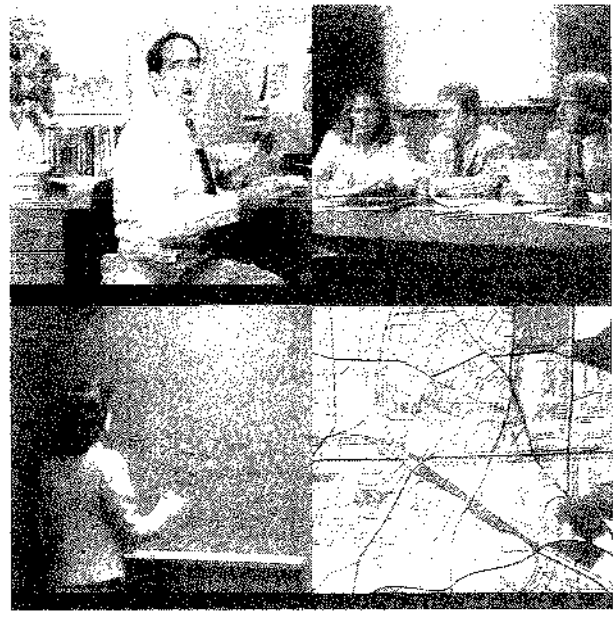
The networks implemented at ITS include a coaxial cable and 3 fiber Ethernet Local Area Networks (LANs) and a fiber Ethernet backbone Metropolitan Area Network (MAN) all operating at 10 Mbps. The MAN is connected to a Ku-band (14/12 GHz) satellite earth station serving as an interface to the DS1 (1.536 Mbps) Wide Area Network (WAN) pipe interconnecting Navy sites.

Objective Assessment of Video Teleconferencing Quality. Video teleconferencing has evolved as the primary service for the Navy network to support intersite communication and review of the shipbuilding progress. Research at ITS has focused on objective quality assessment of the NTSC codec input and transmitted data at 384 kbps, 768 kbps, and 1.536 Mbps. A database has been developed using these 4 rates for the 4 typical VTC scenes of desktop, conference table, graphics, and lecture/blackboard applications shown to the right.

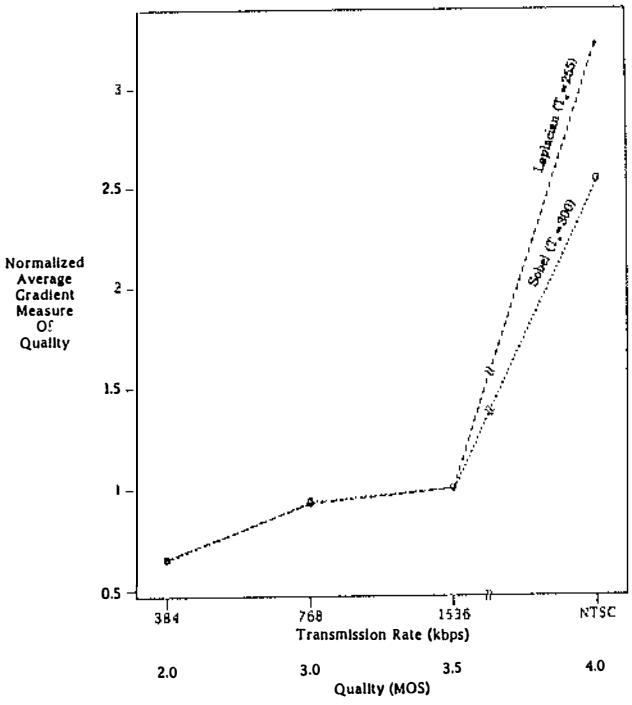


Project personnel (from left) Tim Butler, Dave Wortendyke, Keith Junker, and Ed Quincy

Two gradient measures for objective quality assessment were developed, based on the Laplacian and Sobel operators. Both measures were optimized over the threshold selection to insure maximum sensitivity to subjective quality. An example of applying these measures to desktop VTC is shown at the top right of opposite page where they monotonically increase with transmission rate and subjective quality.



Typical VTC test scenes



Laplacian and Sobel average gradient measures of quality on desktop VTC

Measurement of Data Performance Parameters for CAD/CALS file transfers. Software was developed at ITS based on American National Standards X3.102 and X3.141 and used to measure the end-to-end user-oriented performance of networked CAD/CALS computers. The networking consisted of LAN, MAN, and WAN technology, with a simulated satellite connection for the WAN link. For local networks, the computer hardware and higher level protocols have an important effect on the performance as viewed by the user. Wide Area Networks with links that involve long delays show very poor performance if the protocols are not specifically tailored for that purpose.

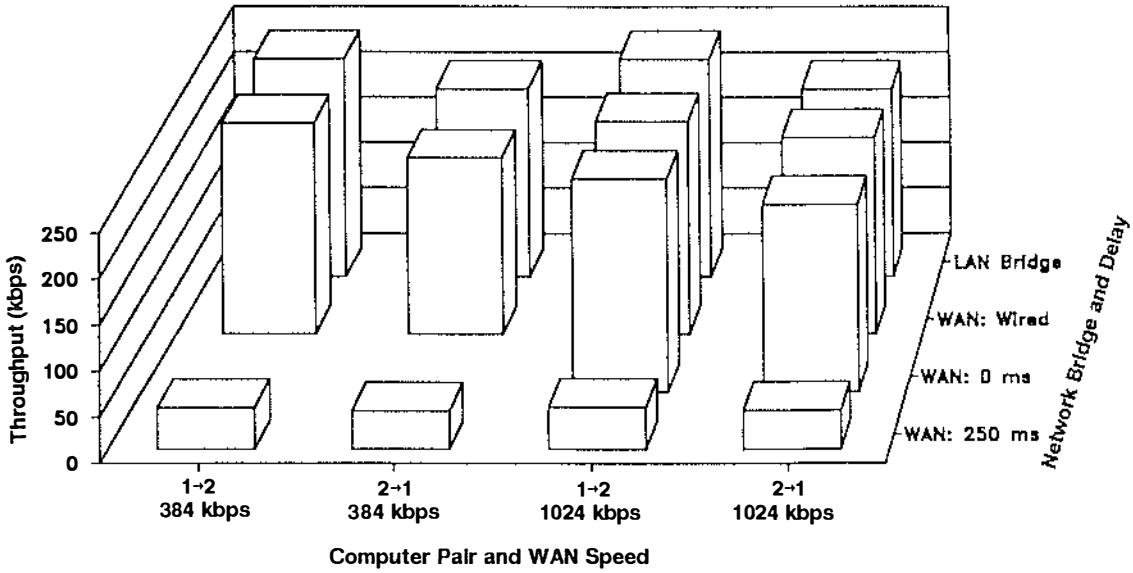
Tests were run between workstation and server pairs under a variety of network configuration complexity, loading, and error rates. Access times ranged from 40 ms to 15 s and file (2 Mbytes) transfer times ranged from 13 s to 6 min. Disengagement time was either very short at 32 ms, or if an acknowledgement was required, it included a round trip delay of the satellite link. Files were always received without bit errors, but sometimes were not transferred under high error rates and/or heavy loading conditions on the WAN. The File Transfer Protocol (FTP) throughputs on the LAN were less than one quarter of the Transmission Control Protocol (TCP) counterparts. However, the FTP throughputs were almost the same as the TCP for WAN tests. The throughputs are shown below for the FTP measurements as a function of network bridge with WAN delay and workstation-server pair with WAN speed varied.

Recent Publications

Video Quality Gradient Measures for Digital Networks (by Quincy)

Image Data Compression Overview: Issues and Partial Solutions (by Nesenbergs)

For information, contact:
Ed Quincy (303) 497-5472



FTP performance on WAN

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.

There has been an increased interest in the representation of ionospheric propagation predictions in the form of a communication network. Predictions such as the maximum usable frequency (MUF), circuit reliability, signal-to-noise ratio, and median field strength could assist communication engineers, designers, and others if presented in a form that specifies the value of the ionospheric parameter for each possible link of each pair of nodes in a network. The modeling effort presented here is the initial stage of development in establishing such a network capability with IONCAP.

The task consists of development of a procedure to generate a network representation of ionospheric characteristics. The network is identified by specifying a set of node numbers and descriptors for the nodes and a connection table for the nodes to define the actual network. The ionospheric propagation predictions are computed for every pair of connected nodes and represented in a tabular output. The network capability is, therefore, a representation of all point-to-point communication paths that constitute the network.

There are three specific aspects of the IONCAP network capability. These include (1) an input processor to generate the standard IONCAP input from the nodal information and connection table, (2) an interface to the IONCAP program to generate the propagation predictions, and (3) an output processor to represent the propagation predictions as a network. Collectively these three parts of the network capability are called IONNET.

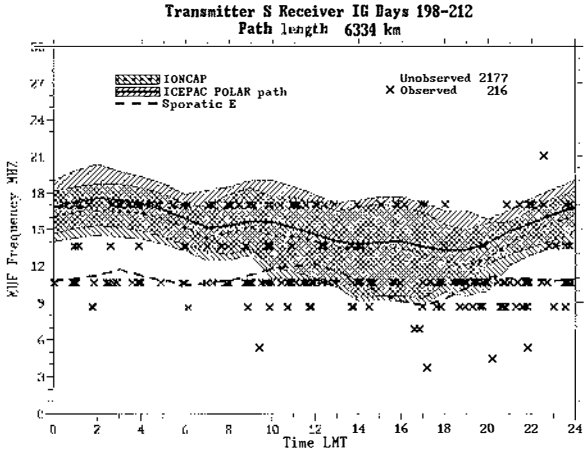
There are distinct advantages to this design. The IONCAP program is a point-to-point communications model and does not directly allow network representation. The input processor portion of IONNET generates all of the possible links between two nodes in the network and represents these as a set of point-to-point communication paths that IONCAP can use without a significant modification to the IONCAP program. The interface portion of IONNET allows for the efficient computation of the ionospheric predictions. The IONCAP program, for instance, is utilized more efficiently if the propagation predictions for an individual path are generated for all necessary hours and frequencies. The network representation might require that all the links be available for a specific hour and frequency. The interface portion allows that the predictions be calculated and saved for a representation not available with IONCAP. The output processor of IONNET provides the network representation of the ionospheric parameters.

There are several other tasks that have been initiated or completed that use the IONCAP program. The development of a simplified digital model has been initiated for IONCAP. The methodology of this effort consists of the identification of a specific digital system and bit error rate. The model will predict the relationship between the specified bit error rate and the signal-to-noise ratio for an impulsive noise environment. This signal-to-noise ratio will then be considered as the required signal-to-noise ratio for IONCAP. Therefore, the digital model consists of determining a required signal-to-noise input value for the IONCAP program.

A propagation program (ICEPAC) has been developed that uses parts of IONCAP and the ICED models to improve the predicted structure of the polar ionosphere. The polar ionosphere is a highly variable medium characterized by dynamic processes of ionospheric and magnetospheric origin. Many of the features of the polar ionosphere--ionization troughs, electron density enhancements, and irregularities in ionospheric structure--are associated with the auroral oval. Changes in the ionospheric representation given in IONCAP were made to include the auroral oval-related features. This has enabled the results of

ICEPAC to be used to assess changes to propagation conditions that are likely to be associated with the passage of radio waves through the polar ionosphere.

The ICEPAC model uses the ICED polar model in the polar region and the IONCAP model in the low and mid latitude. The profile structure is the Dudney profile for both low and high latitude. The figure below shows the results of a polar path study comparing MUF's predicted by IONCAP and ICEPAC with estimates of MUF's for sporadic E and observed MUF values in a frequency-time grid. The MUF's shown for IONCAP and ICEPAC are for median values banded by their upper and lower deciles.



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 freeform card images that are 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 micro computers.

It is often useful to have ionospheric propagation predictions presented in a form to 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, 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 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 these 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 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.

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 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 micro computers. The area coverage model developed has been given the name QUILT.

The IONCAP program has also been structured 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 that 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 could allow batch processing capability and ease of transport from one computer to another.

For information, contact:
James Washburn (303) 497-3109

Transmission System Performance Measurement, Monitoring, Evaluation, and Control

Outputs

- Transmission monitor and control software
- Consultative services on transmission network management
- Network monitor hardware and software architectural design
- Field support for pilot system implementation

The Institute has developed a set of functional requirements for a network management system for a global data communication network managed by the U.S. Army Information Systems Command. The network consists of a mix of point-to-point microwave, Defense Satellite Services, and leased commercial services that include satellite and foreign PTT services.

Functional requirements of the network management system include the ability for failure detection, fault isolation, remote switching of redundant elements, confirmation of restored service, circuit data quality measures, and interface with the Defense Communications System monitor systems. Final output of this effort includes technical solutions to the requirements and an implementation and acquisition strategy.

During the fiscal year, the Institute has worked primarily on a quick response test system that would allow the testing of a global data circuit from a single location. The purpose of the testing system is to perform one way tests of the data circuit and to control the tests from one point. The development resulted in a system, shown in the figure, that allows a personal computer at one location to dial a remote location, control the patching or switching of the data channel from normal operation to a test configuration, to set the test parameters on a data test set, and to monitor or record the test results. These functions were made possible with the use of a code operated switch (COS) that allows the PC to address selectively the bit error rate test set or a circuit configuration switch and to control functions of the test set. In addition, an RS-232 controlled switch allows remote configuration of the mission data channel.

