INSTITUTE FOR TELECOMMUNICATION SCIENCES

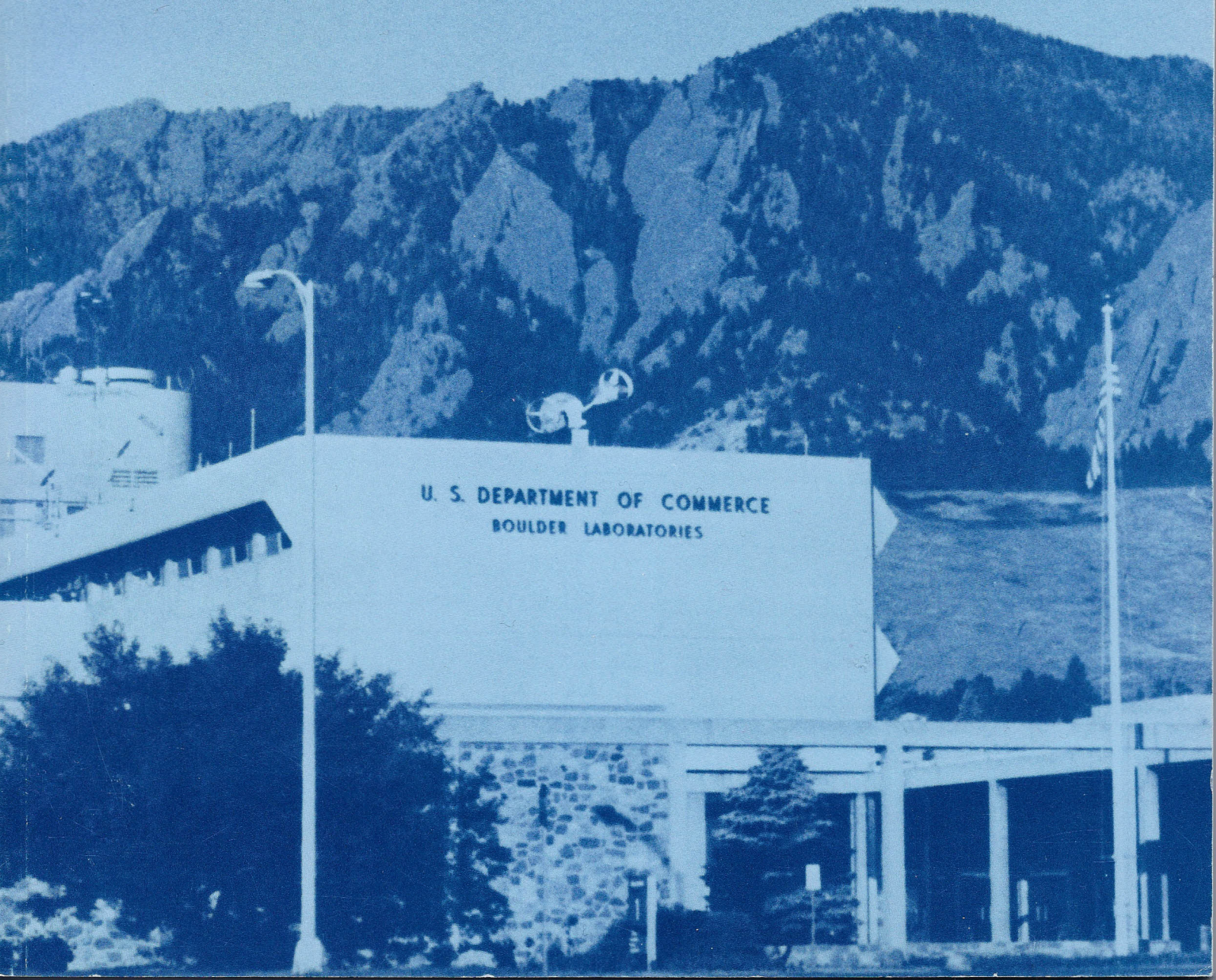
OF THE

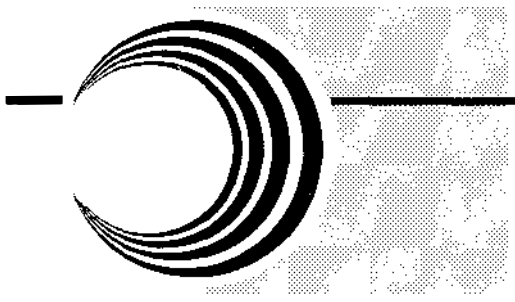
NATIONAL TELECOMMUNICATIONS AND

INFORMATION ADMINISTRATION

1992 TECHNICAL PROGRESS REPORT

For the Period October 1, 1991 through September 30, 1992





ITS

1992

TECHNICAL PROGRESS REPORT

For the Period
October 1, 1991 through September 30, 1992

U.S. Department of Commerce
Barbara Hackman Franklin, Secretary

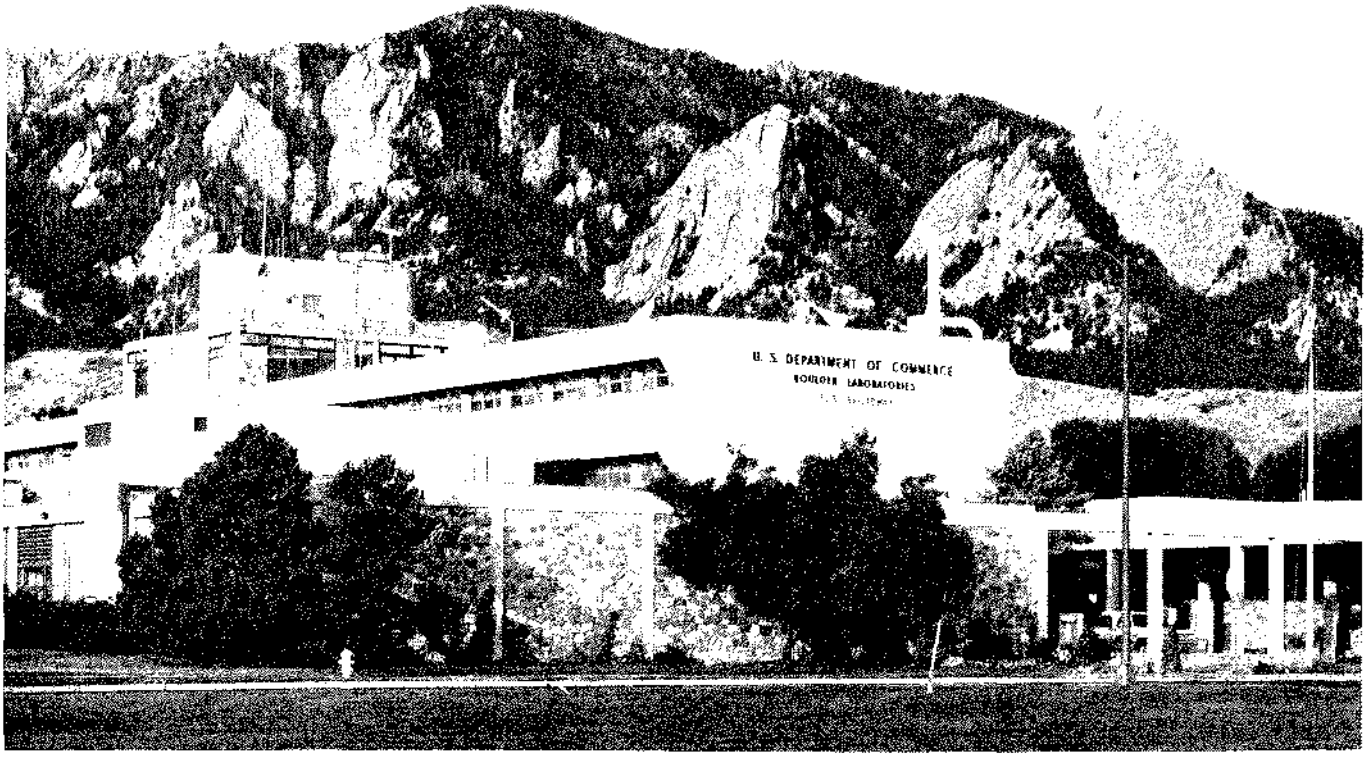
Gregory F. Chapados, Assistant Secretary
for Communications and Information

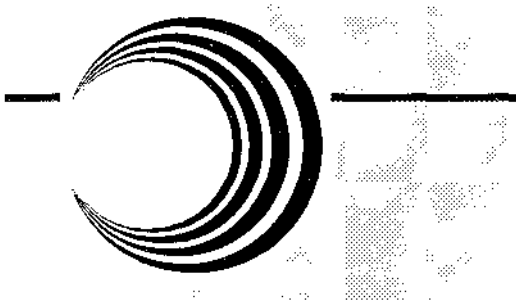
THE ITS MISSION

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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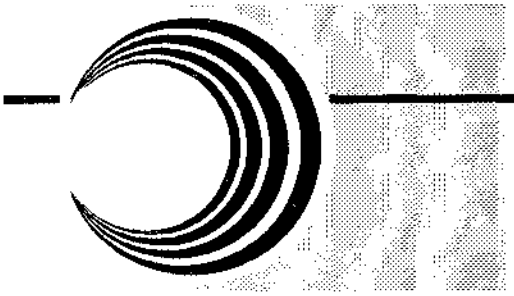


OVERVIEW

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 100 permanent program staff. Many of these employees bring substantial engineering and scientific backgrounds and skills to our technically oriented programs. Indeed, 60% of our employees are electronics engineers, 7% are mathematicians, 2% are physicists, 7% are computer scientists, and 2% are computer programmers. During FY 92, ITS support consisted of $3.7M of direct funding from Commerce and approximately $8.8M in work sponsored by other Federal agencies and industry.

