INSTITUTE FOR TELECOMMUNICATION SCIENCES

OF THE

NATIONAL TELECOMMUNICATIONS AND

INFORMATION ADMINISTRATION

1991 TECHNICAL PROGRESS REPORT

For the Period October 1, 1990 through September 30, 1991

ITS

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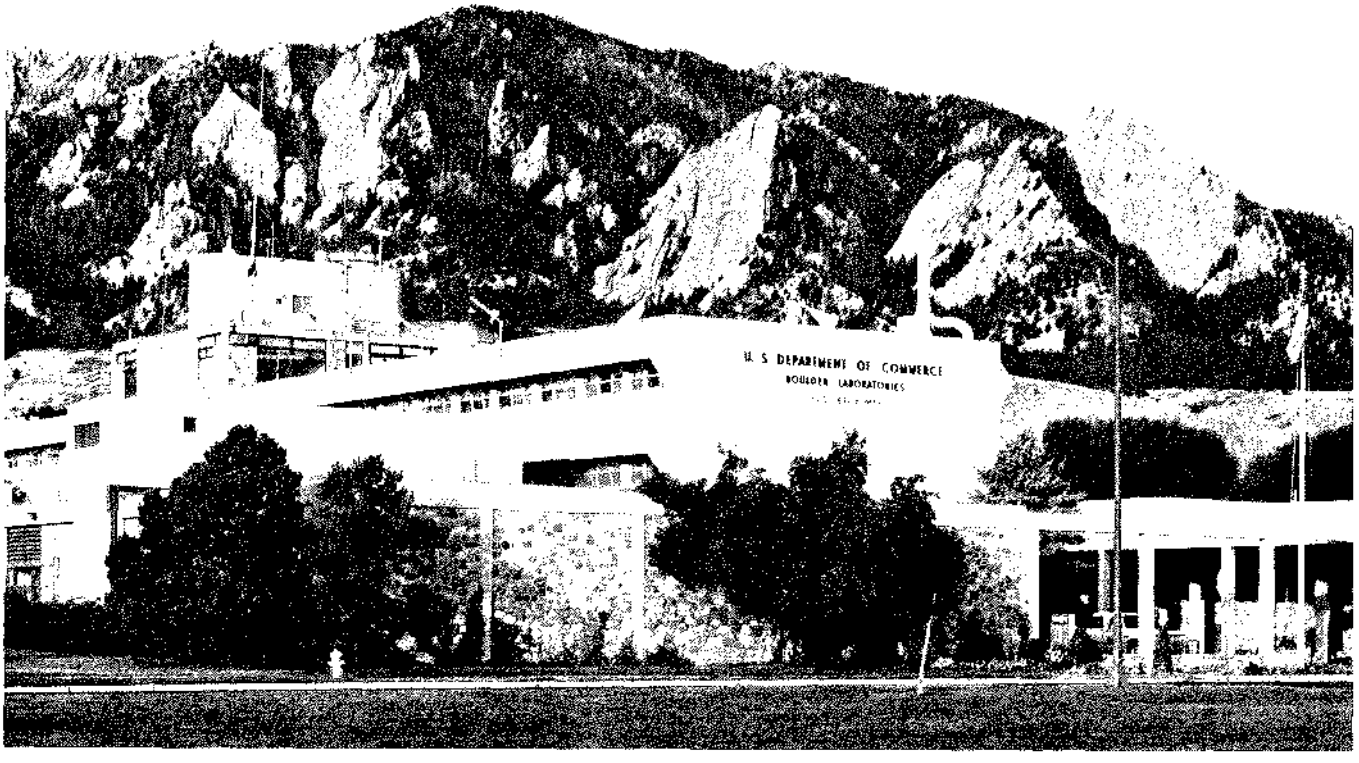
U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
Janice Obuchowski, Assistant Secretary
for Communications and Information

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.

A principal means of aiding the private sector is by means of cooperative research agreements based upon the Federal Technology Transfer Act of 1986. This Act provides the legal basis for and encourages shared use of government facilities and resources with the private sector in advanced technologies to aid in attaining commercialization of new products and services.



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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 105 permanent program staff. Many of these employees bring substantial engineering and scientific backgrounds and skills to our technically oriented programs. Indeed, 54% of our employees are electronics engineers, 8% are mathematicians, 3% are physicists, 7% are computer scientists, and 4% are computer programmers. During FY 91, ITS support consisted of $3.3M of direct funding from Commerce and $8.1M in work sponsored by other Federal agencies.

HISTORY

ITS had its organizational beginning during the 1940's as 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.

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. An Executive Office handles 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.

SPONSORS

The activities of the Institute are undertaken through a combination of Commerce-sponsored and other-agency-sponsored programs. 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 technical progress report summarizes specific FY 91 technical contributions made by ITS that have significance for the public and private sectors.

HFBC Team, Jean Ratzloff, Greg Hand, and Jim Washburn, Examining Results of HF Propagation Prediction Modeling

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

CCIR Activities

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

International Radio Conference Support

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

Domestic Spectrum Analysis

Includes projects funded by the National Telecommunications and Information Administration and BellSouth Enterprises

Spectrum Usage Measurements

Includes projects funded by the Department of Defense, the National Telecommunications and Information Administration, the U. S. Naval Research Laboratory, and Telesis Technology Laboratories, Inc.

Spectrum Surveillance System Development

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

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 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.

The reports and recommendations of the CCIR are used by radio conferences to establish technical criteria that are the basis for spectrum allocation decisions and system standards on a global and regional basis. The agreements reached at the World Administrative Conferences (WARC) have the status of international treaties for the United States. Therefore, it is important to the United States that CCIR documents accurately reflect the U.S. position on many important spectrum policy matters. Because of its preeminent position in the field of telecommunications research and development, members of ITS staff participate actively in the work of the CCIR at the national and international levels.

The CCIR is organized into Study Groups. Each study group addresses a specific area of radio system technology. The particular topics treated by each Study Group reflect the topics that will be discussed by forthcoming radio conferences. The CCIR Study Groups include:

SG1	Frequency management & 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
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

In the past, the CCIR had a 4-year cycle of activity centered about the Plenary Assembly. Modifications to CCIR documents created by the Study Groups are approved in the Plenary Assembly. In preparation for the Plenary Assembly, the CCIR has met at an Interim Meeting about 2 years before the Plenary Assembly, with a Final Meeting for the Study Groups shortly before a Plenary meeting.

Recently, however, the CCIR has been streamlining its organization and procedures to be able to react more quickly to a myriad of changes throughout the world. Spectrum and standards need to be selected for new communication services, such as personal communications system (PCS), low earth orbit (LEO) mobile satellite systems, high definition television (HDTV) and direct broadcast satellite (DBS). Since many of these proposed services are inherently worldwide, users gain considerable benefit from worldwide standards. The need for international standards, however, implies that many systems must delay widespread deployment until the standards have been completely specified. Hence, there is considerable pressure upon CCIR to quicken the process of setting standards.

The new CCIR organization has designed its processes to operate in a two year cycle with a major spectrum reallocation conference to be held every two years. An International Frequency Registration Board (IFRB) has been downsized and may be eliminated completely. Its previous function of partially coordinating HF and satellite assignments will be partly moved to specialized international user groups. More recent proposals include the creation of a Standardization Section, intended to deal with the organizational "gap" between the CCITT and CCIR: when radio systems are hooked into telephone systems--exactly where many decisions will be needed to support personal communication services.

The study groups have been given more authority to make some decisions on their own, including approval of recommendations without an international conference. The task groups are

limited to studying specific questions assigned to them and are expected to produce recommendations before the next WARC.

Most government participation in CCIR-related activities has been related to the 1992 WARC, which will be held in Spain in February 1992. This conference will deal with many questions of proposed allocations in many frequency bands across the entire radio spectrum, establishing the basic frequency bands that various radio services may use.

The process of deciding what allocations the United States will propose or support parallels the organization of the U.S. frequency management structure. Federal Government agencies have proposed reallocations through ad hoc 206, a committee of the Interdepartmental Radio Advisory Committee (IRAC). The Federal Communications Commission (FCC) solicited comments from industry via a "Notice of Inquiry" (NOI) on the WARC-92.

Large numbers of comments and suggestions were received, which were considered as the FCC and NTIA prepared their recommendations for the WARC. These deliberations are still underway, and many U.S. frequency management personnel are actively engaged in studying the technical issues and weighing the pros and cons of many competing positions. Corresponding processes are being followed in many other countries, which will come together at WARC-92.

The WARC-92 agenda includes the possibility of many profoundly important spectrum allocation changes. These will likely include allocations for direct broadcast satellite (DBS), terrestrial digital audio broadcasting (DAB), and high definition TV (HDTV), additional HF broadcast bands, satellite mobile service for aircraft, low orbiting satellite mobile services, and personal communication services. 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 that they assign to the uses of the spectrum, there will be many difficult decisions made at WARC-92.

Institute personnel have played an active role in CCIR activities. This includes leadership of U.S. Study Group 1, with active participation in many conference activities. Other personnel have been active in Task Group 1/1, which is working on improved methods of frequency allocation with expected participation in the International Working Group meetings in November 1991.

The Institute has been active in Study Group 6C as national and international chairman for drafting recommendations on radio noise and noise measurements with expected participation in the November international meetings.

Participation in Study Group 10/1 included the addition of new HF broadcasting antenna models, while Study Group 10/10 included extensive preparation for the planned 1992 WARC and 1993 HF Broadcasting Conference (recently postponed).

In addition to personal participation in CCIR activities, several ITS technical projects have contributed substantially to CCIR activities. A set of 23 GHz rain scattering experiments in Hawaii was carried out in support of Study Group 9. Several 1991 studies aimed at deciding U.S. positions on proposed allocation changes in the WARC-92 conference were based on Radio Spectrum Measurement System (RSMS) measurements of existing signals in several frequency bands. RSMS documentation of radar interference to satellite and terrestrial microwave receivers was extensively used in recommendations for the November international meetings.

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

International Radio Conference Support

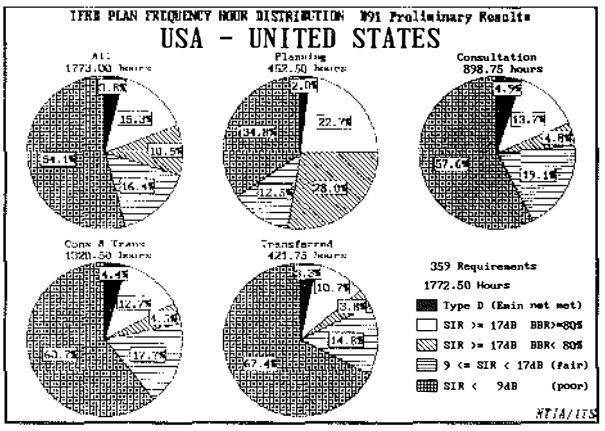
Outputs

- 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 (WARCs) 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 future session of the HF broadcast conference by using the Institute developed improved HF spectrum use model (IHFSUM). IHFSUM is used to study issues raised by the decisions of the WARC HFBC-87 and how they impact U.S. broadcasting objectives. The Institute has actively and extensively tested these decisions. The possible third session of the HF broadcast conference originally scheduled for 1993 was recently postponed by the International Telecommunications Union (ITU) Administrative Council until 1995 or later.

IHFSUM 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 a future competent WARC. 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 to test the International Frequency Registration Board's (IFRB) improved planning system on the HF broadcast requirements for the D91 broadcast season was completed in July of this year. The results of these tests demonstrated the deficiencies of the improved planning system within the constraints of the available spectrum for HF broadcasting. The figure shown below demonstrates some of the graphics capability built into IHFSUM by showing a pie chart of the disposition of all U.S. HF broadcast requirements by the recent test of the improved planning system.



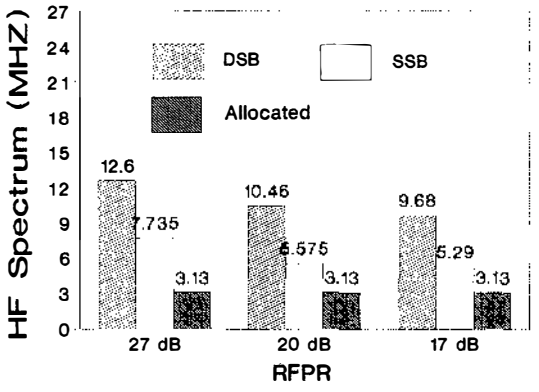
Results of the D91 Broadcast Season Tests Using the IFRB's Improved Planning System

The HF broadcast issues pending and awaiting resolution by a future competent WARC are the acceptance of the improved planning system, the suitability of the HFBC-84 propagation model used by the improved planning system, the suitability of the adopted receiver characteristics for double-sideband (DSB) and compatible single-sideband (SSB) HF broadcast receivers appearing in Appendix 45 of the ITU Radio Regulations, and the availability of "low-cost" SSB HF broadcast receivers. Resolution 517 of the Final Acts of WARC HFBC-87 calls for the transition from the present DSB system to a SSB system by the year 2015. In this regard the Institute works closely with U.S. broadcasters to determine their broadcasting needs both now and in future years. For example, ITS recently completed a study assessing the minimum amount of spectrum

required for HF broadcasting in both DSB and compatible SSB modes. This study also addressed the likelihood that this spectrum could be shared with nonbroadcast services on a noninterfering basis.

The spectrum required for HF broadcasting study provides a technical basis for the U.S. allocation proposals being developed in preparations for the WARC-92. The study applied IHFSUM 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 DSB and the proposed compatible 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.

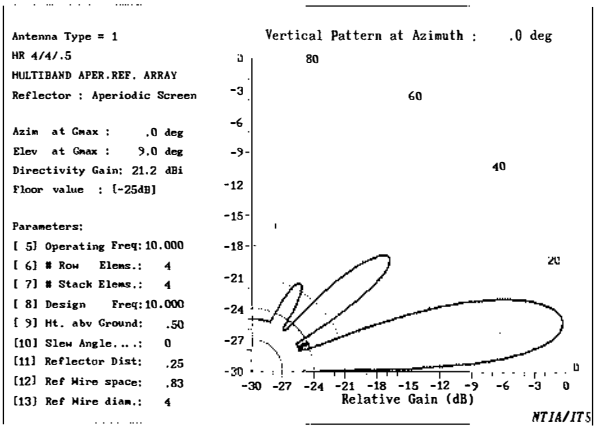
The figure below shows summary results of this study of the minimum amounts of HF spectrum for different radio frequency protection ratios (RFPR's) for a selected broadcasting schedule.



Total Amount of HF Spectrum by HF Broadcast System for Operation of Seasonal Requirements (All Bands)

The next figure (top right column) shows a partial antenna pattern for a typical HF broadcast antenna from the set of such antennas recently adopted by the CCIR to be used for the planning of the HF broadcast bands. The technical parameters for these antennas-including the rhombic-are now part of the IHFSUM software.

In addition to the technical studies related to planning, the Institute has been 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



Partial Antenna Pattern for a Typical HF Broadcast Antenna

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.

The Institute is seeking to continue the use of IHFSUM on a joint basis among NTIA, the Bureau for International Broadcasting (BIB), and the Voice of America (VOA) because of its usefulness as an HF system planning tool in preparations for WARC-92, a future competent WARC, and as a useful tool to efficiently analyze worldwide HF seasonal broadcast requirements under different scenarios. The Institute devised a joint plan for the improvement, porting, and use of IHFSUM by the interested agencies in preparation for these important conferences and as a development tool. This year's activities centered on developing plans for the creation of a database founded on VOA monitors' reports to test the quality of predictions from different HF propagation models and testing receiver characteristics for existing DSB and SSB HF receivers.

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)

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

HF Broadcast Spectrum Sharing Potential: A Study Using the IFRB's J90 Notifications (by Washburn, Hand, Berry, and Ratzloff)

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

Domestic Spectrum Analysis

Outputs

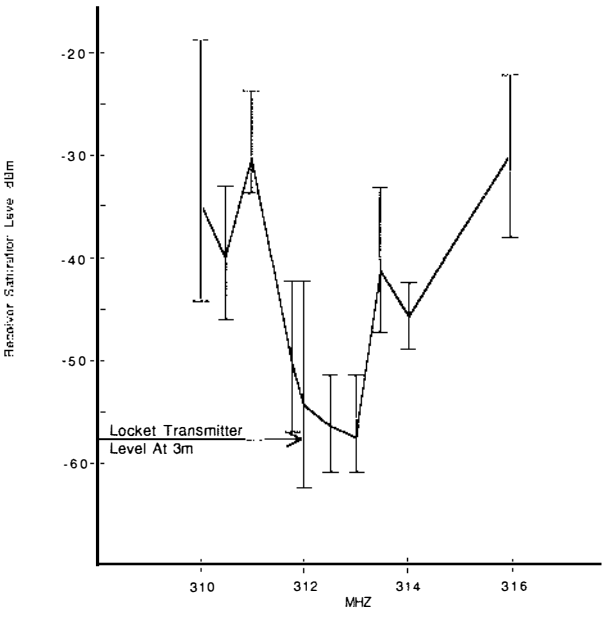
- Measurements on the electromagnetic compatibility characteristics of unlicensed devices
- A paper on the current frequency allocations and assignments for the 1.5-2.5 GHz range

The NTIA, in its role as manager of the Federal Government's use of the radio frequency spectrum, undertakes a number of studies each year dealing with spectrum utilization, 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 managements procedures, and recommend changes to promote efficient use of the spectrum. This year, we continued our studies of the potential interference characteristics of low-powered, unlicensed electronic devices with the goal of predicting their impact on licensed spectrum users.

There has been a recent relaxation of the Federal Communication Commission regulations concerning the use of low power, nonlicensed devices covered by Part 15 of the Code of Federal Regulations. Examples of these so-called "Part 15" devices include cordless telephones, garage door openers, some radio-controlled toys, wireless LANs, etc. The relaxation permitted in the new regulations includes much more freedom of choice of frequency bands, types of service, modulations and bandwidth, and easier clearance to manufacture and sell--thus facilitating development and marketing in the telecommunications industry. The National Telecommunications and Information Administration maintains an interest in the resultant electromagnetic compatibility issues because of the prospect of potential interference to Government systems, as well as the general question of spectrum efficiency.

The Institute continued to add to a database of measured device characteristics, including measurements on an avalanche beeper and a medical-alert locket. These devices are typical of newer Part 15 systems, which have been designed by entrepreneurs to perform a truly indescribable mix of services. The avalanche beeper is worn by skiers. If they are caught by an avalanche, the beeper allows them to be rapidly located and dug out. The medical alert locket is worn by a person who is medically at risk. In case of an emergency in his home, he can push a button on the locket, triggering his phone to call a medical answering service. The answering service can ascertain the type of emergency by talking over a speaker-phone unit and summon the appropriate type of assistance.

Although (by law) Part 15 devices must not cause interference to licensed devices and must accept any degree of interference from licensed devices, the question becomes a little more complicated when Part 15 devices are used in "safety-of-life" situations. A concern with the medical alert locket, for example, was whether existing transmitters would prevent the system from working properly. We measured the receiver saturation level; signals above this level prevent the receiver from working. The figure shows measured saturation levels at frequencies near 300 MHz. The upper and lower bars represent a range of values received at various orientations of the receiver unit. It is also significant that the receiver may not work when the locket is used closer than 3 m to the receiver unit.



Receiver Saturation Versus Frequency for Medical Alerting Locket

In another area of effort, ITS assembled information on the uses of the frequency band between 1.5 GHz and 2.5 GHz. This frequency range is being seriously considered for use by many of the proposed personal communication services (PCS), and a knowledge of what systems are already using various portions of the frequency range may greatly affect the cost and practicality of moving PCS into one of these bands.

The report on this work included the use of the frequency range by Government and non-Government systems, including information on the number of assignments and the characteristics of typical systems used in each band. In some cases, additional information on these bands, including geographical distributions of the systems was also provided. Much of this information was obtained from the Government Master File (GMF) of frequency listings and from earlier spectrum resource assessments (SRAs). The work was funded by BellSouth Enterprises, and it furnishes one viewpoint for looking at the selection of suitable frequency bands for PCS. This work complements other ITS work described in the "PCS" section including summaries of field measurements showing the occupancy of these frequency bands by radio signals.

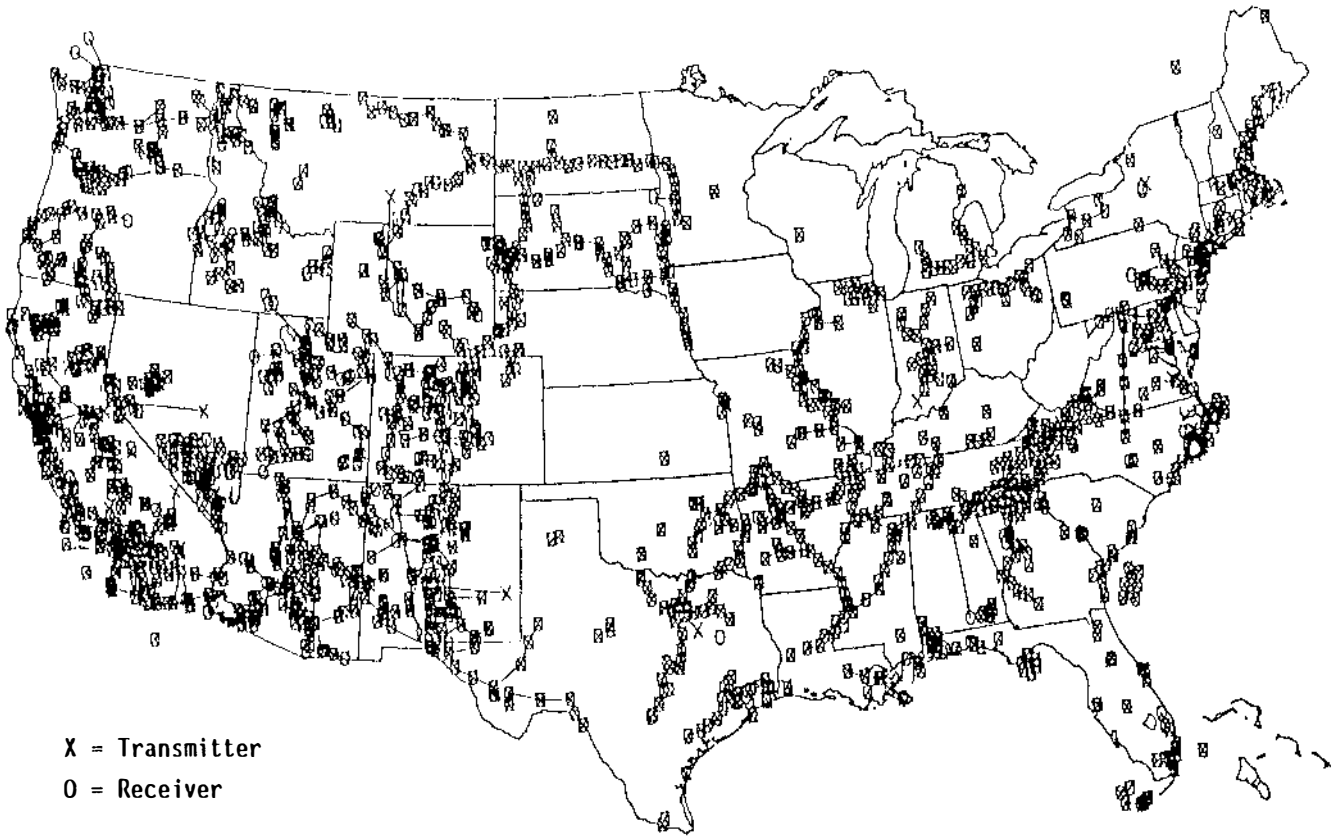
The figure below shows a geographical distribution of Federal Government microwave sites in the 1710-1850 MHz band.

In FY 91, ITS staff provided comments to NTIA on their Notice of Inquiry on U.S. spectrum management policy. This report is now available from the Superintendent of Documents, Washington, DC, and is titled: "U.S. Spectrum Management Policy: Agenda for the Future".

Recent ITS Publications

Frequency Assignment Summary for 1.435 GHz-2.5 GHz Band (Berry, Steele, and Grant)

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



Geographical Distribution of Microwave Sites
in the 1710-1850 MHz Band

Spectrum Usage Measurements

Outputs

- Measurements on wind profiler radars
- Measurement of microwave oven emissions
- Spectrum measurement workshop
- Radar interference solution
- Band occupancy measurements for PacTel
- Microwave site surveys for DOD

The Federal Government's use of the radio spectrum is managed by NTIA, 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), Compact Radio Spectrum Measurement Systems (CRSMS) also called the "suitcase systems", and a low frequency measurement system (LFMS). These systems are used to provide the Government frequency management process with the following types of information:

Occupancy measurements to show the 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

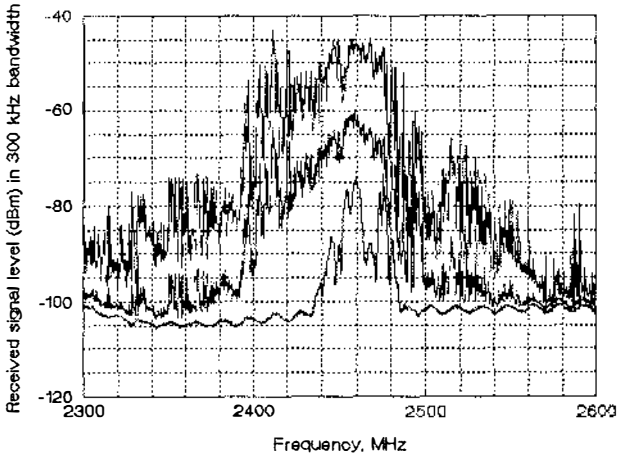
Compatibility measurements to show whether signals will cause interference to each other and to provide information for solving existing and potential problems

Much of the measurement system development was accomplished in previous years; however, system enhancement is a continuing process that is driven by new measurement requirements. The CRSMS, for example, is a dynamic measurement capability that has no permanent configuration. The measurements discussed here were made with variations of the CRSMS configured with standard software and mostly off-the-shelf hardware.

Wind Profiler: Measurements were performed on a newly developed wind-profiler radar system to assist in determining the frequency allocation for this new class of weather instrumentation. Wind profiler systems are expected to be installed at hundreds of sites in the United States to provide much improved data for weather prediction. The Institute measurements determined the radar emission spectrum, antenna pattern at ground level, antenna bandpass selectivity characteristics, and the susceptibility to interference from other signals. The results of these measurements will be used to select a band where these radars can operate without causing interference to other systems or suffering interference from them.

Microwave Ovens: Measurements were performed on both individual microwave ovens and on urban background environments to determine the impact that these devices have on the 2400-2500 MHz industrial-scientific-medical (ISM) frequency band. These measurements were needed to determine the impact that microwave ovens could have on proposed digital transmission systems that may operate in the band.

Occupancy site surveys were performed in the ISM band at a number of urban locations and at hilltop locations overlooking an urban area. These measurements gathered occupancy spectra and time waveforms as a function of time of day. The raw data were processed to produce graphs, like the one below, showing minimum, maximum, and average signal levels. Also, graphs were produced showing amplitude-probability distributions as a function of location and time of day. The measurements showed that peak-detection circuits picked up significant levels of activity in and around urban areas.



Aggregate emission spectrum of the ISM band measured from outside an apartment complex.

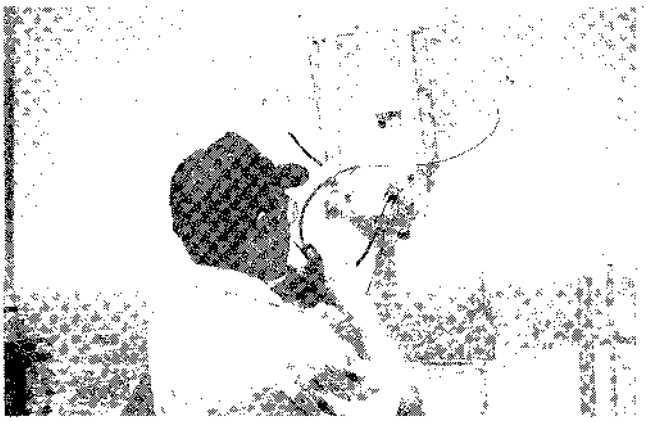
Several ovens were measured to obtain their emission spectra, time waveforms, and radiation patterns. The Institute used peak-response detectors for these measurements because they more nearly simulated the response of digital radio systems proposed for the ISM band and adjacent bands. The characteristics of the ovens were found to be similar over a range of manufacturers and features.

Spectrum Measurement Workshop: The Institute personnel, drawing on 20 years of experience in spectrum measurements, assembled and presented a 3-day in-house workshop for NTIA on spectrum measurement theory and techniques. The workshop, designed for engineers and managers who are responsible for radio frequency measurements, covered topics including convolution theory and application, calibration techniques, measurement algorithms for various types of emitters, especially radars, and "suitcase" measurement system design and utilization. This workshop is now being offered as a 3 1/2 day course to other government agencies and private sector entities.

Radar Interference Solution: A CRSMS was configured and used to evaluate an ongoing interference problem between an ARSR-1E air route traffic radar and a TPS-63 tactical surveillance radar. The measurement results allowed ITS to recommend a solution to the interference problem. The solution was implemented, and the interference problem was resolved.

Initial spectrum measurements showed that the TPS-63 caused interference to the ARSR-1E and quantified the reduction in TPS-63 sideband levels that would be required to end the interference problem. The Institute recommended a tuning adjustment in the TPS-63 transmitter bandpass filter. The retuning was performed, and the retuned filter was tested by ITS to determine that the new bandpass characteristics were acceptable. When the retuned filter was installed in the TPS-63, the interference was immediately noted to have disappeared. Subsequent ITS measurements on the TPS-63 emission spectrum and on the ARSR-1E receiver levels documented that the interference had been eliminated.

DOD Microwave Site Surveys: The CRSMS was used to perform site surveys in point-to-point microwave bands. At seven sites in each of five U.S. cities, the CRSMS system was deployed on the roof of a skyscraper, usually the highest skyscraper in the city. The results were used to verify modelled received-signal levels and to identify anomalous propagation paths. For these measurements the CRSMS computer was used for data acquisition and direction control of an antenna to automatically search out weak microwave signals. A dual polarization feed on the receiving system gave separate vertical and horizontal received signal levels, which aided in identification of observed signals.



Frank Sanders on the Roof of a Skyscraper in Dallas Preparing the CRSMS for Point-to-point Microwave Measurements

PacTel Usage Measurements: A CRSMS was utilized for measurements in several potential Personal Communication Services (PCS) frequency bands (14 identified sub-bands within the 600 MHz to 2600 MHz range). Measurements were performed in five major U.S. cities: Chicago, Dallas, Los Angeles, New York, and San Francisco. More than 35 measurement sites were visited in each city to meet the objective of providing good statistics of geographical variability on spectrum usage. A custom CRSMS with a specially designed rf front end was deployed in a Mini-Van with a wideband omnidirectional antenna mounted on the roof.