For information, contact:
Richard Skerjanec (303) 497-3157

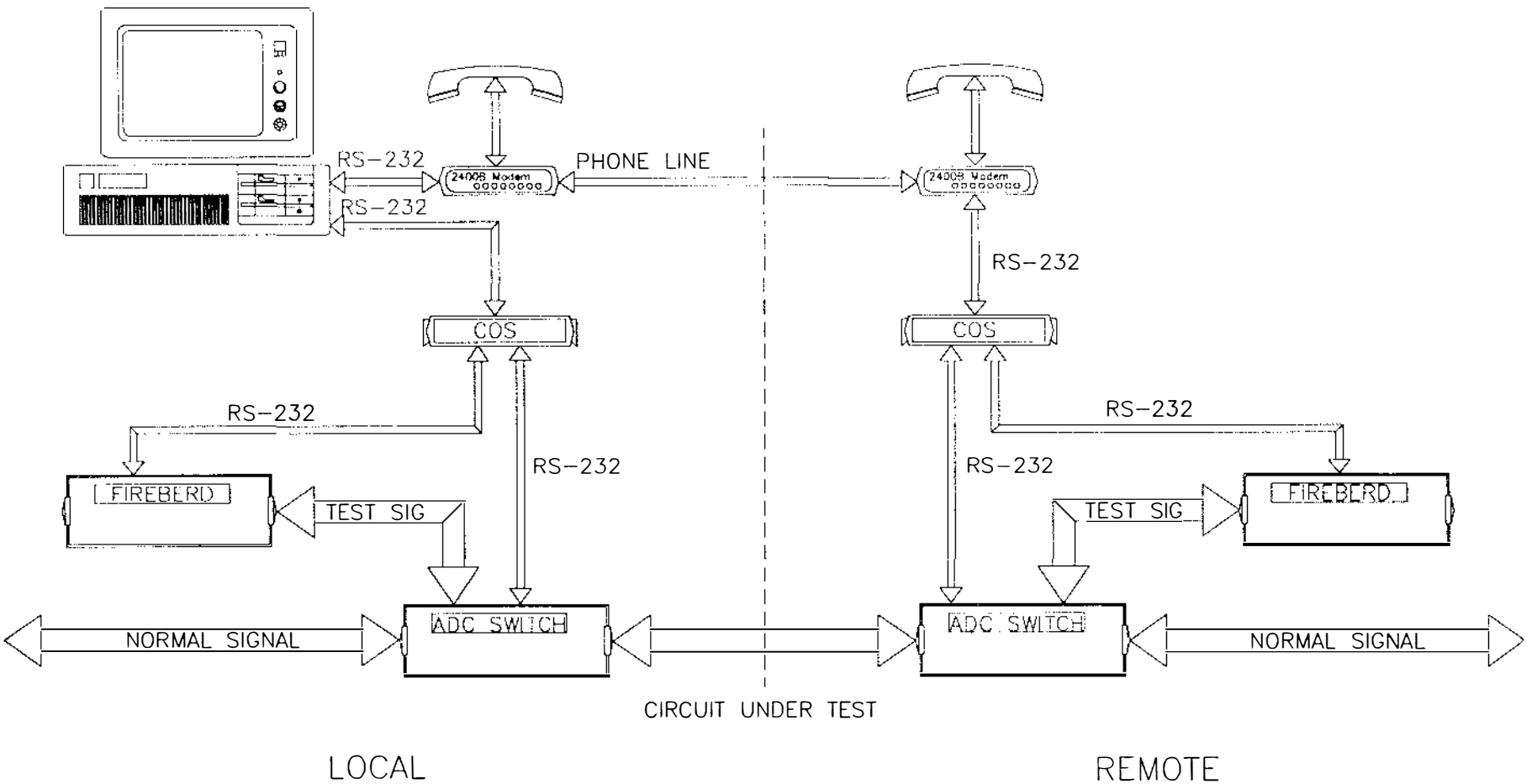
The U.S. Department of Defense is in the process of installing a microwave communications network in Europe. This network, known as the Digital European Backbone (DEB), is now partially operational. The Institute has played a major role in the successful design, development and testing of this network over the last several years. A current example of the Institute's contributions to this critical communications network are the Transmission Monitor and Control (TRAMCON) software development project.

The Institute has developed the software for the TRAMCON system which is used to 1) monitor the status of DEB transmission assets, and 2) provide the means for remotely controlling system configuration and for switching in redundant equipment in the event of failure. The TRAMCON system consists of 20 minicomputers that monitor transmission equipment at over 250 communication sites in Europe.

During FY 90, the Institute initiated turn-over of the network configuration database software maintenance to the Air Force Command and Control Systems Center at Tinker Air Force Base. The configuration database portion of the TRAMCON software package uses detailed tables to define site specific information. The configuration database package is a large program that organizes a complex set of physical, geographical, and electrical data items that describe the actual implementation and connectivity of transmission components.

The TRAMCON system has 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.

As an extension to the TRAMCON effort, the Institute is supporting the fielding of the TRAMCON system. Field support is being made available on location in Europe for TRAMCON installation, testing, training, and database management. Operational support during the initial phases of implementation is an efficient means to obtain user feedback for the critical man-machine interfaces. This information can be used to improve the displays and the type of data to be displayed.



Remote Control Data Circuit Test Configuration

Measurements, Modeling, and Simulation of LOS Microwave Communication Links

Outputs

- Improved methods for prediction of communication system performance
- Improved methods for the design of LOS microwave communication systems
- Communication systems performance data LOS microwave channel propagation data

The Institute has a long history of conducting tests of line-of-sight (LOS) microwave communications systems. Testing modern digital transmission systems includes performance measurements such as bit error ratio and the number of errored seconds.

Typical LOS microwave transmission system tests conducted by the Institute include propagation measurements made simultaneously with the performance measurements. The propagation data are used to characterize the environment at the time the performance measurements were made. The propagation data are also useful for the improvement of LOS microwave channel models, outage prediction techniques, and transmission system design algorithms.

During FY 90, the Institute completed the analysis of performance and propagation data collected on a portion of the U.S. Department of Defense (DOD) communications network located in Germany. The data were collected on LOS microwave links during an 18-month measurement program which was completed in October 1990. The performance data were used for the refinement of a military standard which specifies the performance of transmission systems throughout DOD's worldwide Defense Communications System.

The figures on the facing page provide one example of the analysis of digital radio performance data and one example of the analysis of propagation data. A recent conference paper describes the applicability of the propagation data to open questions in CCIR Study Group 5 dealing with LOS microwave channel modeling, multipath fading, and LOS microwave transmission system outage prediction. The propagation data are also useful for enhancement of the LOS channel simulator designed and developed at the Institute.

During FY 90, the Institute also played a key role in conducting tests of a data telemetry transmission network located in Taiwan (Nationalist Republic of China). The project was part of a U.S. Navy foreign military sales program to provide assistance to the Taiwanese Air Force.

Conducting communications systems performance and propagation measurements requires a complex test system. The Institute has developed a sophisticated hardware and software data acquisition and data analysis system for LOS microwave link testing. For example, the Institute has previously constructed a complex instrument called a channel probe for making multipath measurements on LOS links. During FY 89 and FY 90, the radio performance and propagation data acquisition and data analyses processes were fully automated, thereby reducing the cost of testing LOS communications links.

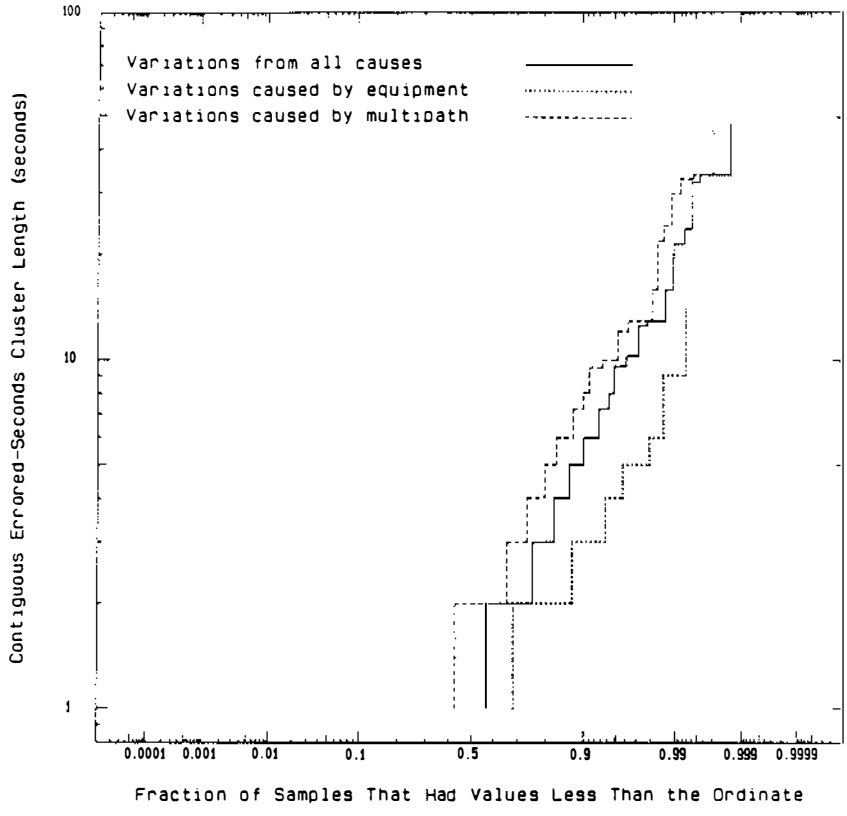
Recent ITS Publications

Application of LOS Microwave Propagation Data to Channel Modeling and Outage Prediction Issues (by Hoffmeyer)

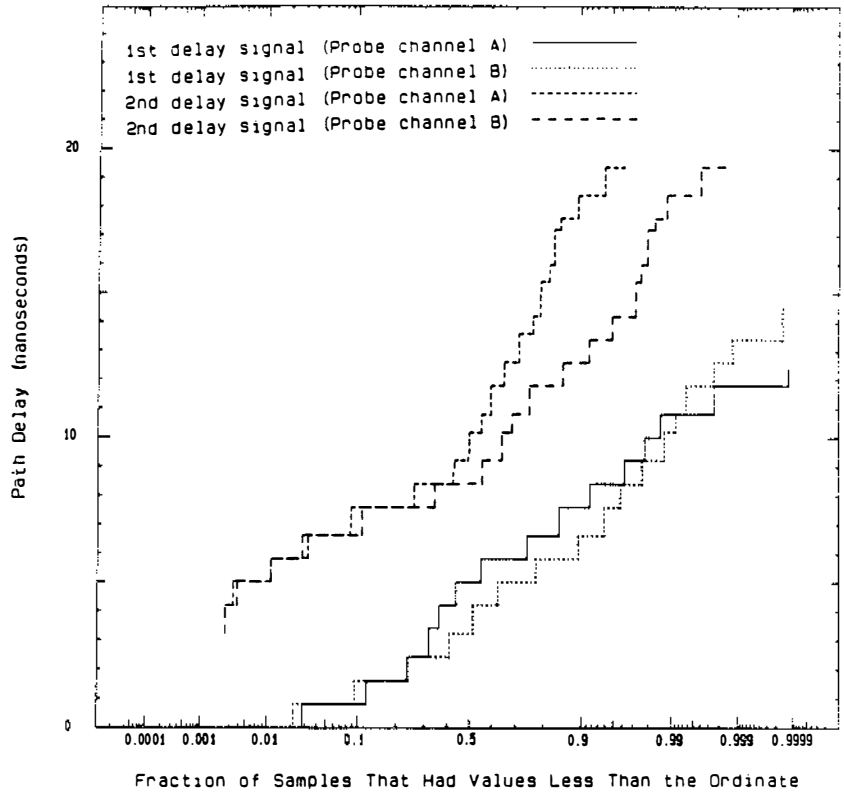
Digital European Backbone Performance: A 12-Month Summary for the Frankfurt North Segment (by Hoffmeyer and Riley)

Long-Term Performance and Propagation Measurements on Single and Tandem Digital Microwave Transmission Links (by Hoffmeyer and Riley)

For information, contact:
James Hoffmeyer (303) 497-3140



Distribution of consecutive errored-second occurences for
Schwarzenborn-Feldberg link for test period 4/1/88 to 10/1/89



Distribution of the path delay for
Schwarzenborn-Feldberg link for test period from 4/1/88 to 10/1/89

Wide Area Prediction Model

Outputs

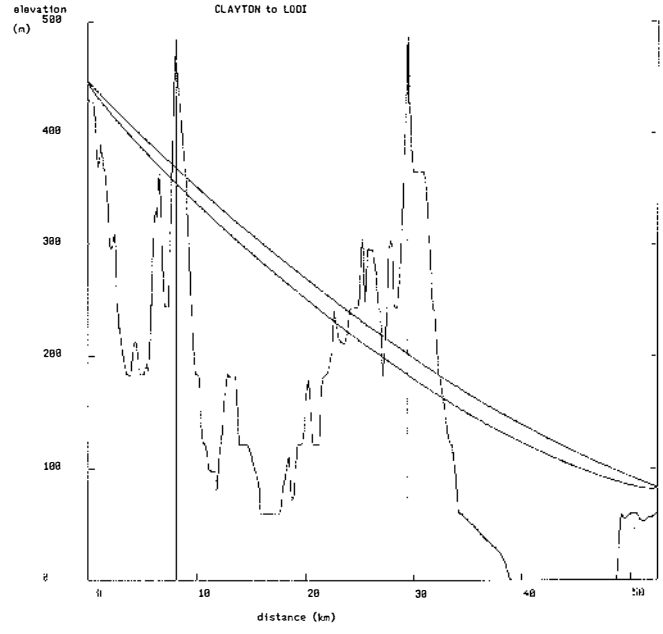
- Fully automated calculation of estimated long-term received signal level and bit-error-rate (BER) performance
- Rapid calculations for all microwave links within a selected area

The intent of the wide area prediction model is to provide predictions of long-term median signal and BER estimates for microwave terrestrial links within a given radius, or circular area. In some metropolitan areas, this circle could include 1000 or more links, depending upon the size of the area. The accomplishment of such a set of calculations in a reasonable period of time has until now required the services of a mainframe computing operation, which can prove costly and involve interfacing delays. The introduction of a workstation environment can now accomplish equally speedy calculations, and provide at-terminal output to the user with the proper workstation periphery.

Wide Area Prediction Model

This model will incorporate many of the features of previous modeling of signal reception on certain microwave terrestrial links. The earlier analog (FM-FDM) signal reception predicted by the use of an earlier desk-top computer program is included, as well as the modeling for several digital modulations (MSK, PSK, QAM, and QPR) typically used on common carrier links. The major advantage here is the elimination of most of the manual data input requirements. Terrain profile and obstacle determination is fully automated, as is link-calculation repetition. In order to evaluate great-circle-link-path terrain data, a U.S.-wide 3-arc-second terrain data base has been incorporated into the wide area prediction model. The terrain is then analyzed (using specified atmospheric refractive conditions) to determine the height of the terrain relative to the expected ray path. By comparing this height to the first Fresnel zone of the path, potential diffracting obstacles on the path can be extracted. Then for the double-knife edge (DKE) evaluation procedure (earth-bulge diffraction is handled separately), pairs of such obstacles are inserted into the DKE evaluation until the pair (if any) that will cause the most diffraction loss is obtained. The figure shows an example of a terrain profile and associated obstacles.

On the figure, the two major diffracting obstacles are indicated by the two vertical lines from their peaks to the horizontal distance axis. Also sketched on the profile is a predicted ray path, and, just below it, the 0.6-Fresnel-zone curve. Obstacles above the Fresnel-zone curve will produce knife-edge diffraction.



A frequency assignment data base incorporated into the wide area prediction model include link data such as terminal latitudes, longitudes and elevations, tower heights, bandwidths and center frequencies, transmitted power, and antenna types. An extensive antenna data base contains detailed antenna pattern data for nearly 2000 antennas. Each antenna pattern is determined from main beam gain and 30 points at specified angles from the main beam boresight direction. This allows the calculation of off-axis signal receivability, needed to realistically assess the possibility of off-axis interference between microwave links. It is anticipated that these data, used throughout the analysis procedure, will be updated at least annually. The surface refractivity gradient data base, essential to the determination of the Earth's effective radius factor, will be enlarged as well. In earlier desk-top computer programs, this data base consisted of 15 specific locations and 6 zones in which the gradient could be evaluated. The enlarged version in the wide area model contains 13 additional specific locations, although the number of zones remains unchanged.

A substantial amount of computing equipment has been required to obtain predictions in a reasonable amount of time. It has been necessary to use a workstation environment providing 12.5 MIPS and 1.4 MFLOPS double precision. Considerable permanent (hard disk) storage has also been required. The basic unit provides around 300 Mbytes, which has been supplemented with an additional 750 Mbyte hard disk. The ability to read disks that contain extensive information has also been required. A CD ROM unit, reading 650 Mbyte disks has been acquired to read the extensive U.S.-wide terrain data base, and an optical disk read/write unit, capable of handling 1.2 GBytes, has also been acquired to read map information.

In the coming year a visual graphics capability will be added that will make use of the optical disk unit and the map information. Microwave link information will then be able to be overlayed on the corresponding map information, and displayed visually. These standard U.S. Coast and Geodetic Survey maps will show terrain features and political boundaries. A further extension of this effort may eventually add realistic information and modeling of buildings and (more remotely) foliage features. Such detailed extension will depend upon the availability of detailed municipal data bases, sophisticated computer programs and considerable computing power. This is presumably beyond the scope of the current effort, but may provide a good tool for the design of numerous small cells that amy be needed in future personal communications applications, using the VHF, UHF, and SHF bands.