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. More recently, ITS has actively pursued cooperative research with industry under the provisions of the Federal Technology Transfer Act of 1986.

ACTIVITIES

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

- Spectrum Use Analysis Performing technical 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.

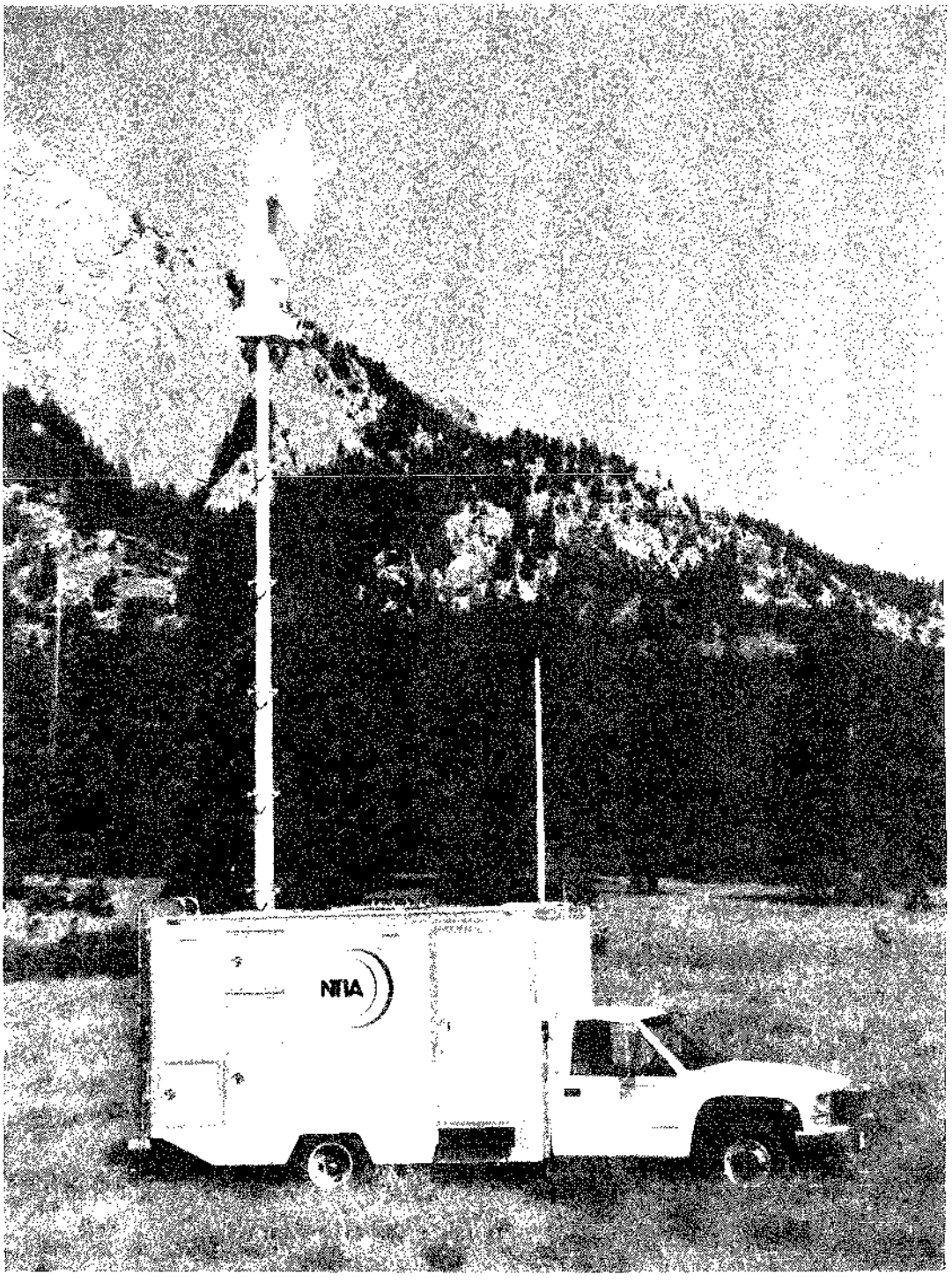
SPONSORS

The activities of the Institute are undertaken through a combination of Commerce-sponsored and other-agency-sponsored programs, and cooperative research agreements with the private sector.. 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. Cooperative research agreements with US West Advanced Technologies, Inc., and Bell Atlantic Mobile Systems support technology transfer and commercialization of telecommunications products and services, which is a major goal of the Department of Commerce. 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 and industry.