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Spectrum Surveillance System Development

Outputs

- Advanced measurement systems supporting spectrum management, testing, and verification
- Software for automated spectrum measurements and analysis
- Improved productivity and capability in spectrum analysis systems

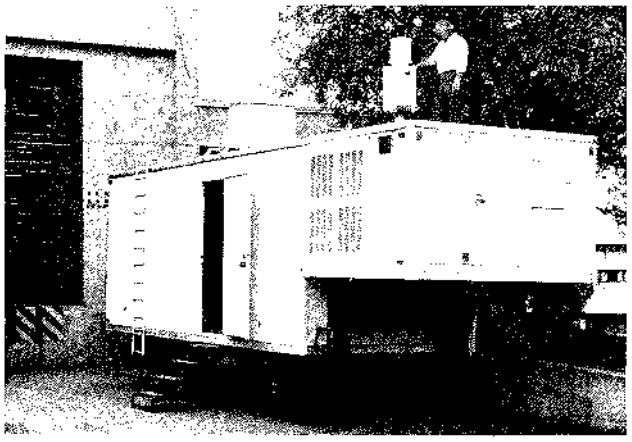
Measurement experience gained with almost 20 years of developing and operating the Radio Spectrum Measurement System (RSMS) and other automated rf measurement systems has given ITS a unique expertise in the design and development of spectrum measurement systems. This expertise has been applied to the problems of other Government agencies, resulting in the development of several prototype systems in the last few years. These systems have been characterized by extensive use of off-the-shelf equipment, MS-DOS software, and excellent capabilities for unattended data collection.

Completion of the two frequency control and analysis (FCA) vans for the Air Force was a major achievement in FY 91. This project provided two highly-mobile, 4-wheel-drive systems, which will be used to monitor the rf environment during testing at the Utah Test and Training Range (UTTR). These systems pack a lot of capability into a small space, including full frequency coverage up to 40 GHz, spinning-dish direction-finding, a 25-ft telescoping mast, advanced radar pulse sorting and characterization, state-of-the-art noise figures, bandwidths to 30 MHz, and many other features.

The FCA Monitoring System Van

These systems are integrated with a computer system based on an MS-DOS 386 computer that allow a full range of control from fully manual to unattended fully automatic operation. Large amounts of measured data can be recorded on 44 M-byte Bernoulli discs with selected data saved on hard copy. The same software has been used on the various versions of the RSMS portable systems.

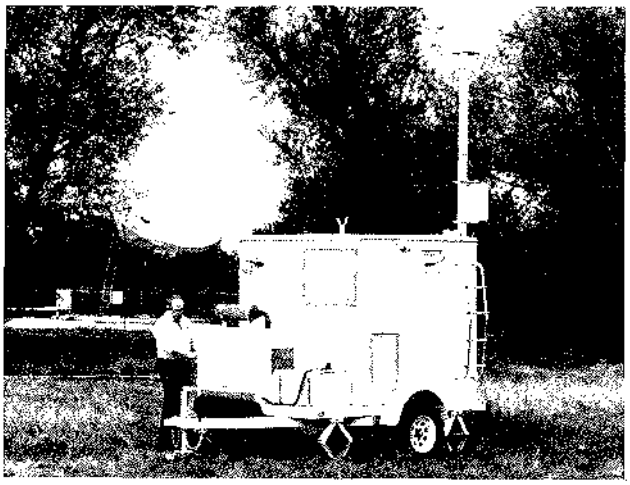
Ground Emitter Monitoring System (GEMS) is designed to intensively monitor the performance of a single radar. This system will be deployed in a 5th wheel trailer and will have a special pulse processing subsystem that will measure and record large amounts of data on every pulse emitted by a radar.



GEMS Trailer with Antenna Extended

A companion system to the GEMS is the remote antenna equipment. A small trailer contains an antenna and spectrum analyzer that are linked to the GEMS over a 10 km fiber optic link. Close-in support for weapons testing will be achieved while Air Force personnel will be able to reliably observe operations of radars and devices under test at a safe distance.

GEMS resulted in an extensive development contract for a pulse measurement system with the capability of measuring and storing data on up to 16,000 pulses per second (pulse descriptor words) to a read/write optical disk. The final system has gained significant capability with a new processor board which adds substantial capabilities to the instrument.



Remote Antenna Systems

These systems will form an integral part of the testing environment at the Utah Test and Training Range for Hill Air Force Base. They will become the test monitor system in support of weapons testing at the Dugway, UT, facility.

This effort by the Spectrum Use & Measurements Group of ITS has provided the Spectrum management community with a substantial software product that can be made available to other government agencies.

The software development program has seen continual improvement in the user-friendliness and flexibility of the measurement system, including many of the measurement techniques acquired over the years of operation of the RSMS. Although the software now runs under MS-DOS, we expect that it will soon be available for other operating systems such as UNIX in the near future.

The results of this development effort are being made available to other government agencies to bring expanded capability to the military as well as other civilian agencies. We will hold a spectrum measurement workshop in December 1991 to further train government personnel in the measurement techniques used with the UTTR and RSMS vans.

The vehicle that has transported the Radio Spectrum Measurement System (RSMS) since 1973 finally wore out mechanically and was removed from operational service in 1990. A new vehicle for the RSMS is being procured. It will be somewhat smaller than the previous vehicle and have a potential for air transport via a C-130. Four racks for equipment, two pneumatic masts with rotators, an elevation/azimuth antenna pedestal, a generator, and an integrated (cool/heat/ventilation) air-conditioning system are included in the basic vehicle configuration.

The entire instrument area will be shielded and all lines entering this area will be filtered. Previous measurement vehicles had some problems caused by electrical noise from the computer and instrumentation systems radiating noise outside the vehicle. Isolation from and direct access to the driving compartment will be provided by a sliding shielded door. The proposed RSMS vehicle is shown below.

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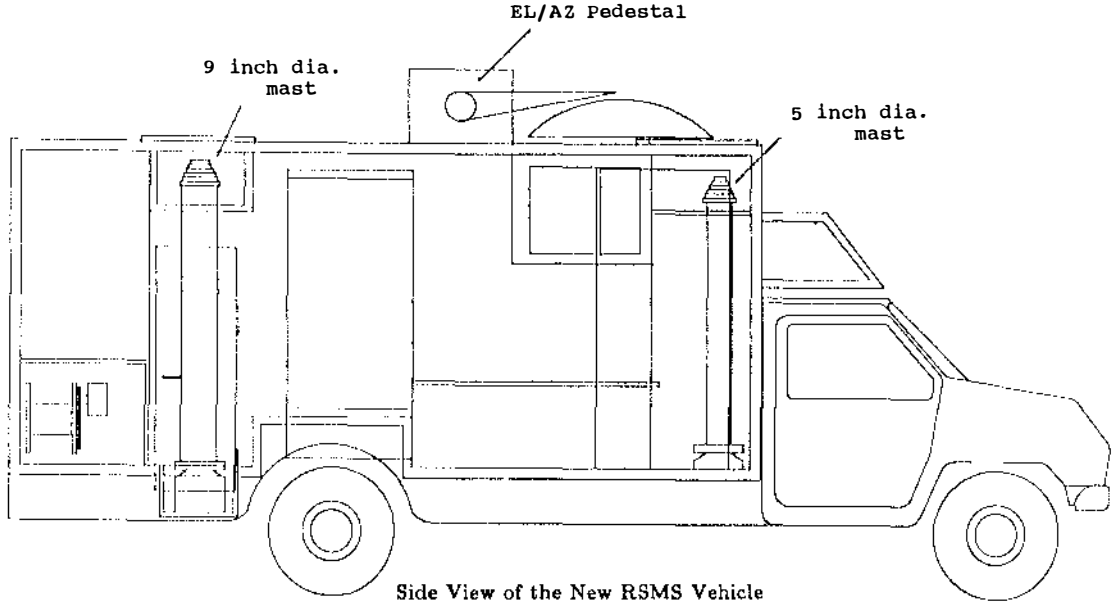
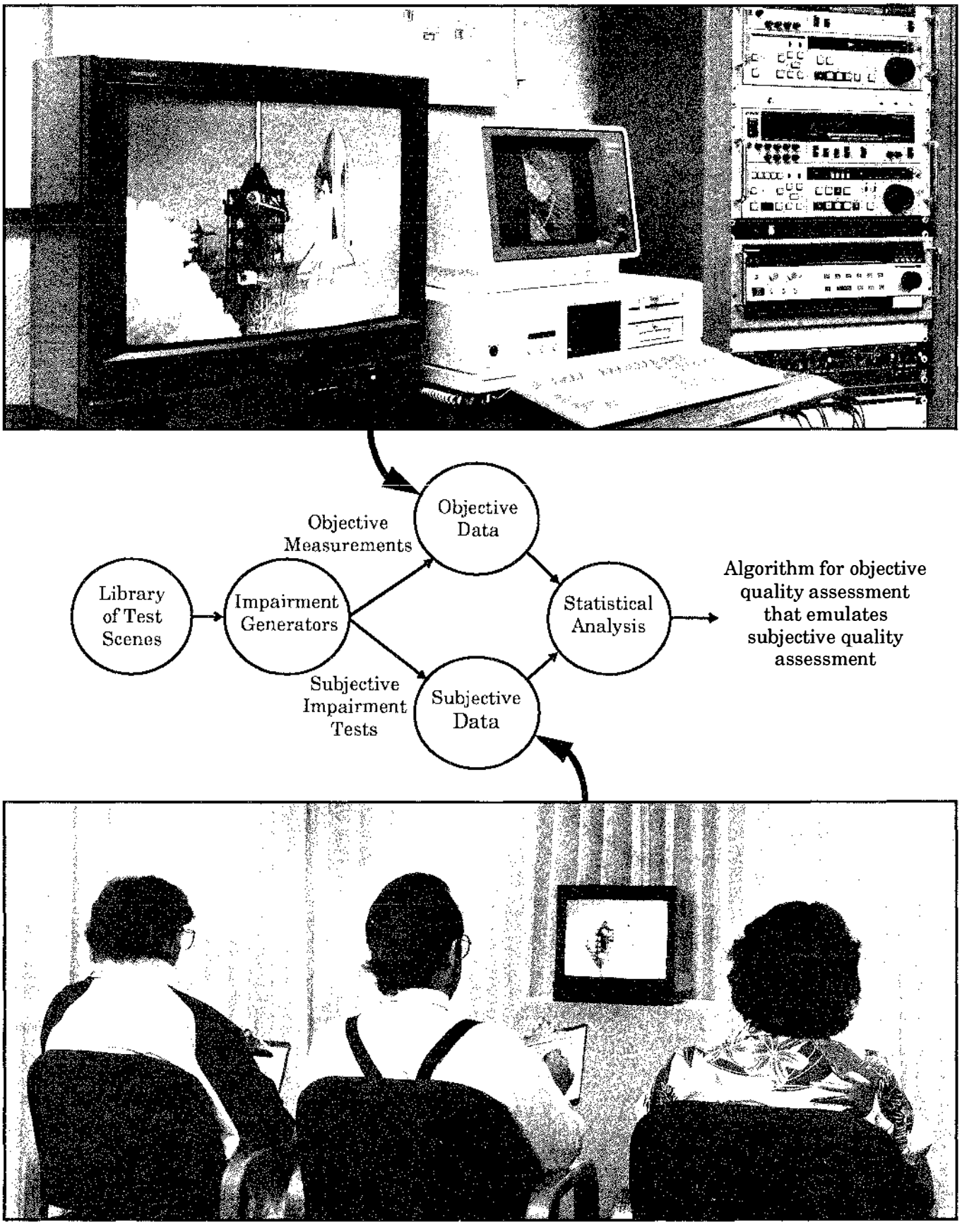


Side View of the New RSMS Vehicle



Video Quality Algorithm Development Process

TELECOMMUNICATION STANDARDS DEVELOPMENT

The Institute contributes significantly to the development and application of national and international telecommunication standards. These standards enhance the quality and reliability of our domestic telecommunications infrastructure, promote healthy competition in telecommunications products and services, and expand international trade opportunities for U.S. telecommunications firms.

During FY 91, ITS placed special emphasis on development of standards for Integrated Services Digital Networks (ISDNs) and supporting applied research in the areas of voice, video and data communications quality. These efforts address a growing need for efficient means of relating the telecommunications performance requirements of users with the capabilities of competing equipment and service providers.

Through its leadership roles and focused technical contributions, ITS assists the development of key Federal, national, and international standards. Institute staff members chair and contribute to national and international standards groups in ANSI-accredited Standards Committee T1 (Telecommunications) and in the two principal standardization bodies of the International Telecommunications Union (ITU): the International Telegraph and Telephone Consultative Committee (CCITT) and in the International Radio Consultative Committee (CCIR). The technical standards and Recommendations developed in these forums are increasingly becoming the blueprints for future telecommunications technology development.

Areas of Emphasis

CCITT Activities

Includes projects funded by the National Telecommunications and Information Administration

Video Quality Standards Development

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

Voice Quality Standards Development

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

Digital Network Performance Standards Development

Includes projects funded by the National Telecommunications and Information Administration and the National Communications System

Radio System Interoperability Standards Development

Includes projects funded by the Defense Information Systems Agency, the U. S. Naval Ocean Systems Center, the Federal Emergency Management Agency and the National Communications System

Telecommunication Transmission Media Technology Studies

Includes projects funded by the Department of Energy and the National Communications System

Telecommunications Terminology and Standards Information

Includes projects funded by the National Communications System and the U.S. Army Information Systems Engineering Command

CCITT Activities

Outputs

- U.S. CCITT Leadership
- Technical Contributions
- Proposed CCITT Recommendations

Advanced technical planning for public telecommunications has become internationalized and, increasingly, is focused in 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 needs.

The Institute provides strong support to the U.S. Department of State in leadership of the U.S. Organization for the CCITT. During FY 91, Institute personnel served on the U.S. CCITT National Committee, which guides overall U.S. participation in CCITT activities, and continued to provide the chairmanship of U.S. CCITT Study Group B, which coordinates and approves U.S. contributions to the CCITT on Integrated Services Digital Networks (ISDNs). U.S. CCITT Study Group B and its accredited U.S. Delegations contributed significantly to the development of Recommendations on Broadband ISDN (B-ISDN), Universal Personal Telecommunications (UPT), and Intelligent Network (IN) technologies. B-ISDN will provide high-quality video, voice, data, and multimedia services using the Asynchronous Transfer Mode (ATM), an innovative cell-based transmission and switching technology. Coupled with B-ISDN, the deployment of UPT and IN services will have a profound impact on worldwide telecommunications. For example, using wireless access and distributed IN databases, UPT will enable communication among users regardless of their locations. CCITT Recommendations on B-ISDN, UPT, and IN services 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 whose work is particularly relevant to Commerce goals. During FY 91, the Institute continued to lead the CCITT Study Group XVIII Special Rapporteurs Group for Question 5 as well as three standards groups within the ANSI-accredited T1 (Telecommunications) Standards Committee: Technical Subcommittee T1S1 and Working Groups T1Q1.3 and T1Y1.2. The Question 5/XVIII Rapporteurs Group is defining an overall technical basis for ISDN performance standardization and is developing a Specific Recommendation (I.35B) on B-ISDN performance. Subcommittee T1S1 has overall responsibility for developing American National Standards on telecommunication services, architectures, and signaling, and is the principal source of U.S. contributions to the CCITT on ISDN, UPT, and IN services. 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. Working Group T1Y1.2 develops American National Standards on voice quality measures and encoding technologies.

The work of Subcommittee T1S1 was particularly productive in FY 91. This group has grown consistently since its formation in 1988 and is 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 15 subordinate groups. During FY 91, Subcommittee T1S1 processed over 1800 technical contributions from member organizations; developed 283 contributions to international standards committees, including CCITT Study Groups XVIII, XI, and I; and completed seven American National Standards and two T1 Technical Reports. The group's activities involve 20 separate T1 standards development projects and encompass a wide range of topics including the main areas of architecture and services, switching and signaling protocols, common channel signaling, and broadband ISDN. To facilitate international standards development, Subcommittee T1S1 also

maintains important liaisons with counterpart organizations such as the European Telecommunications Standards Institute (ETSI) Network Architecture (NA) Committee. Current T1S1 work is focused on B-ISDN, including user-network interface specifications and connection and call control protocols, ISDN networking including intelligent networks, switch-computer application interfaces, ISDN private networks, and enhancements to Signaling System Number 7.

The Institute's CCITT technical contributions during FY 91 were focused on development of ISDN performance Recommendations within Study Group XVIII. Institute staff members contributed significantly to draft Recommendations I.351R, I.35E, I.35A, I.35P, and I.35B. *Recommendation I.351R* defines the overall structure for a related set of CCITT Recommendations that collectively provide a comprehensive basis for international ISDN performance specification. *Recommendation "I.35E"* defines ISDN performance apportionment boundaries and identifies the set of protocol-specific reference events that are used in defining the ISDN performance parameters. *Recommendation "I.35A"* specifies availability performance of ISDN 64 Kbit/s connection types. *Recommendation "I.35P"* specifies performance of ISDN packet mode bearer services. *Recommendation "I.35B"* defines speed, accuracy, and dependability performance parameters for the ATM layer of a B-ISDN.

Institute staff members are also contributing to CCITT efforts to establish relationships between the ATM performance parameters defined in Recommendation "I.35B" and the error parameters for high-speed digital circuits defined in Recommendation "G.82X". The initial focus has been on examining achievable values for ATM cell error ratio based on values for errored seconds and severely errored seconds. A goal of ongoing work is to analytically relate network performance specified at the physical layer of a B-ISDN with network performance specified at the ATM layer and, eventually, with the network performance of services provided by the ATM Adaptation Layer (AAL).

A major goal of Institute standardization activities is to achieve beneficial synergy between related U.S. national and international standardization activities--and compatibility between the resulting national and international standards. This is demonstrated, for example, by the coordination of U.S. work on an American National Standard (ANS) for ISDN performance ("T1.I") with related work on ISDN performance Recommendations in CCITT Study Group XVIII. The "T1.I" standard will ultimately provide a unified basis for performance specification and allocation of ISDN circuit mode, packet mode, frame mode, and ATM bearer services. The parameter definitions, specifications, and measurement methods being developed in T1.I are technically consistent with the evolving ISDN performance Recommendations. Good synergy and compatibility has also been achieved in the development of ANS T1.504a, "Packet-Switched Data Communication Service--Performance Measurement Methods," and a new CCITT Recommendation, X.138, that defines performance measurement methods for international packet-switched public data networks. A continuing emphasis of the Institute is to provide technically strong, broad-based contributions that assist in the accomplishment of U.S. objectives in both national and international standards bodies.

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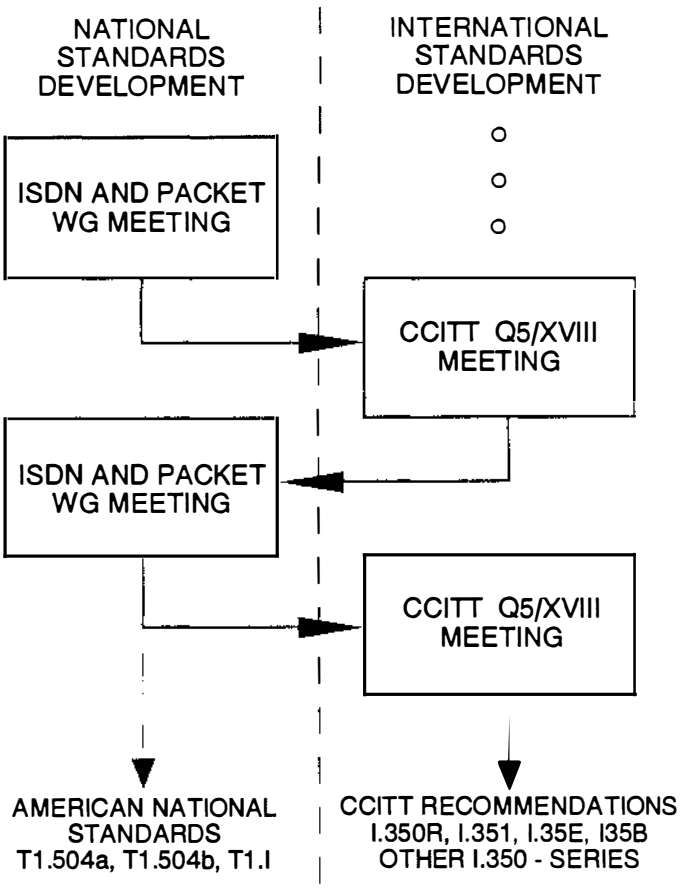

Coordination of National and International Standards Development

Video Quality Standards Development

Outputs

- Automated video quality measurement techniques and software
- Contributions to national and international standards committees
- Video expertise provided to NTIA, Department of Commerce, and other government agencies for establishing U.S. policy on advanced video technologies

Performance is important to end users when selecting telecommunications equipment/services and to providers when designing/operating telecommunications facilities. Objective measures of telecommunications system performance should accurately reflect user-perceived quality. The advent of new technology and services has exposed many shortfalls of current methods used to measure performance. Video signals are now commonly transmitted and stored in compressed digital form, with a potential loss of quality resulting from the compression process itself or from the decreased resilience of the compressed data to transmission impairments. Effective video compression algorithms are dynamic, with the input signal dictating the overall behavior of the algorithm through many sub-algorithms that perform motion prediction, adaptive transforms, adaptive pixel and/or frame prediction, and adaptive quantization, to name only a few. The resulting systems are clearly time-varying systems. Examples of new digital video impairments include edge busyness, blocking, image persistence (the presence of earlier image frames), and jerky motion. While traditional measurement techniques employing simple test signals are indispensable for the characterization of the electrical performance of conventional, time-invariant analog systems, these measurements often do not correlate well with quality as perceived by the end users of modern digital compression and transmission systems. As a result, viewing panels have been used to subjectively evaluate these modern distortion effects on the received video quality. New objective measures of video transmission quality are urgently needed by video designers, service providers, end-users, and standards organizations. Moreover, due to the rapid advancement of video coding and transmission technology, these new measures should be technology independent (independent of the coding algorithm and transport technology) and applicable to a wide range of video systems. For example, the user may need to measure video quality for the following video systems: analog NTSC, D-1 (digital component), D-2 (digital composite), JPEG (Joint Photographic Experts Group, still image compression standard), MPEG (Motion Picture Experts Group, random-access media compression standard), P x 64 (telecommunications video standard H.261), and future high definition television.

The Institute for Telecommunication Sciences (ITS) is conducting research to derive objective measures of video quality that are technology independent and that emulate human perception. These measures are valuable because they provide video designers, service providers, end-users, and standards organizations with a cost effective means for making quality evaluations without convening viewer panels. The derivation of these measures involves the following steps. (1) A set of test scenes is selected and distorted by representative coding and transmission impairments. Since many test scenes are required to characterize the performance of the video codec and transmission channel, and since many impairments must be examined to assure that the objective measures are technology independent, ITS has conducted tests that use a large data set consisting of 36 test scenes and 29 different impairments. (2) A set of candidate objective measurements that quantify video scene distortions that are important to the human visual and perceptual systems are extracted from the digitized original and distorted video signals. In parallel, a panel of viewers watches the same set of test scenes and their subjective judgments of the distortions are recorded. (3) A simultaneous statistical analysis of the objective and subjective data sets is conducted. This analysis reveals which portion of the objective data set is meaningful, and how the objective data should be combined to create an objective metric that emulates human perception.

The work performed by ITS is currently being considered for inclusion into the draft standard of Analog Interface Performance Specifications for Digital Video Teleconferencing/Video Telephony (VTC/VT) Service by the American

National Standards Institute (ANSI) Accredited Standards Committee T1, Working Group T1Q1.5. Very encouraging preliminary results have been obtained. One objective measure, designed to measure the false edges in the output video (edges in the output video that are not in the input video), is illustrated in Figures 1 and 2. The original input video (top image, Figure 1) was a black ring that was moving from left to right. The distorted output video (bottom image, Figure 1) was obtained from a VTC/VT system. Out-of-place artifacts in the output video, such as blocking around the ring and image persistence, are very objectionable to human viewers. The false edge energy measure for the output video of Figure 1 is shown in Figure 2 as black pixel values. Note the well defined blocks in Figure 2. Accumulation of all of the energy in the black pixels in Figure 2 represents the total false edge energy in the output. The false edge measure has been shown to provide a reasonably accurate prediction of user-perceived impairment for a set of 15 video scenes of various quality levels. In Figure 3, the subjective impairment score for each scene is plotted against the false edge energy measure for the scene, along with the best fitting line. Note that video scenes that contained more false edges were judged to be more impaired.

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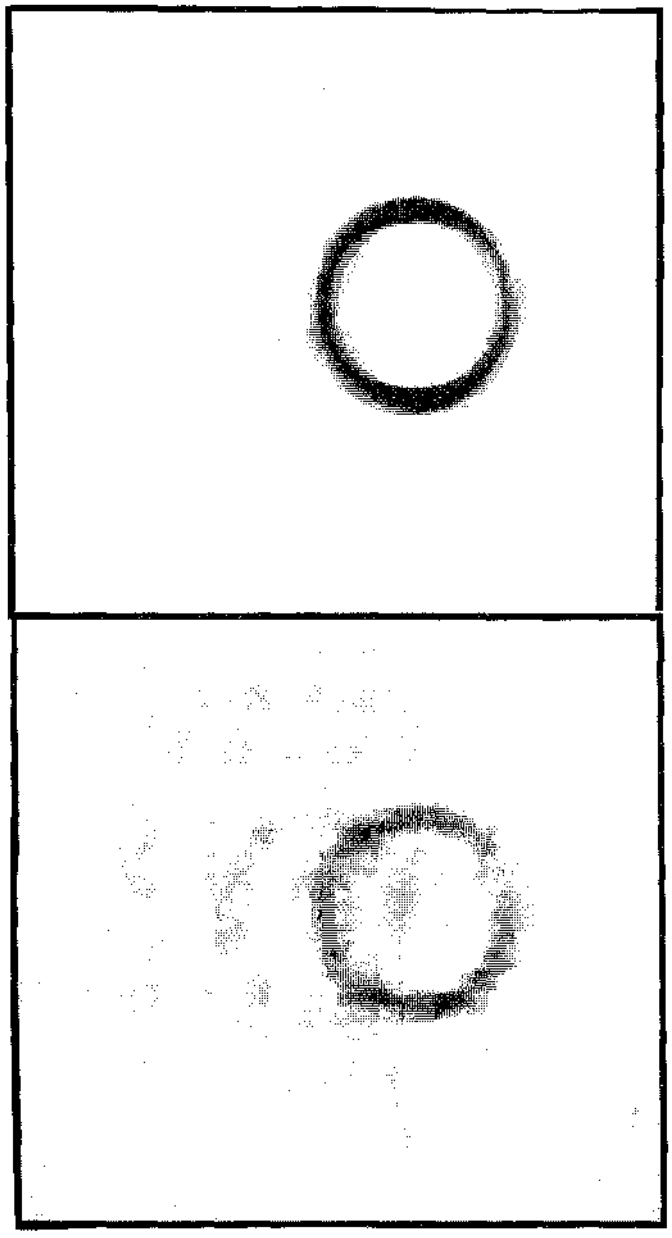


Figure 1. Original Image (top) and Distorted Image (bottom)

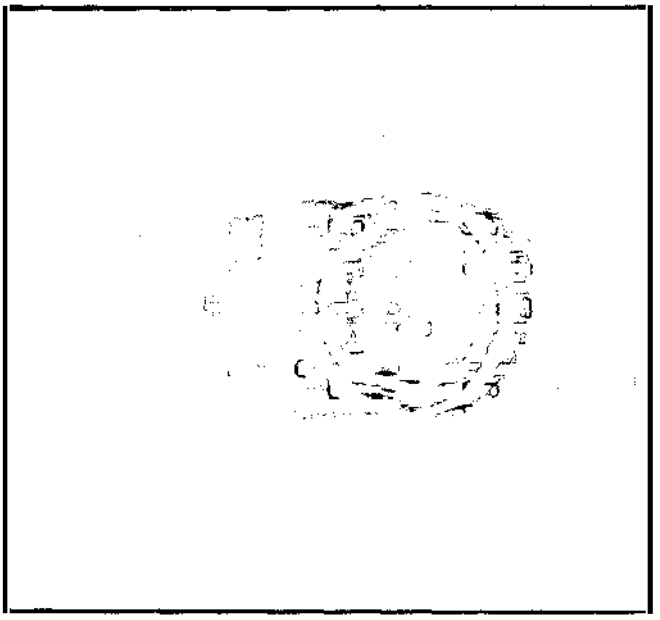


Figure 2. False Edge Energy Measure for Figure 1

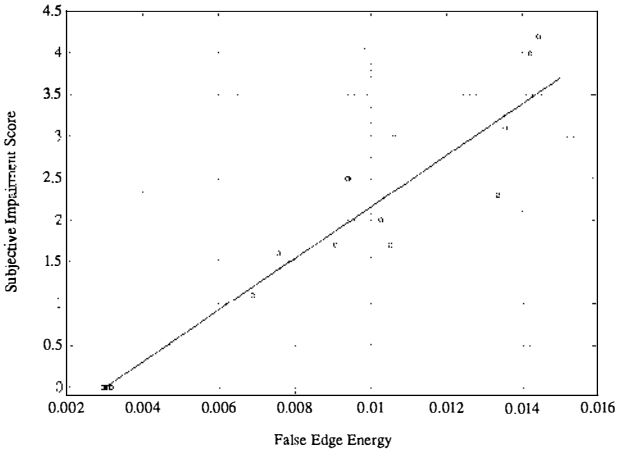


Figure 3. Subjective Impairment Core Plotted as a Function of False Edge Energy

Voice Quality Standards Development

Outputs

- Contributions to standards organizations
- Operational voice quality assessment software
- Techniques for analyzing voice parameters
- Evaluation of speech coding techniques
- Objective assessment of technologies

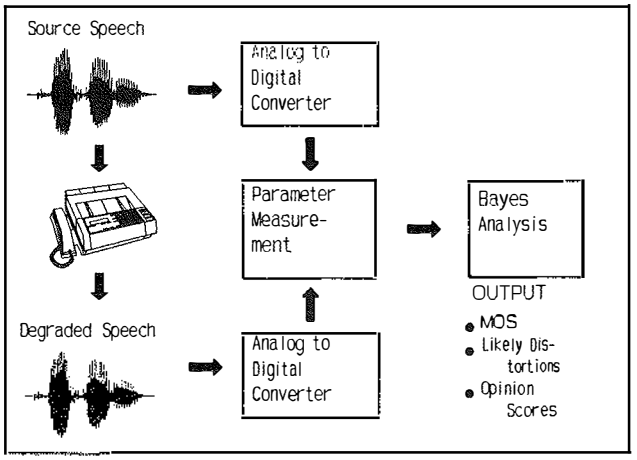
Voice Quality Standards. Gauging the performance of voice communication services and equipment is an important element of the design and operation of modern telecommunication systems. Accurate measurement of speech transmission quality enables the speech communication system engineer to relate system design variables directly to end-user satisfaction. Development of a new digital radio, for example, requires an engineer to select many design parameters that may affect voice quality. Typically, the parameters are chosen to produce what the engineer assumes will be 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 impractical. A tool for automatic, or "objective", assessment of voice quality has therefore been sought for many years. Such a system would offer 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, perhaps requiring only a personal computer and simple analog-to-digital conversion equipment. The low cost of an automated system would make 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 and optimization, 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.

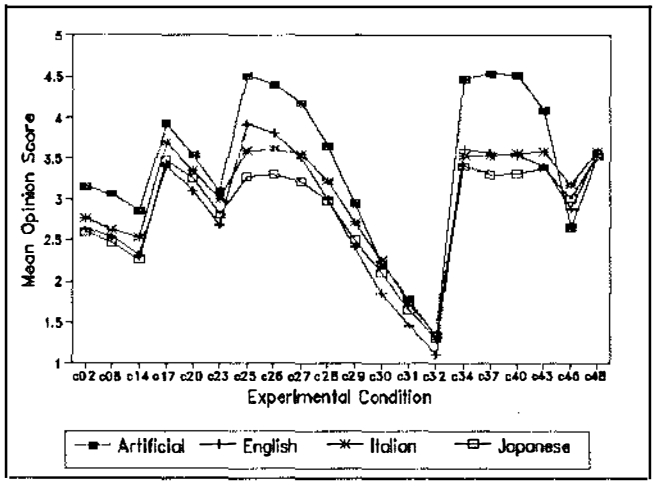


ITS Automatic Voice Quality Assessment System

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 91, 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 participated in a CCITT SG XV subjective and objective test of 16 kbit/s speech coding techniques, and in planning a similar 8 kbit/s test. Included in the codec test was 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.