For information, contact:
Evan Dutton (303) 497-3646

Project personnel (from left) Mike Province, Charles Samora, Duane Hyovalti, Don Dalton, and Evan Dutton

Terrestrial Link Engineering Design Software

Outputs

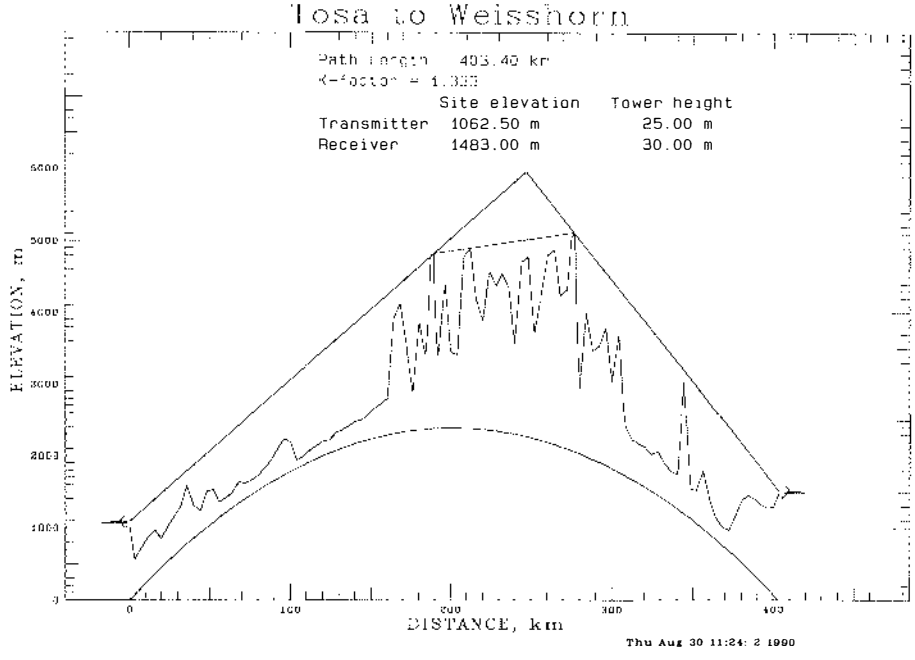
- Complete engineering documentation of terrestrial link designs
- Performance prediction software for wideband communication links

Integrated Radio Link Prediction Software

ITS is currently developing the Radio Analysis and Integrated Design for Engineering Requirements (RAIDER) program set which will run on any personal computer with a DOS 2.0 or later operating system. These programs automate the calculations involved in the design of line-of-sight, marginal line-of-sight, and beyond-the-horizon paths. They emphasize a friendly user interface and incorporate a menu system to assist the operator in entering, editing and processing link design data. Each program allows the operator to make different predictions for the link.

The earth geometry module will accept link terminal location information and calculate the geometric data about the path including the length of the great circle path, the azimuths along the great circle path from each terminal to the other, and at the operator's option, the locations along the path where map edges are crossed.

The profile plotting module will accept data from the operator about the average and extreme Earth's radius factor, the desired Fresnel zone clearance, and the planned antenna heights above the ground. This information, together with the profile data read from the link file, will be used to first, plot a terrain profile on the screen, and then to determine whether the link is clear line-of-sight, difficult line-of-sight, marginal line-of-sight, passive repeater, tropospheric scatter or diffraction. This characterization of the link type will cause the link performance prediction process to branch to the appropriate algorithm. The line-of-sight, difficult line-of-sight, and marginal line-of-sight path loss prediction module will accept inputs of meteorological, climatological, geographic information, and the operating frequency. This information will be used with the data from the profile analysis, to produce a time distribution of transmission loss for the link. This will include calculation of basic transmission loss, multipath effects, rain attenuation, shallow-angle diffraction and a combination of these effects.



Transhorizon Path Profile Plot

The tropospheric scatter and diffraction deep-shadow-zone transmission loss prediction module will calculate the median value of loss and the distribution parameters using the CCIR techniques. The inputs to this module will be the operating frequency and the climate zone. The output will be the distribution of transmission loss expected for the path with the .05 and the .95 confidence bands.

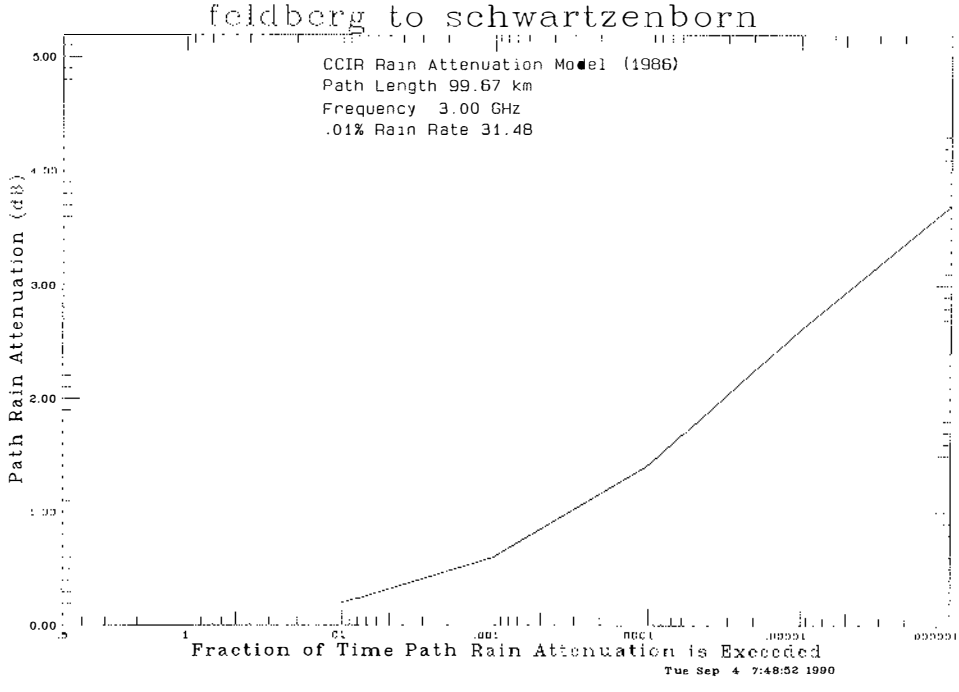
The deep-shadow beyond-the-horizon digital link performance prediction program set will calculate both required and expected performance or the equipment requirements needed to obtain required performance. This module will include the definitions of the capabilities of the TRC-170 digital tropo set as well as the MD-918 digital tropo modem.

The deep-shadow beyond-the-horizon analog link performance prediction program set will calculate both required and expected performance or the equipment requirements needed to obtain required performance.

ITS is also going to develop a set of algorithms that would use the Defense Mapping Agency CD-ROM Digital Terrain Elevation Data (DTED) Level 1 to generate path profiles automatically for all types of terrestrial point-to-point paths. As the Level 2 data bases with their increased resolution become available, these DTED data would be integrated into the system.

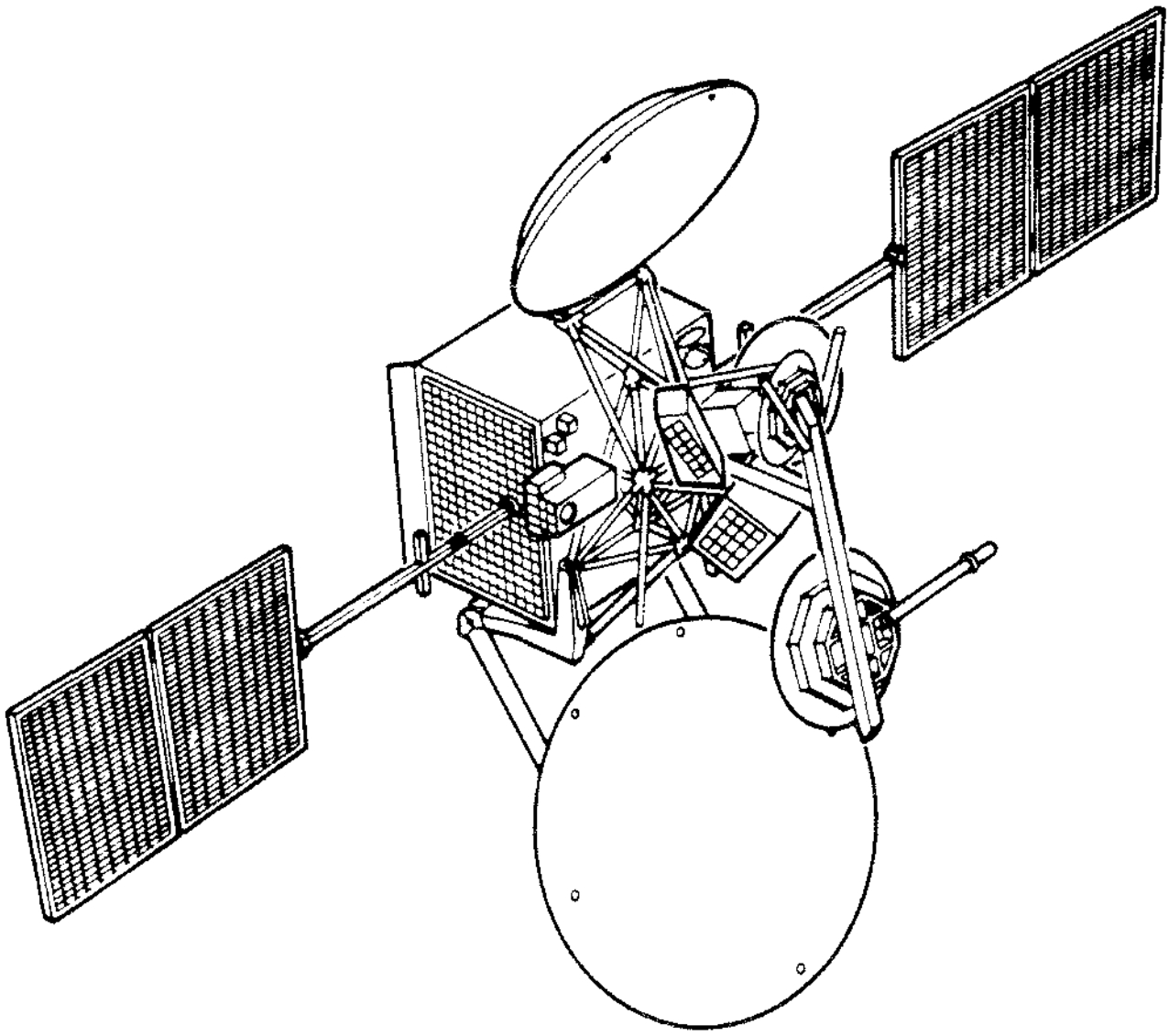
Recent ITS Publications

User-Friendly Software for The Design of Digital Line-of-Sight Radio Links, (by Farrow and Rothschild)



Path Rain Attenuation Plot

For information, contact:
Joseph Farrow (303) 497-3607



Advanced Communications Technology Satellite (ACTS)

TELECOMMUNICATION SYSTEMS PLANNING

The Institute serves as a central Federal resource to assist other Federal agencies in planning new telecommunication systems to meet emerging needs. Specific ITS activities include user requirements analysis, technology assessment, network architecture development, and detailed system and equipment design.

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 Communications System, the National Telecommunications and Information Administration, and the National Aeronautics and Space Administration

Low Frequency Noise Measurements

Includes a project funded by the Department of Defense

Advanced Systems Planning

Includes projects funded by the Agency for International Development, and the Bureau of Land Management

Satellite Studies

Outputs

- Functional and service characteristics study results for advanced hybrid networks
- Advanced communications satellite technology experiments plans
- Technical guidance in reactivation of the PEACESAT network

A major effort has been initiated in the Satellite Program, with extensive synergism between projects, to determine appropriate role(s) for advanced communications satellite systems in future Broadband Integrated Services Digital Networks (B-ISDN) and the functional and service characteristics of these hybrid networks that include advanced satellite systems. Technical guidance and consultations have been provided in reactivation of the Pan-Pacific Education and Communication Experiment by Satellite (PEACESAT) program. There also has been planning for channel probe measurements, to determine characteristics of radio transmission channels such as would be used for mobile satellite services, using signals from the Global Positioning System (GPS) satellites.

Satellites and ISDN. Integrated Services Digital Network (ISDN) technology will play an important role in future telecommunications networks. This project is defining a baseline of networked telecommunications services and network management practices as a basis for evaluating the effectiveness of proposed, advanced, hybrid networks and associated services. Network interface, management, and performance specifications for advanced, hybrid network interoperation will be developed and promulgated. The physical and logical architecture of a hybrid network composed of both terrestrial and space-based switching centers is illustrated in the figure. Institute researchers have completed studies on technical issues associated with interoperation of satellite and terrestrial networks and the basic attributes of broadband services, layered architectures, and advanced technologies that are the foundation of advanced telecommunications networks.

Advanced Satellite Communication Technology Studies. The evolution of communication satellites is being driven by the need for increased service capacity and reliability, lower service costs, and integration with advancing communication system technologies such as optical fiber transmission, ISDN, and mobile services. To help meet these needs, the National Aeronautics and Space Administration (NASA) is developing the Advanced Communications Technology Satellite (ACTS) to be launched in 1992 as a testbed for advanced communications technology studies. This satellite will provide on-board switching of digital signals, at megabit rates, between highly-directional, scanning spot beams generated by phased-array antennas, thus effectively putting a high-speed digital switch in the sky with the capability to establish megabit channels to hundreds of Earth stations within microseconds. The Institute is developing test-sets to conduct a unique set of end-to-end system performance experiments using the framework of American National Standard (ANS) X3.141-1987, "Measurement Methods for User-oriented Performance Evaluation."

Reduced Vulnerability to Telecommunication Outages. Deregulation of the telecommunications industry and the resulting plethora of new and competing services are factors that have led to growing concerns about vulnerabilities of the public switched network to serious service interruptions. Institute researchers believe that the technology of advanced communications satellite systems could provide extremely powerful and flexible capabilities for network restoration and/or augmentation and, thus, substantially mitigate the consequences of these vulnerabilities. A study on congestion-reduction and service-restoration strategies for telecommunication networks, along with planning for simulation studies of various hybrid networks, has completed the first phase of this project.

ACTS Earth Station Functional Specification Development. The Institute hosted an ACTS experimenters' workshop for potential experimenters in the Denver spot-beam region. These experimenters are being identified and their unique requirements assessed. From this, a functional specification is being developed for an ACTS experimenters' Earth station to be located at ITS and made available to the interested experimenters.

PEACESAT. Institute engineers have continued to provide consultative support to the PEACESAT program, funded by a Public Telecommunication Facility Program grant that is administered by the University of Hawaii. The Geostationary Operational Environmental Satellite-3, operating in the 2-GHz

band, has been selected as the satellite to support this network on an interim basis. This choice means that the network users must be equipped with new Earth stations. The ITS consultative role has involved technical investigations of the suitability of the GOES-3 and engineering support in the contractor selection and purchase of the new Earth stations.