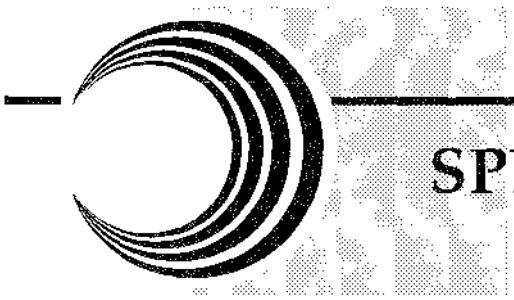
Scientific research and engineering are critical to continued U.S. leadership in the provision of telecommunications and information equipment and services. In the pages that follow, this technical progress report summarizes specific FY 92 technical contributions made by ITS that have significance for the public and private sectors.

DISCLAIMER

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



New Radio Spectrum Measurement System (RSMS)



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 made 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

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

RSMS Spectrum Survey Measurements

Includes projects funded by the Department of Defense, the National Telecommunications and Information Administration, and the National Oceanic and Atmospheric Administration.

RSMS Mobile System Development

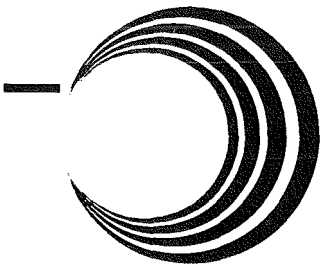
Includes projects funded by the National Telecommunications and Information Administration

Spectrum Surveillance System Development

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

Interference Assessment and Resolution

Includes a project funded by the National Weather Service



CCIR Activities

Outputs

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

The International Radio Consultative Committee (CCIR) is one of the two consultative committees of the International Telecommunications Union (ITU). The International Telegraph and Telephone Consultative Committee (CCITT) is the other. Both of these committees are permanent organs of the ITU, which is one of the standing committees of the United Nations. The ITU is presently undergoing a major reorganization which will merge some of the functions of the CCITT and CCIR, particularly in the area of personal communication systems (PCS) and other areas where radio systems become closely tied to the public switched network. This reorganization is intended to clarify jurisdictional problems on systems like PCS, as well as accelerating the rate of development of international standards for PCS.

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 spectrum use on a global and regional basis. In addition, 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 U.S. 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 should be expected to evolve to meet the needs of the times and to reflect the topics that will be discussed by forthcoming radio conferences. The present CCIR Study Groups include:

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

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 meets at an Interim Meeting about 2 years before the Plenary Assembly, with a Final Meeting for the Study Groups shortly before the Plenary assembly. The reorganized CCIR will be moving to a 2-year cycle of radio conferences, in line with the development of procedures for more rapid approval of recommendations and other technical documents.

There were many CCIR activities this year, including the World Administrative Radio Conference held in Spain in January of 1992 (WARC 92), new activities associated with guiding the reorganization of the ITU, and the normal activities needed to keep up with the progress of radio systems.

The WARCs are conferences authorized to make changes in the international allocation of the radio

frequency spectrum. The unusually large number of requests for new and modified frequency allocations at WARC 92 reflected, more than ever, the turmoil of changing world telecommunication needs and the need to develop standards for systems that are used worldwide. The varied histories and disparate requirements of various regions of the world resulted in many different proposed allocations, resulting in hard-fought discussions before conclusions were finally reached. In many cases, the United States was well satisfied with the outcome; in other decisions, the U. S. view did not prevail.

Some of the new allocations include frequencies for systems with world-wide coverage, like direct broadcast TV satellite (DBS), additional HF broadcasting bands, satellite sound broadcasting, and low earth orbit (LEO) satellite systems for providing mobile coverage anywhere on the Earth. Another allocation action included a frequency band for personal communication services (PCS), a service where worldwide standards would greatly facilitate convenient communication with travelers throughout the world.

Activities associated with the reorganization of the ITU include extensive efforts throughout all of the Working Groups to convert selected CCIR Reports into Recommendations. The Reports are intended to disappear in their present form, and those which are expected to be valuable for international standards are being converted into Recommendations. In addition, much committee work, especially in Task Group 1/1, has been concerned with proposing simpler, more flexible ways to allocate the uses of international radio frequency bands. These more flexible allocations would reduce the complexity of radio regulations (making them easier to understand and use) and would also make it easier for various regions of the world to use a given band in different ways depending on the particular needs of that region. A September 1992 meeting of the Voluntary Group of Experts (VGE) is expected to act on many of the suggestions on radio allocation techniques which have been developed over the past year.