Test Results of ITS Voice Quality Assessment System

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 above 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.

Data from the following table illustrate the performance of several voice quality measurement techniques. As indicated, the techniques used are those submitted by France, Japan, Canada, and ITS. The table shows the degree of correlation between each technique and the set of subjective scores for a North American English (NAE) speech database including samples from both male and female talkers. A value of 1.0 indicates perfect correlation between the objective technique and the subjective scores, while a value above 0.9 is considered very good performance for a technique.

Squared Correlation Coefficient

Talker	France	Japan	Canada	ITS
Female	0.694	0.896	0.836	0.975
Male	0.658	0.891	0.784	0.958
All	0.688	0.902	0.816	0.977

The Institute is providing leadership in the development of national standards for related areas of voice telecommunications. A member of the ITS voice quality project chairs the ANSI accredited Specialized Voice and Data Processing Working Group, T1Y1.2.

Synergic Research. Voice Communication Interoperability Standards research was added as a component of the Voice Quality Program in FY 91. The voice quality assessment system described previously will be used to develop and optimize interoperability standards for existing and proposed advanced voice communication systems, since it provides an objective means of comparing alternative voice transmission technologies and has shown promise in predicting levels of human perceived quality.

Additional tasks in this component include evaluation and work towards standardization of contemporary speech coding techniques, evaluation of the Quantization Distortion Unit (QDU) and its use as a measure for network planning versus the use of a new objective measure, and objective assessment of the voice quality of application-specific communications such as digital mobile radio.

In a related project, ITS is applying statistical speech segmentation techniques, derived from voice quality research, to develop phonemic correlated features and a phonemic classification algorithm to be used in spoken language identification.

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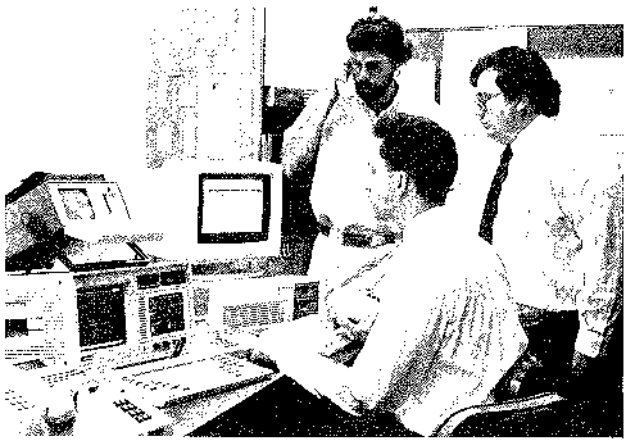
Digital Network Performance Standards Development

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, Institute staff members have 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. All Federal departments and agencies are now required to employ the ITS-developed performance specification and measurement standards 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 91, the Institute expanded the capability of its digital network performance test facility and began planning future testing capabilities to better serve the interests of NTIA, Commerce, other Federal agencies, and standards bodies.



Engineers Tim Butler, Keith Junker, and DJ Atkinson Conduct ISDN Performance Experiments

ISDN Performance Measurement Laboratory. A major current 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 implemented two significant enhancements to the ISDN laboratory established in FY 90. First is the ability to provide switched video teleconferencing services at 64 and 128 kbit/sec. Second is the integration of error and delay generation equipment into the primary rate interfaces (PRIs) of the ISDN mini-switch.

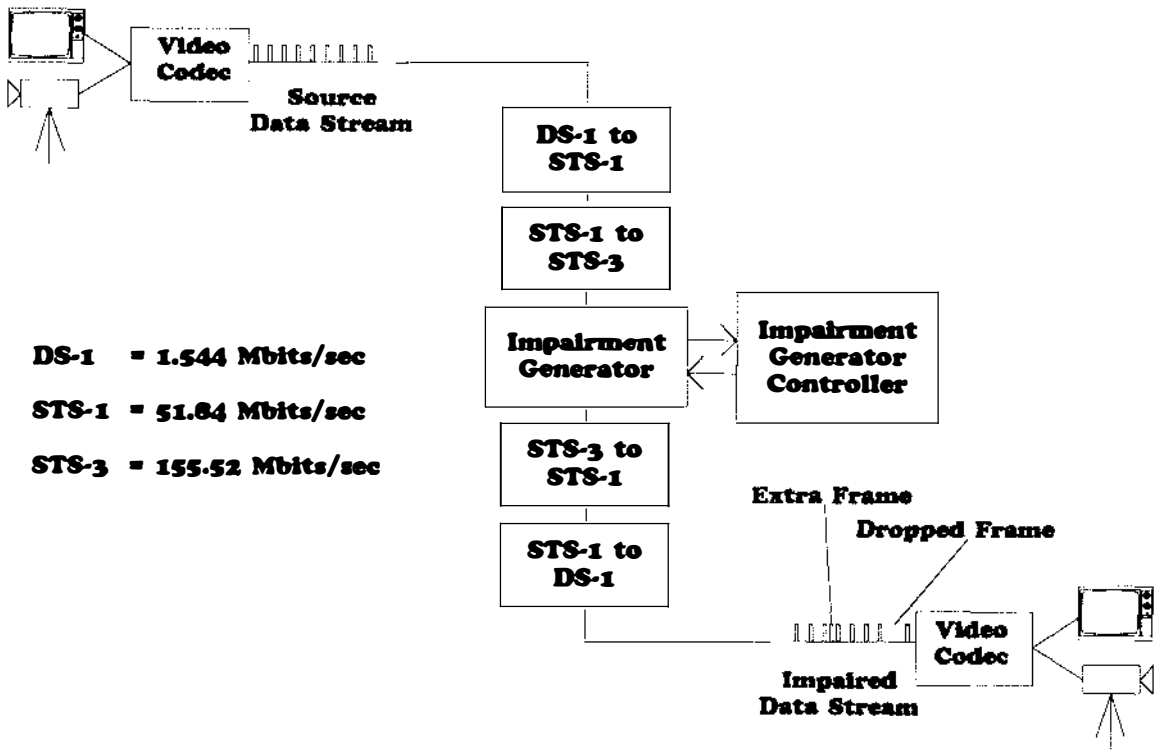
Advanced Telecommunications Standards Development. The National Communications System (NCS) has tasked the Institute to assist it in the development of telecommunication standardization strategies based on emerging ISDN technologies. Current technical support includes enhancing existing Institute data 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. Toward this goal, Institute personnel implemented measurement tools in software to allow measurement of all performance parameters specified in Draft American National Standard T1.I ("Specification and Allocation of Performance for ISDN"), which is under development in Technical Subcommittee T1Q1. The new software, in conjunction with previously written Data Reduction and Data Analysis software, provide a capability to quickly implement new T1.I parameters as they are proposed. The performance measurement system, including software and terminal equipment, is implemented in the ITS digital network test facility and will be thoroughly tested on basic rate and primary rate ISDN connections established using the laboratory's stand-alone ISDN mini-switch. Once the test system is deemed ready, the mini-switch will be supplemented by operational ISDN network capabilities, including one or more commercial ISDN services and a satellite-based ISDN transmission and switching system. 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. As part of its advanced telecommunications standards development work, the Institute keeps NCS informed of progress on relevant developments in national and international ISDN performance standards committees by providing technology summaries and strategy briefings on a monthly basis.

Integrated Voice/Video/Data Performance. The Institute is also working to assist NCS in evaluating how emerging technologies will affect the ability of networks to provide adequate communications under conditions of national emergency. ITS has been tasked by NCS to study aspects of one particular emerging technology, Broadband ISDN (B-ISDN). B-ISDN will provide multi-media (voice, video, and data) communication services that are fully integrated. ITS began developing quality assessment capabilities for multi-media B-ISDN services in FY 91 and will continue that work into FY 92. An initial step was to develop a capability to encode and transmit multi-media communication signals in an integrated fashion in the laboratory. That capability was achieved by connecting video teleconferencing codecs through 64 kbit/sec and 128 kbit/sec ISDN channels established by the ISDN mini-switch. These capabilities are sufficient for preliminary research into integrated services performance, but for proper study, higher bandwidths must be made available. In order to accomplish this, ITS began the design of a B-ISDN Asynchronous Transfer Mode (ATM) simulator. The simulator will be developed in two phases. The simulator developed in phase 1 will operate at 1.544 Mbits/sec (DS-1), which will allow a significant portion of the development work to be focused on the selection and implementation of impairment models. Phase 2 will concentrate on increasing the data rate from 1.544 Mbits/sec to 155.52 Mbits/sec (STS-3). To provide maximum flexibility, staged interfaces will be used in providing a data stream to the impairment generator. This will allow the simulator to be compatible with interfaces which have data rates of 1.544 Mbits/sec, 51.84 Mbits/sec (STS-1) and 155.52 Mbits/sec.

The Institute will use the simulator in conducting experiments to determine the effects of impairments in a single communications medium (e.g., voice) on overall quality of a multi-media service (e.g., video teleconferencing). This will be done with subjective testing in the ITS CCIR Recommendation 500 compliant subjective viewing room. The subjective results obtained from these experiments will be used to develop new objective measures that combine quality aspects of all elements of a multi-media service into one number which represents overall quality of that service.

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



ATM Simulator Concept

Radio System Interoperability Standards Development

Outputs

- FTSC subcommittee leadership and technical support
- Interoperability standards for radio systems
- Radio systems interoperability evaluations
- Standards impact assessments
- Emergency antenna evaluation

Standardization has long been used by Government as a means of achieving cost reduction in large procurements. Telecommunication standards also improve the effectiveness of Government operations by promoting interoperability among systems used by cooperating agencies. Improved interoperability in turn benefits providers by increasing aggregate markets for telecommunication products. The Institute works to achieve these benefits by assisting the National Communications System (NCS) and other Federal agencies in a number of programs focused on the development of Federal Standards for radio communications. This work involves leadership of Federal telecommunication standards committees, extensive liaison with radio system providers to identify concepts suitable for standardization, and actual implementation of selected concepts in prototype hardware to demonstrate their feasibility. The prototype testing also helps ensure product interoperability.

Development of Advanced HF Radio System Standards. The goal of this standards development program is to promote the implementation of advanced communication protocols and signal processing technologies in practical HF radio systems. The resulting improvements in system performance will substantially enhance the effectiveness of many essential functions of the U.S. Government, including liaison with other countries. For example, counter-drug initiatives cannot be effective without interoperability of radios between participating organizations. During FY 91, the Institute promoted the development and standardization of advanced HF radio system concepts through its leadership of a joint industry/Government HF radio technical advisory committee.

HF Radio Enhanced Interoperability Testing Facility (EITF). The EITF is an enhancement to the very successful Interoperability Test Facility established during the 1989-1990 Fiscal Years to support the development of the Fed Std 1045 family of adaptive HF radio standards. The EITF will be used in developing and validating adaptive HF radio standards including pFS 1046 (Networking of HF ALE radios), pFS 1047 (Message Store and Forward), pFS 1048 (Multi-media), and pFS 1049 (HF radio in Stressed Environments). The EITF will provide an environment for proof-of-concept testing prior to the release of each standard. The EITF will also assist Federal Government agencies and manufacturers of adaptive HF radio systems by providing a capability for interoperability testing of products manufactured to the new standards. In preparation for testing of message store and forward and multi-media standards, the Institute is developing plans to expand the laboratory to include VHF and UHF capabilities, and will be developing a computer-controlled patching facility for audio, RF, and data signals.

HF Radio ALE Interoperability Testing. The Institute's HF test facility operations have demonstrated the benefits of testing early in the standards development process. ITS performed verification testing of the concepts being developed in the preparation of proposed FS (pFS)-1046 and 1049 during the fall of 1990. Several radio systems were modified to implement pFS 1046/1049 concepts. These two standards will specify advanced features that provide networking and linking protection capabilities for the HF radio systems.

Advanced HF Radio Interoperability Assessment. The Institute provided assistance to the Naval Ocean Systems Command (NOSC) to enable laboratory evaluation of new protocols for the transmission of data over HF radio channels. Watterson HF channel simulators were used to enable the measurement of bit error rates through a variety of data modems provided by NOSC. Experimenters were able to quantify the effects of various data modem options on the data throughput.

Operational and Technical Analysis of Broadband Antennas. An evaluation of several commercially-available, low-cost broadband antennas was performed in support to the Federal Government's Shared HF Resources (SHARES) Program. The findings of this study will provide recommendations to the membership of SHARES

regarding which antennas are suitable for portable, tactical, or emergency service.

FEMA Survivable Antenna Refurbishment or Replacement Assessment. As part of a Congressionally-mandated upgrade program, ITS is performing an assessment of the Federal Emergency Management Agency (FEMA) National Radio System (FNARS) survivable antenna systems. This HF antenna system is a "pop-up" vertical telescoping monopole antenna designed for below-surface installation in a steel and concrete silo. Twenty-four of these systems are currently installed at ten sites. These antennas have experienced deployment and operational problems and are considered to be in poor structural and mechanical condition. The ITS project includes: (1) individual site inspections and antenna pattern measurements plus development of a computer-based antenna performance model; and (2) solicitation to industry for candidate replacement antennas, assessment of the proposed antennas' abilities to meet FNARS survivable antenna requirements, cost/performance comparisons between the current antennas and each of the proposed replacement antennas, and final recommendations to the sponsor.

Testing of Advanced Concepts. The EITF will be utilized, on an "as-required" basis, to provide testing services in the evaluation of advanced communication systems, modems and protocols that are being suggested by manufacturers to enhance HF radio operations in stressed environments. Plans are being made to evaluate new Automatic Link Establishment (ALE) protocols and frequency hopping systems in the very near future. Laboratory evaluation using the EITF's Watterson model simulators as well as over-the-air tests will be conducted.

Land Mobile Radio Interoperability Standards. The Institute serves as the Secretariat and provides technical support to the FTSC Land Mobile Radio Subcommittee. Support to this subcommittee includes waveform analysis, critical technical review of proposed standards, and economic analyses for proposed standards. The Institute also provides technical assistance to the Advanced Technology Subcommittee of the Associated Public-Safety Communications Officers, Inc. (APCO) Project 25 Committee in fostering land mobile radio interoperability among Federal and civilian law enforcement and public safety organizations, nationwide.

Federal Standard 1055 Validation. The Institute provides technical support to the National Communications System (NCS) in the development of three Federal interoperability standards related to Meteor Burst Communications (MBC). Proposed Federal Standard 1055 defines the basic interoperability requirements and technical characteristics for communications between master and remote stations. Proposed Federal Standard 1057 defines interoperability requirements for communications between gateway master stations located in different networks. A companion document, proposed Federal Standard 1056, defines standard methods of encryption for sensitive or classified data transported via MBC. During FY 91, the Institute prepared drafts of all three standards and began their coordination with NCS and industry participants.

Recent Publications

In addition to the various formal publications noted below, the radio systems interoperability standards work has provided working documents that contribute to the development of the following segments of Military Standard 187-721: linking protection, automatic message exchange, and sounding and polling. Work also was directed to the development of Proposed Federal Standard 1049, "Telecommunications: HF Radio Automatic Operation in Stressed Environments".

Interoperability Testing of Tactical HF Radio Systems to Ensure Operational Mission Fulfillment (by Peach)

Methods for Development of Telecommunication Standards that Provide User Flexibility and OSI Conformance (by Peach and Adair)

For information, contact:
Robert T. Adair (303) 497-3723

Dave Peach, Nathaniel McMillian, and Dave Wortendyke Perform HF Radio Automated Test and Data Collection Activity

Telecommunication Transmission Media Technology Studies

Outputs

- ANSI standards for on-premises telecommunication wiring, optical fibers, and optical-fiber cables
- Federal standards that adopt the technical content of these industry standards
- Survivability criteria for long-haul optical fiber systems

The Federal Telecommunication Standards Committee (FTSC), chaired by the National Communications System, 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 when Federal and industry standards objectives coincide. The goal of this cooperative process is adoption of the resultant industry standards as Federal standards, thereby ensuring Government/industry compatibility in technical specifications. An extension of this goal, in the interest of promoting U.S. trade and commerce, is international standards harmony, achieved by encouraging the participation of non-U.S. standards organizations in the standards-development process. During FY 91, the Institute continued its contributions to Federal and industry standards efforts, focused on an often-neglected component of modern high-capacity telecommunication systems: the transmission line. The Institute's contribution proposed standards for: (1) metallic and fiber optic transmission media used in on-premises applications; and (2) survivability of long-haul optical-fiber systems. This work involved participation in activities of the Telecommunications Industry Association (TIA) in collaboration with the Canadian Standards Association (CSA), the FTSC, and the ANSI-Accredited T1 Standards Committee.

On-Premises Transmission Media Standards. Institute staff members have contributed significantly to TIA TR-41 Working Groups in standardizing technical specifications for on-premises metallic and optical fiber telecommunication wiring, and to TIA FO-6 Working Groups in technical specification of optical fibers and optical-fiber cables. The TR-41 work resulted in publication of three industry standards during FY 91. The first is ANSI/EIA/TIA-568, proposed Federal Standard (pFS-) 1090. This standard defines a generic telecommunication wiring system for commercial buildings and will support a multiproduct, multivendor environment. The standard specifies performance and topology for various media. It adopts the multimode optical-fiber specifications of ANSI/EIA/TIA-492AAAA (FIPS-PUB-159), authored by ITS staff. The second is a companion standard, ANSI/EIA/TIA-569 (pFS-1091), which defines commercial building architectural requirements for telecommunication-media pathways (e.g., conduits) and spaces (e.g., rooms for associated equipment). The third is ANSI/EIA/TIA-570 (pFS-1092), which defines a generic telecommunication wiring system for residential and light commercial buildings. Two additional allied standards are being developed to address administration of commercial building wiring, and separately, the bonding and grounding of telecommunication wiring. They are planned for adoption as Federal Standards 1093 and 1094.

The first nine of a family of optical-fiber cable standards in the hierarchical EIA/TIA-472-series have been developed with the strong participation of Institute staff members. The Detail Specifications (the EIA/TIA procurement documents) on indoor and outdoor cable, which give minimum values for optical, mechanical, and environmental parameters, are planned for adoption as both American National Standards and Federal Standards. This will be the first time that performance standards for optical-fiber cables have been available to the user community.

These Detail Specifications are parts of a comprehensive set of EIA/TIA performance standards for optical fiber cable. This hierarchical specification system comprises four tiers:

(1) The singular Generic Specification, EIA/TIA4720000-A, which is the umbrella document for all optical fiber cables. It delineates minimum requirements that are common to all optical cable types, and it

provides a "shopping list" of test requirements and test methods that may be applied to application-specific or design-specific cable families.

(2) A set of multiple Sectional Specifications, which defines requirements for a cable family, ordered by primary applications (e.g., indoor or outside use). Each sets forth minimum testing requirements applicable to all cables of the cable family. Sectional Specifications reference the Generic Specification, extracting requirements applicable to the cable family. They may introduce other requirements that are not addressed in the Generic Specification. Values for most requirements are delegated specifically to the Detail Specification.

(3) Blank Detail Specifications, which are prepared for each of a limited series of cable designs (e.g., optical fibers with metallic elements) within the family of the relevant Sectional Specification. Blank Detail Specifications give specific editorial directions for writing individual Detail Specifications and may introduce additional requirements that are not addressed in the higher order documents.

(4) Detail Specifications, which follow the applicable Blank Detail Specification and provide detailed requirements for specific applications. They also may introduce additional requirements not addressed in the higher order documents. Values for primary performance requirements are given in the Detail Specification. Detail Specifications may be written by EIA/TIA Working Groups or by manufacturers. Some attributes that are normally expected to vary between purchases (e.g., cable length) may be delegated to individual procurement documents. The procurement document references the applicable Detail Specification.

Survivability Standards for Fiber Optic Links. Institute staff members have been assisting the National Communications System (NCS) in developing a proposal for a series of standards for protection of fiber optic links. The protection will provide an enhancement of durability (survivability) when links are subjected to physical stress (e.g., earthquake, wet conditions, extreme temperatures, rodents, backhoes) and radiation. The radiation threat could come from radiation leaks near telecommunication facilities or fiber cables (e.g., a nuclear power-plant excursion or an industrial spill of radioactive material), natural radiation sources, or nuclear explosion. This proposal has received preliminary approval by the ANSI-accredited T1Y1 standards group and will be promulgated to the T1 Committee for final review.

This project will develop baseline and above-baseline standards addressing the durability of fiber-optic (and copper outside plant) telecommunication links when exposed to different levels of physical stress and radiation effects.

The **Baseline Standard** is intended to establish foundation level protection from damage due to physical stress and radiation under typical geographic and local environmental conditions. This standard will establish generally accepted practices to meet the needs of public telecommunications networks.

The **Above-Baseline Standard** is intended to be a classification standard that sets forth various levels of physical stress and radiation protection over and above the typical levels addressed by the baseline standard.

In general, the standards will apply to fiber-optic and copper links for trunk, feeder, and local distribution. The standards are intended for new installations, not the replacement of existing systems. The standards will include information for the design and installation of aerial, buried, and underground plant, as appropriate, and will apply to all providers of telecommunications services, including exchange carriers and interexchange carriers.

Estimated completion of the Baseline Standard is the beginning of calendar year 1993; the completion of the Above-Baseline Standard is estimated to be the end of calendar year 1993.

For information, contact:
A. Glenn Hanson (303) 497-5449

Dave Peach, Glenn Hanson, and Mike Meister Discuss Fiber Optic Link Survivability Enhancement Techniques

Telecommunications Terminology and Standards Information

Outputs

- FED-STD-1037B, *Glossary of Telecommunication Terms*
- Compilation of U.S. Army comments on FED-STD-1037B
- U.S. Contributions to ISO-2382--*Information Systems Vocabulary*
- Prototype acquisitions-oriented database on telecommunication standards

By participating in telecommunication standards committees, the ITS staff assists the Federal Telecommunication Standards Committee (FTSC)--chaired by the National Communications System (NCS)--in establishing Federal standards to promote end-to-end interoperability of telecommunication systems owned or leased by the Federal Government. Clearly, interoperability of telecommunication systems was necessary for success in *Desert Storm*; it is also important to successful telecommunications in the every-day functioning of Government. Institute staff members and programs promote interoperability and support the FTSC in several ways. Among these are contributions to industry work in telecommunication terminology standardization and the development of an acquisitions-oriented database of Federal Telecommunications and Federal Information Processing Standards. Both efforts are motivated by the need for interoperability. Telecommunication glossaries promote interoperability through standardized language for evolving technologies; the standards database will promote interoperability by facilitating the application of standards in procurement specification and system design.

Telecommunication Terminology--FED-STD-1037B. Published 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 development of FED-STD-1037, a widely used glossary of telecommunication terms, and its first revision, FED-STD-1037A. During FY 90 and FY 91, the Institute chaired an FTSC Subcommittee responsible for revising FED-STD-1037A. The revision addressed more than 4000 definitions in such fields as ISDN, HF radio, optical fiber communications, automated data processing, secure communications, networks, and facsimile. The camera-ready draft of the glossary was delivered to the sponsor on schedule (December 31, 1990) and was approved for printing in July 1991.

Army Comments on FED-STD-1037B. The Institute was funded separately to assist the Department of the Army in developing comments on FED-STD-1037B. The Institute was chosen for this role because of its prior experience in the development of the 1037-series of standards. In addition to its active participation in the development of all the predecessor documents (MIL-STD-188-120; FED-STD-1037, FED-STD-1037A), the Institute developed two editions of a pioneering fiber optics glossary, published as NTIA Special Publication 79-4 and NBS Handbook 140. The Institute compiled the Army comments, with documented rationale, and submitted them to a DoD working group for coordination.

U.S. Contributions to ISO Vocabulary Standards. The Institute provides a Vice Chair for the ANSI Accredited Technical Committee X3K5, which develops vocabulary standards for information systems. During FY 91, the X3K5 Committee refined and updated definitions on information systems vocabulary for such fields as computer graphics, text processing, computer security, programming languages, and local area networks. The ITS Vice Chair also participated in the FTSC subcommittee for FED-STD-1037B, and was therefore able to promote convergence of definitions in these related terminology standards.

Database on Telecommunication Standards. This project, begun in July 1991, addresses the need for a readily accessible and user-friendly database on telecommunication standards for the use of persons involved in procurement (both technical staff and procurement personnel). The database will be required to have extensive indexing/cross-referencing (e.g., through key words) to access information on all standards pertinent to a subject area (e.g., facsimile). Thorough abstracts are also required to provide user information adequate to make decisions on applicability of standards germane to a given subject area.

Agencies participating in the new FTSC Standards Database subcommittee (chaired by ITS) have described their particular problems in obtaining the correct standards in writing requests for proposals (RFPs). In many cases, the problem of locating and invoking the proper standard for an RFP was worsened by the fact that, often, the procurement specialists responsible for writing the RFP had little knowledge of the technology and/or the technical standards.

The FTSC subcommittee met three times in FY 91 to design a prototype data base of Federal Telecommunication Standards and Federal Information Processing Standards Publication that would exclude classified, sensitive, or proprietary data, but that would include the following elements:

- Title
- Document number
- Document source (preparing activity)
- Publication date & revision date
- Key words
- Abstract
- Cross references to other required/related standards
- Status of the standard
- Full text (on some documents).

Benefits of such a database include:

- Interoperability of equipment and services is promoted.
- Support is provided for those who require standards in government acquisitions of telecom equipment and services.
- National Security/Emergency Preparedness (NS/EP) interoperability is promoted.
- Standards distribution costs may be lowered.
- Standards review processes may be streamlined.
- Developing and writing of standards may be aided.
- Statements of Work and Requests for Proposals referencing standards may be improved.

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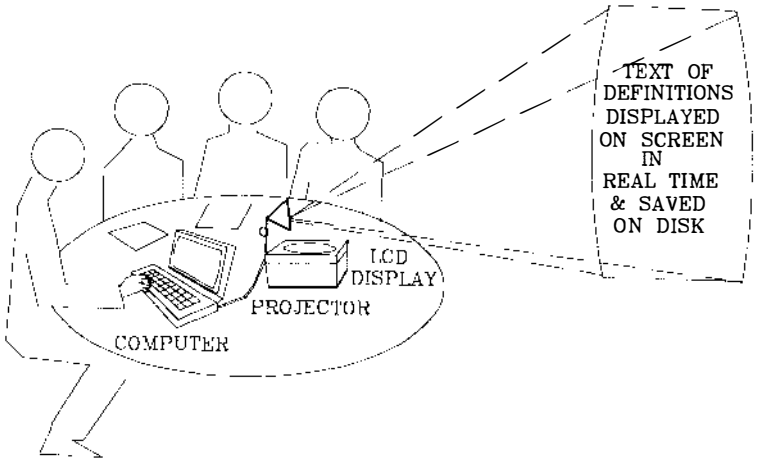
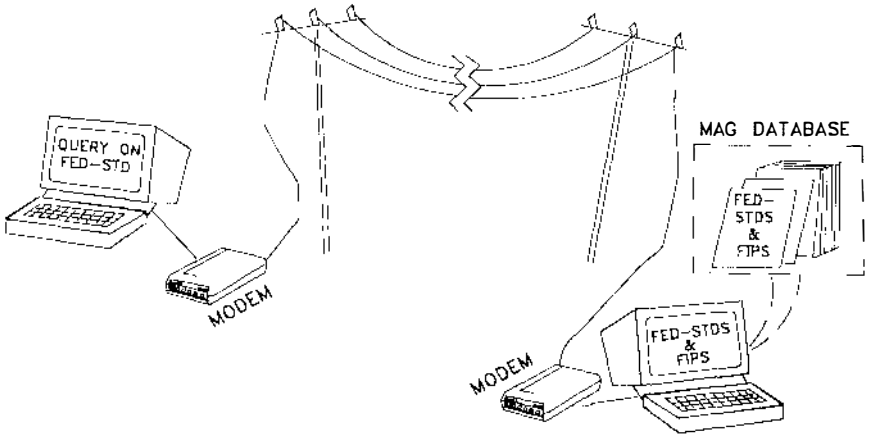
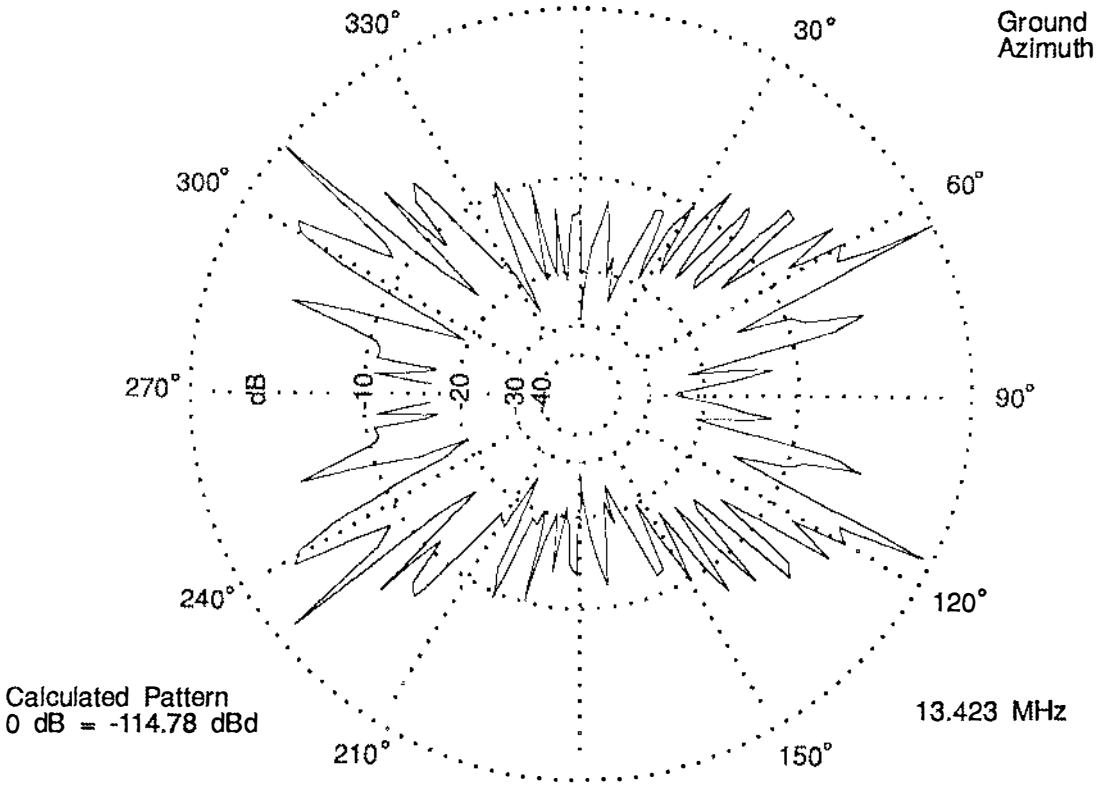
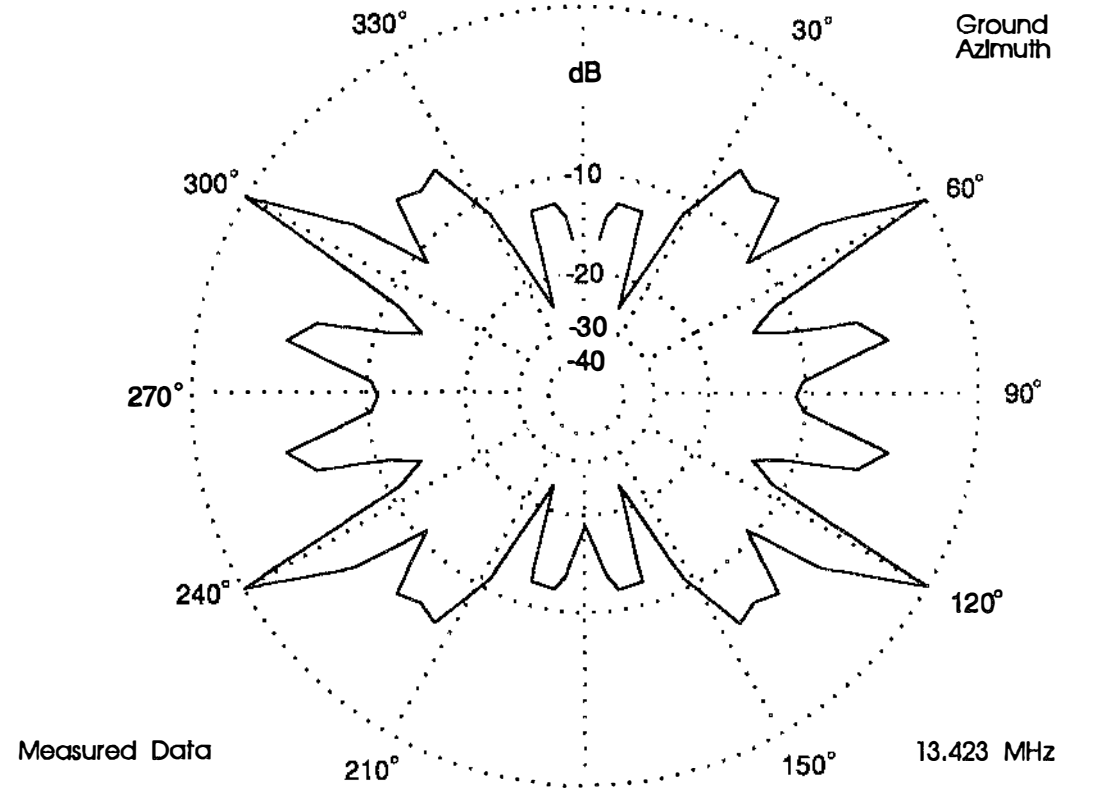


Real-Time Editing Procedures Used for In-Committee Development of Telecommunications Terminology Standards



A Typical Means of Accessing the Database of Federal Standards and FIPS Publications





Theoretical and Measured Patterns for SHARES Antenna Evaluation Program

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 Coverage Analysis

Includes projects funded by the National Telecommunications and Information Administration

Reserve Component Automation System Testing

Includes projects funded by the U.S. Army Communications-Electronics Command

HF Systems Assessment

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

Wide Area Prediction Model

Includes projects funded by the Department of Defense

Radio System Design and Performance Software

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

Video Surveillance Equipment Performance

Includes a project funded by the National Institute of Standards and Technology

High Definition Television Coverage Analysis

Outputs

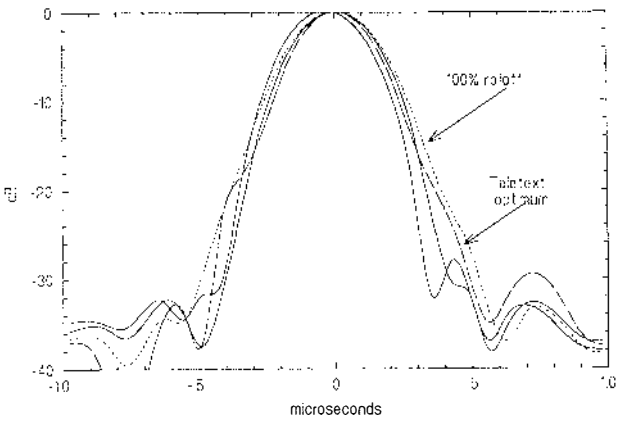
- NTIA reports presenting multipath statistics from measurements conducted in Denver, CO, and San Francisco, CA
- Consultation on development of HDTV field testing procedures
- Consultation on coverage and interference models for HDTV

High Definition Television (HDTV) is being developed in the United States (and also in Europe and Japan) as a means of providing greatly improved picture quality to television customers. The U.S. development of a successful HDTV system will provide the basis for revolutionary new video services to many home, industry, scientific, and medical customers, as well as affecting billions of dollars of international trade.