Multipath Measurements in the Land Mobile Satellite Radio Channel. The Institute is involved in an effort to perform channel probe measurements of the impulse response of radio transmission channels over space/Earth paths using signals from the GPS satellites. In collaboration, ITS will perform the channel probe measurements and analyze the data; the University of Colorado is developing an appropriately modified GPS receiver and measurement system. The project is jointly sponsored by NASA and the European Space Agency, and is expected to provide an exciting first look at channel characteristics of vital importance to the design of mobile satellite services.

Recent ITS Publications

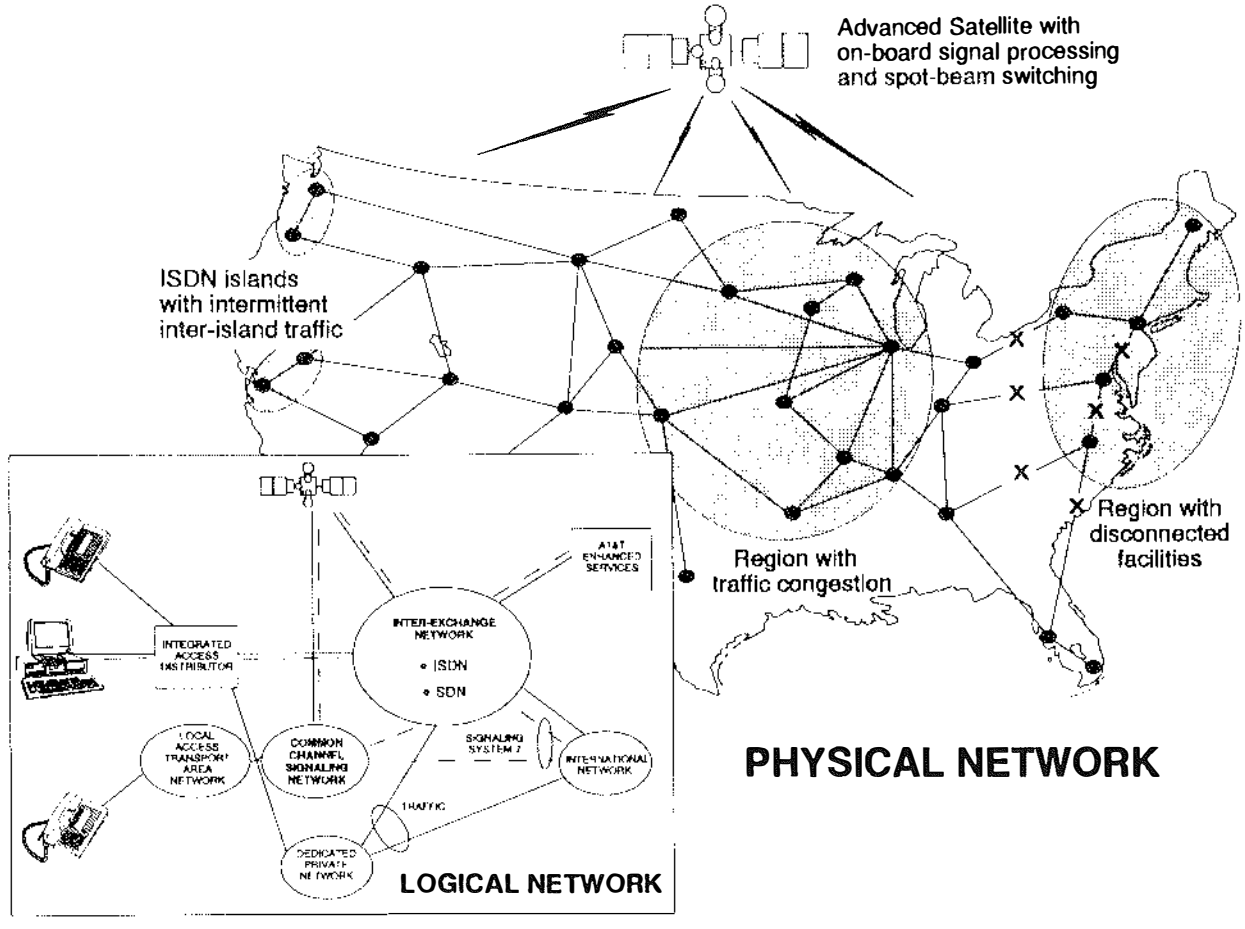
Stand-Alone Terrestrial and Satellite Networks for Nationwide Interoperation of Broadband Networks (by Nesenbergs)

Congestion-Reduction and Service-Restoration Strategies for Telecommunication Networks (by Linfield)

Technical Considerations Concerning Use of a Geostationary Operational Environmental Satellite to Support the PEACESAT Network on an Interim Basis (by Jennings and Cass)

Codeless GPS Applications to Multipath Measurements (by McDoran and Lemmon)

For information, contact:
Ray Jennings (303) 497-3233



Physical and logical architectures of a hybrid network composed of terrestrial and space-based switching centers with various stress conditions indicated

Low Frequency Noise Measurements

Outputs

- Specialized System Development
- Diurnal and Spectral Plots
- Amplitude Probability Distributions
- Time Domain displays

Because of ITS' unique expertise in the area of low frequency measurements the Spectrum Usage and Measurements Group was tasked to make a study of the ELF signal and noise environment in a sampling of office buildings.

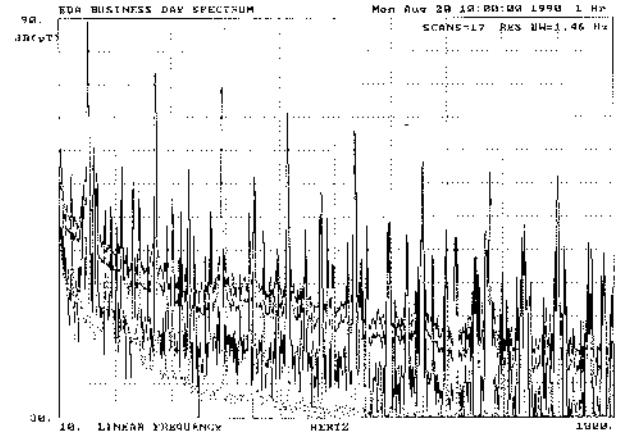
Measurement System. Due to high dynamic range requirements of the measurements a specialized development effort was required. The Low Frequency Measurement System (LFMS) uses a new Digital Audio Tape (DAT) recorder with 16 bit resolution and Digital Signal Processing (DSP) boards giving a dynamic range of 96 dB and capable of storing 1.4 Gbytes of data. Magnetic flux density is measured with a very sensitive low noise magnetometer capable of detecting signals as weak as 0.03 picoTesla. The LFMS has a frequency range of 5 Hz to 24 Khz, is fully automated, and requires no user intervention after initial setup.

Measurements. Measurements covering the 10 hz to 10 Khz frequency range were made at two sites in New York City, NY, and at four sites in the Denver/Boulder area. To establish a record of peak and minimum levels these measurements include time samples from a normal business day and from night and weekend hours.

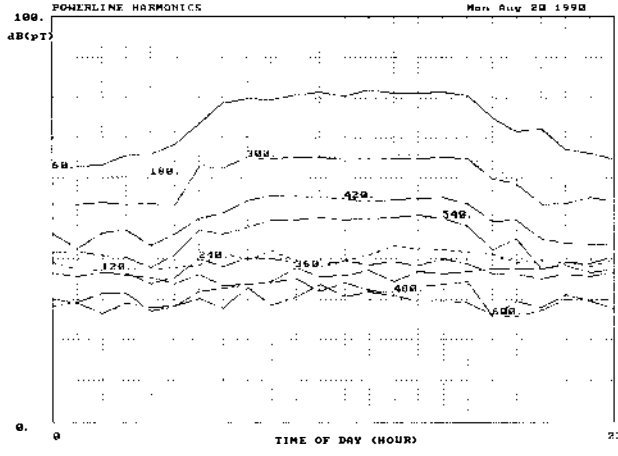
Development and Future. The LFMS was developed for a specific application but has been designed is such a way as to be a general purpose signal processing tool. The sensor can be interchanged with any number of other devices, acoustic transducers for example, to suite the needs of the measurement scenario.

There is currently great interest in the biological effects of low frequency fields. The LFMS is ideally suited for measurement of exposure levels, especially as those levels change over time.

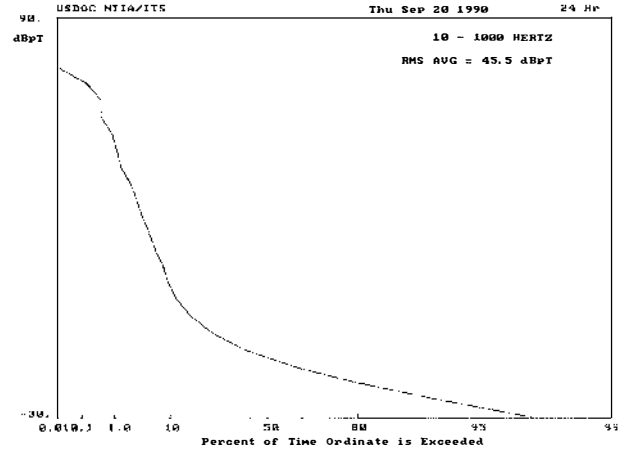
For information, contact:
Michael Laflin (303) 497-3506



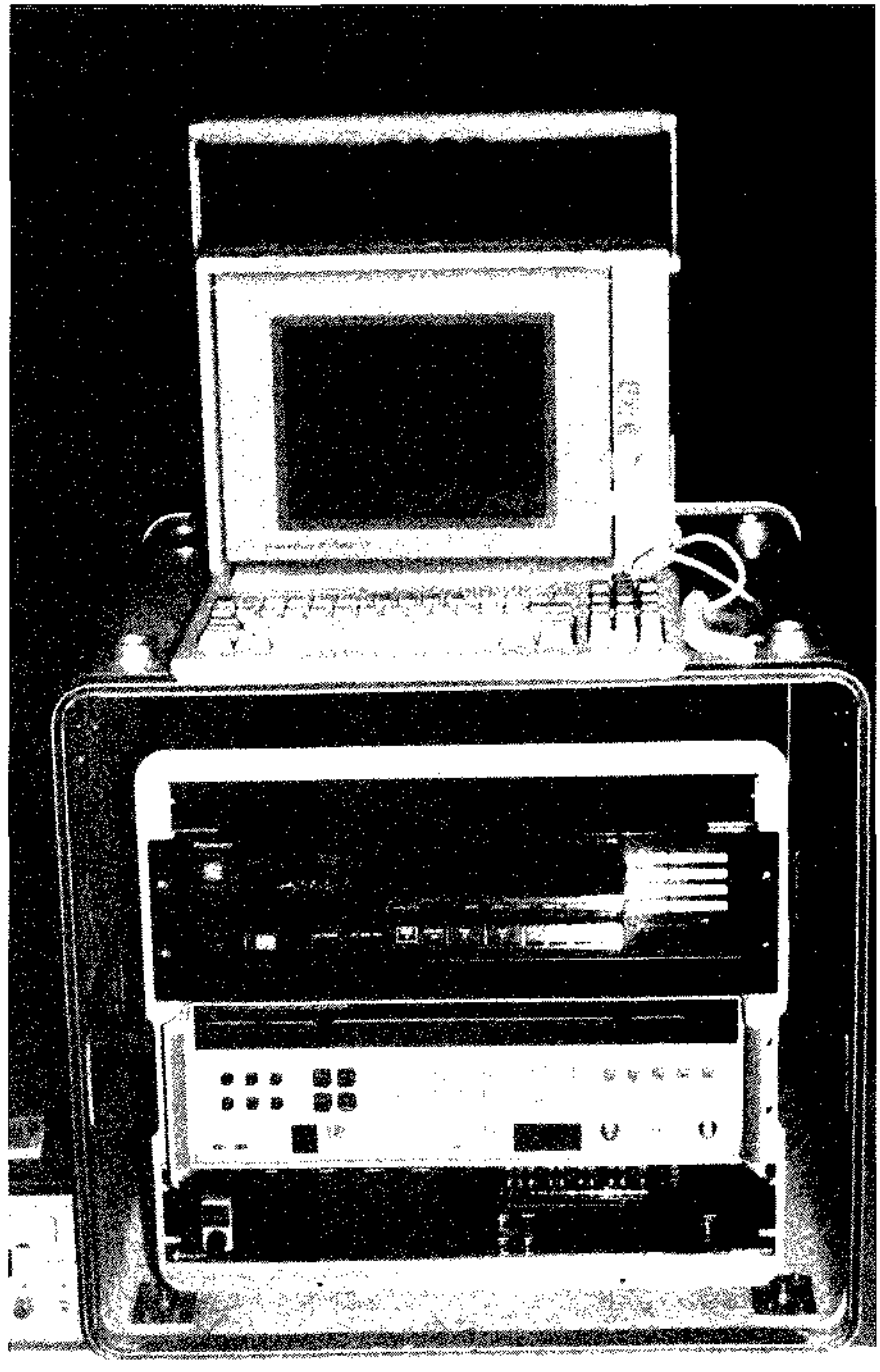
Spectral Display



Diurnal Amplitude Variation



Amplitude Probability Distribution



Low frequency measurement system

Advanced Systems Planning

Outputs

- Telecommunications infrastructure study reports
- Intra-government and inter-government technology transfer

Thailand Infrastructure Study. During FY 90, ITS participated in a six-month telecommunications infrastructure study for the Kingdom of Thailand. Carried out on a government to government basis by NTIA in cooperation with the Infrastructure Projects Division of Thailand's National Economic and Social Development Board, the study was funded by the U.S. Agency for International Development. The overall objective of the study was to determine the extent to which Thailand's telecommunications needs are being met, and to make recommendations designed to optimize the efficiency, availability, and cost of all services.

To support accomplishment of this objective, consistent with U.S. Government and industry interests, the Institute conducted, as part of the overall study, a comprehensive technical assessment of Thailand's networks and services (extant and planned). Based on this assessment, recommendations on technology and equipment development were made to high-level officials of the Thai government. The recommendations focus on opportunities resulting from technology trends in the areas of telecommunication services, networks, and equipment.

Currently, the Thai telephone network is significantly underdeveloped (less than 2% of the citizens are served) and constitutes a serious threat to Thailand's continued economic growth. The NTIA study identified the contribution of both technical and nontechnical (e.g., funding, management, human resources) factors to this situation. With respect to the nontechnical factors, substantial structural changes were recommended, including privatization of the telecommunications sector.

With respect to the technical factors, which were the principal focus of the Institute's study, an aggressive technology development strategy was recommended to provide opportunities for achieving Thailand's goals for rapid development of its telecommunications infrastructure. Indeed, as Thailand enters the Information Age the capabilities of its networks will be shaped by the next-generation technologies that it adopts during the 1990s (over 80% of the access lines projected to exist in 2000 will have been installed during the 1990s). Analysis, in relation to Thailand's needs and plans, of technological trends in both developed and developing countries led to recommendations in the following general areas: broadband and advanced cellular systems, intelligent networks, Integrated Digital Services Networks (ISDNs), and Telecommunication Management Networks. Additional important recommendations concern, for example, the use of international standards to competitively procure equipment and to achieve multivendor interoperability, both domestically and internationally.