ITS personnel have played an active role in CCIR committees. In addition to holding the chairmanship of US Study Group 1, ITS personnel have been active in the International Working Party meeting in November 1991 and made contributions to new handbooks on monitoring, and a proposed Recommendation on spread spectrum technologies. ITS personnel were also active in Task Group 1/1, which is working on improved methods of frequency allocation and participated in the International Working Group meetings in November 1991. Contributions to this group included a document on technology trends which should be considered in future frequency allocations.

ITS measurements of the leakage from microwave ovens near 2450 MHz played a major role in U.S. reluctance in WARC 92 to allocate nearby frequencies for satellite broadcasting of digital sound. An extensive set of measurements on individual ovens, as well as in large apartment complexes and from a mountain top overlooking a nearby city, provided the needed data. These measurements are continuing based on the need to understand how microwave ovens will affect the operation of the wireless local area networks (WLANs) planned for this band.

The Institute is active in Study Group 6C as national and international chairman for drafting recommendations on radio noise and noise measurements, including participation in the November 1991 international meetings. ITS personnel participated in Study Group 8, especially in meetings dealing with the definition of future land mobile public radio systems (FLMPRS), one possible approach to the development of personal communication systems (PCS).

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 1992 WARC. The level of effort has decreased somewhat since a planned 1993 HF Broadcasting Conference was recently postponed. Nevertheless, an active HF Broadcasting program continues based partly on real-time planning requirements and partly on the need to maintain competence for a future HF Broadcasting Conference.

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 actively participated in the preparation and defense of U.S. positions at the limited reallocation world administrative radio conference (WARC) held in Torremolinos, Spain (WARC-92) and have assessed many of the decisions of WARC-92 as they effect high-frequency (HF) broadcasting, low earth-orbit satellite systems, mobile satellite, mobile services including future public land mobile telecommunications systems, broadcasting satellite (sound) and complementary terrestrial broadcasting, and broadcasting satellite for high definition television (HDTV). The United States was guided in preparations for this WARC by using models developed at the Institute such as the improved HF spectrum use model (IHFSUM).

IHFSUM was used to study the issue of spectrum required for HF broadcasting and how it impacted U.S. broadcasting objectives. As a result the U.S. proposed the HF broadcast band be expanded by 1325 kHz. The WARC-92 decision was to expand the HF broadcast bands by 790 kHz of which 200 kHz are below 10 MHz. The intention is to end the persistent shortage of spectrum allocated exclusively for domestic and international broadcasting and includes the proviso that the expanded bands will be for single-sideband (SSB) systems, thereby nearly doubling those channel capacities. The inclusion of these expanded bands for exclusive HF broadcast use and the SSB issues are left to a future competent WARC to implement. In the meantime it is reported HF broadcasters are moving into the expanded bands under Article 342 of the International Telecommunication Union (ITU) Radio Regulations using double-sideband (DSB) systems.

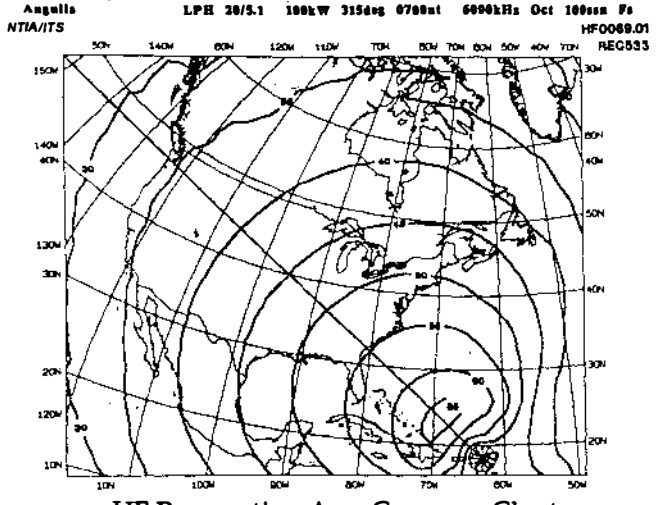
IHFSUM determines the effect of a priori planning of HF broadcasting requirements on U.S. broadcasting objectives, assesses signal-to-interference (S/I) levels for given channel assignments, and optimizes those assignments in accordance with planning principles established by the Final Acts of the 1987 WARC for the Planning of the HF Bands Allocated to the Broadcasting Service (HFBC-87). 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 mandate some requirements to be transferred to the consulted portions on a least-interfering basis. This model remains a crucial tool available for use by U.S. broadcast planners.