In the United States, several proposed systems using different modulation, encoding, channel equalization, and data compression techniques are being developed. A system of industry and government advisory committees has been set up under the auspices of the Federal Communication Commission (FCC) Advisory Committee on Advanced Television Systems (ACATS) to advise and oversee various aspects of HDTV planning, development, testing, and deployment. The Institute is involved in several aspects of this work, including measurements of multipath propagation distortion for over-the-air transmission of HDTV signals and consultation on the development of a coverage and interference model for allocation and assignments for the new HDTV stations. This model may be more fully developed by ITS, drawing heavily on the characteristics of the terrain-dependent model developed for the ITS Telecommunications Analysis Services.

Multipath distortion occurs when a radio wave reflects off of obstacles (buildings, mountains, etc.) in such a way that multiple copies of the signal arrive at the receiver at different times. Standard television produces ghosts when multipath is present; the digital transmission techniques used by HDTV systems might produce intersymbol interference which would degrade the system in other much different ways. All of the currently proposed HDTV systems plan to use an equalizer or ghost-canceler. A detailed knowledge of the multipath environment likely to be encountered by future HDTV systems will help engineers to design the HDTV systems as well as design the tests and interpret the results from HDTV systems.

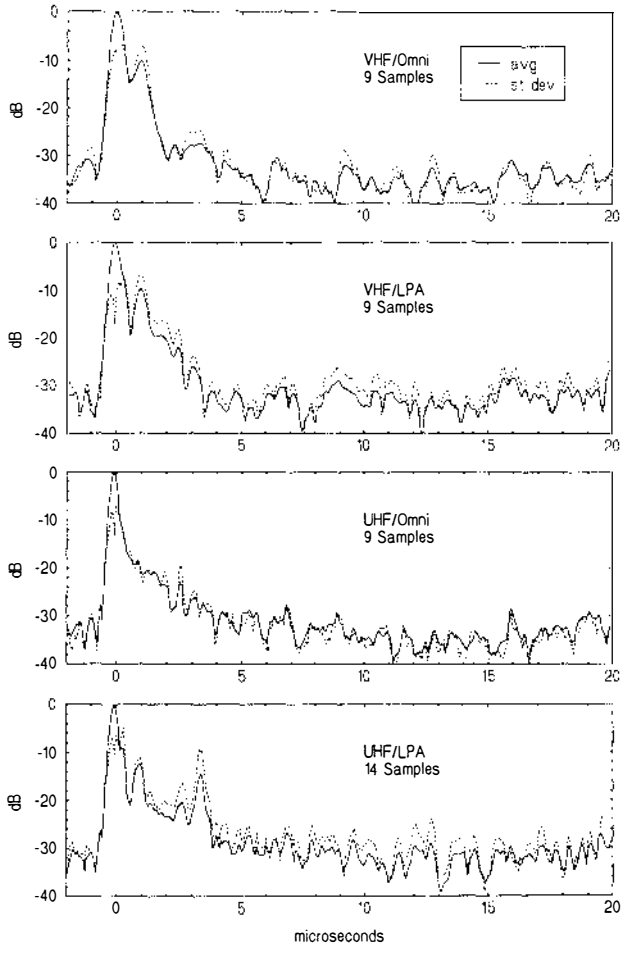
The Institute personnel designed a system to measure multipath distortion on TV channels. This system was designed to make use of existing full-power television stations as well as commercially available studio test equipment. A pseudo-noise (PN) sequence was inserted on an unused line in the vertical 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 still available. Two 127-bit PN sequences at a chip rate of 5.73 Mbits/s were utilized, allowing detection of reflections -2 μs to +20 μs from the main signal. Since each television line is approximately 50 μs long, ghosts having a length up to 40 percent of the width of the television screen can be detected. Four PN signals with different frequency spectra were tested to see whether better time resolution could be obtained in the impulse response and to compare their usefulness as ghost cancellation training signals.



A Closeup of Pulse Shapes from Four PN Sequences

For these tests, we worked with KMGH-TV Channel 7 and KDVR-TV Channel 31 in Denver and KGO-TV Channel 7 and KBHK-TV Channel 44 in San Francisco. In both cities the VHF station provided 316 kW ERP, and the UHF station provided 5 MW ERP.

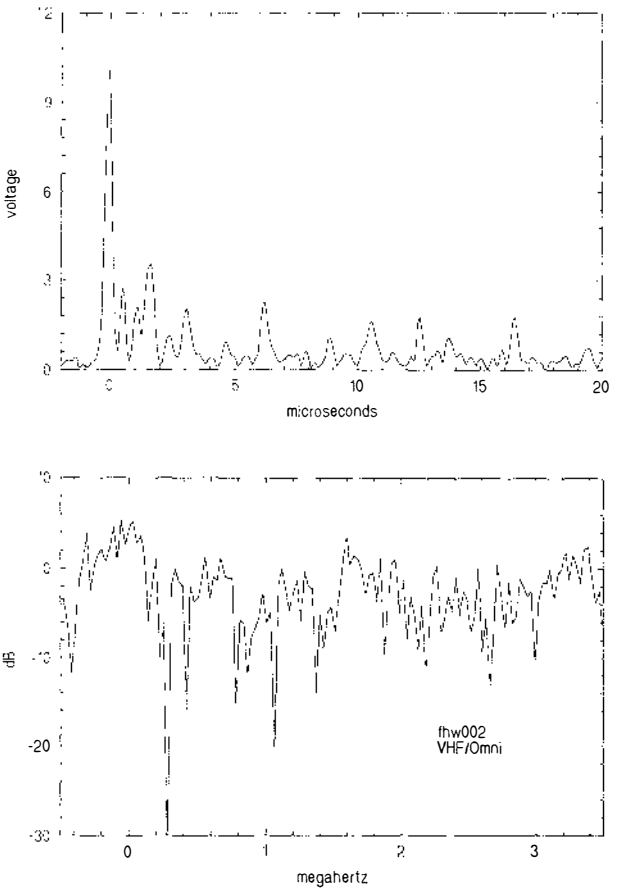
The receiving system includes a log periodic directional antenna and two omnidirectional antennas (one for each band). A microcomputer collects and stores 32 sweeps of the VBI line, which contains the PN sequence. At each site, data are recorded for two antennas and two frequencies (VHF and UHF). The omnidirectional 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.



Multipath Statistics for an Urban Area

The raw data are 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. Over 400 sites were visited in the Denver/Boulder and San Francisco Bay areas to provide data on the distribution of the relative time and magnitude of reflections for different archetypal areas (e.g., urban high rise, open or heavily wooded residential, light industrial, etc.). The figure shown in opposite column is a typical result.

By taking the Fourier transform of the impulse response, the frequency response of the channel can be plotted. The figure below shows the impulse response and frequency selective fading associated with severe multipath.



The Impulse Response and Spectrum on a Path With Severe Multipath

Recent ITS Publications

Characterization of the HDTV Channel in the Denver Area (by Hufford, Godwin, Matheson, Lawrence, and Pratt)

Characterization of the HDTV Channel in the San Francisco Area (by Hufford, Godwin, and Lawrence

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

Reserve Component Automation System Testing

Outputs

- Competitive Demonstration Evaluation
- Test Design Plans
- Test Bed Design

The United States Army is developing and preparing to field the Reserve Component Automation System (RCAS) to fulfill long-standing plans to improve the operational readiness of the Reserve Component part of the total force. The Reserve Component consists of the Army National Guard and U.S. Army Reserve.

The RCAS is to be an automated information system that supports the decision-making needs of all commanders, staffs, and functional managers responsible for Reserve Component forces. The RCAS will use state-of-the-art office automation, telecommunications, data bases, and processing capability to provide timely and accurate information to plan, prepare, and execute mobilization and to improve the accomplishment of routine administrative tasks. The system will be self sufficient, but will also be capable of exchanging data with related information systems used by the Active and Reserve Components.

One goal of the RCAS program is to support mobilization as it is defined in the Army Mobilization and Operations Planning System, U.S. Forces Command Mobilization and Deployment Planning System, and to support the mobilization plans of other Major Army Commands. Another goal is to improve the management of routine administrative processes in the Reserve Component. The following specific objectives for the RCAS program support these goals:

- Provide an integrated system to support the decision-making needs of all commanders and staffs responsible for Reserve Component force readiness, mobilization planning, and mobilization execution;
- Provide verification and validation of the information in the system by the peacetime chain of command after data are entered at their source;
- Provide efficient data sharing throughout the system and with external systems to avoid redundant data entry, reduce errors, and improve the capability to handle the wartime surge in operations workload;
- Provide processing and transmission of classified data within the system;
- Provide data processing and office automation utilities down to the unit level to improve the accomplishment of routine administrative tasks; and
- Develop the RCAS, within the guidelines set by Congress, in harmony with Army automation architecture planning and those systems with which the RCAS must interface.

The RCAS Program Management Office (PMO) has selected ITS to provide technical support in evaluating the contractors' competitive demonstrations and to serve as the technical tester and evaluator for the RCAS. The ITS is supporting the PMO in implementing the RCAS by developing technical test plans, establishing a technical test bed, and conducting a series of technical tests to evaluate the functionality, conformance with specifications, and performance of the RCAS as it is developed and deployed.

Competitive Demonstrations of the Proposed RCAS. The Institute provided experts in telecommunications, UNIX operating systems, and computer and network hardware to observe and validate the competitive demonstrations at the two contractor sites. Daily notes and summary report were provided to the source selection and evaluation board for the RCAS.

Test Bed Development. The Institute is developing an RCAS test bed at the Boulder Laboratories that will be capable of simulating any two Army Reserve or National Guard echelon system configurations of the proposed RCAS. The test bed will include representative data base servers, office automation servers, mail servers, X-terminals, local area networks, FTS-2000 services, communication routers and modems, a network management system, and encryption devices. Functional capability will

include commercial office automation software elements and specific software applications for RCAS functional capabilities. Additional test equipment will include network simulators, network analyzers, a remote terminal emulation system, traffic generators, and test software. The general test bed hardware configuration is shown in the figure below. The test bed is planned to be implemented and in operation in the second quarter of FY 92.

Technical Testing. In coordination with the PMO, the Test Integration Working Group (TIWG), and participating operational test and evaluation personnel, ITS has developed the technical test sections of the Test and Evaluation Master Plan (TEMP). The technical testing encompasses four levels of testing: static and dynamic test bed tests and limited configuration and extended configuration wide area network tests. Both hardware and software components of the RCAS will be delivered in a number of blocks, with each block building on the previous ones and adding functionality to the fielded system. Technical testing will be performed on a system level to validate the engineering and design of the system as required by the specifications and to establish the performance limits of the system. Technical testing of the first block is scheduled to begin the second quarter of FY 92.

For information, contact:
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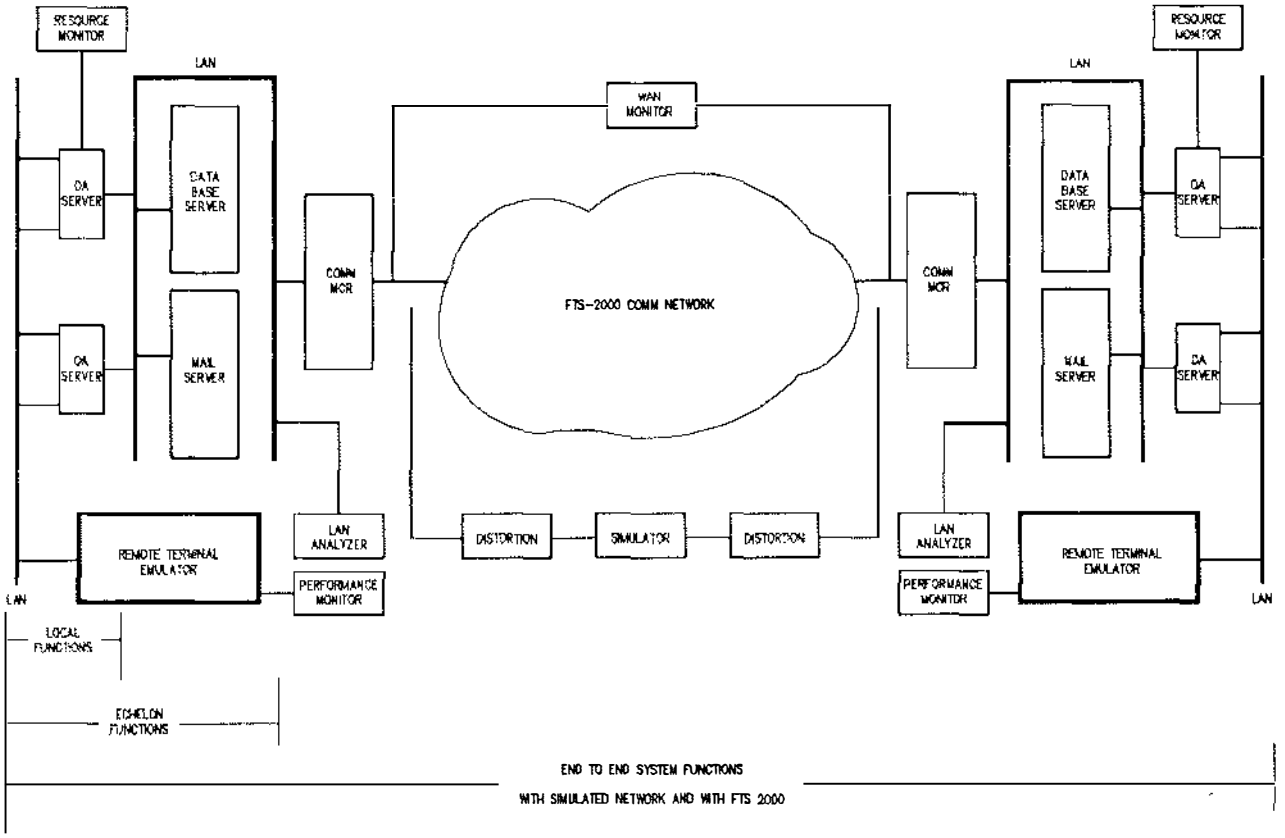

RCAS Test Bed Configuration

HF Systems Assessment

Outputs

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

The Institute for Telecommunications 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 to analyze ionospheric parameters.

There has been an increased interest in the representation of ionospheric propagation predictions as applied to 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 communications models 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 specialized personal computer implementation of IONCAP has been developed to provide a specific selection of specialized output options intended for tactical operation use.

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.

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.

A propagation program (ICEPAC) has been developed that uses the Ionospheric Conductivity and Electron Density Profile Model (ICED) in the polar region and the IONCAP model in the low- and mid-latitude region, except that the electron density profile is the Dudney profile for both low and high latitudes.

To enable further improvements to the ICEPAC HF prediction program, many data comparisons have been made in order to find areas where improvement is required. Data comparisons have been made with several data bases including the CCIR data base 1 (DB1). The figure displays merely one example of the comparison made. This figure shows a comparison of the 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. This example is a nonpolar path; therefore, both predictions are approximately the same.

Of note is the fact that the plot of the sporadic E predictions better approximates the data between 0800 LMT and 1600 LMT. The sporadic E predictions are not included in the MUF predictions of either IONCAP or ICEPAC. More work needs to be done to incorporate appropriate sporadic E predictions in the MUF calculations.

Another area of work has been the development of numerical coefficients representing the F2 layer of the ionosphere. The currently accepted coefficient and the URSI 88 set the coefficients for sunspot 0 and 100 for each of the 12 months of the year. Coefficients that represent the URSI 88 coefficients for continuous evaluation for each day of the year have been developed. Modifications have been made to a version of the IONCAP propagation prediction program to use these coefficients for evaluating predictions for any month and day.

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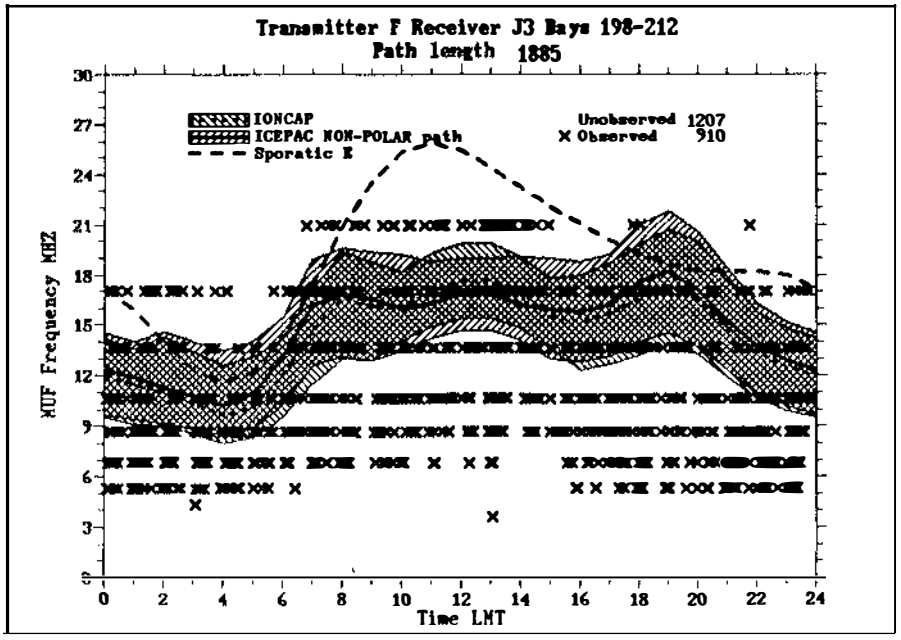

Transmitter F, Receiver J3, Days 198-212, and
Path Length 1885 km

Wide Area Prediction Model

Outputs

- Integration of frequency databases, propagation models, terrain mapping, and user application
- Simple user interface via Graphic Information System
- Prototype tool for easy estimates of coverage and interference based on existing microwave links

A simple visualization of the position of radio transmitters and the reception areas that they might cover has been difficult in the past because of the complexities of combining the several technologies associated with frequency management data bases, equipment characteristics, terrain and map information, complex propagation models, and a specialized user application program. The wide area prediction model (WAPM) performs this complex task for microwave common carriers on a desktop workstation, using a Graphic Information System (GIS) for simple visualization and user interaction. Programs like this will eventually provide much more convenient frequency assignment and interference resolution tools to users, particularly when they must examine how a particular assignment may interact with a large number of existing assignments.

The visual display version of WAPM gives the user of this fully automated model for the prediction of received signal levels (RSL) and bit error rates (BER) an option for visualization of the geography surrounding an area of interest. Personal computer and workstation capabilities allow us to do this with a variety of display techniques. The GIS has been provided by Fairchild Space and Defense Corporation through purchase of their MULTIMAP software series.

Operationally, an effort has been made to make the visual display extension of WAPM as user friendly as possible. This is achieved by a sequenced set of input choices from which the user must make selections.

After a series of questions designed to identify the proper map area for display relative to the input area of concern, the user is asked a series of questions needed to run WAPM. Information is required on various receiver parameters, including the percentile of receivability of interest, receiving site latitude and longitude, receiver antenna height above ground, and dimensions of the analysis area, among other things. The program runs after the completion of the input sequence, and results are visually displayed. The figure on the next page is an example of displayed output on a 1:24K map in the Washington, DC, area. Symbols for antennas at the location of all microwave common carrier antennas in the 2, 4, 6, 11, 18, and 23 GHz bands are displayed. White symbols indicate transmitting locations that are receivable and black symbols indicate unreceivable transmitting locations. Note that the monitor display is actually in color, so that a greater variety of color coding is used than is indicated here.

The figure also shows the capability of the program to display output information on a given link. The link is shown in this figure as a black line joining two antennas at the end points of the link. A window in the upper righthand corner of the display gives specific link information, including the transmitter identification, RSL, and BER information. There is no BER prediction for the link in this figure, since it is a video link.

Some coding and modeling changes were made in WAPM to make more realistic predictions of median (and other percentile) bit error rates caused by terrain. The statistical variability of the received power of a line-of-sight microwave link encountering two-ray terrain multipath over a 1-year period was analyzed and incorporated into the model.

It is hoped that future extensions to WAPM will include expanding the necessary databases to worldwide sites. This will require conversion of many foreign frequency management databases and digital mapping information into a form compatible with the present U.S. databases.

It would also be desirable to extend the modeling efforts to include passive reflector (billboard) propagation analysis, modeling the diffraction of manmade objects (buildings and

towers represented by rectangular and round cylindrical solids), and determining the dielectric constant and conductivity for a wider array of frequencies and surface construction materials.

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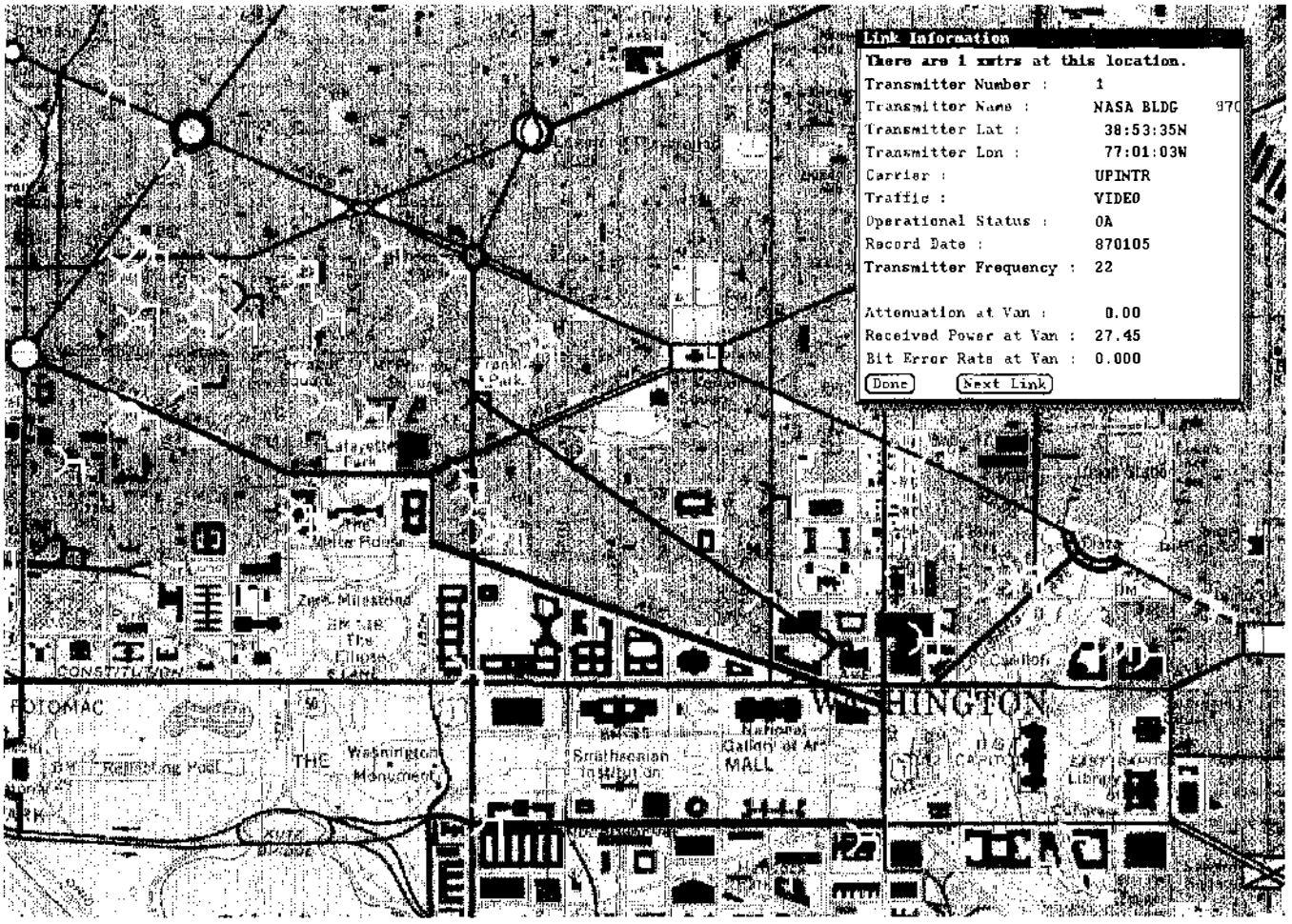


Sample Display of Output With Windowed Information

Radio System Design and Performance Software

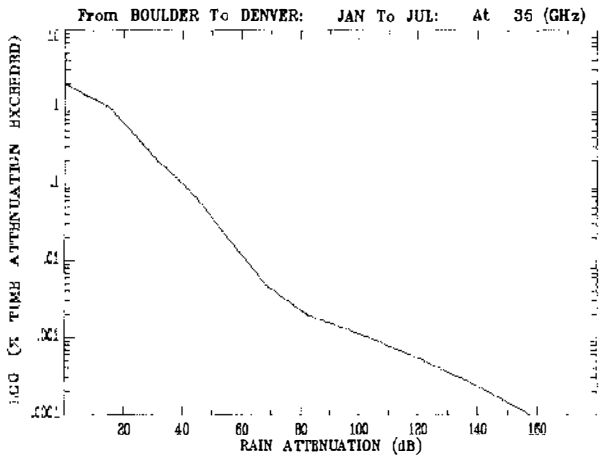
Outputs

- Public version of AMOS model (MOSES)
- Additional versions of AMOS under development for other Government agencies
- Performance prediction software for wideband communication links (RAIDER)

Versatile User-Friendly Desktop Software. Advances in radiowave propagation modeling have continued at ITS in 1991 with the improvement of the AMOS (Analysis of Microwave Operational Scenarios) software, MOSES (Microwave Operational Scenario Evaluation Software), and RAIDER (Radio Analysis and Integrated Design Engineering Requirements) software. All of these powerful software programs are user friendly and menu driven. They can be conveniently run on a personal computer under MS-DOS by users with minimal training. The extensive analysis and design capability of these codes have been previously limited to mainframe computers.

AMOS/MOSES/ROSES Models. The AMOS/MOSES/ROSES (radio operational system evaluation software) family of models continue to serve as development and analysis tools for Government and private industry. They are highly structured and modular in design which allows for greater flexibility and expendability. The major components of these models include 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, and aircraft-to-satellite.

The AMOS-MOSES-ROSES propagation library includes subroutines for use in calculating clear air attenuation, rain attenuation, multipath attenuation, diffraction, troposcatter and others. An example of an output plot is shown top right column. It is a cumulative distribution of rain attenuation for a terrestrial path between Boulder and Denver.



Cumulative Distribution of Rain Attenuation

Development is presently underway to enhance the graphics capability in AMOS. The MOSES software performs analyses in the microwave frequency range (1-300 GHz). The newest version of MOSES is ROSES. ROSES is in a development phase where the frequency range is being extended downward below the microwave region. The frequency range covered by ROSES will include 2 MHz to 300 GHz. These frequencies were needed for the addition of a jammer effectiveness model (JEM) which is presently under development for integration into the ROSES software model. The 2-30 MHz range will include propagation models for both the ground wave and the sky wave. An irregular terrain model for the 20 MHz-20 GHz frequency range is also being integrated into ROSES. The jammer effectiveness model includes scenario types for different combinations of transmitters, receivers, and jammers that are at ground and airborne stations.