Members of the NTIA Telecommunications Infrastructure Study Team participating in the NTIA-NESDB seminar (February, 1990, Bangkok, Thailand)

BLM Interstate Network design study. The Bureau of Land Management Denver Service Center requested ITS to assist them in the use of the new Federal Telecommunication System 2000 and to consider different connectivities for the information flow through their Interstate Network. Institute staff members prepared a report describing the current network utilization and providing cost figures and an implementation strategy to allow a more flexible information flow and a more complete interconnectivity among the BLM state offices. Close coordination between ITS and BLM Denver Service Center personnel generated a set of specific network requirements.

The study was undertaken to provide BLM with several optional network configuration alternatives, and associated cost analyses, for an upgrade of the present network. Particularly important requirements of the new architecture were to provide greater communication capacity and to allow connection among the state offices, a function not supported by the current network. The study report describes the present system briefly and demonstrates how the present users would be supported by the upgraded network. Three options were considered:

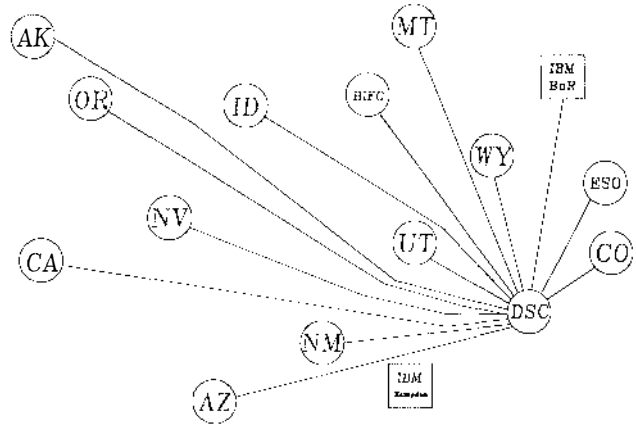
Option 1: Use of FTS-2000 Packet Switched Service with BLM ownership of the terminal equipment, or Packet Assembler/ Disassemblers (PADs).

Option 2: Use of full FTS-2000 Packet Switched Service including FTS-2000 terminal equipment, or PADs.

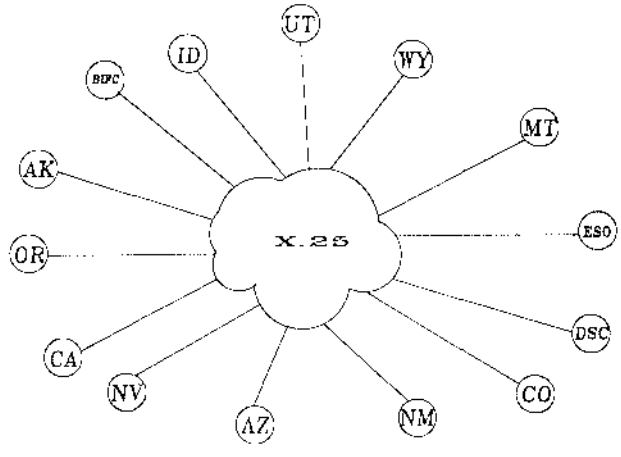
Option 3: Use of FTS-2000 Dedicated Transmission Service to interconnect BLM-owned PADs and packet switch.

The options were evaluated on the basis of estimated traffic volumes. Results included detailed cost break-downs for each separate circuit under each option. Within the options, costs for different service offerings were given for various assumed traffic levels. A final comparison was made of the life cycle costs among the three options considered.

A matrix was developed to assist BLM in evaluating the options in terms of basic network attributes. Each of these attributes was assigned a weight and each of the three options was scored for its degree of satisfaction of the quality represented by the attribute. The product of the attribute weight and score values for each option were summed and the results were presented as numerical measures of how fully each option would meet the stated requirements for BLM's Interim Interstate Network.

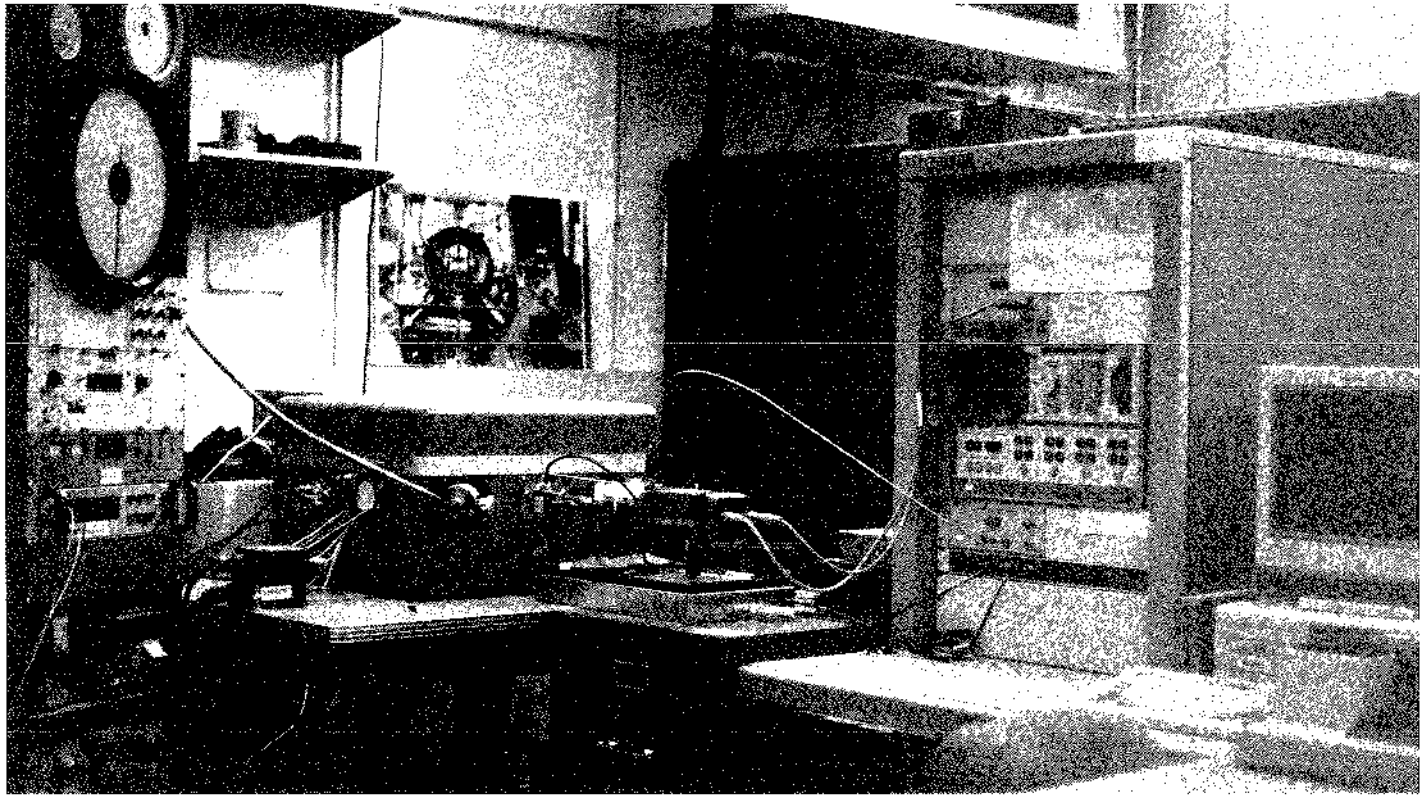


BLM InterState Connectivity via existing dedicated links



BLM Interstate Connectivity with Packet Switching

For information, contact:
Val Pietrasiewicz (303) 497-5132



Fabry-Perot cavity and vector network analyzer
in the ITS millimeter-wave laboratory

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 an 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 Department of Defense, the Naval Ocean Systems Center, and the U.S. Air Force

Propagation Measurements

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

HF Radio Environment Simulation

Includes projects funded by the Army Communications-Electronics Command, the Defense Communications Agency, the Joint Tactical Command, Control, Communications Agency, and the Rome Air Development Center

Millimeter-Wave Propagation Modeling

Outputs

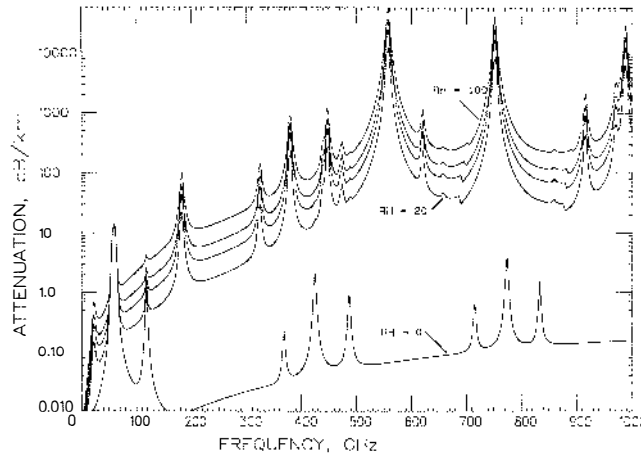
- Updated AMOS model
- Public version of AMOS model called MOSES
- Additional scenarios added to AMOS and MOSES models

Advances in millimeter-wave propagation modeling have continued at ITS in 1990 with the improvement of the AMOS (analysis of microwave operational scenarios) model and the millimeter-wave prediction model (MPM). These models continue to serve as development and analysis tools for Government and private industry.

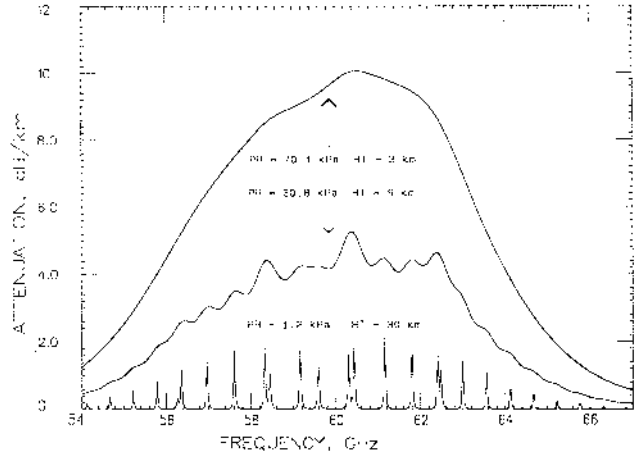
The ITS millimeter-wave propagation modeling effort has resulted in four software packages that combine state-of-the-art propagation models with user-friendly, high-level languages to provide users with effective means for developing and analyzing millimeter-wave telecommunication systems. These computer programs are ETSEM, MPM, MZM, and AMOS (MOSES).

ETSEM (EHF Telecommunication System Engineering Model) was developed in previous years to predict the performance of terrestrial links. It is an aid to engineers in the determination of cost-effective design trade offs while maintaining required link availability. Prediction of performance accounting for attenuation due to rain, clear air, and multipath effects are provided for any interval of months for the year. Due to the continuing efforts in the development of AMOS and MOSES, no changes have been incorporated into the ETSEM model during this past year.

The MPM program predicts, at frequencies up to 1000 GHz, loss and delay effects for a nonprecipitating, isotropic atmosphere. Contributions from dry air and water vapor are included as well as suspended water droplets that simulate fog or cloud conditions. For clear air, a local absorption line base is employed (44 oxygen and 30 water vapor lines) complemented by an empirical water vapor continuum. Suspended water droplet obscuration is treated with the approximate Rayleigh scattering theory. Input variables are barometric pressure, temperature, relative humidity, and droplet concentration.



An example for sea level conditions with a varying relative humidity from 0 to 100 percent is illustrated above. Across the spectrum, one notices more or less transparent window ranges separated by molecular resonance peaks. A similar figure showing the attenuation rate as a function of frequency for a series of pressures is illustrated below. This figure shows that as the pressure increases, the sharp attenuation peaks and valleys due to the oxygen resonance lines broadens into a continuum. The laboratory measurement program undertaken by ITS will yield results which will improve the MPM model. These improvements will be incorporated into an improved MPM model over the next several years.



The millimeter-wave Zeeman model (MZM) has been developed as an aid in understanding propagation effects in the mesosphere. The mesosphere lies between the stratosphere and the thermosphere from above 30 km to about 100 km in altitude. In this region, the air is dry so that the parameters of interest are pressure (from 1.2 to 3x10-5 kPa) and temperature (from -2 to -87°C). In this region, oxygen line absorption is strong enough to affect radio propagation. Because the pressure is low, the lines are very sharp, and new phenomena appear due to the Zeeman effect. The Earth's geomagnetic field splits each line into a number of sublines that react to an electromagnetic field in a way dependent on the polarization state of that field. Over a few megahertz around the line centers, the medium is anisotropic, making radio waves subject to polarization discrimination and Faraday rotation. The reasons for this behavior and applications are discussed in the reference cited below.

The MZM program models an anisotropic refractive index in three dimensions as a function of frequency about each oxygen line. For a given propagation direction with respect to the geomagnetic field, a transmission matrix is derived the eigenvectors of which define the characteristic waves' polarizations. The eigenvalues of this matrix define the phase delay and attenuation rate for each characteristic wave.

As a wave propagates through the mesosphere, its polarization approaches that 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 parallel to the lines. Modifications to the ITS laboratory equipment could allow ITS to verify much of the MPZ model. It is our hope that this will be done in the near future. Results of this effort will improvement this model and the MPZ program.

ITS has continued development of a new software model for the analysis of millimeter-wave operational scenarios. The AMOS-MOSES model is highly structured and modular in design, which allows for greater flexibility and expansion. The major components of AMOS are a user created catalog of equipment, ground stations, aircraft and satellite platforms, and the software for creating and maintaining this catalog; a climatological data base for much of the world; a library of propagation subroutines; and the analysis software. Current scenario types that can be analyzed are ground-to-ground, ground-to-satellite, ground-to-aircraft, aircraft-to-satellite and a generic MODEL EXERCISER option that allows the user to run programs that are not part of AMOS such as ETSEM, MPM, and MZM, from the AMOS-MOSES environment.

Strengths of the AMOS-MOSES model include:

1 - A uniform, user friendly interface which is intuitive in nature and includes on-line help capability.
2 - The model is easily expandable without re-writing existing software.
3 - Technical users can add their own analyses to the model using the current model structure.

The AMOS-MOSES propagation library includes subroutines for use in calculating clear air attenuation, rain attenuation, multipath attenuation, diffraction, troposcatter and others. The MOSES version of AMOS has been tailored more to the needs of the general telecommunication user rather than the specific needs of government and defense agencies. This version will also be improved using object oriented programming languages and techniques in the coming year.

ITS Publications

Mesospheric Radio-Wave Propagation in the 60 GHz Band Affected by Zeeman-split Oxygen Lines (by Liebe, Hufford, and Katz)
Millimeter-Wave Propagation In the Mesosphere (by Hufford-Liebe)
Modeling millimeter-wave propagation effects in the atmosphere (by liebe-Hufford)
Software for the Analysis of Microwave Operational Scenarios (by K.C. Allen)

For information, contact:
Rob DeBolt (303) 497-5836

Propagation Measurements

Outputs

- Clear-air absorption measurements made near 60 GHz in millimeter-wave laboratory test chamber
- New millimeter-wave field instrumentation
- Polarimetric measurements at 9.6 and 28.8 GHz in the ocean surface evaporation duct
- Wideband impulse response measurements at 30 GHz of propagation through deciduous trees
- Development of a low cost receiver for the Olympus Satellite 12.5 GHz propagation beacon

ITS has maintained a premier millimeter-wave laboratory measurement program under the direction of Dr. Hans Liebe for many years. Measurements of clear-air absorption and phase delay are made using a Fabry-Perot cavity and a vector network analyzer.