The next HF Broadcast WARC will have to resolve issues still facing international broadcasters. These issues include the transition from the present double-sideband (DSB) system entirely to a SSB system by the year 2015, the acceptance of the improved planning system, the suitability of Rec 533 as the accepted propagation model for this improved planning system, the suitability of the adopted receiver characteristics for SSB HF broadcast receivers appearing in Appendix 45 of the ITU Radio Regulations, the availability of "low-cost" SSB HF broadcast receivers, and using out-of-band broadcasts under Article 342. IHFSUM can be used to study the issues and contribute recommendations for their resolution as U.S. broadcast planner's prepare for this next WARC which will likely be convened sometime in 1995.

The importance of demonstrating the consequences of adopting any planning system is documented by the outcome of WARC HFBC-87. That is why the Institute continues to participate in the improvement of the HF propagation model called for in Recommendation 514 (HFBC-87) which invited the International Radio Consultative Committee (CCIR) to recommend both improvements in the propagation method used (called "HFBC84") and an improved method to be used in the future for the HF

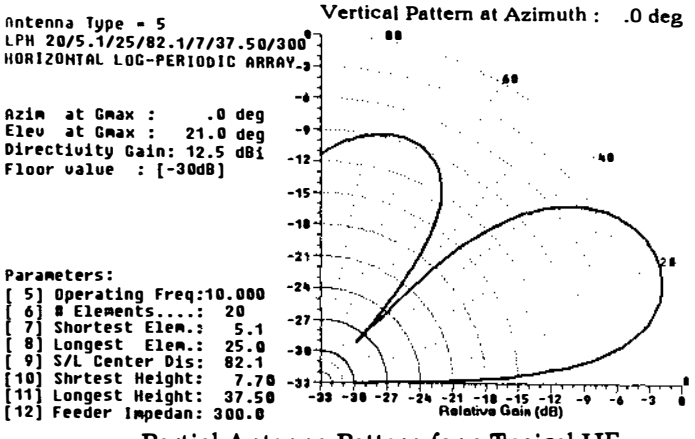
bands allocated exclusively to the broadcasting service. The result of this invitation is CCIR Recommendation 533 (Rec 533) the improved propagation model; the product of CCIR Study Group 6 (propagation in ionized media) Working Party 6A (HF propagation). ITS continues to play a key role in contributing to Recommendation 533 vis-a-vis Working Party 6A. The contributions include technical improvements as well as improvements to understanding the outcomes of the calculations.

Area coverage charts such as the example in the next figure show the capability the Institute has for comparing predictions using Recommendation 533 with other propagation models such as HFBC84, CCIR91, and IONCAP.



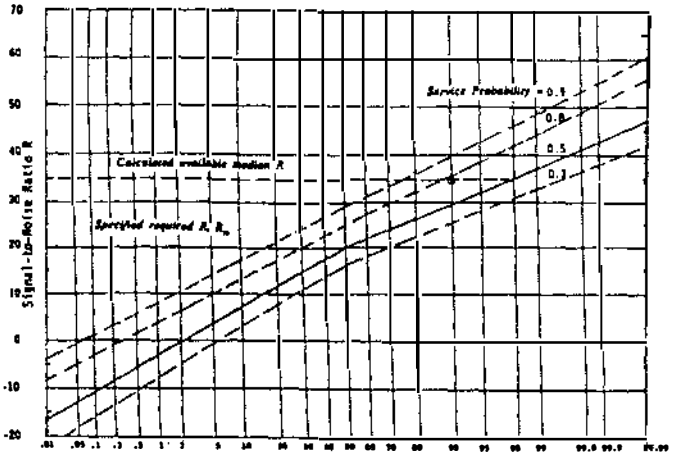
HF Propagation Area Coverage Chart

In addition, ITS contributed to the improvements in the antenna package incorporated in Rec 533 also as a contribution to Study Group 6A. The figure below shows an example of one of the antennas available from the package incorporated by ITS personnel in the Rec 533 model.



Partial Antenna Pattern for a Typical HF Broadcast Antenna

The Institute continues to support USIA/BoB (VOA) in its preparations for the next HF broadcasting WARC and its seasonal frequency coordination activities with other U.S. broadcasters and administrations. Work was completed for VOA in adapting a suite of HF propagation programs to ITS' unique graphics processor and installing these on several different computer platforms ranging from workstations to laptops; in installing an algorithm in those propagation programs that needed them (HFBC84, CCIR91, Rec 533) to estimate the lower decile value of the signal-to-noise distribution; and in analyzing and explaining the system performance calculations performed by the reliability and service probability subroutines of the IONCAP derivative called VOACAP. This latter study reviewed the origins of the three components needed to specify system performance taking account of the short- and long-term statistical variations of the desired signals and interference, and the inherent prediction errors. The following figure provides an example of reliability with various service probabilities (statistical confidence). This study recommends a more versatile method by which reliability information can be made available to the user.