Integrated Radio Link Prediction Software. The use of terrestrial radio links to provide high-speed digital connections or multi-voice channel analog communications is important for both civilian and military government activities. The Radio Analysis and Integrated Design for Engineering Requirements (RAIDER) program is an integrated, user-friendly set of software modules that automates the calculations for the design and prediction of line-of-sight and

beyond-the-horizon path terrestrial links that had previously required extensive hand calculations and main-frame computers. RAIDER can be used easily and efficiently both in the field and in the office by users who are familiar with radio systems.

RAIDER currently consists of 13 modules that use state-of-the-art programming interfaces and the newest engineering models developed by ITS, industry, and the International Radio and Consultative Committee (CCIR). The program provides a complete design and documentation of terrestrial radio links operating in the frequency range of 1 to 30 GHz. Tabular and graphical outputs are developed and may be displayed on the screen or saved in hard copy form. The user is prompted to input all required values for the calculations and each user input is compared with a range of acceptable values to ensure accurate and complete calculations. As the individual RAIDER modules are executed, the inputs and outputs for each link are saved in a file. If the program is run in the order suggested by the menu, many of the inputs required by the current modules will have already been input or calculated by the previous module. This greatly reduces the amount of data that must be input by the user.

Initially, the user must input the site coordinates and path profile. RAIDER then determines the clearance for the link. It calculates whether the path is line-of-sight, single diffraction, double diffraction, or scatter. The path type designation determines the remaining modules and calculations that can be executed for the path. System gain and voice channel performance parameters may be calculated for all path types. The effects of climate on the received signal, the dispersive fade margin, and a link design summary may be computed for line-of-sight paths. Median basic transmission loss, the expected distribution of the hourly median basic transmission loss, the confidence bands for the path, and the median basic transmission loss over isolated obstacles may be calculated for over-the-horizon paths.

The RAIDER program will be further enhanced with the development of a set of modules to generate path profiles automatically for all types of terrestrial point-to-point paths using the Defense Mapping Agency CD-ROM Digital Terrain Elevation Data (DTED) data bases. Equipment parameters will also be preloaded into RAIDER, which will determine the appropriate algorithms required to predict link performance. Calculations of beyond-the-horizon links based on the performance of modems will also be incorporated in RAIDER.

Recent ITS Publications

The RAIDER Program: Radio Algorithms for Integration and Design of Engineering Requirements (by Rothschild and Farrow)

Software for the Analysis of Microwave Operational Scenarios (by Allen)

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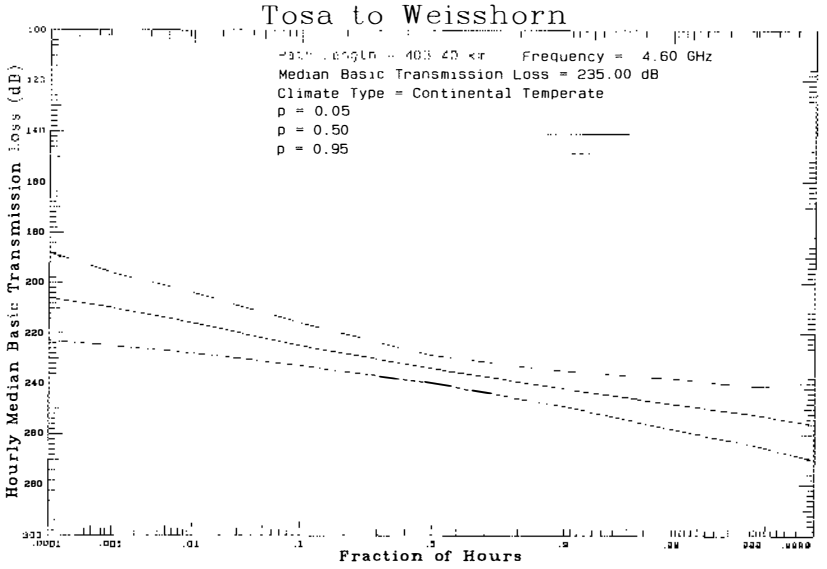


Basic Transmission Loss Distribution and Confidence Interval

Video Surveillance Equipment Performance

Outputs

- Technical support for Law Enforcement Standards Laboratory
- Guide to video surveillance equipment

Video Surveillance Equipment Requirements and Performance. The Law Enforcement Standards Laboratory of the National Institute of Standards and Technology sponsored the Institute to develop a Selection and Application Guide to Police Video Surveillance Equipment. This Guide is intended to assist state and local law enforcement agencies in making intelligent purchase decisions by acquainting them with the factors governing video surveillance equipment performance, and by correlating police applications with required technical specifications.

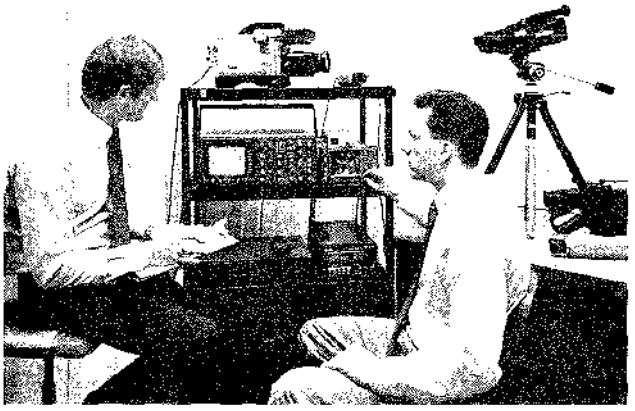
Personnel in the law enforcement agencies wishing to utilize video surveillance systems (for collecting evidence and promoting officer safety, as examples) often find it difficult to select among the many equipment choices available while staying within an established budget. Police officers and their procurement officials are not technically trained in video equipment and are not sure what will satisfy their needs. The ITS-developed selection guide will provide the necessary information in a readily-understandable form. The Guide is intended primarily to address general-use video equipment, including separate video cameras, self-contained camcorders, video recorders/players, and video display systems (monitors). However, special-purpose video equipment, such as the Patrol Car Surveillance System, is also described.

The Guide begins with a discussion of typical video surveillance assignments, that is, a definition of user requirements for the law enforcement community. General requirements can be categorized into six functional areas:

1. Identifying subjects at varied distances and at varied light levels.

2. Recording or documenting data and/or evidence during or after a crime.

3. Handling scenes and locations with multiple activities and/or multiple subjects.



Project Personnel Val Pietrasiewicz and Keith Junker Perform Tests on Video Surveillance Equipment

4. Covering indoor and outdoor activities in different geographic areas.

5. Establishing multi-purpose flexibility and compatibility with other existing equipment.

6. Promoting operational effectiveness.

This general requirements definition was used as a starting point and reference base for the detailed video equipment descriptions provided in later sections of the Guide.

An overview of the available video technology is presented next in the Guide, along with a summary of video tape formats (VHS, S-VHS, 8mm, Hi-8, C, U-Matic, Betacam, and Betacam-SP), and typical features of the different equipment units. The video technology overview addresses such topics as analog and digital cameras, still video, low-light cameras, light-intensified cameras, and monitors. The discussion on video tape formats leads to descriptions of specific characteristics related to various types of camcorders and tape recorder/players. The applicability of certain video formats to surveillance requirements is also provided. A features section for each kind of video gear is offered to assist the prospective buyer in deciding what "bells and whistles" really have utility and are worth the additional cost.

A delineation of the technical parameters that most influence operational performance for the various types of gear follows. Terms such as "Resolution", "Signal to Noise Ratio", "Minimum Illumination" (e.g., "lux"), "Color Accuracy", and "Contrast Maximization Autofocusing" are explained in general and in the context of surveillance scenarios. Guidance is provided regarding the application of specific types of video equipment to meet functional requirements.

Another important element of the Guide is the detailed performance assessment of video quality for each type of equipment under various operating conditions. ITS laboratory test results not only provide an independent confirmation of the basic equipment specifications published by manufacturers, but also assess the ergonomic aspects of the equipment. Some items of video gear have particular physical and operational attributes that facilitate (or complicate) their use. These peculiarities are pointed out.

Surveillance Applications and Recommended Equipment

Surveillance Application	Recommended Video Tape Formats[1]	Recommended Equipment Types[2]
Building or area access	V,S,8,H	C,T,M
Building or area security	V,S,8,H	C,T,M
Operation/protective detail coordination	S,H,B,C	C,T,M
Crowd monitoring	V,S,8,H	C,T,M
Monitor officer on routine stops	V,S,8,H	C,T,R
Monitor officer/suspect in dangerous situation	S,H	C,T,R
Monitor confinement areas	V,S,8,H	C,T,M
Record bomb squad work	V,S,8,H,B	R,C,T
Record crime scene	V,S,8,H,B	R
Record forensic data	V,S,8,H,B	R
Record interrogations/ polygraph examinations	V,S,8,H,B	C,T,R
Record physical evidence	V,S,8,H,B	R
Search and rescue	S,H,B	C,T,R
Airborne surveillance	S,H,B	C,T,R,M
Indoor surveillance	S,H,B	C,T,R,M
Outdoor surveillance	S,H,B	C,T,R,M
Vehicular surveillance	S,H,B,C	C,T,R,M
Video mug shots	V,S,8,H	C,T,R

Notes:

1. Video Tape Format abbreviations: C = C; V = VHS and VHS-C; S = Super VHS and Super VHS-C; 8 = 8 mm; H = Hi-8; B = Betacam. Beta and U-matic formats are not recommended for new equipment purchases because of the short projected support lifetime of these products.

2. Equipment Type abbreviations: C = Cameras; R = Camcorders; T = Video Tape Recorders; M = Monitors and Televisions.

With current cost information, the user will be able to use the performance assessment data of the Guide to sort out the lowest cost equipment that can effectively satisfy at least the minimum surveillance requirements established by the law enforcement community. Some relative price ranges are included in the Guide to give a feel for funding needs.

Typical Light Levels Based on Outdoor and Indoor Conditions

CONDITION	TYPICAL LIGHT LEVEL IN LUX
Overcast Night Sky	0.0007
Clear Night Sky	0.002
Quarter Moon	0.01
Full Moon	0.1
Twilight	4.0
Sunrise/Sunset	500.0
Heavily Overcast	7000.0
Unobscured Sunlight	100000.0
Office (Florescent Lights & No Windows)	320.0
Office (Florescent Lights & Windows)	430.0
Office Building Hallway (Well Lit)	54.0
Narrow Hallway (Dimly Lit)	10.8
180 Square Foot Room with one 150 Watt Lamp on	16.1

Reference for Outdoor levels: **Light Intensity Conversion Chart, XYBION Electronic Systems**, not dated.

Appendices to the Guide offer the means to directly compare the specifications of many different items of equipment--cameras, camcorders, video recorders/players, and display systems. Tables list the characteristics of particular products in each equipment category. Although brand names and model numbers are presented in the tables, the tables are not meant to serve as a one-step buying guide. Rather, they serve to bring the technical descriptions of the guide into a "real world" setting. The information contained in the appendices is time-sensitive, since models, features, and formats change frequently. The representation of information may not change much, however, and the buyer will always have to deal with several technical concepts in order to make a proper purchase.

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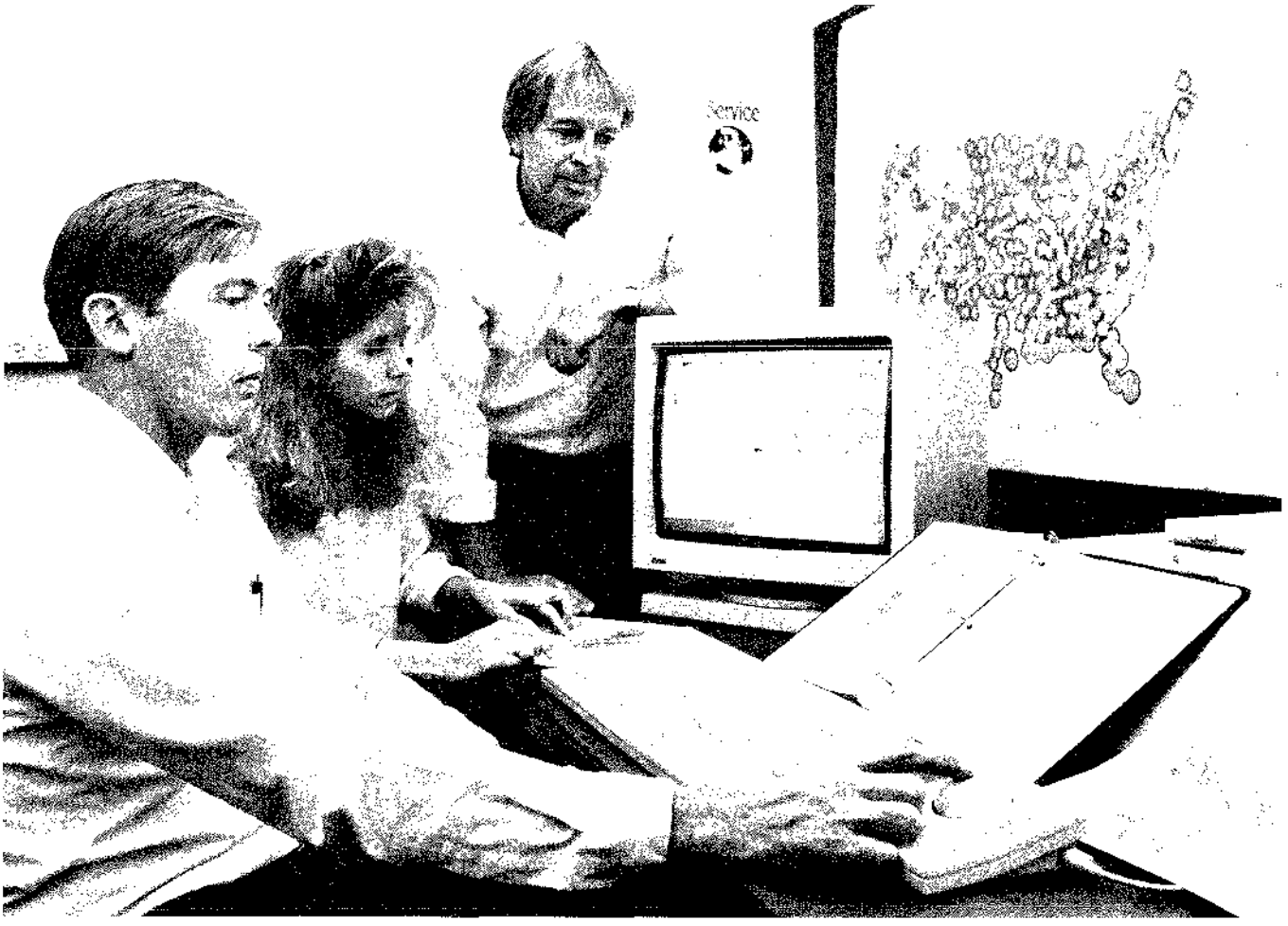


ITS Engineers, Rob DeBolt, Elizabeth Pol and Eldon Haakinson, Ponder the Wide Choice of Telecommunication Models Available through Telecommunications Analysis Services

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

Personal Communication Services

Includes projects funded by the National Telecommunications and Information Administration, BellSouth Enterprises, and Telesis Technology Laboratories, Inc.

Satellite Studies

Includes projects funded by the National Telecommunications and Information Administration and the National Aeronautical and Space Administration

Telecommunications Analysis Services

Includes projects funded by the U.S. Coast Guard and many commercial and government agencies

Advanced Systems Planning

Includes projects funded by the U. S. Department of Agriculture-Forest Service and the National Institute of Standards and Technology

Local Area Network Implementation

Includes a project funded by the U.S. Navy

Personal Communication Services

Outputs

- Survey of propagation models
- Survey of frequency assignments in the 1.435 to 2.5 GHz range
- Measurements of building penetration loss at 900 MHz, 11.4 GHz, and 28.8 GHz
- Measurements of spectrum usage in the 600 MHz to 2.5 GHz range in five cities
- Measurements of signal strength in microcells in urban/suburban environments

Personal Communication Services (PCS) is an exciting new technology moving rapidly through the initial stages of development. PCS can be thought of as providing two major improvements in communication services. The first is portability. Many small cells can be used to provide low-cost telephone services through pocket-size, low-power, portable telephones to individuals wherever they may be within the service area. The other improvement is personalized telephone service. This requires an intelligent network that can provide customized service under the users' control. For example, the user may notify the network that until further notice he will accept voice messaging from all callers except selected numbers which he will answer immediately and personally.

In response to the Federal Government's desire to promote technological advancement through the transfer of technology from Federal laboratories to the private sector, ITS has been actively developing and participating in cooperative research agreements with proponents of PCS. The Institute's contributions to date have concerned the development of the radio technology needed to connect the portable PCS phone with the service providers' network.

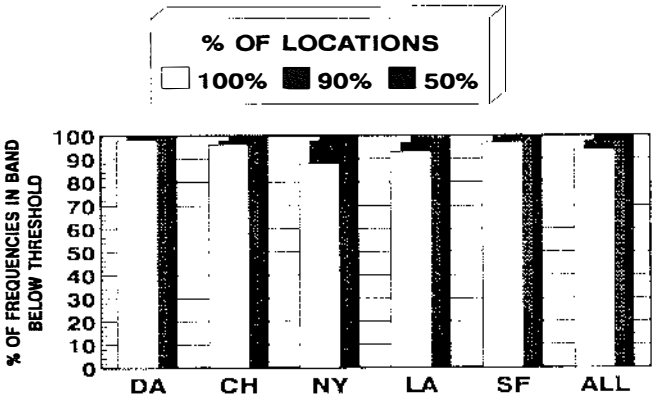
Traditional radio systems have involved well designed links over longer distances. Little is known about providing reliable radio links over short distances to arbitrary locations within man-made environments. Knowledge of noise, potential interferers, signal strength, and delay spread is needed before PCS systems can be effectively designed, radio spectrum assigned, and proper regulations and policies developed.

Under a cooperative research agreement with BellSouth Enterprises, ITS conducted a study of frequency assignments in the 1.435-2.5 GHz range. The results of this study have been published in a NTIA Technical Report. As part of the same agreement, ITS conducted a survey of existing propagation models in the 1.5-2.5 GHz range.

The Spectrum Usage Measurement Van Used for the Pactel Measurements

Through a cooperative research agreement with Telesis Technology Laboratories, Inc., a Pacific Telesis subsidiary, ITS has been able to share in and contribute to a comprehensive technology development program with Pactel Cellular. The Institute assisted Pactel in the development of an experimental plan for spectrum usage, noise, signal strength, and delay spread measurements. The Institute also made significant contributions to the design of the measurement system.

As part of the agreement with Pactel, ITS conducted spectrum usage measurements at 37 locations in each of five cities: Dallas, Chicago, New York, Los Angeles, and San Francisco. The measurement bands were 614-806 MHz, 824-944 MHz, 1850-1994 MHz, 2110-2182 MHz, and 2400-2600 MHz. The results of these measurements have been published as a NTIA Technical Report. They show the amount of spectrum usage by other services that would be observed by portable PCS phones. Further work with Pactel is expected regarding measurements of delay spread of radio signals on PCS paths.

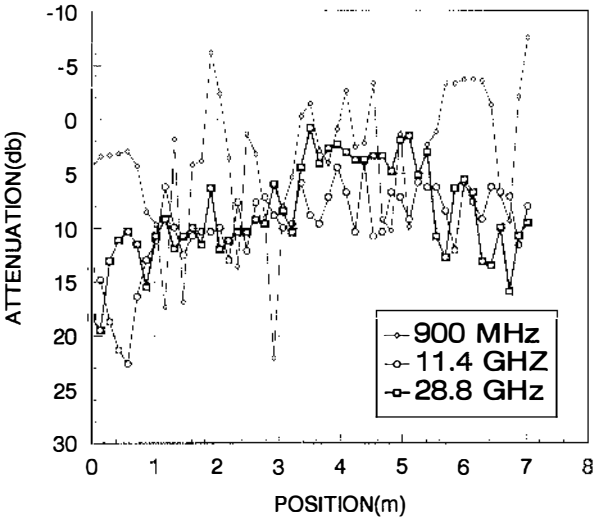


A Summary Bar Chart of Measured Band Usage in the 1850-1990 MHz Band for Five Cities

Under a cooperative research agreement with US West Advanced Technologies, Inc., ITS is conducting measurements of signal strength and will, in the future, conduct delay spread measurements. These measurements will assist US West with the planning and implementation of an experimental PCS system.

In addition to the work conducted under cooperative research agreements with the private sector, ITS made measurements of building penetration loss at 900 MHz, 11.4 GHz, and 28.8 GHz. The purpose of these measurements was to determine the frequency dependence of building penetration loss. Although the loss at 28.8 GHz was nearly always the largest, the loss at 11.4 GHz was often comparable or even less than the loss at 900 MHz. This surprising result occurred when there was only an exterior wall between the transmitter and receiver.

Because of the great commercial importance of PCS, ITS plans to vigorously pursue cooperative



A Plot of Building Penetration Loss as a Function of Location in the Front Rooms of a Ranch Style House

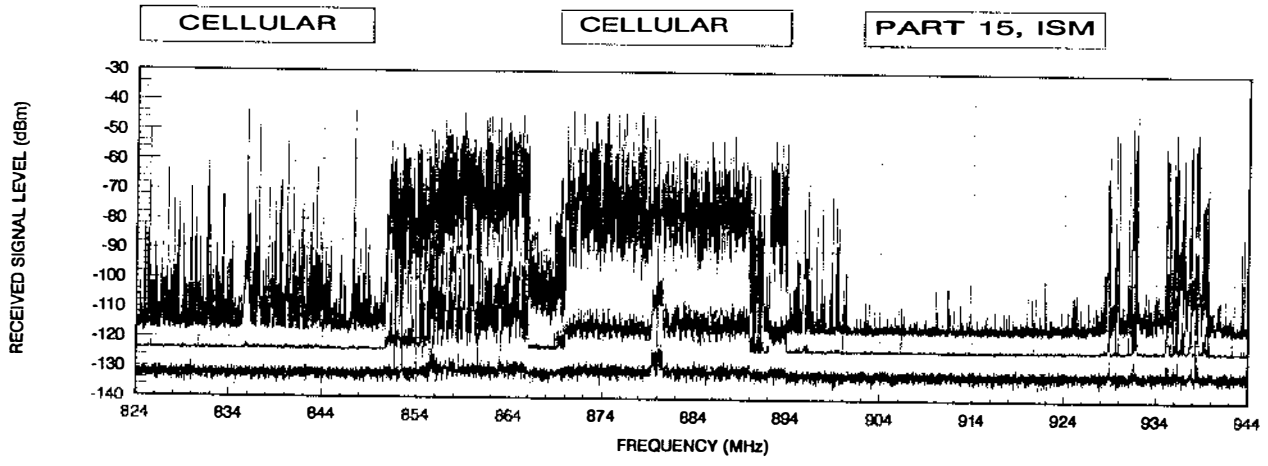
research agreements with private industry as vehicles of technology transfer and thereby contribute to the rapid commercialization of the technology. In addition, ITS plans to commit substantial resources of its own to contribute to the development of PCS technology and standards.

Recent ITS Publications

Frequency Assignment Summary for 1.435-2.5 GHz Band (Berry, Steele, and Grant)

Spectrum Usage Measurements in Potential PCS Frequency Bands (Wepman, Matheson, Allen, and Achatz)

For information, contact:
Kenneth C. Allen (303) 497-5474



A Plot of the Maximum, Average, and Minimum Signal Level Observed at 37 Locations in Dallas, TX

Satellite Studies

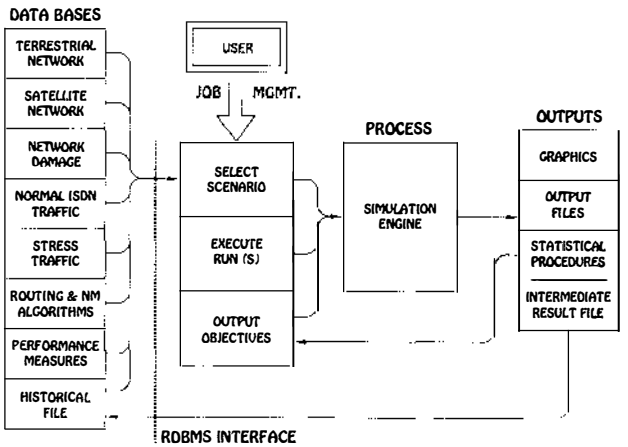
Outputs

- Contributions to network interface and management standards for advanced hybrid networks
- Simulation model for evaluating the performance of advanced hybrid networks
- Prototype test equipment for advanced satellite system performance measurement
- Functional specifications for an advanced satellite experimenters' Earth station

During FY 90, the Institute brought together resources and facilities from several projects to begin a major satellite studies program aimed at determining the appropriate role(s) for advanced communication satellite systems in future Broadband Integrated Services Digital Networks (B-ISDNs). These studies continued during FY 91, with emphasis directed to understanding and defining the interface and management requirements for hybrid networks that include advanced communication satellite systems. In related work, the Institute continued to plan with the University of Colorado for channel probe measurements that will use signals from Global Positioning System (GPS) satellites to assess propagation impairments in Earth-satellite communication paths.

Satellites and ISDN. These studies are intended to provide a basis for network interface and management standards supporting advanced hybrid networks. A conceptual view of a customer's network that uses the Public Switched Network (PSN), augmented with a satellite network, is illustrated in the figure on the facing page. Note that many independent "managers" are used throughout the network. The introduction of ISDN expands the management problem even more. Integration and interoperation of network management systems (including customer-operated private network management systems) has been one emphasis of these studies. The other emphasis has been the development of a computer-based model for estimating the survivability performance of advanced hybrid networks--a network survivability performance simulation model. Much of the work performed in development of the simulation model also is applicable to the Advanced Satellite Designs and Experiments for ISDN Services project, described in the paragraph that follows.

Advanced Satellite Designs and Experiments for ISDN Services. The concept and major components of the hybrid network simulation model, intended to simulate a large network (on the order of 100 nodes), are illustrated in the figure below. The "heart" of the model is being developed using the capabilities of the OPtimized NETwork (OPNET) Engineering Tool, a workstation-based network simulation tool originally conceived through research started in 1984 at the Massachusetts Institute of Technology. The ITS-developed model also requires that extensive database information be developed and managed using a Relational Database Management System. A Silicon Graphics Personal IRIS Workstation (16.7 MIPS) is being used for this development. The model, being developed first to simulate circuit-switched networks, addresses four principal areas of concern: the network, the traffic offered to the network, scenarios that define situations of interest, and performance measures by which the simulation results are evaluated. Work during the next year will extend the model to simulation of packet-switched networks and the representation of network traffic typical for ISDNs.



Hybrid Network Simulation Model

Advanced Satellite Communication Technology Studies. In response to needs for increased service capacity and reliability, lower service costs, and integration with advancing communication system technologies such as optical fiber transmission, ISDN, mobile services, high-speed computing, and HDTV, the National Aeronautics and Space

Administration (NASA) is developing the Advanced Communications Technology Satellite (ACTS), to be launched in 1993, as a testbed for advanced communications satellite studies. The Institute is developing test equipment and conducting preliminary performance measurements to validate the test equipment in preparation for a unique set of end-to-end system performance experiments in which ACTS satellite channels will be evaluated using the framework of an NTIA-developed American National Standard X3.141-1987, "Measurement Methods for User-Oriented Performance Evaluation."

ACTS Earth Station Functional Specification Development. A functional specification was developed for an ACTS experimenters' Earth station which will be located at ITS and made available to interested experimenters. The specification identifies potential ACTS experimenters in the Denver spot-beam region and defines their specific requirements. The specification was delivered to NASA for their use in planning the ITS ACTS Earth station.

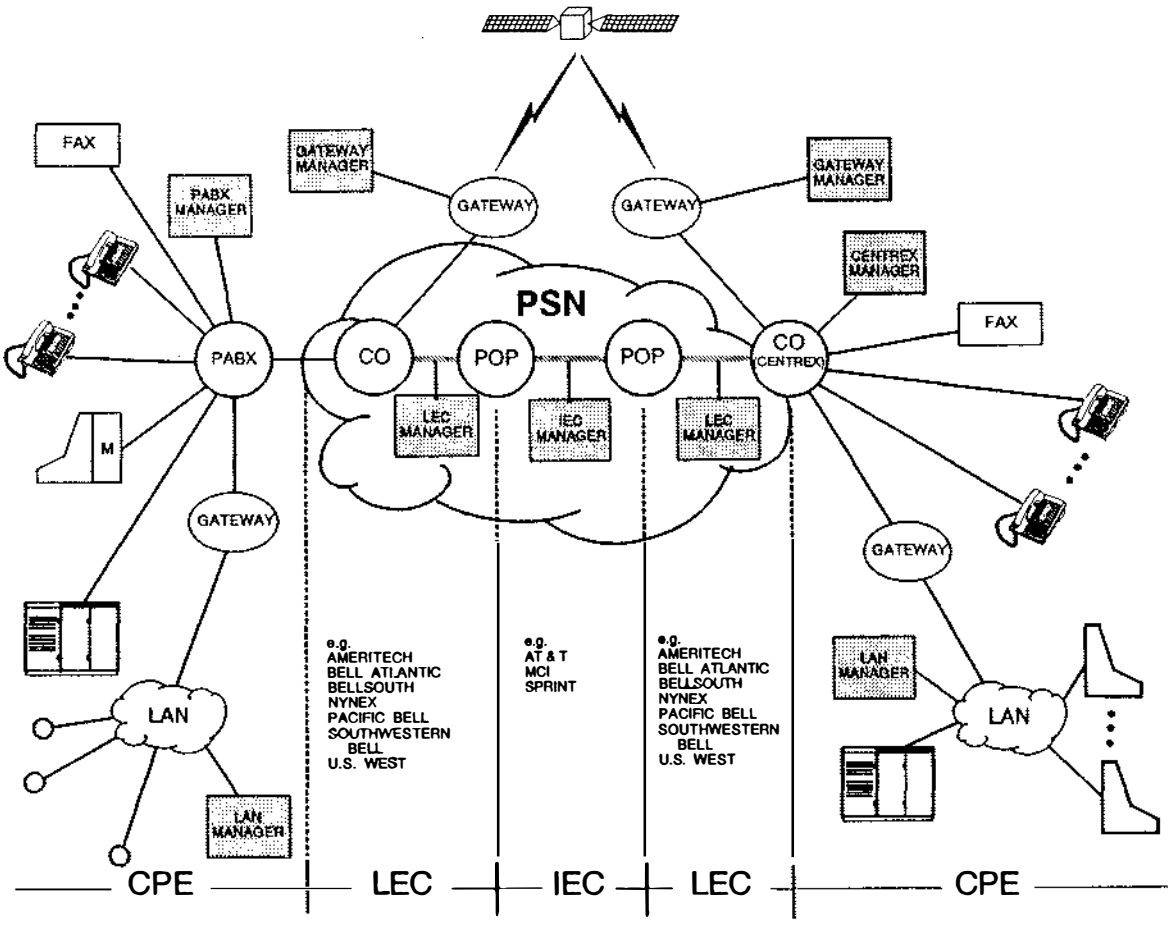
Multipath Measurements in the Land Mobile Satellite Radio Channel. As part of NASA's mobile satellites communications program, the Institute is involved in a collaborative effort with the University of Colorado to measure the impulse response of radio transmission channels over space/Earth paths using signals from the GPS satellites. The University of Colorado is developing a modified GPS receiver and measurement system; the Institute will use the system to perform the channel probe measurements and will analyze the data. The project is jointly sponsored by NASA and the European Space Agency.