In FY 90, the most extensive and accurate set of measurements of clear-air absorption ever made were completed. Measurements of absorption rates in the oxygen-absorption band centered at 60 GHz were made at temperatures from 5 to 55 Celsius for pressures corresponding to altitudes from sea level to 30 km. Previous measurements have addressed the effects of molecular oxygen and water vapor up to 140 GHz.

The measurement system allowed the production and processing of more than 800 million measurements in FY 90. Processing of the data resulted in measurements at low attenuation rates with accuracies better than 0.05 dB/km. The system is now available to support telecommunication and remote sensing requirements.

Dr. Liebe has also been consulting with NIST to assist them in the development of similar measurement systems for studying the electromagnetic properties of materials.

In addition to laboratory measurements, ITS has placed a major emphasis on field measurements. They help identify areas where further modeling work is needed and are the ultimate test of the validity of models.

ITS millimeter-wave receiver van in Hana, Maui, Hawaii

In FY 90, ITS modified its narrowband, fully polarimetric, millimeter-wave measurement system. The technique used in the ITS instrumentation is to transmit one polarization at 28.8 GHz and the other simultaneously at 28.815 GHz. A dual polarization receiver is used in which each received polarization results in two IFs (intermediate frequencies), one for the copolarized wave and one for the crosspolarized wave. All signals are coherently received. The same technique is used simultaneously at 9.6 and 9.605 GHz and at 96.1 and 96.15 GHz.

A two-stage conversion scheme is now used to produce IFs in the receivers ranging in frequency from 2.6 to 26 kHz. The IFs are digitally sampled and then processed. For example, using FFTs (fast Fourier transforms) the phase and amplitudes of all of the IFs can be found so that all of the elements of the transmission matrix are measured simultaneously. Other processing methods can be used to observe extremely rapid changes in relative phase and amplitude of the different polarized components.

The system was installed on a 52 km over the ocean path between the islands of Hawaii and Maui. Both the transmitting and receiving antennas were within a few meters of the ocean surface so that it was a none line-of-sight path. The signal levels at 9.6 and 28.8 GHz were greatly enhanced by the almost continuous existence of an ocean surface evaporation duct. Signal levels only 10 to 20 dB below free space levels were normal. No signal at 96.1 GHz was observed.

The system was subsequently installed on a 112 km over-the-ocean path, again between the islands of Hawaii and Maui. Again both antennas were within a few meters of the ocean surface and again the signal levels at 9.6 and 28.8 GHz were greatly enhanced. Signal levels comparable to those on the shorter path were observed. However, they suffered a greater variability.

No polarization dependent effects have been found from the initial analysis of the data. A detailed report of the results of the ocean surface duct measurements will be published in FY 91.

This year, ITS continued its efforts to characterize millimeter-wave propagation through various types of vegetation. While previous measurements were conducted using the narrowband measurement system, measurements this year were made with the wideband impulse response probe. The wideband probe employs a 500 Mb/s pseudo-random noise signal, which is BPSK modulated on a 30.3 GHz millimeter-wave carrier. By correlating the received signal with a local reference, an impulse response of the propagation channel is generated.

The probe was used to make measurements of impulse response, BER and RSL in a pecan grove through which earlier narrowband, cw measurements had been made. Measurements were made with the trees in the de-foliated and foliated states in April and August, 1990, respectively. These measurements will provide insight into the complex scattering phenomena which occur as millimeter-wave signals propagate through vegetation. A report describing the results of these measurements will be published in FY 1991.

Results of earlier measurements of millimeter-wave propagation through a conifer orchard in Washington State made with the narrowband system were published in a report released in FY 1990.

In FY 1990, ITS developed a low cost receiver for the Olympus satellite propagation beacon at 12.5 GHz using commercially available components. (The Olympus satellite is an advanced technology research satellite operated by the European Space Agency.) The receiver will be deployed in the eastern U.S. in FY 1991. It will be used to make path diversity gain measurements in conjunction with other research organizations also receiving the beacon.

Recent ITS Publications

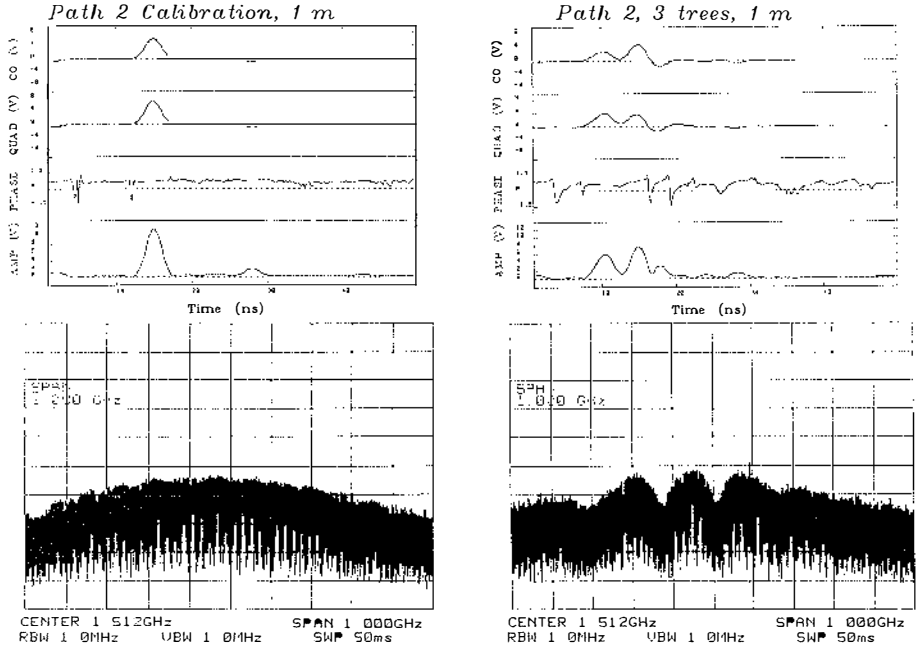
Millimeter-wave attenuation and delay rates due to fog/cloud conditions (by Liebe, Manabe, and Hufford)

Modeling and measurement of the spectral properties of atmospheric oxygen around 60 GHz (by Liebe, Hufford, and DeBolt)

Pattern recognition techniques applied to the NASA-ACTS order-wire problem (by Allen)

Vegetation loss measurements at 9.6, 28.8, 57.6, and 96.1 GHz through a conifer orchard in Washington state (by Jones, Espeland, and Violette)

For information, contact:
Ken Allen (303) 497-3412



Plots of impulse response and frequency spectra showing multipath propagation through vegetation

HF Channel Modeling and Simulation

Outputs

- Improved capability for testing HF radio systems
- New propagation model for the HF channel
- New noise/interference model of the HF environment
- New channel propagation, noise/interference, and jamming signal simulators for HF communications systems testing

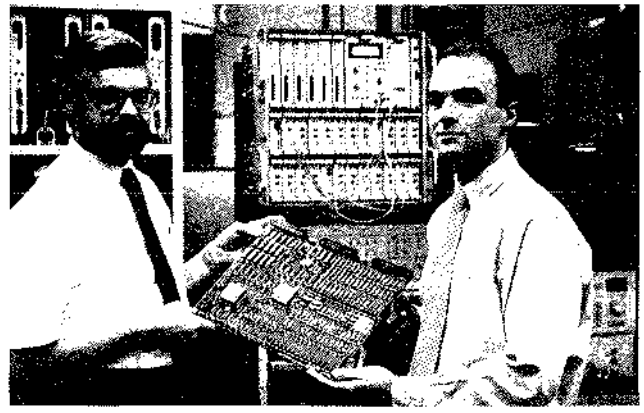
There is currently renewed interest in the high frequency (HF) media for meeting numerous military and non-military communications requirements. Advanced HF communications systems are being designed, developed, and implemented into operational networks. One exciting example of new HF communications technology is the application of direct sequence spread spectrum techniques to HF radio communication systems.

Evaluation of the advanced capabilities incorporated in modern HF radios can best be accomplished through a combination of laboratory and field (over-the-air) testing. Laboratory testing can save many thousands of dollars by reducing the time necessary for field testing which is inherently more expensive.

Accurate results can be obtained in laboratory tests through the use of a channel simulator which properly emulates the fading conditions that are encountered on a wide variety of HF communication links. Previous HF channel simulators have been based upon a HF channel model that is restricted in both its bandwidth and its ability to simulate propagation on dispersive, non-stationary HF links. These conditions are frequently encountered on disturbed (e.g., spread-F) mid-latitude channels as well as the more difficult polar and transauroral paths.

During FY 90 and prior years, the Institute has carried out a research program to develop a new HF channel model that is representative of the HF media for a wide variety of conditions. Validation of the channel model requires comparisons between the model output and empirical data obtained on numerous HF communications links.

For information, contact:
James Hoffmeyer (303) 497-3140



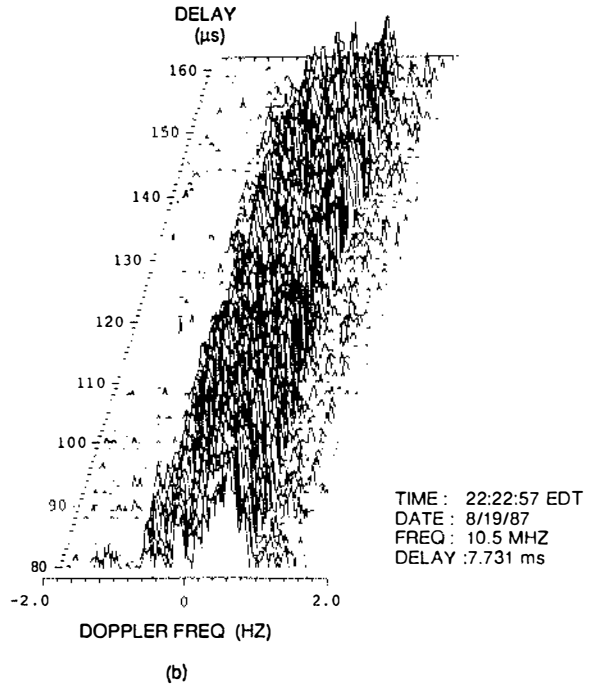
Project personnel (from left) Jim Hoffmeyer and John Mastrangelo with digital signal processor board for HF channel simulator.

The figures on the facing page provide a comparison of a scattering function output from the new HF channel model with a scattering function obtained from propagation data collected by the Naval Research Laboratory. Good agreement has been obtained to date in making such comparisons with propagation data obtained from several different paths. Also shown on the facing page is a theoretical scattering function obtained from currently used HF channel models. Note the conspicuous, and unrealistic, absence of time dispersion that is a characteristic of current narrowband HF channel models.

The Institute has begun the construction of a hardware channel simulator which implements the new HF channel model. This development program will be completed during FY 91. The hardware simulator will be used for testing associated with the development of a family of Federal Standards for HF communications systems and networks. It will also be used for testing equipment being developed as part of a large military communication system procurement.

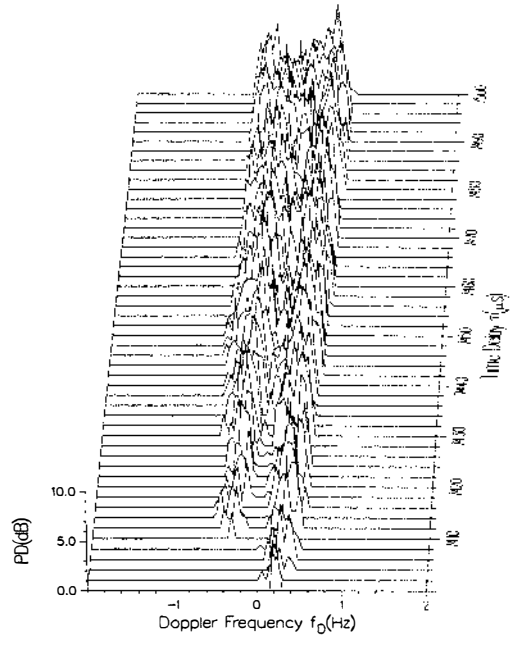
Recent ITS Publications

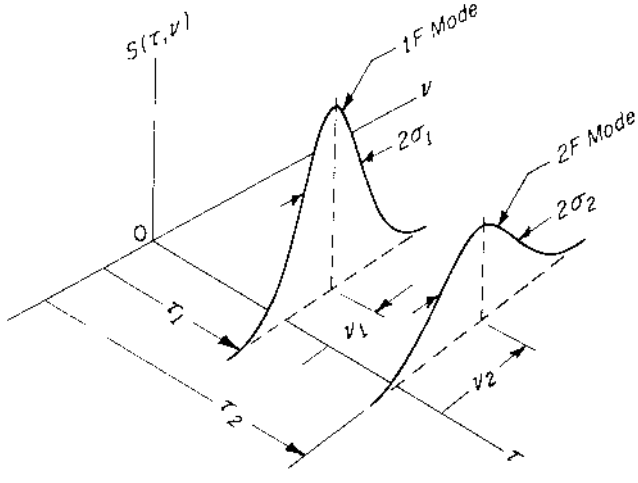
A New Approach to HF Channel Modeling and Simulation (by Hoffmeyer and Vogler)
A New Approach to HF Channel Modeling and Simulation - Part I: Deterministic Model (by Vogler and Hoffmeyer)
A New Approach to HF Channel Modeling and Simulation - Part II: Stochastic Model (by Vogler and Hoffmeyer)
Recent Progress in the Development of a Wideband HF Noise/Interference Model (by Lemmon)



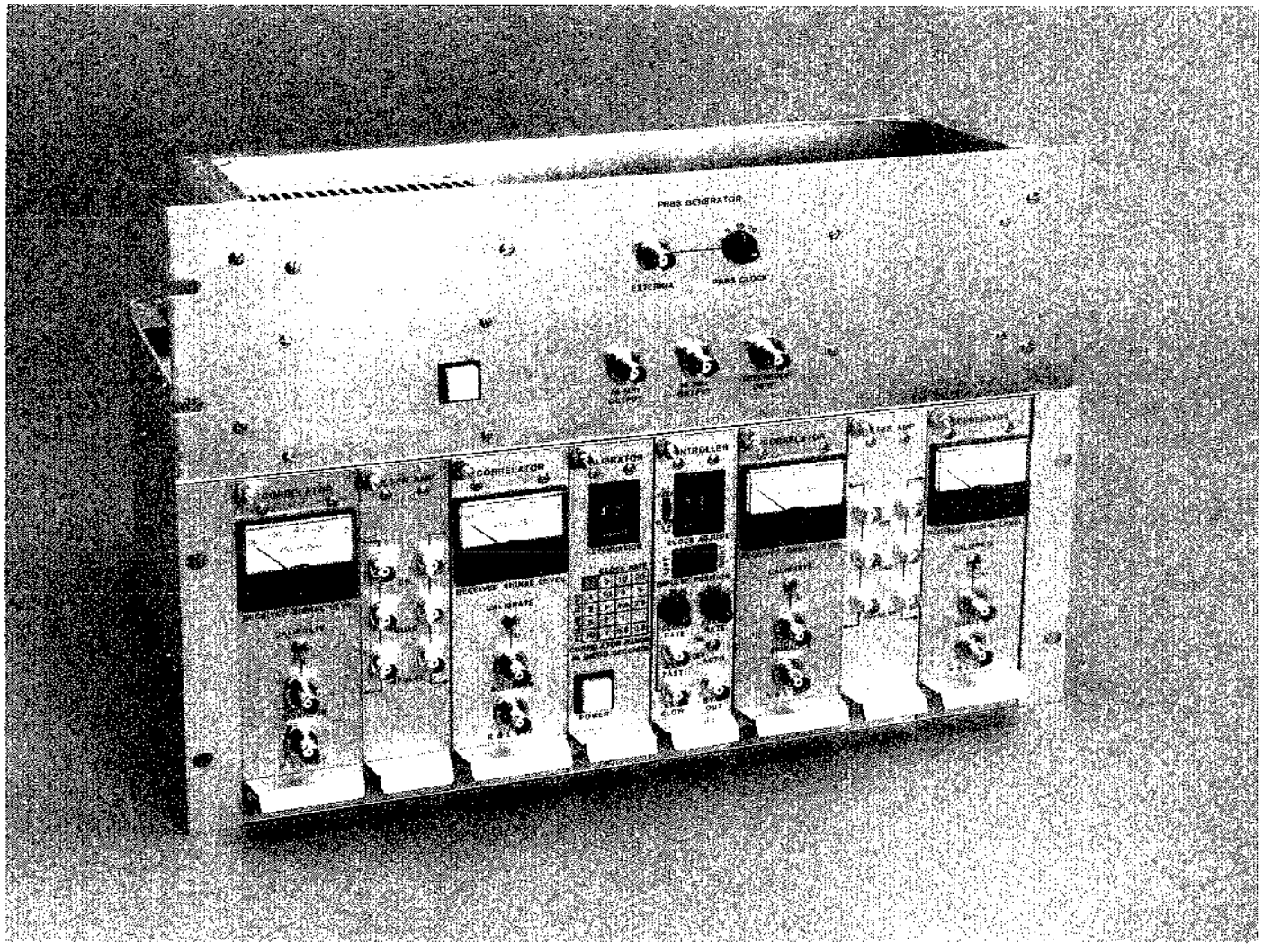
Scattering function diagram from real propagation data for a long path midlatitude channel: moderate spread-F conditions.
(Provided courtesy of U.S. Naval Research Laboratory)

Scattering function from new HF channel model





Hypothetical scattering function from narrowband channel model



Tropospheric scatter channel probe built by ITS

ITS Tools and Facilities

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 actual data which can serve as the basis for refinements and improvements to developing standards of working groups and standards committees.