Time Availability (IONCAP Reliability x100)

Recent ITS Publications

HF Broadcast SSB Receiver Study: A Program Plan (by Washburn, Bedford, and Godwin)

Fading Allowance for Lower Decile SNR Calculations for HF Propagation Models (by Kuester)

User's Guide and Reference Manual for the Improved High-Frequency Spectrum Use Model (by Ratzloff, Hand, and Washburn)

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

Domestic Spectrum Analysis

Outputs

- 75-8400 MHz Propagation Data report.
- Microwave oven measurements — six manufacturers.
- Spectrum Crowding Paper.
- Spectrum Requirements for the Fixed Services— A preliminary look. ITS comments on the NTIA Spectrum Requirements Notice of Inquiry.

The Federal Government has begun to play an increasingly proactive role in frequency management in the last couple years. The FCC has initiated an Emerging Technologies" plan, which proposes to move existing microwave users from a band of frequencies near 2 GHz to make room for Personal Communication Systems (PCS). Congress has been working on bills to move about 200 MHz of spectrum from Government use to commercial use. NTIA has begun a series of studies under a new Strategic Spectrum Planning program, including a recently released Notice of Inquiry (NOI) on future spectrum requirements.

As part of the effort to predict future spectrum requirements, ITS has produced a study of the present use of more than 30 fixed (microwave) frequency bands, government and non-government between 400 MHz and 30 GHz. This report will be presented as an ITS contribution to public comments on the NOI and will be used later as a partial basis for an overall NTIA spectrum requirements report. The public report will contain data on all other services in addition to the fixed bands.

The ITS microwave usage report showed that fiber optics has replaced microwaves as the major medium to transport information. One calculation suggested that 20 times more capacity was being installed with optical fiber, as compared with microwave systems. The telephone companies have been quickest to adopt fiber in their networks. Figure 1 shows frequency assignments in the 5.925-6.425 GHz band over the last 5 years, this clearly indicates that the past very heavy use of the 6 GHz band is now decreasing as microwave systems are replaced by optical fiber. Aggressively pursued improvements in fiber components, including higher speed laser modulators, optical amplifiers, optical switches, soliton modulation, will continue to improve fiber networks and decrease their cost.

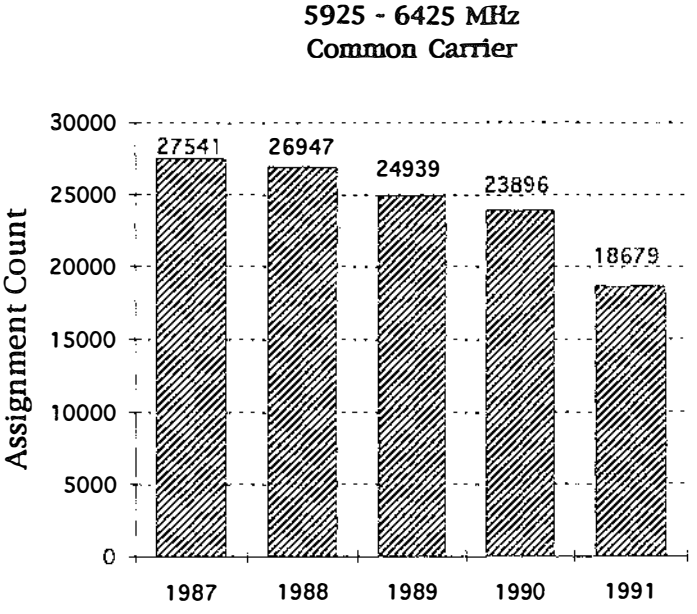


Figure 1. Frequency assignment trends in the 5.925-6.425GHz microwave band

On the other hand, microwave radios continue to have many advantages where fiber is not available yet and where the amount of traffic or the type of terrain will not support the installation of expensive fiber. Some of the higher frequency microwave bands have been "discovered" recently, as less expensive compact microwave equipment has become available. Figure 2 shows recent growth in

the 23 GHz band used extensively by industry, government, and common carriers alike.

The future use of microwave will be affected by many factors, including legal regulations on access to telephone company "dark" fiber, fiber competition by the cable TV companies, and the use of satellite very small aperture terminals (VSATs) in remote locations. In general, this study suggests that traditional microwave systems would continue to play an important, but possibly diminishing, role in the delivery of telecommunication services.