Recent ITS Publications

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

Design of Experiments to Quantify Communication Satellite System Performance (by Cass and Miles)

For information, contact:
Raymond D. Jennings (303) 497-3233



Conceptual Hybrid Customer Network Using the Public Switched Network and a Commercial Satellite Network

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 for proposed telecommunication services
- Access to NTIA report abstracts and bibliographies, important public information, and documents of interest to telecommunications specialists

Telecommunications Analysis Services (TAServices) is provided by the Institute to all of the telecommunications community. It gives industry and Government agencies access to the latest Institute research and engineering on a cost-reimbursable 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 by the Institute's engineering and research programs.

Over the coming year the current TAServices computer system will be replaced with a state-of-the-art computer providing for greatly increased data base and user services. The current terrain data base will be enhanced with data at 3-arc-second intervals, the 1990 census data will be incorporated, and other government data bases and reports will be available through a Bulletin Board service available to all users of TAServices.

The following is a brief description of current programs on the TAS computer that perform user-requested calculations on-line and immediately sends 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 great circle distances and bearings between 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. Program options allow the user to easily look at the effects 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 - These programs 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 by determining the probabilities of successful communications for the transmission of various length messages 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. It also calculates the skywave for MF systems.

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

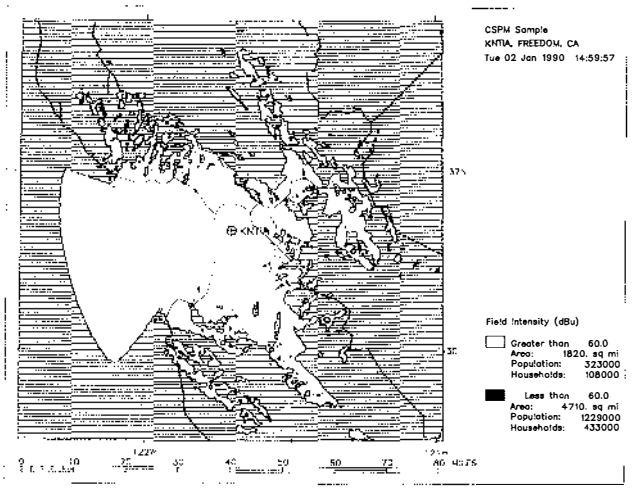
PROFILE - The Institute maintains a digitized topographic data base of elevations of the terrain in various parts of the world. The data currently varies in density from 3 to 30 arcsecond increments, but is generally derived from 1:250,000 scale maps of the Defense Mapping Agency. This program extracts path profiles according to user specified input parameters of location, bearing, etc. After the data are extracted, either the individual elevations or an average elevation along the profile are 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.

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 sighting 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 census data. The user can use either the FCC Broadcast rules or the ITS irregular terrain model 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 allows the user to have the output plotted in brilliant colors on clear plastic to a specified scale 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 a point-to-point mode. It is capable of combining 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 a table of reliability or other user requested performance measures.

For information, contact:
Robert DeBolt (303) 497-5324

Advanced Systems Planning

Outputs

- Technical Planning Support for Region 9, U.S. Forest Service
- Technical Planning Support for Washington Office, U.S. Forest Service
- Technical Consulting and Specification Development for the National Institute of Standards and Technology

Lake States Forests Telecommunications Plan. Telecommunication system planning within user organizations is often done on a very near-term basis, with little consideration of emerging technologies or evolving organizational needs. Such an ad hoc approach can maintain essential capabilities, but often does not use telecommunications effectively in meeting the business goals of the organization. The Institute provides advanced system planning services to assist user organizations in analyzing their telecommunications needs--and selecting systems that will meet those needs within budgetary and policy constraints.

Presently, ITS is assisting the Eastern Region of the U.S. Forest Service, Region 9, to develop a complete telecommunications plan to serve the 14 Forests of that Region. The work is being conducted in three steps: 1) assess needs and constraints; 2) develop a strategic plan; and 3) produce a set of tactical plans for the Forests.

Needs and Constraints. Telecommunications system users are interviewed to determine their requirements for voice, data, video, and radio communications, and their ideas for using telecommunications to improve the way they do business. Applicable regulatory and policy constraints are identified--for example, regulations may require the use of the public telephone network rather than a private microwave link or policy may require that equipment be leased rather than owned. Finally, technology constraints are identified and evaluated.

Strategic Plan. After information on needs and constraints have been analyzed, a Regional strategic plan is developed. The purpose of strategic planning is to investigate alternative courses of action for the future. Then, as choices are made among the alternatives, those choices become the basis of current decisions. ITS is working with Region 9 to develop a strategic plan that will look 10 years into the future. With the extremely rapid changes in telecommunications technology, the strategic plan must be dynamic and will be reviewed for updating every year.

Tactical Plans. These short-term plans provide for the needs of today but are consistent with the strategic plan. Each of the 14 National Forests located in Region 9 will have a tactical plan developed by ITS and approved by the Forest Service. The tactical plan for each Forest will identify equipment to buy, equipment and services to lease, and how to configure and manage the telecommunications system.

U.S. Forest Service National Strategic Telecommunications Plan. On August 1, 1991, the Institute began a project for the Washington (national) Office of the U.S. Forest Service aimed at developing a national strategic telecommunications plan for the entire Forest Service. The Strategic Plan is intended to encompass the 10-year period from 1991 through 2001, and to address both present and projected mission requirements. It will provide the framework for the Forest Service to conduct comprehensive planning and analyses of normal and emergency telecommunication operations, and establish regulations and guidelines pertaining to the procurement, implementation, ownership, management, maintenance, and alteration/reassessment of telecommunication system elements across all operational units.

The **Strategic Plan** will be designed to insure that the selected telecommunication systems and services are mission-effective (i.e., able to satisfy current requirements), have a low cost over their life cycle, and are flexible enough to adapt gracefully to future needs. The Plan will be definitive, so that the strategic plans of the Forest Service Regional Offices and the tactical plans of the Forests can be logically developed and implemented within a consistent Service-wide architectural philosophy.

The following tasks will be performed during the study:

Task 1. Requirements Definition. This task will establish the baseline for all subsequent tasks. It will create a "Vision" of future Forest Service Telecommunications. Requirements definition considerations will include National and Regional Business Plans, prioritized operational and technical performance, telecommunications connectivity between Regions, Forests, State and local agencies, etc.

Task 2. Review and Assessment of Internal Factors. Tasks 2 through 4 define Forest Service "Reality" today. Task 2 will define the economic, technological, regulatory, and policy constraints imposed by the Forest Service and its organizational units, which need to be taken into account when analyzing the definition of requirements and formulating strategies. Internal factors to be considered in this task include cost guidelines, physical, environmental, and aesthetic restrictions on facilities, etc.

Task 3. Review and Assessment of External Factors. Factors beyond the control of the Forest Service are "external factors". This task will define the economic, technological, regulatory, and policy constraints imposed by the Department of Agriculture and other Government Departments and agencies, and State and local jurisdictions.

Task 4. Review of Existing Systems. This task will develop a description of the radio, voice telephone, and data communication architectures currently being used in the Forest Service. This task will also describe the implementation, and estimate the impact, of the change in October 1991 when the Department of Agriculture network (DEPNET) will be replaced by FTS-2000 services throughout the Forest Service.

Task 5. Technology Assessment. Tasks 5 and 6 will help determine the best "Transition to the Vision". Task 5 offers explanations of technologies which may provide the means for the transition. Subject areas to be addressed in this task will include FTS-2000 offered services including ISDN, fiber optics, satellite service including leased versus owned issues, digital switching, video services including video teleconferencing, personal telecommunications, etc.

Task 6. Formulation of Issues and Alternative National Strategies. This task will use the results of all previous tasks in formulating potential strategies for satisfying the Forest Service's requirements over the next 10 years. Specific economic, technological, regulatory, and policy issues will be addressed. The most important of these will be chosen as evaluation criteria for comparing strategy alternatives.

Task 7. Recommended National Strategy or Strategies. This final task will present and explain the National strategy (or strategies) selected by the Forest Service in Task 6. The Strategy/Plan will emphasize broad policy matters, and address the underlying principles which may be changing across telecommunication planning elements.

Boulder Switching System Project. The Institute acted as a consultant to the National Institute of Standards and Technology (NIST) in specifying an on-premise telecommunications system to replace the system currently in place at the Department of Commerce Boulder Laboratories. Working with representatives of NIST and other resident Government agencies, ITS personnel developed the technical procurement package and proposal evaluation criteria, and participated in the assessment of submitted proposals.

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

Wayne Rust and Val Pietrasiewicz Analyze Forest Service Telecommunication System Requirements

Local Area Network Implementation

Outputs

- Local area network (LAN) system designs
- LAN prototype testing
- Technical consulting
- LAN troubleshooting

The U.S. Commander in Chief Pacific (USCINCPAC) is replacing the existing DOD Intelligence Information System (DODIIS) interface, which uses network terminal concentrators, with Ethernet gateways at several locations in the Pacific area. Fiber optic Ethernet LANs will be installed at these locations to connect various DODIIS workstations together with the DODIIS gateway. The LANs will replace the currently used RS-232 links and will provide enhanced connectivity and performance.

The figure on the facing page shows the initial design for the LAN implementation on the island of Oahu. The figure shows that a number of DODIIS workstations are located at various DOD facilities on Oahu and indicates how these workstations are connected to the DODIIS. The Packet Switching Node (PSN) in the upper right half of the figure connects to a wide area network (WAN) and gives local users (on Oahu) access to other DODIIS facilities located throughout the world. Ethernet gateways serve as interfaces between users attached to the fiber optic LANs and the PSN. A local gateway is directly connected to the PSN via a serial RS-232 interface, while the remote gateway is connected to the PSN via a multiplexed encrypted circuit.

The LANs are Ethernet local area networks that meet the interface and signaling specifications of IEEE Standard 802.3-1985. Fiber optic cabling is used as the backbone transmission medium. While the logical network architecture is a bus topology, the physical network (fiber cabling) is a ring. The ring is formed using single-strand fiber optic cable to connect transceivers at each node. Transceivers serve to regenerate the fiber optic signal. They also contain an automatic optical bypass switch which helps avoid single point failures in the network. A fiber optic network implementation is employed to minimize RFI, EMI, security, and TEMPEST problems.

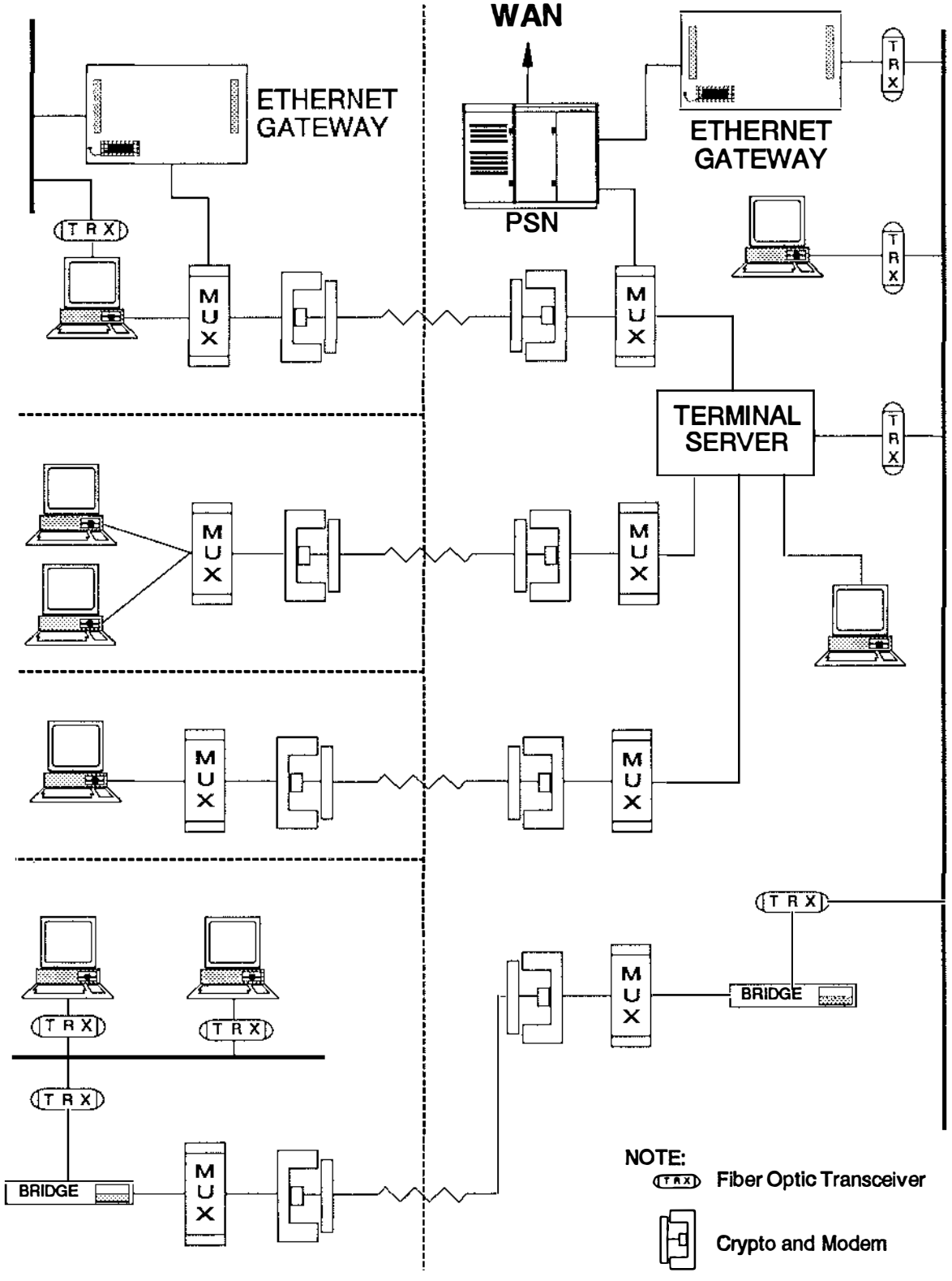
The DOD's Transmission Control Protocol/ Internet Protocol (TCP/IP) suite is employed on all DODIIS networks, including the LANs.

Since the DODIIS LAN upgrade was embedding new equipment at critical points in an existing network, it was important to discover and solve any possible operational problems at an early stage in implementation. It was decided to prototype the system and conduct tests to verify its operation at one location prior to the installation of gateways and LANs at the other network locations. It is believed that this prototyping and test effort will aid in minimizing service interruptions during general system installation. It also will insure that the system is operationally viable.

During FY 91, personnel from ITS conducted both laboratory and operational testing of a prototype DODIIS LAN system configuration on Oahu. This testing was successful, and several potential system problem areas were discovered and resolved before additional equipment was purchased and the remaining systems installed. The prototype testing should save the USCINCPAC program considerable funds which might otherwise have been required during a future upgrade to "fix" the system. Related prototyping efforts for sites other than Oahu are continuing. The Institute is also providing technical consulting services to USCINCPAC to resolve any operational problems which may occur as the system is fielded.

For information, contact:
William J. Pomper (303) 497-3730

ITS Electronics Engineers Dave Wortendyke and Bill Pomper Review LAN Testing Data



The original design for the DODIIS LAN on Oahu.

Silver Medal Winners, Dr. Hans Liebe and Dr. George Hufford, Working on Measurements in the Millimeter-Wave Laboratory

APPLIED RESEARCH

The rapid growth of telecommunications over the past 40 years continues to cause crowding in the radio spectrum, even though greatly increasing amounts of telecommunications are now carried by fiber optic systems. New applications of technology have required a new understanding of the behavior of radio waves in all parts of the radio spectrum. Research work at ITS includes projects from the lowest frequencies (LF noise measurements) to the highest frequencies in use (millimeter-wave propagation modeling).

This work extends ITS traditional expert understanding of the ways that propagation of radio signals are effected by the propagation medium constituted by the earth's surface, the atmosphere, and the ionosphere. It is resulting in new broadband models for the broadband signals used in some of the new radio systems. Other efforts are increasing our understanding of propagation of millimeter-wave frequencies, providing a huge band for future expansion of new radio communication services. A new study of optimum detector theory shows how to make better use of the radio spectrum at any frequency. Finally (though reported on in another section), a myriad of new convenient short-range communications services such as cordless phones, wireless LANs, and PCS are causing us to look more closely at the ways that radio waves travel very short distances--especially within man-made environments.

The Institute has a long history of radio-wave research and propagation prediction development that provides a substantial knowledge base for the development of state-of-the-art telecommunication systems. A major goal of ITS is to transfer this technology to the user community, both public and private, where knowledge is transformed into new products and new opportunities.

Areas of Emphasis

Millimeter-Wave Propagation Modeling

Includes projects funded by the National Aeronautical and Space Administration and the U. S. Naval Ocean Systems Center

Propagation Measurements

Includes projects funded by the U. S. Army Communications-Electronics Command, the U. S. Army Missile Command, the U. S. Air Force, and the National Telecommunications and Information Administration

HF Channel Modeling and Simulation

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

Optimum Detection Theory

Includes a project funded by the Department of Defense

Millimeter-Wave Propagation Modeling

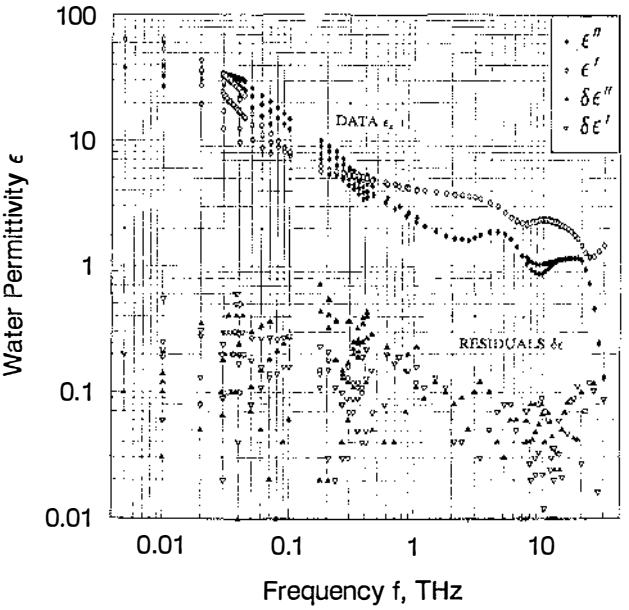
Outputs

- Complex permittivity model for water at frequencies below 1 THz
- Complex permittivity model for ice at frequencies below 1 THz
- Laboratory measurements of oxygen absorption for NASA remote sensing channels
- Improvements in clear-air millimeter-wave propagation model (MPM)

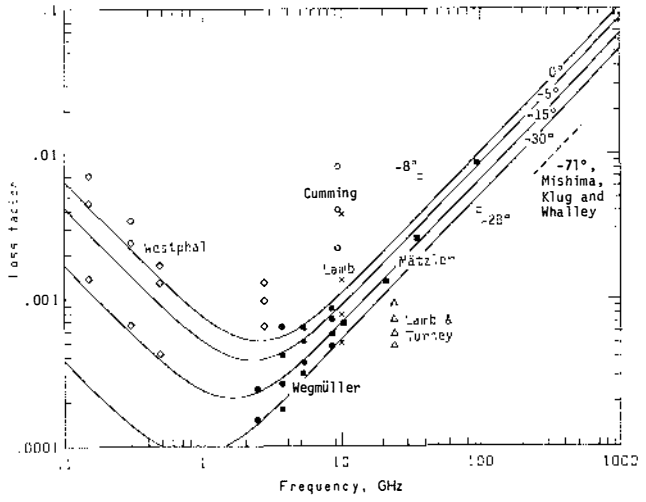
The Institute has actively pursued a premier millimeter-wave (MMW) program for many years, since these frequencies provide the main opportunity to increase the spectrum available to carry radio signals. In addition, mmw-frequencies may offer the only frequency bands with enough room to carry future very wide bandwidth signals exceeding 1 GHz. In FY 91, particular emphasis was placed on modeling.

The dielectric properties of water play a key role in the propagation of millimeter waves in the atmosphere. Rain in particular is an extremely severe attenuator of millimeter waves. Experimental permittivity data of liquid water, compiled from the open literature, were analyzed to develop a model of the dielectric properties of pure water for the spectral range from 0 to 1 THz at atmospheric temperatures. A double Debye model was developed that predicts the measured permittivity data more accurately and in a simpler fashion than the generally accepted Ray model. The single Debye model is supported by a large body of data below 100 GHz. The double Debye model is a *best* fit to reported experimental data up to 1000 GHz. A resonance model extends to 30 THz.

The dielectric properties of ice are also important in the propagation of millimeter waves. In particular, more study of the interaction of millimeter waves with snow and hail is needed. Experimental permittivity data of ice, compiled from the open literature, were analyzed to develop a model of the dielectric properties of ice for frequencies from 0 to 1 THz and temperatures from 0 to -40 Celsius. The model agrees well with available measured data. UHF measurements at low temperatures and millimeter-wave measurements at higher temperatures would be particularly useful.

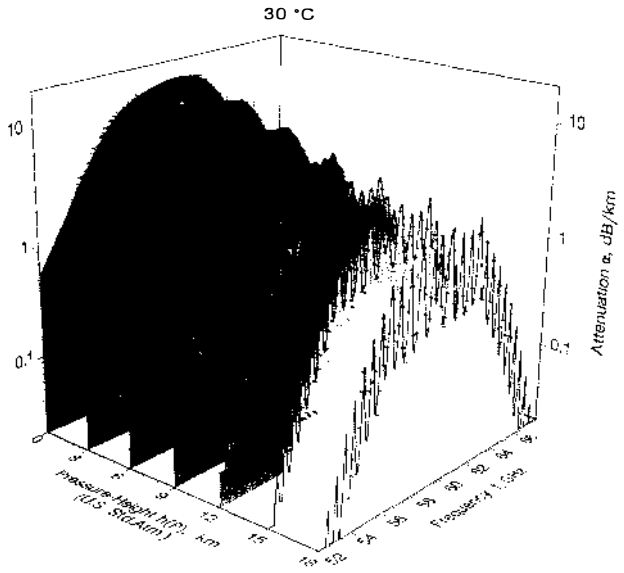


The Water Permittivity Data and Residuals After Subtracting the Model Predictions



The Loss Factor of Ice as a Function of Frequency

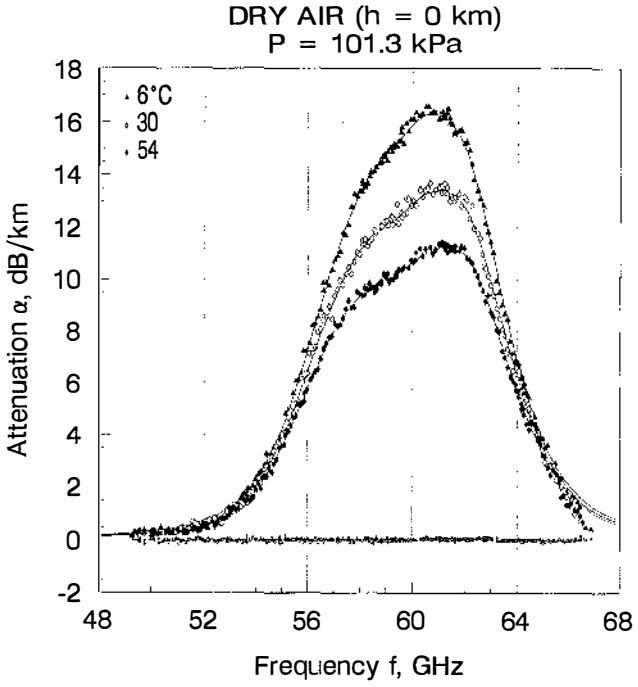
Measurements of absorption and phase delay made using a Fabry-Perot cavity and a vector network analyzer provide the basis for an accurate clear-air millimeter-wave propagation model (MPM). In FY 90, the most extensive and accurate set of measurements of absorption by atmospheric oxygen ever made was 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.



A Comparison of MPM Predictions and Measured Absorption by Atmospheric Oxygen Showing Pressure Dependence

An initial analysis of these more than 5000 measurements has been used to make interim improvements in the MPM. A first comparison of the experimental results with MPM89 predictions revealed systematic differences, in some cases larger than 15 percent, that correlate with line broadening and overlap parameters. An interpretation of the extensive data set with Rosenkranz's overlap theory will result in an updated model.

Additional measurements of absorption by atmospheric oxygen were made this year for NASA space borne remote sensing channels, MSU-2,3,4. These measurements and the updating of the MPM model provide a foundation for the interpretation of remote sensing data in global climate change studies.



A Comparison of MPM Predictions and Measured Absorption by Atmospheric Oxygen Showing Temperature Dependence

Recent ITS Publications

The Atmospheric 60-GHz Oxygen Spectrum: Modeling and Laboratory Measurements (by Liebe, Hufford, and DeBolt)

A Model for the Complex Permittivity of Water at Frequencies Below 1 THz (by Liebe, Hufford, and Manabe)

A Model for the Complex Permittivity of Ice at Frequencies Below 1 THz (by Hufford)

For information, contact:
Kenneth C. Allen (303) 497-5474

Propagation Measurements

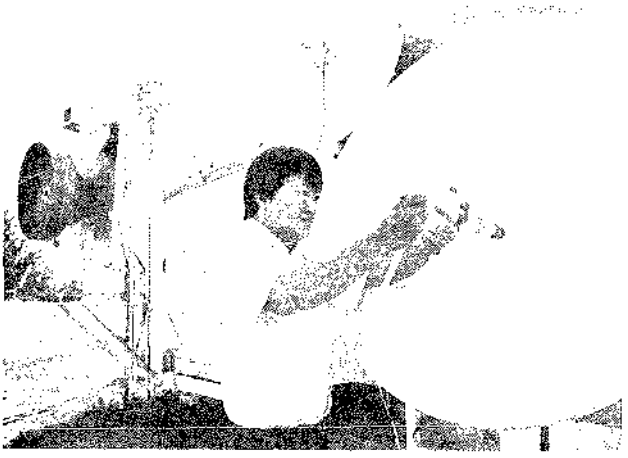
Outputs

- Polarimetric measurements of millimeter-wave propagation through rain
- Measurements of differential attenuation in rain on nearby paths at 23 GHz
- Impulse response measurements through deciduous trees at 30.3 GHz
- Plan for characterization of multipath environment at Dugway Proving Grounds

For many years ITS has placed a major emphasis on propagation field measurements. These measurements help identify areas where further modeling work is needed and are the ultimate test of the validity of models. In FY 91, polarimetric measurements of millimeter-wave propagation through rain and simulated rain were made.

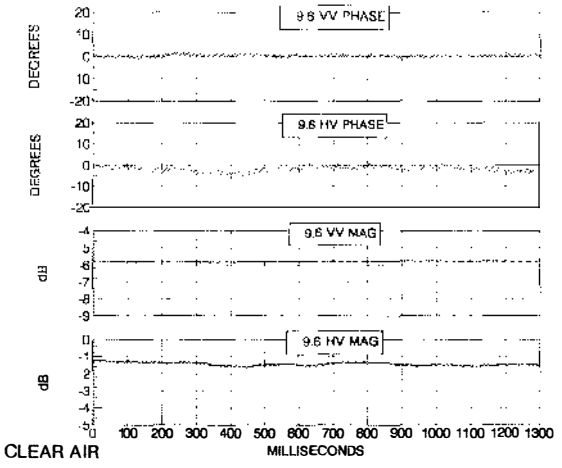
The most common technique for measuring the elements of the transmission polarization matrix is to switch between combinations of polarizations at the transmitter and receiver. However, with such a method, the measurements are not simultaneous and are limited in time resolution by the time required for switching and settling. This limits the usefulness of the measurements for systems that may be sensitive to amplitude and phase fluctuations at rates up to 10 kHz.

The technique used in the ITS instrumentation is to transmit one polarization at 9.6 and 28.8 GHz and the other, simultaneously, at 9.605 and 28.815 GHz. A dual polarization receiver is used in which each received polarization results in two IFs--one for the co-polarized wave and one for the cross-polarized wave. All signals are coherently received and mixed down to IFs of 2.6 to 15.6 kHz. These are then digitized for later processing. The Fast Fourier Transform is applied to the digital data, and the amplitude and phase of each component is extracted. Thus, all the elements of the transmission matrix are measured simultaneously, and the time resolution of the measurements is limited only by the IF bandwidth and system noise.



Antennas of the Polarimetric System

The system was installed on a 1 km slant path in Boulder, CO, and later moved to a folded path using a 1 m square flat plate reflector. Measurements were made on the folded path during rain and rain simulated with a fire hose. The phases and amplitudes of all four polarimetric components at each frequency were measured each 500 μs. The clear-air amplitudes and phases for the signals transmitted with vertical and horizontal polarization and received with a vertically polarized antenna are shown below.



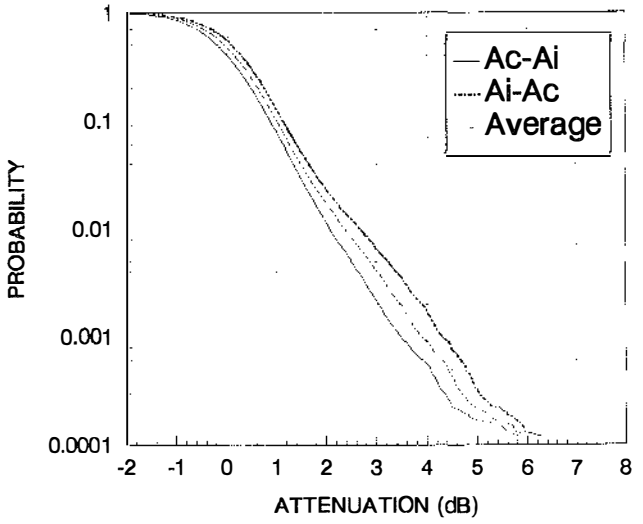
Measurements of Phases and Amplitudes of Polarimetric Components

Measurements were made to determine to what degree rain might attenuate a desired signal more than an undesired signal, resulting in an increase in interference. In particular, the desired signal is assumed to be from a fixed, terrestrial microwave transmitter while the undesired signal is from a satellite visible to the main beam of the receiving antenna. Thus, what is of interest is the differential attenuation on the two nearby propagation paths.

Two 23 GHz transmitters were located about 12 km from their common receiver in Hilo, Hawaii. At the receiver, the apparent angle separating the transmitters was about 1 degree. This geometry was chosen to simulate a terrestrial link together with an earth-space link in which the satellite is just above the horizon. Because the actual earth-space path would extend beyond the 12 km terrestrial path, the simulation geometry gives the worst case for the satellite interfering with the terrestrial link. On the other hand, the geometry is overly optimistic for determining the interference of the terrestrial link to the earth-space link.

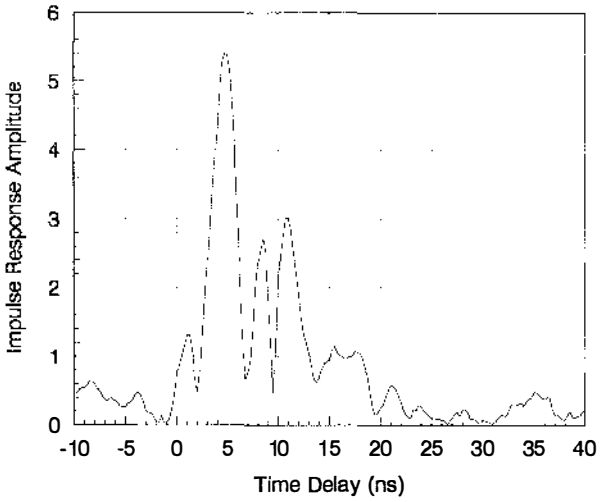
The frequencies of the transmitters differed by 5 MHz and resulted in IFs of about 1 and 6 MHz at the receiver. A PC data acquisition system was used to digitize the IF, compute the Fast Fourier Transform, extract the two signal amplitudes, and record them.