-Building a representative database of user-oriented performance parameter values for real-world data communication systems such as the INTERNET, several public data networks, local area networks, and alternate services.

-Evaluating the performance of alternative data communication technologies, systems, and services in terms of specified user needs.

Three computers, each running UNIX and equipped with ITS-developed performance measurement software, comprise the nucleus of the equipment used in testing. Normally, one of the computers serves as the local host to one or more networks, and a transportable machine is taken to a distant city to function as a remote user of the network under test.

High Frequency Interoperability Test Facility •

The ITS Interoperability Test Facility (ITF) was developed in FY 89-90 through funding from NCS. This facility exists to serve a dual purpose: first, to assist in the development of a family of Federal Standards relating to adaptive HF radio systems, and second, to assist other Government agencies in the selection and procurement of adaptive HF radio systems by providing unbiased testing of these adaptive radios for both performance and interoperability among vendors.

The ITF is equipped with three portable HF Channel simulators based on the Watterson model, several HF transceivers with FED-STD-1045 Automatic Link Establishment (ALE) modems, several broadband HF Antenna systems and a suite of test and measurement equipment. A large, rotatable log periodic antenna will be erected on the ITF's Green Mountain Mesa transmitter site in the near future. The ITF has been issued ten HF Radio frequencies, spread across the entire HF spectrum, for use in over-the-air tests between ITS and other Government agencies and manufacturers of ALE radios.

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 90, the Systems and Networks Division focused its attention on establishing in-house capabilities for testing prototype ISDN services. The equipment includes personal computer ISDN co-processor boards, ISDN terminals (telephones), ISDN terminal adapters, an ISDN mini-switch, a video codec, and a sophisticated ISDN protocol test system. Functionally, the equipment allows ISDN basic rate (2B+D) bearer service to be delivered to the various types of Terminal Equipment. The protocols used to provide this service are monitored between two ISDN workstations. Performance measurement software developed by ITS is used to determine the quality of voice, video, and data communications through the network. This software is modified as necessary to measure the validity of performance parameters under study.

Laboratory Atmospheric Simulator •

ITS has a unique laboratory atmospheric simulator facility to measure the radio refractive index of moist air. A computer-controlled environmental chamber, resonator, and millimeter-wave vector network analyzer provide highly accurate measurements of attenuation and phase delay in the frequency range 10 to 220 GHz. The 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.

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 - 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.

Network Laboratory Test Bed •

The ITS Network Laboratory features a multimedia communications network used to study the interoperability and performance of a variety of networks under many conditions. The network incorporates Local Area Networks (LANs), Metropolitan Area Networks (MANs), and Wide Area Networks (WANs) to carry CAD/CAM, voice, video, and high-resolution graphics to teleconferencing data. ITS designed the network so that data paths between any two nodes can span any scale of network (from LAN to WAN) or cross diverse transmission media. ITS has also developed software that measures ANSI X3.102 user-oriented performance parameters at various layers in the TCP/IP protocol stack. The network consists of IEEE 802.3 coaxial Ethernet (10 Mbps), 10 Mbps fiber optic Ethernet, a 14/12 GHz (Ku-band) satellite transmit/receive earth station, and a satellite network simulator. The Network Laboratory provides the Video Quality Lab-oratory with image transmission and the Voice Quality Laboratory with voice transmission through a video/voice/data CODEC.

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 •

This van-deployed measurement system is used by ITS to support NTIA frequency management programs. The RSMS contains two independent, computer-controlled measurement systems--one general-purpose system and one optimized for land mobile radio channel usage measurements. A wide range of capabilities includes automated site surveys over the 2-MHz to 18-GHz range, radar pulse sorting and measurement, emission spectra, and band occupancy studies. Specialized software and hardware have been developed for many customers, taking the RSMS to locations ranging from the Aleutian Islands to Florida. Lightweight, portable systems can be used when the full RSMS capabilities are not needed.

TASERVICES •

This is a service providing the latest engineering models and research data developed by ITS to industry and other Government agencies. It is an interactive, computer-based service designed to be both user friendly and efficient. The services offer a broad range of programs that allow the user to design or analyze the performance of telecommunication systems. The services cover terrestrial, ionospheric, and space systems and include built-in data bases that allow the consideration of terrain, atmospheric, and precipitation affects on the systems. TASERVICES

have been used in the solution of interference problems, design of cellular radio systems, and FCC applications for licenses.

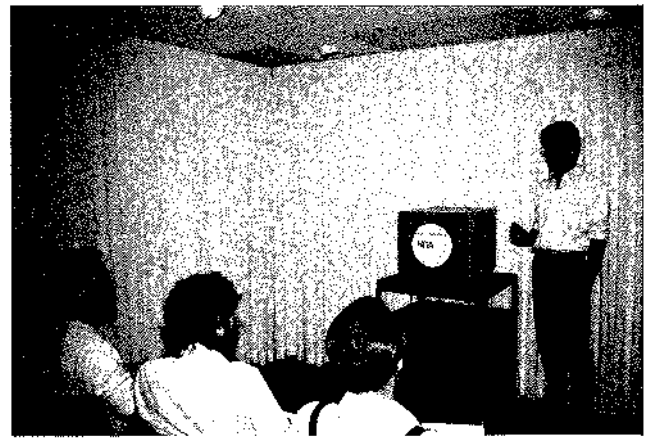
The Table Mountain Radio Quiet Zone •

This unique facility (one of only two in the Nation) is controlled by public law to keep the lowest possible levels of unwanted radio frequency energy from impinging on the area. This situation allows research concerned with low signal levels (such as from deep space, extraterrestrial low-signal satellites, or very sensitive receiver techniques) 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 front ends of these receivers are often saturated by the background signal level. 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. The 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 ensemble of broadcast quality video recorders/players, image capture/display equipment, and image processing workstations. An 80386 based workstation is capable of capturing and displaying broadcast quality 756 x 486 NTSC color images. Once captured, images are stored and processed using standard ITS-developed methods. Computer hardware for video image processing includes an 88000 based Data General Aviion VME Server with 16 MBytes of main memory and 1.5 GByte of hard disk space with an attached 88000 based diskless workstation with a 1280 x 1024 monitor. A high resolution color Tektronix printer may be used to obtain video prints or transparencies of processed imagery. Video equipment includes a 35 mm camera, broadcast quality camera and monitor, Betacam SP video recorder/players, and a VHS video cassette recorder. A Compression Labs Inc video teleconferencing Codec may be used to generate distorted video teleconferencing data. Other laboratory facilities include a viewing room built to CCIR Recommendation 500 specifications. The viewing room is used to view and subjectively grade video data, providing a means for validating the objective video and image parameters.



ITS electronics engineer, Steve Voran, with a test audience in the subjective viewing room

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 laboratory consists of two 80386-based workstations equipped with a high-speed, high precision analog-to-digital converter, and is capable of processing CD-quality audio. A "Write Once Read Many" (WORM) drive provides removable data storage capacity of over 8700 Mbytes per cartridge, and is used to store results and access speech databases generated by CCITT for international testing. The equipment is linked by Ethernet to the Video Quality Laboratory's high-speed workstation, enabling future joint voice/video objective quality research. Laboratory computers are equipped with several state-of-the-art software packages for signal analysis and processing, statistical analysis, and graphics display, as well as many specialized voice analysis programs developed in-house.

ITS physicist, Joe Hull checking documents
at EIA/TIA (Electronic Industries Association/Telecommunications Industry Association)
meeting, September, 1990

ITS Projects for Fiscal Year 1990

AGENCY FOR INTERNATIONAL DEVELOPMENT (AID)

Telecommunications **Infrastructure Study** - Randall S. Bloomfield (497-5489). Perform telecommunications infrastructure study for the Kingdom of Thailand.

BELLSOUTH ENTERPRISES

Propagation Study **for BellSouth Enterprises** - Eldon J. Haakinson (497-5304). Investigate the 1.5-2.5 GHz band to determine suitability for personal telecommunications systems and to determine what propagation model information is available.

BOARD FOR INTERNATIONAL BROADCASTING (BIB)

BIB **HF Studies** - James S. Washburn (497-3109). Estimate the total number of 10 KHz-wide channels required to satisfy worldwide broadcasting requirements, in the respective HF bands allocated for broadcasting.

HF Planning **Studies using HFSUM** - James. S. Washburn (497-3109). Provide high-quality graphics capability for ITS's High Frequency Spectrum Utilization Model (HFSUM) and perform selected HF broadcast planning studies for the BIB.

BUREAU OF LAND MANAGEMENT

BLM Data Communications **Plan** - Joseph E. Farrow (497-3607). Develop a short-range data communications plan for the Denver Service Center of the BLM.

DEPARTMENT OF COMMERCE

National Telecommunications and Information Administration (NTIA)

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.

Broadcasting and Related Propagation Studies - John R. Godwin (497-5191). Provide support to NTIA's Office of Policy Analysis and Development for high-definition television studies. This program develops fundamental data and more accurate modeling of radio propagation that will lead to improved methods of planning spectrum sharing among the various users.

Common Carrier Technical/TELECOM 2000 - Roger K. Salaman (497-5397). Perform assessments to support common carrier and information industry deregulation and competitive thrusts.

Digital Networks Performance - David J. Atkinson (497-5281). Promulgate and demonstrate compatible Federal and American National Standards and international 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 Studies - 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 - Neal B. Seitz (497-3106). 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.

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.

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** - John D. Smilley (497-5218). Enhance the measurement capabilities of the RSMS and suitcase system as needed to provide improved measurement data.

RSMS **Operations** - John D. Smilley (497-5218). Provide measurement of spectrum usage and other technical parameters of radio systems, needed for frequency management planning activities.

Satellite/ISDN - Raymond D. Jennings (497-3233). Perform research aimed at determining the role of advanced satellite systems in future broadband ISDNs.

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 (497-5475). Assess spectrum utilization, identify existing or potential compatibility problems among Federal telecommunication systems, provide recommendations for resolving any compatibility conflicts in the use of the frequency spectrum, and recommend changes to improve spectrum management procedures.

Telecommunication **Analysis Services (TASERVICES)** - Eldon J. Haakinson (497-5304). 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.

Video **Quality Standards** - Stephen Wolf (497-3771). Develop video quality assessment techniques and standards contributions in support of ISDN standards within T1 and CCITT, focusing on applications in video teleconferencing, high-definition television, and video communications over broadband ISDN.

Voice Quality **Standards** - Robert F. Kubichek (497-3594). Develop voice quality assessment techniques and standards contributions in support of ISDN standards within CCITT.

National Institute of Standards and Technology

Boulder Switching System - Val J. Pietrasiewicz (497-5132). Perform technical consulting services regarding the acquisition of a new digital voice/data switching system at the Boulder Laboratories.

EM Properties of Materials - Hans J. Liebe (497-3310). Assist in developing accurate measurement techniques for the dielectric properties of solid materials at microwave and millimeter-wave frequencies.

Video Surveillance Equipment Requirements and Performance - David J. Atkinson (497-5281). Develop a guide to assist law enforcement agencies in the selection and application of video surveillance equipment.

DEPARTMENT OF DEFENSE (DoD)

Alaska Site Survey - John D. Smilley (497-5218). Perform a radio frequency site survey at three sites in Alaska.

AMOS Model Development - Robert O. DeBolt (497-5324). Continue the development of the millimeter-wave prediction model for tactical scenarios known as Analysis of Microwave Operational Scenarios (AMOS) with the addition of new propagation models and outputs.

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.

HF Modeling - Frank G. Stewart (497-3336). Use the ITS IONCAP to analyze the extensive data base to verify the median predicted field strength values and obtain a better estimate of the statistical distribution about this median.

HF Polar - Frank G. Stewart (497-3336). Implement a polar model in IONCAP to correct inconsistent predictions of polar paths.

Low Frequency Signal and Noise Measurement - Michael G. Laflin (497-3506). Study signal and noise environment the 0 to 10 KHz frequency range in a typical office/business environment.

Millimeter-Wave Propagation in the Ocean Surface Evaporation Duct - Ken C. Allen (497-3412). Enhance the polarimetric millimeter-wave probe and perform propagation measurements in the ocean evaporation duct with the updated probe.

REAMS **Performance Verification** - Robert J. Matheson (497-3293). Analyze and test RFI/EMI Automatic Measurement System (REAMS) used for quantitatively-accurate noise measurements in order to characterize system performance.

Wide Area **Prediction** - Evan J. Dutton (497-3646). Refine computer programs that analyze the receivability of common carrier links to allow the analysis of an entire metropolitan area, or any wide area in the United States, in a single program run.

Wide Area **Graphics Capability** - Evan J. Dutton (497-3646). Refinement of system/software in wide area graphics capability. Provide special visual representation utilizing topographic elevation data.

Wideband HF Study - James A. Hoffmeyer (497-3140). Analyze wideband HF propagation data tapes to validate WBHF channel model.

Air Force (USAF)

54 to 66 **GHz Laboratory Study** - Hans J. Liebe (497-3310). Provide propagation data for the frequency interval from 54 to 66 GHz at simulated atmospheric conditions over the height range from 5 to 30 km.