The results showed that the desired signal would be attenuated by 4 dB more than the undesired signal only about 0.1 percent of the raining time.



Differential Rain Attenuation
Conditional Probability, February 13 to March 23
r = 4 dB, M = 20 dB

Measurements of the wideband impulse response (2 ns resolution) at 30.3 GHz when propagating through deciduous trees with leaves and without leaves were completed. Delay spreads as large as 20 ns were observed. An example of the data from these measurements is shown below.



Measured impulse response through trees

A plan was completed for the characterization of multipath propagation on the Dugway Proving Grounds by measurements. The signal from a radar may sometimes arrive at a distant point by multiple paths, typically one direct path and one path by reflection from objects in the environment. When testing systems that home in on signals, it is particularly important to know whether the strongest signal is coming from a radar or from a reflection.

The plan to characterize the Dugway Proving Grounds calls for several stages of investigation. First, the geographical area will be studied and modelled using the TA Services facility of ITS. With this information, plans will be formulated for on-site measurements of multipath. A computer controlled measurement system will be used. Initial tests of the system will be performed in the Boulder area using ground-based measurements on local area radars. The actual measurements conducted at Dugway Proving Grounds will be performed using a helicopter.

<u>Recent ITS Publications</u>

Observations of Geographical Variability of the Attenuation Rate in Rain (by Allen)

For information, contact:
Kenneth C. Allen (303) 497-5474

HF Channel Modeling and Simulation

Outputs

- Simulation model of HF propagation
- HF channel noise/interference model
- Propagation, noise/interference, and jamming signal simulators for HF system testing
- Improved HF radio system test capability

Over the past several years there has been a resurgence of interest in HF communication systems, particularly those using wide bandwidths (on the order of 1 MHz or more). This interest has been stimulated by the evolution of spread spectrum technologies, which offer the potential for improved transmission performance and resistance to signal detection, interference, and jamming. However, many uncertainties exist concerning the performance of wideband HF systems. The Institute is working to resolve these uncertainties by developing a wideband HF channel simulator. The simulator will enable designers to evaluate the performance of HF radio equipment in a repeatable, objective fashion without the cost of running extensive field tests.

The design and implementation of a channel simulator requires a channel model that accurately describes the real-world conditions encountered on communication links. Previous HF channel simulators have been based on a 1970-vintage HF channel model that is restricted to narrow bandwidths (on the order of a few kHz). This model is also restricted in its ability to describe propagation in dispersive media, which are often encountered on complex HF paths.

Over the past several years, the Institute has made substantial progress in developing a wideband HF channel model which will overcome many of these restrictions. The objective has been to develop a model that is accurate not only for narrowband technology, but also over bandwidths of 1 MHz or more; that can be validated with measured data; and that is suitable for implementation in a real-time, wideband HF channel simulator. The model includes the channel transfer function, describing the characteristics of ionospheric skywave propagation, as well as a model of wideband HF noise and interference.

Good agreement has been obtained to date in making comparisons between outputs of the new HF channel model and measured data. Outputs of the simulation model have been compared with propagation data collected by the Naval Research Laboratory on a variety of different paths. The figures on the facing page provide comparisons of the outputs of the noise/interference model with data collected by the MITRE Corporation.

The first figure shows raw data (in the form of the instantaneous voltage of the received noise/interference) over a time interval of 4 ms and a bandwidth of 800 kHz at a center frequency of 23 MHz. The second figure shows the amplitude probability distribution (cumulative probability distribution of the power of the noise/interference) generated from the data in the first figure. The third figure shows the power spectrum generated from these same data (the discontinuity of approximately 20 dB in power spectral density in the middle of the plots is due to the filter in the HF receiver). These examples, as well as numerous others, demonstrate the similarities of the measured noise/interference with that generated by the model.

The Institute is currently building a hardware channel simulator which implements the new HF channel model. This development will be completed during FY 92. The simulator will be used for the testing associated with the development of a family of Federal Standards for (narrowband) HF communication systems and networks. It will also be used for testing wideband equipment being developed as part of a large military communication system procurement.

Recent ITS Publications

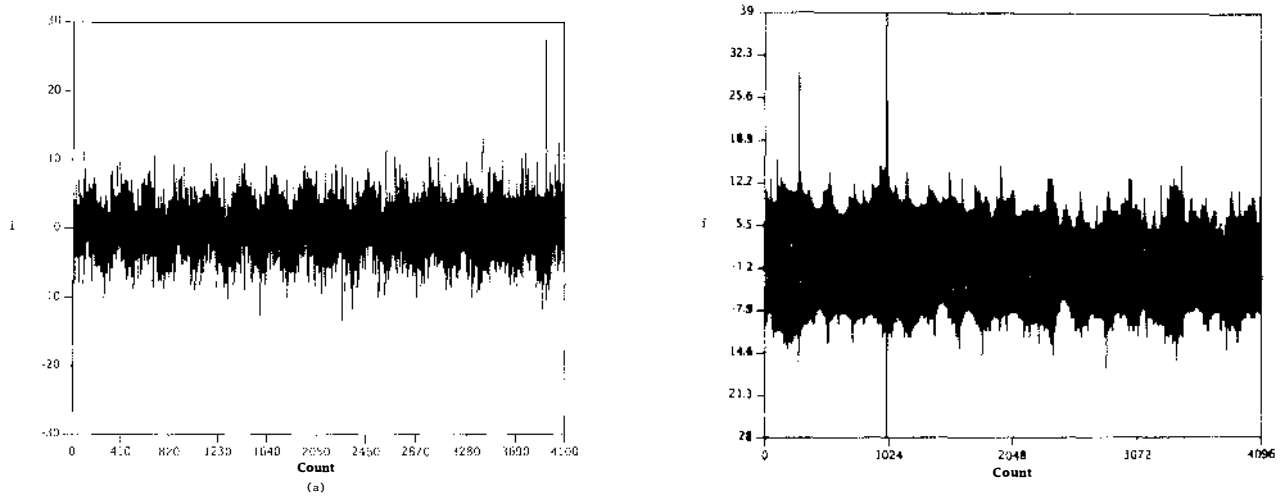
Wideband HF Noise/Interference Modeling - Part I: First-Order Statistics (by Lemmon and Behm)

Model for the Simulation of Wideband HF Noise and Interference (by Lemmon)

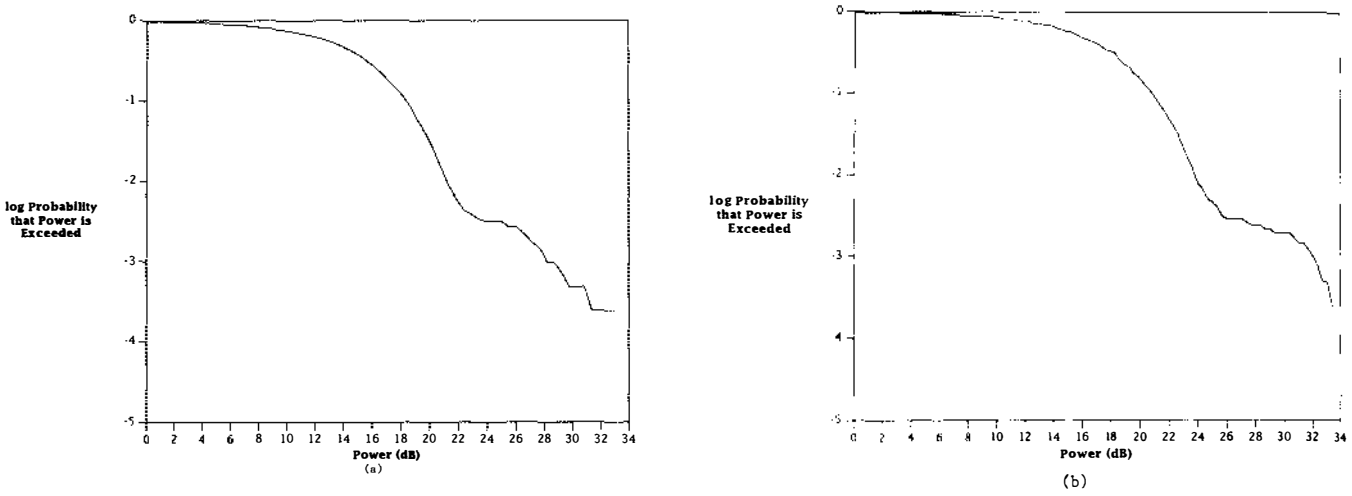
A New HF Channel Model and Its Implementation in a Real-Time Simulator (by Hoffmeyer, Vogler, Mastrangelo, Pratt, and Behm)

A New Wideband HF Simulation System for Testing HF Radios (by Mastrangelo, Hoffmeyer, Behm, and Pratt)

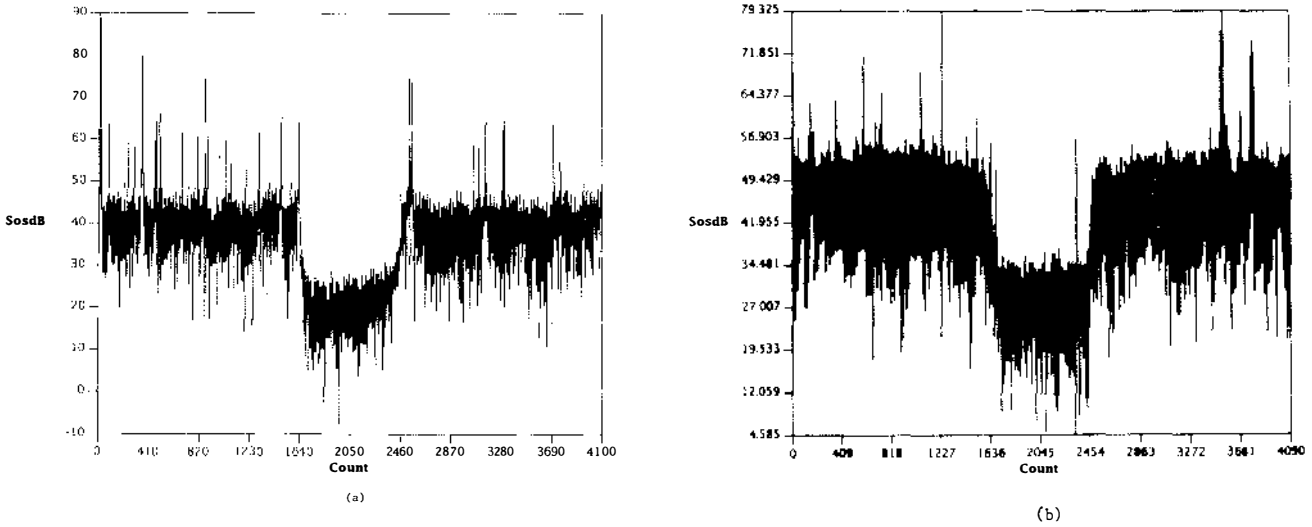
For information, contact
James A. Hoffmeyer (303) 497-3104



Comparison of (a) Simulated and (b) Measured Noise/Interference in the I-Channel



Comparison of (a) Simulated and (b) Measured Cumulative Probability Distribution of the Power Envelope in the Time Domain



Comparison of (a) Simulated and (b) Measured Power Spectra

Optimum Detection Theory

Outputs

- Statistical-physical models of non-Gaussian interference processes
- Statistical-physical models of near- and far-field interference and noise vector/tensor fields
- Measurements of non-Gaussian interference time and spatial processes
- Locally optimum and appropriately suboptimum adaptive or robust nonparametric signal detection, extraction, and estimation algorithms

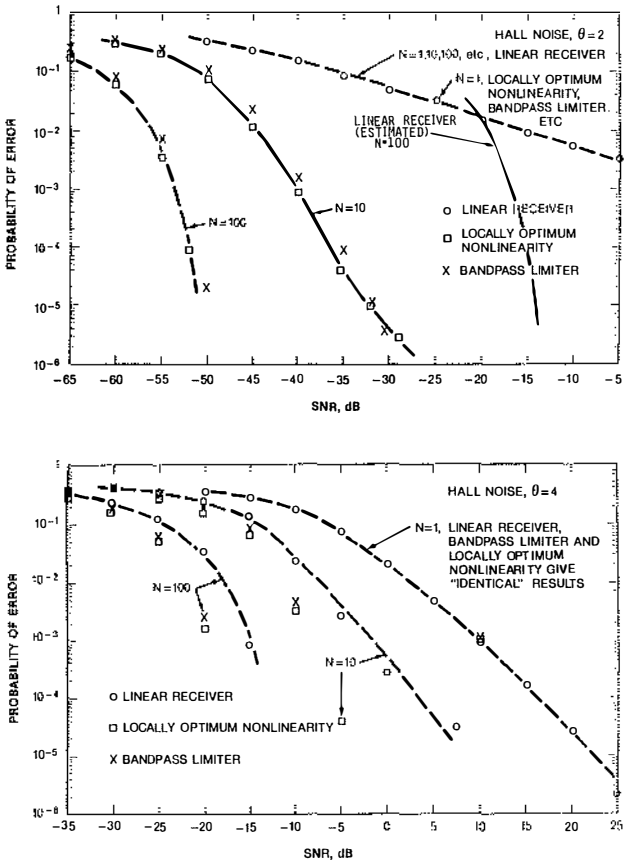
There are important communication systems that need to operate in an environment where the noise background is non-Gaussian. This includes systems operating at low frequencies (where the background noise is impulsive signals from distant lightning storms) and systems operating at HF (where interfering signals form the major part of the noise background). Some of these systems are critical strategic systems where the message must get through even if signal levels are far below the level of background interference. Although non-Gaussian noise and interference have long been recognized as a significant degrader of telecommunication system performance, most traditional systems are designed for a Gaussian noise environment. It is well known that Gaussian interference is the "worst" kind of interference in terms of minimizing channel capacity or in its information destroying capability, so that very significant improvements are achievable when appropriate account is taken of the actual real-world interference environment.

Analytically quantifiable procedures for optimal signal processing at all desired signal levels in arbitrary interference are not generally possible. Restrictions as to the class of signals and interference, mode of observations, etc., must be made or the approach limited to threshold signals where there is no restriction on signal type or interference class. These approaches require the development of usable, physically correct models since more information about the interference process is required than can be obtained from measurement alone.

New models of electromagnetic interference (EMI) have been developed that provide canonical, analytically tractable, and experimentally well established quantitative descriptions of nearly all EMI environments. The models are physically derived, canonical in the sense that they are invariant of the nature and waveform of the source and details of propagation, as far as the formal analytical structure is concerned. They can be highly non-Gaussian, but analytically and computationally manageable. Their principal quantitative and most widely applied form is embodied in the first-order probability distributions of the instantaneous amplitude and envelope of the received interference waveform. Although the original motivation for these interference models has stemmed from problems of electromagnetic compatibility and signal processing in telecommunications, their canonical nature makes them equally well suited to applications in other areas, particularly underwater acoustic, radar, and remote sensing.

In developing "optimum" systems, the threshold signal approach is taken in that if the signal is "small enough" and the time bandwidth product large enough optimum receivers can be realized. These receivers generally take the form of current receivers (based on white Gaussian noise), preceded by one or more particular adaptive nonlinearities. Such receivers approach true optimality for small signal levels and often perform 20 or 30 dB better than current receivers at all signal levels.

The following two figures show simulation results for two impulsive noise cases using the Hall model, which is mathematically nice for simulation and represents a special case of the much more general physical-statistical models. In the first case, the noise (typical of atmospheric noise, automotive ignition noise, etc.) is highly impulsive, and a gain of 37 dB (when compared to the linear receiver) is indicated for 100 independent samples (N) per symbol. (The system is binary symmetric coherent phase shift keying.) In the second case, the noise is still impulsive and highly non-Gaussian, but only 6 dB improvement is achievable.



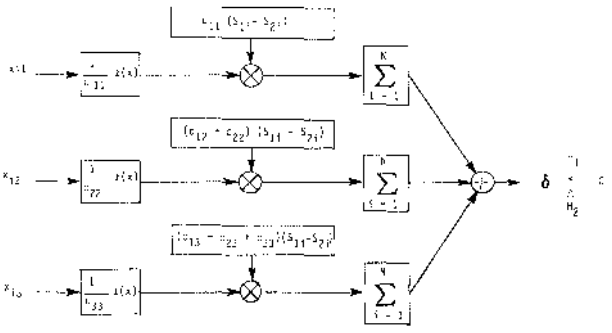
Simulation Results for Two Impulsive Noise Cases Using the Hall Model

Large gains are achievable only if the number of independent received waveform samples is relatively large for each detection interval. One way to overcome the requirement for a large number of temporal samples is to use both spatial and time sampling. This has required the development of detection and extraction algorithms appropriate for interference fields and the expansion of the earlier, physical-statistical, non-Gaussian interference models to vector/tensor nonuniform electromagnetic signal and interference field (both near and far) models. These models play the central role in the structure of optimal threshold detection, extraction, and estimation algorithms.

In many applications of threshold, or weak-signal detection theory, it is reasonable to postulate independent interference samples, particularly for time-sampling procedures. In addition, independent samples are often postulated in order to avoid intractable analytic difficulties when the interference is non-Gaussian, and attempts are made to approximate such idealized situations. The problem becomes acute in many cases when spatial sampling in nonuniform interference is involved, because it is usually not possible to position the sensors of practical arrays sparsely enough to achieve spatial independence and still maintain coherence in the desired signal field across the array. Account must be taken of the fact of correlated samples in order to obtain optimal or near-optimal processing algorithms. When this is done, improved performance is obtained over that of processors optimized for uncorrelated noise samples when the latter are employed in correlated interference.

When the correlated interference fields cannot be sampled at statistically independent intervals, either in space or time, or both, use of threshold algorithms that are optimal for independent samples can be very suboptimum. Accounting for the first-order correlations can greatly improve performance, albeit at the expense of considerably more complex threshold algorithms. Correspondingly, the recently developed field models are termed "first-order correlation models" and are much more general than the "moving average" model, which investigators often use to introduce correlation into random processes.

The figure below shows the receiver for three spatial sensors and N time samples for a binary symmetric coherent system. The c coefficients are from the Cholesky decomposition matrix for the inverse of the correlation matrix for the interference field and $\ell(x)$ is the locally optimum nonlinearity.

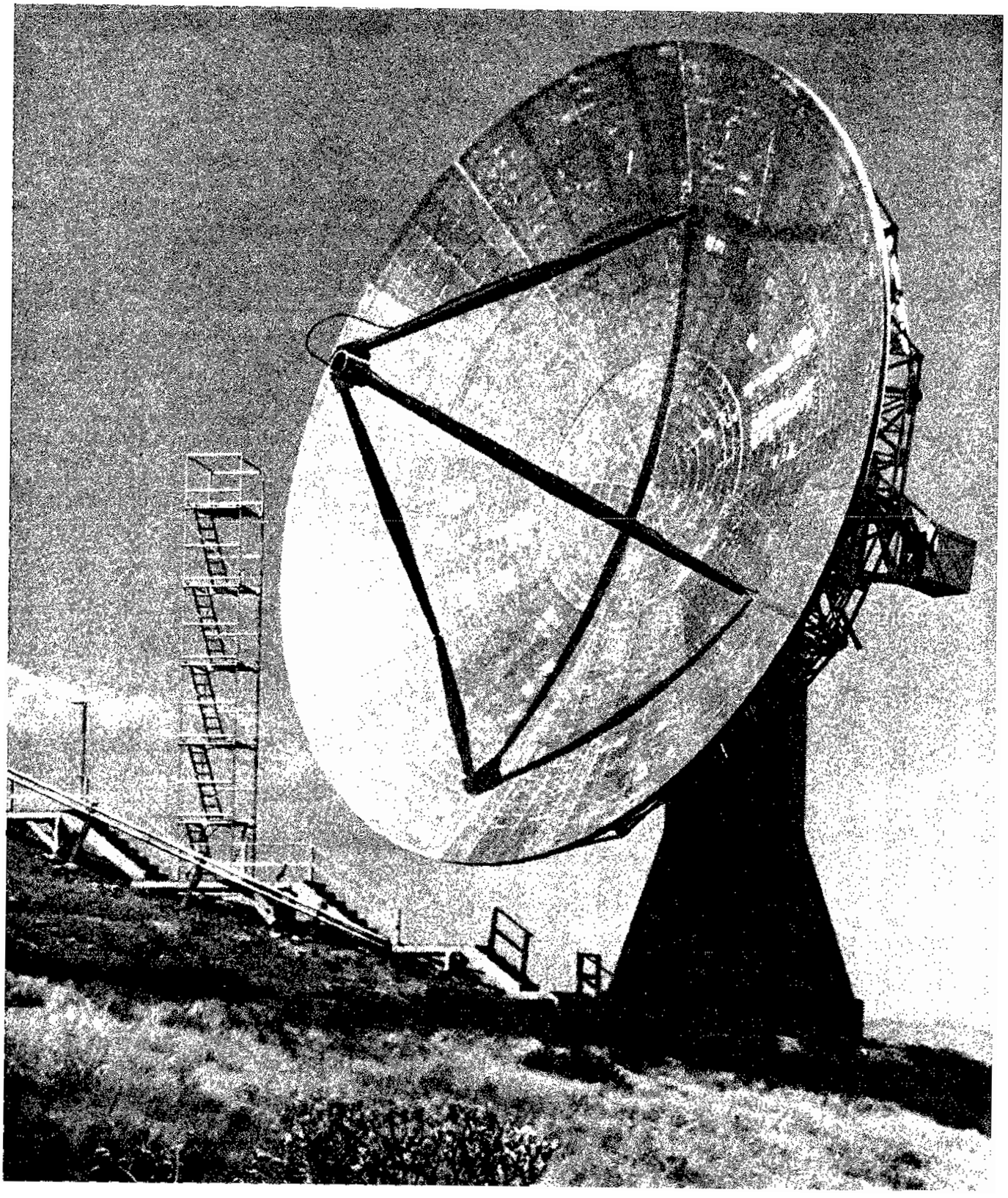


Receiver for Three Spatial Sensors and N Time Samples for a Binary Symmetric Coherent System

Recent ITS Publications

Threshold Detection and Estimation in Correlated Interference (by Middleton)

For information, contact:
A. Donald Spaulding, (303) 497-5201



Sixty-Foot Parabolic Radio Antenna at the Table Mountain Test Facility

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, ANSI, and CCITT data communication standards. It provides empirical data to expedite refinements and improvements of developing standards by working groups and standards committees.

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

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

Three computers, including a transportable desktop UNIX system, comprise the field testing portion of the equipment used in the test bed. Normally, one of the computers serves as the local host to one or more networks, and the transportable machine is taken to a distant city to function as the user of the network under test.

High Frequency Interoperability Test Facility •

The ITS Interoperability Test Facility (ITF) was developed in FY 89-90 through funding from the National Communications System (NCS). This facility continues 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 is currently under construction on the ITF's Green Mountain Mesa transmitter site. 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. Work is under way to add an HF interface to other transmission modes to create a multimedia test facility.

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. The Systems and Networks Division established in-house capabilities for validating proposed performance measures and testing prototype ISDN services. The equipment includes personal computer ISDN co-processor boards, ISDN 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. ISDN performance measurement software developed by ITS is used to send voice, video and data information between the workstations to measure the performance parameters under study.

Laboratory Atmospheric Simulator •

ITS has a unique laboratory atmospheric simulator facility to measure the radio refractive index of moist air. 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. It 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 inter-operability 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 Laboratory 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 wave-lengths. 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.

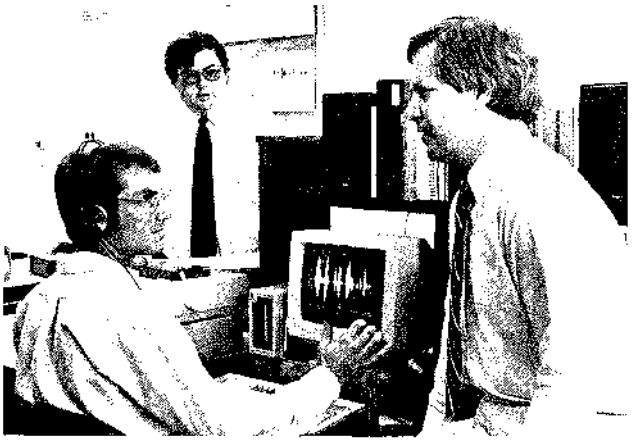
Video Quality Laboratory •

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.

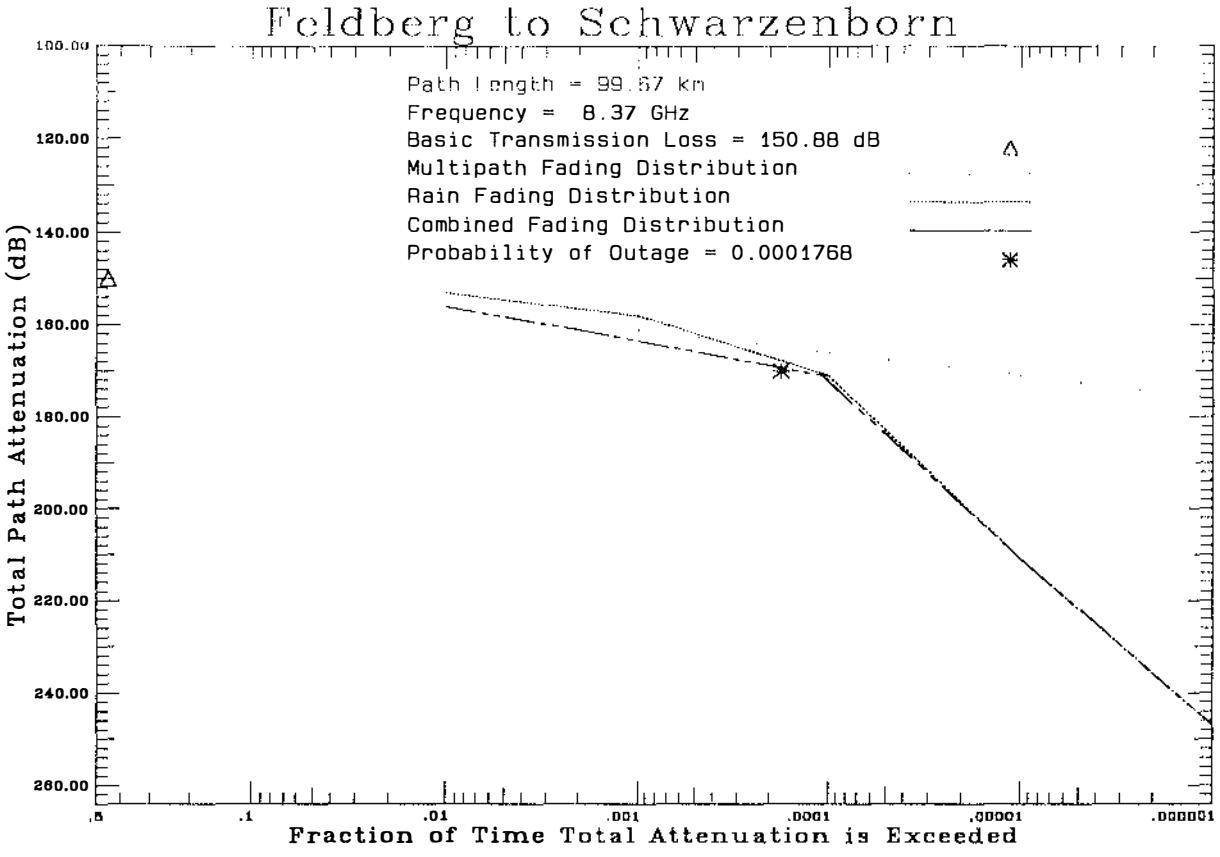
Laboratory hardware consists of an ensemble of broadcast quality video recorders and players, image capture and display equipment, and image processing workstations. An 80386 based workstation is capable of capturing and displaying broadcast quality 756 x 486 NTSC color images. Once captured, images are stored and processed using standard ITS-developed methods. Computer hardware for video image processing includes four reduced instruction set computer (RISC) workstations with high resolution monitors (1200 x 1024) and over 3 GBytes of hard disk space for storing images. A high resolution color printer may be used to obtain video prints or transparencies of processed imagery. Video equipment includes a broadcast quality camera and monitor, Betacam SP video recorder and players, and a VHS video cassette recorder. Video teleconferencing codecs 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.

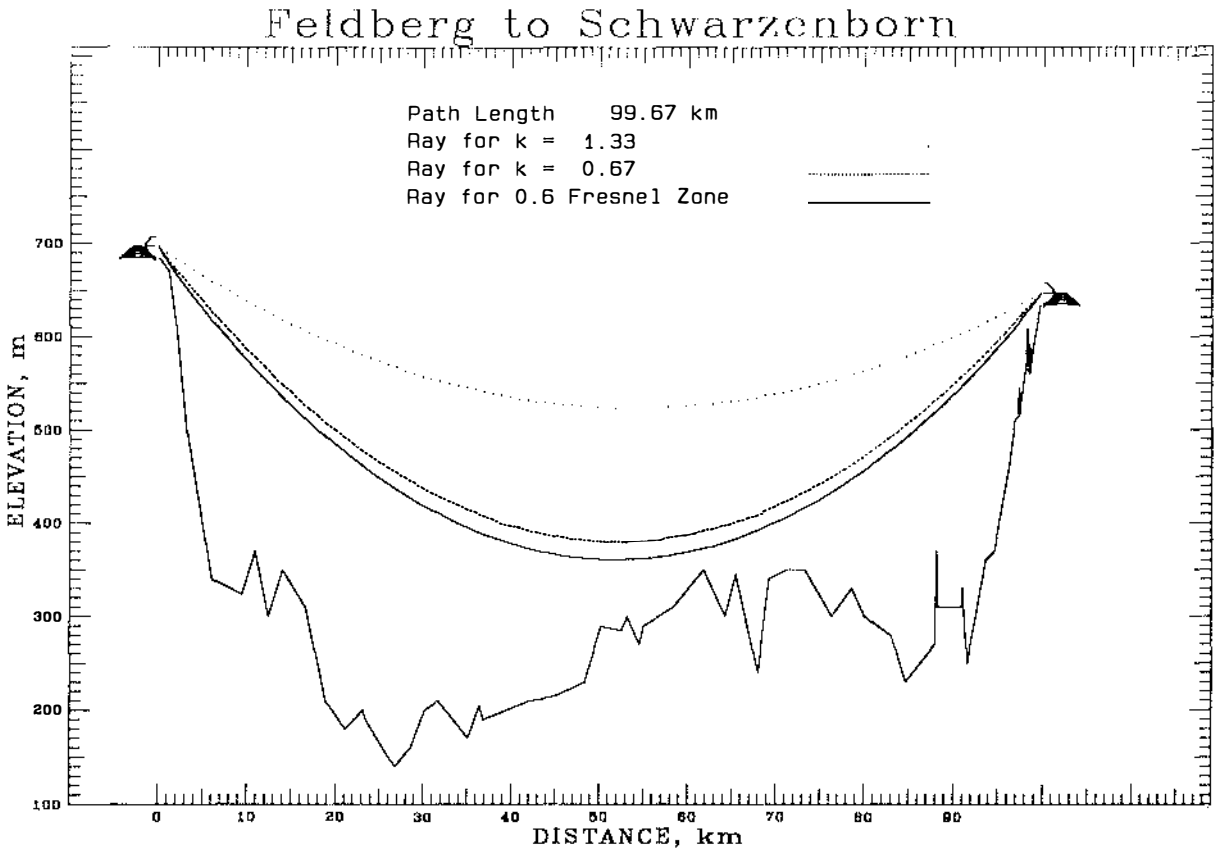
Voice Quality Laboratory •

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.



Project personnel at work in the Voice Quality Laboratory (Steve Voran, David Atkinson and William Hughes)


Feldberg to Schwarzenborn
Path Length = 99.67 km
Frequency = 8.37 GHz
Basic Transmission Loss = 150.88 dB
Multipath Fading Distribution
Rain Fading Distribution
Combined Fading Distribution
Probability of Outage = 0.0001768
Total Path Attenuation (dB)
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
.5
.1
.01
.001
.0001
.00001
.000001
Fraction of Time Total Attenuation is Exceeded


Feldberg to Schwarzenborn
Path Length 99.67 km
Ray for k = 1.33
Ray for k = 0.67
Ray for 0.6 Fresnel Zone
ELEVATION, m
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
DISTANCE, km

ITS PROJECTS - FY 1991

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.

DEPARTMENT OF AGRICULTURE

U. S. Forest Service

Forest Service National Strategic Telecommunications Plan - Val J. Pietrasiewicz (497-5132). Develop a strategic (10 year) telecommunications plan for the entire U.S. Forest Service.

Lake States Forests Telecom Plan - Eldon J. Haakinson (497-5304). Develop a telecommunications analysis and implementation plan for the forests of the Eastern Region.

DEPARTMENT OF COMMERCE

National Telecommunications and Information Administration (NTIA)

Advanced Satellite Communication Technology Studies - Raymond D. Jennings (497-3233). 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 - Eldon J. Haakinson (497-5304). 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.

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, ISDNs, and BISDNs.

Millimeter-Wave Modeling - Kenneth C. Allen (497-5474). 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 - Gary D. Gierhart (497-3292). Enhance the measurement capabilities of the RSMS and suitcase system as needed to provide improved measurement data.

RSMS Operations - Gary D. Gierhart (497-3292). 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 - Robert J. Matheson (497-3293). Develop the general principles for efficient use and management of the spectrum, and resolve specific current issues related to spectrum efficiency.

Spectrum Engineering Models - Robert J. Matheson (497-3293). Develop and implement spectrum engineering models necessary to effectively manage the Government's use of the radio spectrum.

Spectrum Resource Assessments - F. Ken Steele (497-5626). 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 - William R. Hughes (497-3728). Develop objective voice quality assessment techniques and standards contributions in support of advanced voice coding and ISDN standards within T1 and CCITT.

National Institute of Standards and Technology

Boulder Switching System - Val J. Pietrasiewicz (497-5132). Perform technical consulting services regarding the specification and acquisition of a new digital telecommunications 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 - Val J. Pietrasiewicz (497-5132). Develop a guide to assist law enforcement agencies in the selection and application of video surveillance equipment.

DEPARTMENT OF DEFENSE (DoD)

AMOS Model Development - Kenneth C. Allen (497-5474). 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.

Evaluation of SPRS - Martin Nesenbergs (497-3337). Develop evaluation procedures, conduct technical evaluations of proposals and produce evaluation reports associated with the procurement of Switched Protected Routing Service (SPRS) from common carriers.

ICEPAC Consulting - Frank G. Stewart (497-3336). Provide consultation and advisory services regarding the accuracy of the auroral absorption and ways of better implementing the sporadic E (foes) in the ICEPAC HF predictions program.

Low Frequency Signal and Noise Measurement - Michael G. Laflin (497-3506). Study signal and noise environment in the 0 to 20 KHz frequency range in a typical office/business environment.

Microwave Receivability Survey - Frank H. Sanders (497-5727). Determine the receivability of point-to-point microwave links at four locations in four metropolitan areas in the continental United States.

Non-Median Reception - Evan J. Dutton (497-3646). Model digital system performance (especially PSK and QAM) variability with respect to long-term averages. Assess the consequences of this variability when caused by terrain multipath and atmospheric layering and ducting. Determine year-to-year variability of the refractive gradient distribution. Predict reception on terrestrial microwave common carrier links for wide range of percentages of time.

Ocean Duct Measurement Analysis - Kenneth C. Allen (497-5474). Analyze the evaporation duct data taken in Hawaii for polarization dependent propagation and depolarization.

Speech Segmentation/Language Identification - Edmund A. Quincy (497-5472). Apply statistical speech segmentation techniques to develop phoneme correlated features and a phoneme classification algorithm which could then be used in a language identification algorithm.

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 Noise/Interference Data Analysis - James A. Hoffmeyer. Analyze wideband HF noise/interference data tapes to validate WBHF N/I model.

Air Force (USAF)

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 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.

Hill AFB Multipath - Patricia J. Longstaff (497-3568). Investigate multipath characteristics of the Hill Air Force Base test range.

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

Air Force--Electronic Systems Division (ESD)

European TRAMCON Support - Robert A. McLean (497-3778). Support the TRAnsmission Monitor and CONtrol program (TRAMCON) operation in Europe for a period of 42 months including problem isolation, training, testing support, and configuration management.

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 89 - Richard E. Skerjanec (497-3157). Develop, test, and support the TRAnsmission Monitor and CONtrol program (TRAMCON), which was developed to monitor and control the digital transmission system for the Defense Communication System in Europe.

URSI 88 Coefficient Analysis - Frank G. Stewart (497-3336). Provide U. S. Air Force with current ITS HF propagation models and enhance the propagation in current use at ITS. Analyze coefficients and create a coefficient data base that is continuous over a 1-year time interval using the URSI 1988 Coefficient data base.

Army Communications-Electronics Command (CECOM)

MMW Studies of Propagation Through Vegetation Peter Papazian (497-5369). Modify the wideband millimeter-wave propagation measurement system for enhanced sensitivity and accuracy and make propagation measurements through vegetation.

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

Army Foreign Science & Technology Center

Jammer Effectiveness Model - Eldon J. Haakinson (497-5304). Develop a Jammer Effectiveness Model using the AMOS interface shell and ITM, GWAPA, and IONCAP propagation models.

Army Information Systems Engineering Command (ISEC)

DoD Glossary WG - Evelyn M. Gray (497-3307). Support the DoD WG in developing, recording and coordinating DoD definitions for a revision of FED-STD-1037A, Glossary of Telecommunication Terms.

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.

HF Study - Larry R. Teters (497-5410). Assist ISEC in the study of analytic techniques for tactical operational use through HF propagation study.

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 (497-5474). Provide information on time-dependent polarimetric effects of rain on millimeter waves that may affect specific polarimetric sensors.

Army Reserve Component Automation System (RCAS)

RCAS Competitive Demonstration Support - Edmund A. Quincy (497-5472). Provide technical expert evaluation of two contractor prototypes of the U.S. Army Reserve Component Automation System (RCAS). The RCAS is an automated information system including computers, software and networks connecting over 5000 sites to improve operational readiness of the Army National Guard and Army Reserves.

RCAS Test/RCAS Test Equipment - Richard E. Skerjanec (497-3157). Provide technical testing and evaluation during the development and fielding phases of the Reserve Component Automation System.

Defense Information Systems Agency (DISA)

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.

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

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.

Enhanced HF Radio Interoperability Test Facility Paul C. Smith (497-3677). Enhance the capabilities of the existing HF Radio Interoperability Test Facility (ITF) to include the ability to perform interoperability testing of VHF/UHF/SHF single-channel radios, meteor-burst radios, satellite and fiber optic transmission systems.

Interoperability/Standards Procurement Information Source - A. Glenn Hanson (497-5449). Provide technical support for the development of a specialized computer-based Interoperability/Standards Procurement Information Source on Federal telecommunication standards.

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 B-ISDN Performance Measurement - David J. Atkinson (497-5281). Provide expert technical support in the area of integrated voice/video/data measurement and standardization.

NCS Voice Quality Interoperability Standards - William R. Hughes (497-3728). Provide expert technical support in the area of voice communications performance measurement and standardization.

Operational and Technical Analysis of B&W Broadband Antennas - Paul C. Smith (497-3677). Evaluate the operational and technical effectiveness of the B&W broadband HF dipole antennas for use by Federal agencies as portable, tactical or emergency antennas.

R&D/O&M Engineering Services for NCS - A. Glenn Hanson (497-5449). Provide technical support to NCS in areas relating to performance and interoperation of Government telecommunication assets for National Security Emergency Preparedness purposes.

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.

Test of Concepts and Prototypes for Possible Inclusion in Proposed FED-STD-1049 - Paul C. Smith (497-3677). Evaluate concepts and prototypes to perform appropriate testing to ascertain performance and functional interoperability capability.

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

Naval Air Test Center

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

Naval Ocean Systems Center (NOSC)

Advanced HF Radio Interoperability Assessment - Paul C. Smith (497-3677). Assess degree of interoperability between NOSC ALE HF radio system and ITS's RF-350/RF-7210 ALE radio.

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.

USPACOM DODIIS LAN IMPLEMENTATION - Robert T. Adair (497-3723). Support USCINCPAC in developing, installing, and verifying the prototype DODIIS fiber optics Ethernet Local Area Network (LAN) at Camp Smith, HI and the Wide Area Network (WAN) at other Pacific Basin sites.

Naval Sea Systems Command

Navy CAD/VTC Satellite Networks - Edmund A. Quincy (497-5472). Continue development of digital video quality measurements for digitized and compressed video teleconferencing networks used in managing shipbuilding and weapons manufacturing.

DEPARTMENT OF ENERGY

Communication Predictions & Sounding Networks Frank G. Stewart (497-3336). Develop an application methodology and measurement capability that will allow development of 'best available estimates' of ionosphere parametrics and variable time window trends required to enhance frequency management and assignment.

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.

Solar Activity Reception and Warnings - Frank G. Stewart (497-3336). Install and interface a Westar IV Satellite receiver for early warning and prediction of ionospheric disturbances.

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.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

Pop-Up Antenna Refurbishment/Replacement - Nathaniel B. McMillian (497-5750). Provide engineering and technical service support to the FEMA National Radio System (FNARS) upgrade program, phase V.

McLEAN RESEARCH

HF Support - Frank G. Stewart (497-3336). Provide consultation and advisory services regarding radio propagation.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

ACTS Earth Station Functional Specification Development - Raymond D. Jennings (497-3233). 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.

0_2 Absorption Measurements - Hans J. Liebe (497-3310). Measure 0_2 absorption at selected frequencies corresponding to radiometric, remote sensing channels used by NASA.

SCAR Advanced Satellite Designs & Experiments for ISDN Services - Raymond D. Jennings (497-3233). Identify and demonstrate effective means of integrating advanced satellites with terrestrial, fiber-based ISDNs to enhance the overall network efficiency and survivability and to support broadcast, mobile, and thin-route applications.

TELESIS TECHNOLOGY LABORATORIES, INC.

PCS Measurements Plan - Jeffrey A. Wepman (497-3644). Develop plans for Spectrum-Usage, Signal-Strength, and Delay-Spread measurements for Personal Communication Services (PCS) applications for Telesis Technology under the FTTA.

Spectrum Usage Measurements and Data Analysis Jeffrey A. Wepman (497-3644). Provide information on spectrum usage in frequency bands being considered for potential PCS implementation.

U.S. INFORMATION AGENCY (USIA)

Support for USIA HF Conference Activities - James S. Washburn (497-3109). Provide VOA with the capability ot assess the impact of the decisions taken at WARC-87 on U.S. high-frequency (HF) broadcasting interests, the determination of the validity of broadcast service quality predictions and a plan for performing receiver measurements, standards review, and new receiver development.

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.

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

ITS PUBLICATIONS - FY 1991

Akima, H. (1991), Algorithm #697: Univariate interpolation that has the accuracy of a third-degree polynomial, ACM Transactions on Mathematical Software, Vol. 17, No. 3, September, p. 367.

Akima, H. (1991), A method of univariate interpolation that has the accuracy of a third-degree polynomial, ACM Transactions on Mathematical Software, Vol. 17, No. 3, September, pp. 341-366.

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Allen, K. C. (1990), Observations of geographical variability of the attenuation rate in rain, Proc. of URSI Commission F Open Symp. on Regional Factors in Predicting Radiowave Attenuation due to Rain, Rio De Janeiro, Brazil, December 3-7, 5 pp.

Berry, L. A., F. K. Steele, and W. Grant (1991), Frequency assignment summary for 1.435 GHz -2.5 GHz band, NTIA Report 91-274, May, 42 pp. (NTIS Order No. PB 91-225029/AS)

Cass, R. D., and M. J. Miles (1990), Design of experiments to quantify communication satellite system performance, NTIA Report 90-269, November, 102 pp. (NTIS Order No. PB 91-129635)

Dutton, E. J. (1991), Error rate prediction for PSK and QAM when affected by terrain multipath, Electronics Letters, Vol. 27, 10, May, pp. 795-796.

Dutton, E. J. and M. A. Province (1990), An automated wide area prediction model for microwave common carrier links, NTIA Technical Memorandum 90-147, December, 16 pp.

Hoffmeyer, J. A., L. E. Vogler, J. E. Mastrangelo, L. E. Pratt, and C. J. Behm (1991), A new HF channel model and its implementation in a real-time channel simulator, Proc. IEEE 5th International Conf. on HF Radio Systems and Techniques, Edinburgh, U.K., July 22-24, 5 pp.

Hufford, G. A. (1991), A model for the complex permittivity of ice at frequencies below 1 THz, International Journal Infrared and Millimeter Waves, Vol. 12, No. 7, July, pp. 677-682.

Hufford, G. A., J. R. Godwin, and V. S. Lawrence (1991), Characterization of the HDTV channel in the San Francisco area, NTIA Report 91-278, July, 31 pp. (NTIS Order No. PB 92-108331/AS)

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Kubichek, R. F. (1991), Standards and technology issues in objective voice quality assessment, Digital Signal Processing - A Review Journal, Vol. 1&2, April, pp. 38-44.

Kubichek, R. F. and J. E. Schroeder (1991), L_1 and L_2 normed cepstral distance controlled distortion performance, Proc. IEEE Pacific Rim Conf. on Communications, Computers, and Signal Processing, Victoria, B.C., May 9-10, 4 pp.

Lemmon, J. J. (1991), Model for the simulation of wideband HF noise and interference, Proc. IEEE 5th International Conf. on HF Radio Systems and Techniques, Edinburgh, U.K., July 22-24, 5 pp.

Lemmon, J. J. and C. J. Behm (1991), Wideband HF noise/interference modeling part I: First-Order statistics, NTIA Report 91-277, May, 110 pp. (NTIS Order No. 91-208454)

Liebe, H. J., R. DeBolt, and G. A. Hufford (1990), Studies of the pressure-broadened atmospheric oxygen spectrum with an automated millimeter-wave resonance spectrometer, Proc. Fifteenth Int. Conf. on Infrared and Millimeter Waves, Orlando, FL, December 10-14, pp. 56-58.

Liebe, H. J., Hufford, G. A., and R. O. DeBolt (1991), The atmospheric 60-GHz oxygen spectrum: modeling and laboratory measurements, NTIA Report 91-272, March, 134 pp. (NTIS Order No. PB 91-172809)

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Middleton, D. (1991), Threshold detection and estimation in correlated interference, Proc. Ninth International Zurich Symp. and Technical Exhibition on EMC, Zurich, Switzerland, March 12-14, pp. 9-12.

Nesenbergs, M. and D. L. Smith (1991), Mean synchronization times for ATM cells: derivations and computational background, NTIA Report 91-273, March, 38 pp. (NTIS Order No. PB 91-204651/AS.)

Peach, D. F. (1990), Interoperability testing of tactical HF radio systems to ensure operational mission fulfillment, 6th Asia/Pacific Armed Forces Communications & Electronics Association (AFCEA) Conf. & Exp., Seoul, Korea, November 6-8, 16 pp.

Peach, D. F, and R. T. Adair (1990), Methods for development of telecommunication standards that provide user flexibility and OSI conformance, 11th AFCEA Europe Symp. & Exp, Brussels, Belgium, October 23-25, 20 pp.

Quincy, E. A. (1991), Gradient measures of compressed video teleconferencing quality, Proc. IEEE Pacific Rim Conf. on Communications, Computers, and Signal Processing, Victoria, B.C., May 9-10, Vol 1, pp. 356-364.

Rothschild, S. L. and J. E. Farrow (1991), The RAIDER program: Radio algorithms for integration and design of engineering requirements, NTIA Report 91-276, April, 112 pp. (NTIS Order No. 91-218073/AS)

Smith, D.R. and J. A. Hoffmeyer (1990), Observed results from the performance evaluation of tandem digital microwave links, IEEE Global Telecommunications Conference, (GLOBECOM '90), San Diego, CA, December 2-5, pp. 504.2.1-504.2.7.

Smith, P. C., D. R. Wortendyke, C. Redding, and W. J. Ingram (1991), Interoperability testing of Fed-STD-1045 HF radios, Proc. RF Expo West Conf. & Symp., San Jose, CA, February 4-10, 8 pp.

Steele, F. K., W. B. Grant, and W. E. Frazier (1991), Measured characteristics of selected non-licensed radio devices, NTIA Technical Memorandum 91-149, April, 33 pp.

Voran S. D. and S. Wolf (1991), The development and correlation of objective and subjective video quality measures, Proc. IEEE Pacific Rim Conf. on Communications, Computers, and Signal Processing, Victoria, B.C., May 9-10, 3 pp.

Washburn, J. S., G. R. Hand, L. A. Berry, and J. M. Ratzloff (1991), HF broadcast spectrum sharing potential: A study using the IFRB's J-90 notifications, Proc. 5th International Conf. on HF Radio Systems & Techniques, Edinburgh, U.K., July 22-24, 5 pp.

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Wepman, J. A., R. J. Matheson, K. C. Allen, and R. J. Achatz (1991), Spectrum usage measurements in potential PCS frequency bands, NTIA Report 91-279, September, 153 pp. (NTIS Order No. not yet available.)

Wolf, S., M. H. Pinson, S. D. Voran, and A. A. Webster (1991), Objective quality assessment of digitally transmitted video, Proc. IEEE Pacific Rim Conf. on Communications, Computers, and Signal Processing, Victoria, B.C., May 9-10, 6 pp.

Wortendyke, D. R. and T. W. Butler (1991), Measurement of data performance parameters for data/VTC networks, Proc. IEEE Pacific Rim Conf. on Communications, Computers and Signal Processing, Victoria, B.C., May 9-10, 4 pp.

Special Publications:

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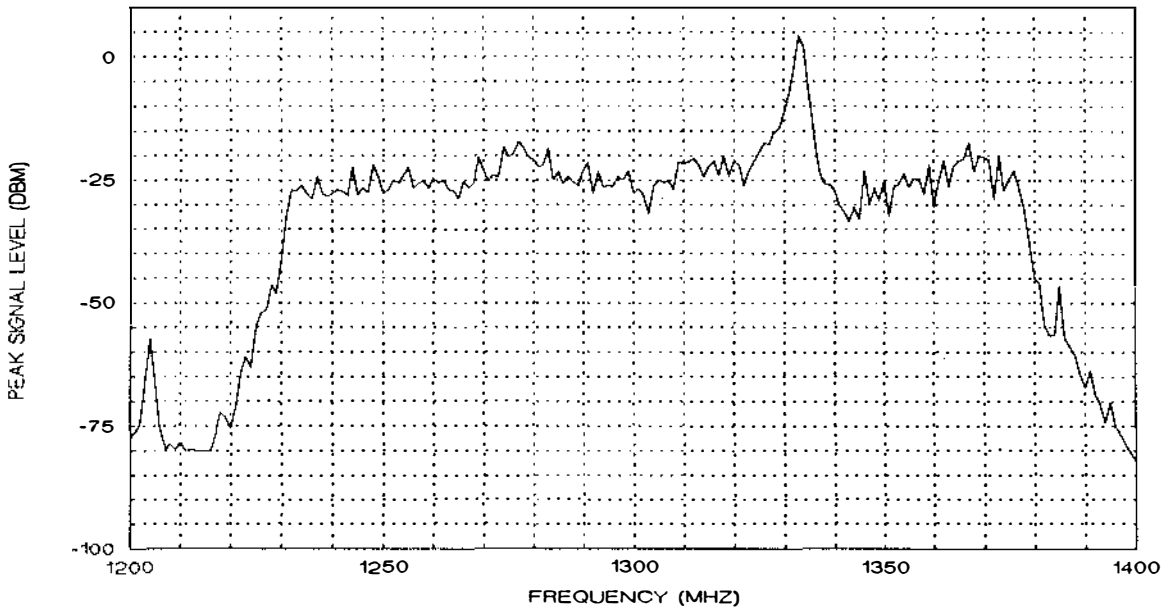
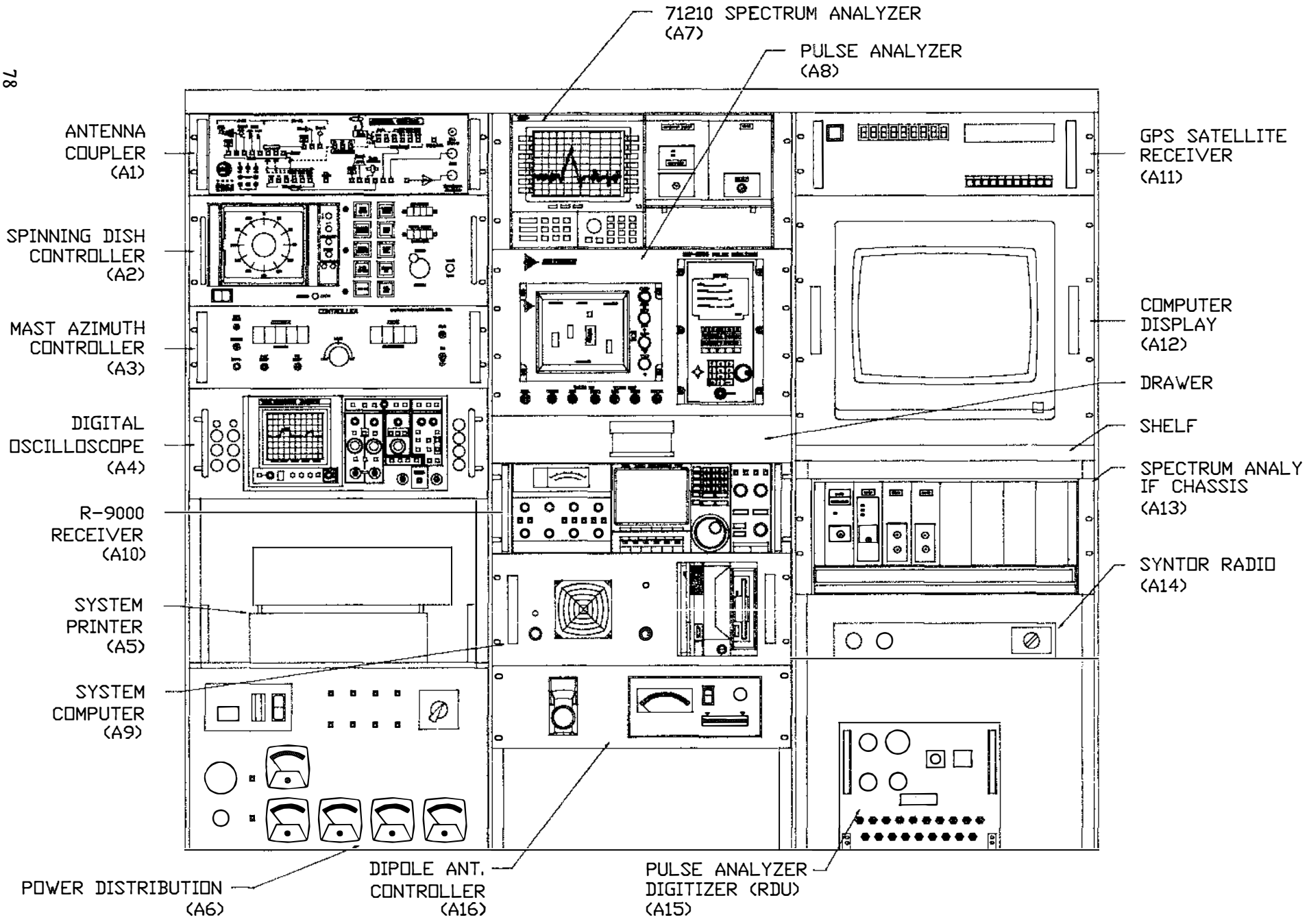
Matheson, R. J., L. A. Berry, and R. F. Linfield (1991), Project contributors to *U.S. Spectrum Management Policy: An Agenda for the Future*, NTIA Special Publication 91-23, U.S. Dept. of Commerce, National Telecommunications and Information Administration, February, 183 pp.

AVAILABILITY OF PUBLICATIONS

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



Emission Spectrum of an L-Band Long-Range Radar Using a Crossed-Field Power Amplifier



FCA Van Equipment Racks

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ACRONYMS AND ABBREVIATIONS

ACTS	-	Advanced Communications Technology Satellite
ALE	-	Automatic Link Establishment
AMOS	-	Analysis of Microwave Operational Scenarios
ANSI	-	American National Standards Institute
ARPANET	-	Advanced Research Project Agency Network
BER	-	Bit Error Rates
BIB	-	Bureau for International Broadcasting
BSS	-	Broadcast Satellite Service
CCEB	-	Combined Communications Electronics Board
CCIR	-	International Radio Consultative Committee
CCITT	-	International Telegraph and Telephone Consultative Committee
CRSMS	-	Compact Radio Spectrum Measurement System
DBS	-	Direct Broadcast Service
DRAMA	-	Digital Radio and Multiplexer Acquisition
DSB	-	Double Sideband
FCA	-	Frequency Control and Analysis
FCC	-	Federal Communications Commission
FEMA	-	Federal Emergency Management Agency
FTSC	-	Federal Telecommunication Standards Committee
GEMS	-	Ground Emitter Monitoring System
HDTV	-	High Definition Television
HFSUM	-	HF Spectrum Utilization Model
ICEPAC	-	Ionospheric Communications Profile Analysis & Circuit Prediction Program
IEMCAP	-	Intrasystem Electromagnetic Compatibility Analysis Program
IFRB	-	International Frequency Registration Board
IHFSUM	-	Institute High Frequency Spectrum Use Model
IONCAP	-	Ionospheric Communication Analysis and Prediction Program
IRAC	-	Interdepartmental Radio Advisory Committee
ISDNs	-	Integrated Services Digital Networks
ITS	-	Institute for Telecommunication Sciences
ITU	-	International Telecommunications Union
JTSSC	-	Joint Telecommunications Standards Steering Committee
LAN	-	Local Area Network
LFMS	-	Low Frequency Measurement System
MMW	-	Millimeter-Wave
MOSES	-	Microwave Operational Scenario Evaluation Software
NCAM	-	Network Connectivity Analysis Model
NCS	-	National Communications System
NTIA	-	National Telecommunications and Information Administration
OSI	-	Open Systems Interconnection (Model)
PMO	-	Project Management Office
RAIDER	-	Radio Analysis and Integrated Design Engineering Requirements
RCAS	-	Reserve Component Automation System
REAMS	-	Radio Environment Automatic Measurement System
ROSES	-	Radio Operational System Evaluation Software
RSL	-	Received Signal Levels
RSMS	-	Radio Spectrum Measurement System
SHARES	-	Shared HF Resources
SSB	-	Single Sideband
TAS	-	Telecommunication Analysis Services
WAPM	-	Wide Area Prediction Model
WARC	-	World Administrative Radio Conference

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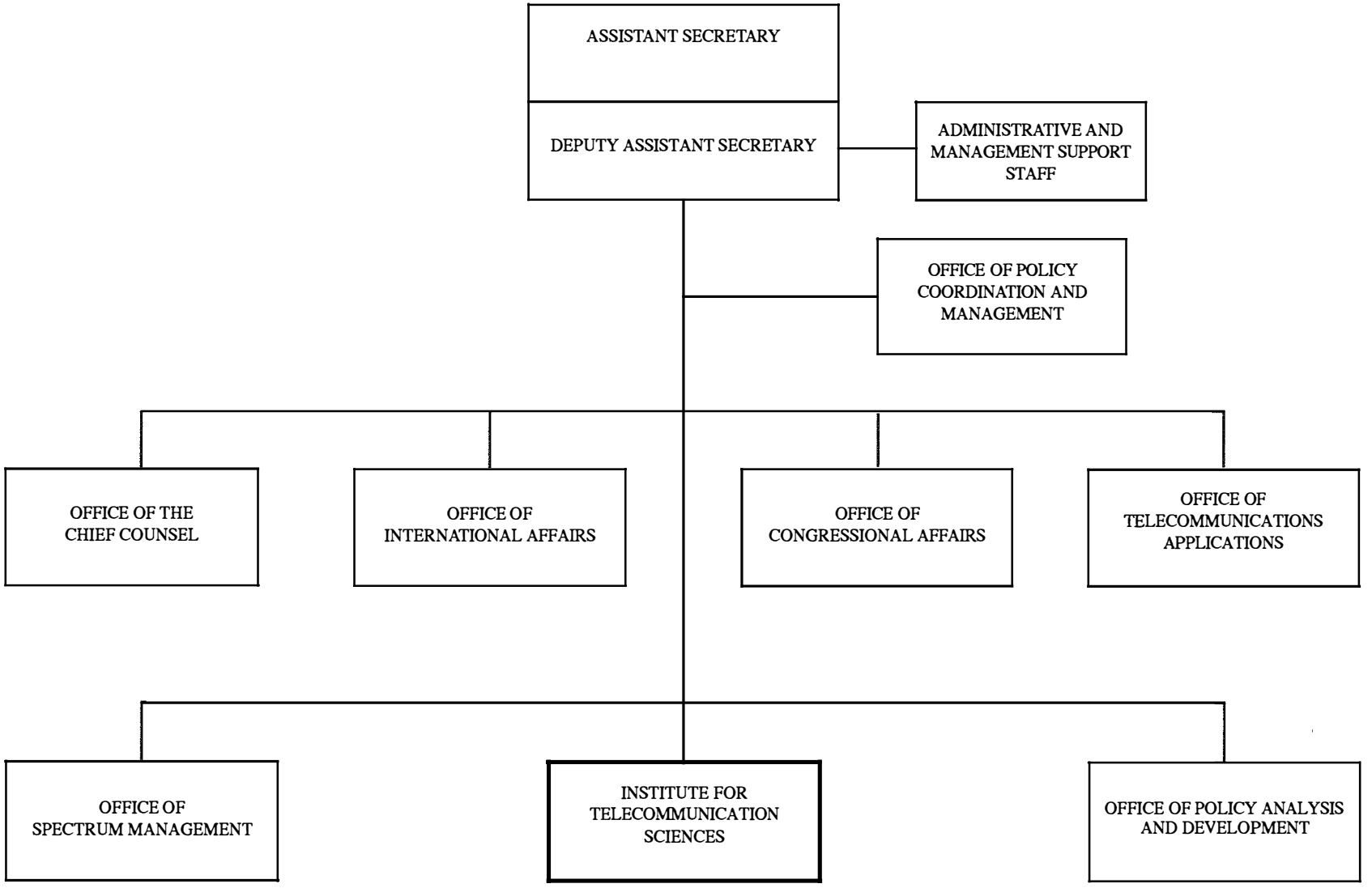

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