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

Hill AFB GEMS Van - Donald H. Layton (497-5496). Design and procure a ground emitter monitoring system (GEMS) van for Hill Air Force Base, UT.

FCA Frequency Extension - Donald H. Layton (497-5496). Modify designs of the frequency control and analysis systems and ground emitter monitoring system (GEMS).

Hill AFB Remote Antenna - Donald H. Layton (497-5496). Design and construct a remote antenna system for Hill Air Force Base.

MOTES-R - Donald H. Layton (497-5496). Assist the USAF in maintaining and upgrading the MObile Test and Evaluation System-Radar (MOTES-R) performance and reliability.

Air Force--Electronic Systems Division (ESD)

European TRAMCON Support - Robert A. McLean (497-3262). Support the TRAnsmission Monitor and CONtrol program (TRAMCON) operation in Europe for a period of 30 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.

Network/Link Performance Data Analysis - James A. Hoffmeyer (497-3140). Use ITS Microwave Test Facility to investigate DRAMA equipment pseudo-errors reported to the TRAnsmission Monitor and CONtrol program (TRAMCON) and investigate effects of high signal levels on DRAMA radio performance.

TRAMCON 87/89 - 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).

Air Force--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 (CECOM)

Ionospheric Variability Study - Mary W. Sowers (497-3820). Conduct studies that will model on a global scale the effects of variability in the critical frequencies of the F2 region of the ionosphere.

MMW Studies of Propagation Through Deciduous Vegetation - David L. Jones (497-6295). Modify the wideband millimeter-wave propagation measurement system for enhanced sensitivity and accuracy and make propagation measurements through deciduous vegetation.

Wideband **HF Channel Modeling and Simulation** - James A. Hoffmeyer (497-3140). Analyze propagation tapes to obtain statistical distributions of values for the previsously defined parameters.

Army Information Systems Engineering Command (ISEC)

Development **of Techniques and Standards Criteria for** Advanced **Automated HF Radio Systems** - David. F. Peach (497-5309). Develop additional techniques and specifications for the automation of HF radios used by the military and other Federal agencies.

IONCAP **Model Development** - Larry R. Teters (497-5410). Undertake a specific HF propagation study to assist the Army in the development and implementation of analytic techniques for tactical operation use.

Military Standard 187-721 Development - David F. Peach (497-5309) and Paul C. Smith (497-3677). Develop, and expand upon, features that will allow automated message exchange among all adaptive HF radios used by the military services.

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.

TROJAN **Communications Network Management** System - Richard E. Skerjanec (497-3157). Continue development of the TROJAN communication network system (TCNMS) and provide a quick-response test methodology.

Army Missile Command

Millimeter-Wave Polarimetric Studies - Kenneth C. Allen (497-3412). Provide information on time-dependent polarimetric effects of rain on millimeter waves that may affect specific polarimetric sensors.

Defense Communications Agency (DCA)

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

HF Radio ALE Interoperability - David F. Peach (497-5309). Perform interoperability testing of HF radio equipment built to FED STD-1045. This testing is in support of the Counter-Drug Telecommunication Integration Office (CDTIO) preparation for possible procurement of HF radio equipment with the ALE feature.

NSEP/FOCS - 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.

Video Teleconferencing Quality Assessment for Standards - Stephen Wolf (497-3771). Specify, order, and install into the ITS video quality assessment system, all componenets necessary for ISDN video quality assessment.

Wideband HF Channel Modeling and Simulation - James A. Hoffmeyer (497-3140). Develop validated models for the wideband HF channel, HF noise and interference, and HF jamming signals and implement those models in simulator hardware.

National Communications System

Federal Standard 1055 Validation - William J. Pomper (497-3730). Ensure that the protocols contained in proposed Fed Std-1055 are fully validated, and that any deficiencies in the standard are found and corrected before the draft standard becomes a mandatory Federal standard.

HF Radio Interoperability Testing Facility - Paul C. Smith (497-3677). Design, implement, and demonstrate a test facility capable of evaluating the interoperability of automated HF radio systems.

ISDN Standards Support - David J. Atkinson (497-5281). Enhance existing ITS data communication performance measurement tools to include ISDN measurement capabilities that will facilitate the establishment of American National Standards, Federal Standards, and CCITT Recommendations on ISDN performance.

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.

R&D/O&M Engineering Services for NCS - Joseph A. Hull (497-5726). Provide technical support to NCS in areas relating to performance and interoperation of Government telecommunication assets for National Security Emergency Preparedness purposes.

Reduced **Vulnerability to Telecommunication Outages** - Raymond D. Jennings (497-3233). Provide technical investigations of the potential for using advanced satellite system technology to enhance rapid restoration of services provided by the public switched network following a natural or "manmade" disaster.

Revision of FED-STD-1037A - A. Glenn Hanson (497-5449). Develop, edit, and maintain a data base for the revision of Fed-Std-1037A, Glossary of Telecommunication Terms, and correlate this data base with relevant international standards.

Joint Tactical Command, Control, Communications Agency

HF Simulator/HF Test Bed Procurement Consultation - James A. Hoffmeyer (497-3140). Provide technical consultation in the procurement of a narrowband HF channel simulator and the HF distributed test bed.

Naval Air Test Center

Navy **Air Systems Command Consulting** - Joseph E. Farrow (497-3607). Provide consulting services to assist with the resolution of propation problems on the Taiwan Tactical Air Crew Training System (TACTS) 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 Research Laboratory

NRL Measurements - Frank H. Sanders (497-5727). Make emission spectra measurement on the PFS-20 radar on Guam and recommend ways to prevent interference from that radar.

Naval Sea Systems Command

Aegis CAD/VTC Satellite Networks - Edmund A. Quincy (497-5472). Design, develop, and measure performance of a prototype wideband high-data-rate satellite telecommunication network consisting of a series of interconnected Local, Metropolitan, and Wide Area Networks. The networks are optimized to integrate and transfer Computer Aided Design, Computer Aided Logistics Support, digitized Video Teleconferencing, and Interactive High Resolution Graphics Teleconferencing data between the Navy's principal shipbuilders and weapons manufactures and headquarters.

DEPARTMENT OF ENERGY

EME Program Analysis - Nicholas DeMinco (497-3660). Implement an EME (electromagnetic environment) analysis capability for DoE/Savannah River Project, which will be utilized to support the engineering and test/evaluation programs for the production reactor facilities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

ACTS Earth Station Functional Specification Development - Robert D. Cass (497-5478). Demonstrate, through industry, university, and Government agency experiments, advanced on-board switching, signal processing, and dynamic coverage area control, technologies for future communication satellites.

Multipath Measurements in the Land Mobile Satellite Radio Channel - John. J. Lemmon (497-3414). Support the development of a Global Positioning System Multipath Measurement System (MMS) to be used to measure multipath propagation in the land mobile satellite radio channel.

NATIONAL WEATHER SERVICE

NEXRAD radar - Frank H. Sanders (497-5727). Prepare a report on the rf emission spectrum of the NEXRAD radar at Norman, Oklahoma.

DEPARTMENT OF TRANSPORTATION

Coast Guard

Coast Guard Telecommunication Performance Models - Eldon J. Haakinson (497-5304). Provide the U.S. Coast Guard with Telecommunication Analysis Services models in a relocatable form for operation on a Coast Guard HP-1000A computer.

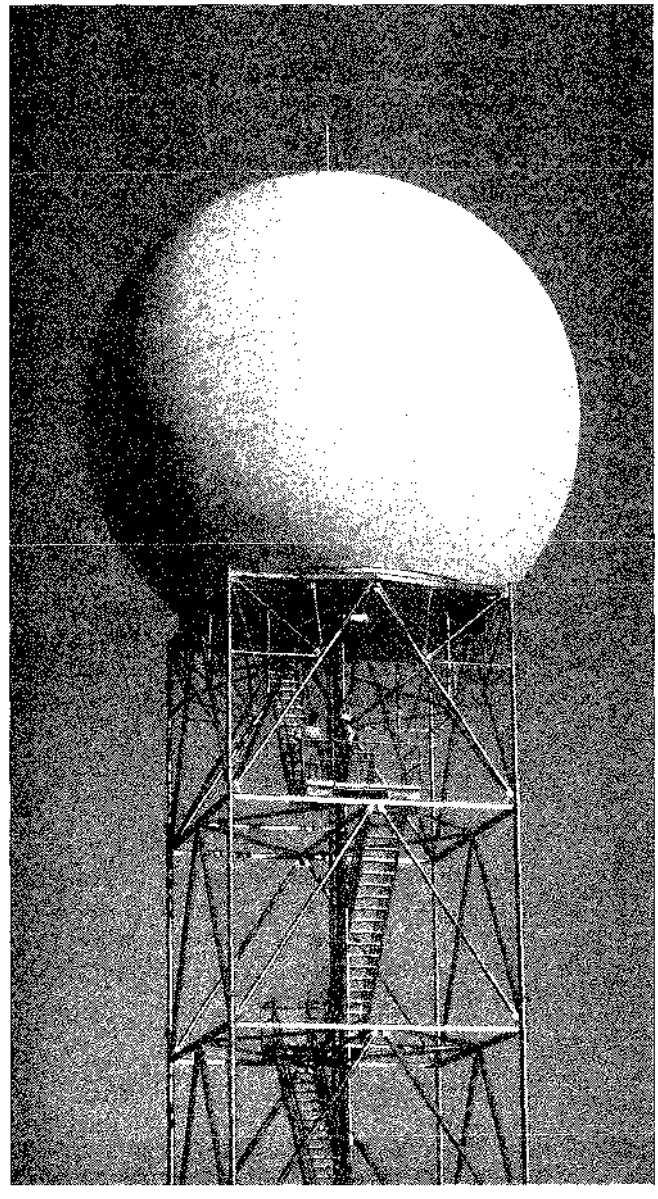
U.S. INFORMATION AGENCY (USIA)

Florida TV Measurements - John D. Smilley (497-5218). Make measurements on specific radio signals in Florida to evaluate the potential interference to existing local TV stations.

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

VOA HF Studies - James S. Washburn (497-3109). Adopt the HFMUFES propagation analysis software to achieve compatibility with VOA's VAX 8300 system, and install HFMUFES software on the VAX 8300.

VOA Predictions - A. Donald Spaulding (497-5201). Provide Voice of America with ionospheric predictions that are used in frequency planning and coordination.



The NEXRAD radar tower at Norman, Oklahoma

Note: Commercial telephone users dial 303 + number shown in parentheses. FTS users dial 8-320 + last four digits shown.

ITS Publications for Fiscal Year 1990

Adair, R. T. (1989), An automatic link establishment standard for automated digitial HF radios, Proc. 1989 IEEE Military Communications Conference, (MILCOM '89), Boston, MA, October 15-18, pp. 48.6.1-48.6.12.

Akima, H. (1990), User's manual for the geostationary satellite orbit analysis program (GSOAP) -- version of 89/09/30, NTIA Technical Memorandum 90-146, May, 42 pp.

Allen, K. C. (1990), Software for the analysis of microwave operational scenarios, MILCOM '90, Monterey, CA, September 30 - October 3.

Bloomfield, R. S. (1990), Technology and equipment development, Ch. 5, *Telecommunications Infrastructure Study, a Report for the Kingdom of Thailand National Economic and Social Development Board*, U.S. Dept. of Commerce, National Telecommunications and Information Administration, July, draft final report, pp 157-251.

Bloomfield, R. S., and J. A. Hull (1989), A perspective on future large scale telecommunication architectures supporting broadband ISDN services, Proc. Information Gatekeepers, Inc., Broadband FOC/LAN '89 Conf., (FOC/LAN '89), October 30 - November 3, San Francisco, CA., pp. 251-257.

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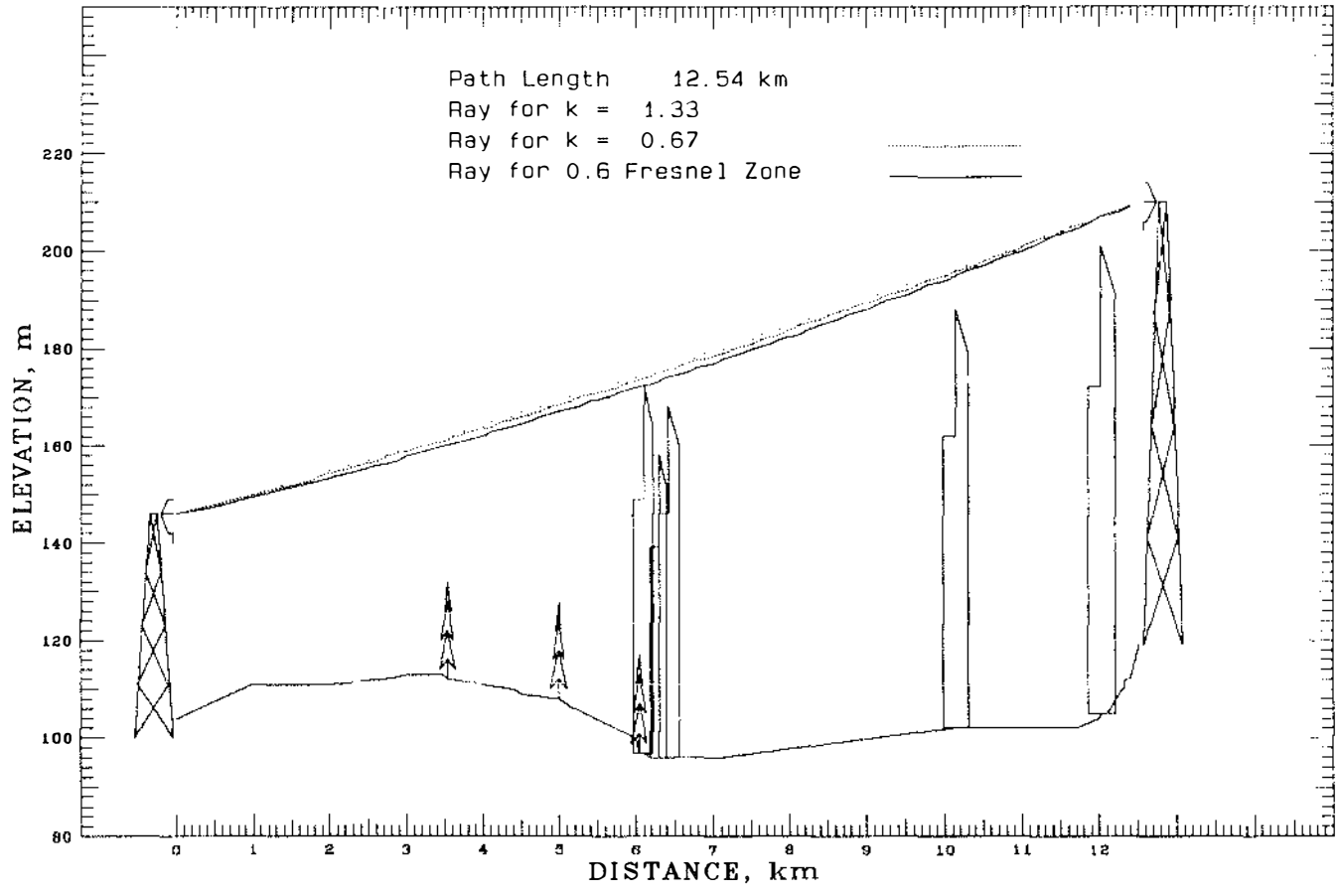

Plot produced from RAIDER software
showing a line-of-sight microwave path in Germany.

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