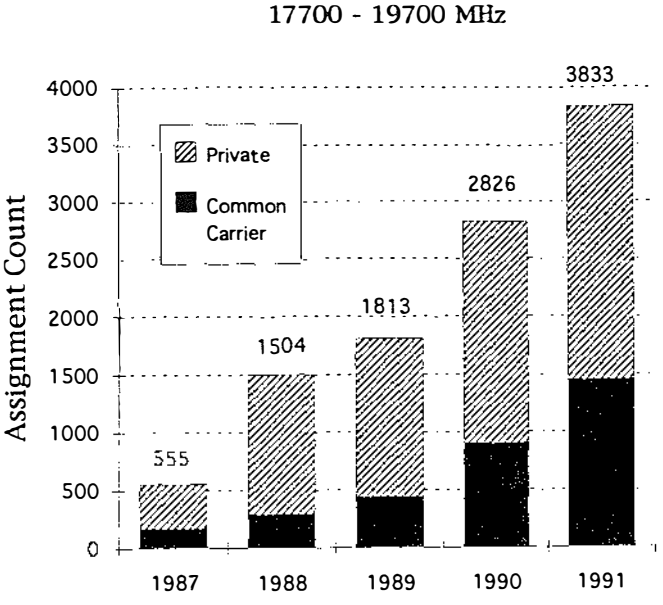


Figure 2. Frequency assignment trends in the 17.7-19.7GHz microwave band

We also included maps showing where microwave assignments were located, graphing them in 1-degree wide blocks. As expected, these maps showed that most microwave systems were concentrated in urban areas. In some cases, however, microwave systems were located more densely in the rural areas where optical fiber and other systems were not yet available.

Another study discussed the possibilities that radio frequencies would become more available, rather than more crowded. Digital technology and data compression techniques are likely to radically decrease the amount of information needed to send a TV signal or a voice signal. Short-range radio systems with efficient frequency re-use (e.g. cellular phone and PCS) are tending to replace the traditional long-range radio system. Much telecommunications traffic has switched from radio to fiber. Fewer special-purpose Government radio systems may be needed in the future, especially since the FTS 2000 legislation has made it particularly convenient for Government agencies to purchase commercial telecommunication services. Electronics technology is beginning to make higher microwave frequencies practical to use, even for low-cost consumer systems. Altogether, the factors which tend to make spectrum more available may turn out to be at least as influential as those factors which increase the demand for new spectrum.

Theoretical studies of spectrum occupancy measures resulted in a change of procedures for making occupancy measurements in the terrestrial microwave bands. These changes have been implemented and tested with the new RSMS system and were also the subject of a paper given at URSI January 1992.

Recent ITS Publications

Tabulations of Propagation Data Over Irregular Terrain in the 75 to 8400 MHz Frequency Range — Part V: Virginia (by Hufford and Steele)

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

RSMS Spectrum Survey Measurements

Outputs:

- Spectrum survey of the Fixed-Service bands in the Denver area
- Spectrum survey of the Industrial, Scientific, and Medical (IMS) band and adjacent bands (2300-2600 MHz) in the Denver area
- Microwave signal receivability survey in the Washington, DC area

NTIA's Office of Spectrum Management (OSM) manages federal government use of the radio spectrum, a function similar to the FCC's responsibility for non-federal spectrum. In support of OSM, ITS operates the Radio Spectrum Measurement System (RSMS). The RSMS also supports tasks that originate within the Interagency Radio Advisory Committee (IRAC), but are assigned to the RSMS by OSM. NTIA does not provide sufficient funding for a year-long effort. Hence, additional RSMS projects are performed with funding from other government agencies and private industry.

Although the RSMS is sometimes used to investigate and resolve specific cases of radio interference, the RSMS capability differs from monitoring systems used by other agencies and industry in that it is also designed to acquire many general-purpose types of measurements on multiple types of emitters (e.g., radars, land mobile radios, point-to-point microwave devices) across the 100 MHz-18 GHz radio spectrum. In particular, the RSMS capability is geared to acquiring broad-band, wide dynamic-range emission spectra and general band usage statistics, rather than simply monitoring activity on one or a few frequencies. NTIA has collected a massive amount of spectrum usage data in recent years for government bands in many metropolitan areas. These data are used to help form a technical basis for policy planning and decisions in spectrum management. The accessibility of all data collected with the RSMS is controlled by OSM.

This year most of the NTIA resources available for the RSMS were devoted to the new RSMS effort described under "RSMS Mobile System Development." This effort was completed in time to allow the new RSMS to perform three measurement tasks, two funded by NTIA and one funded by the Department of Defense (DOD); i.e., Fixed-Service and ISM band surveys performed in Denver along with microwave signal receivability studies performed in Washington, DC. This work is supporting policy formulation for new systems planned for the fixed-services bands. The Department of Defense project determined the receivability of emissions in selected fixed-service microwave bands in and around the Washington, D.C. area.

The NTIA Fixed-Service band surveys were performed in the Denver area to determine actual patterns of usage in the 2, 4, 6, and 8 GHz bands, particularly the amount of spectrum which is actually observed to be occupied, and also the ratio of analog to digital systems actually in use in the selected area. These data may be compared to spectrum assignment listings as part of an effort to determine the accuracy and usefulness of such listings. The Measurement supported policy formulation for new systems planned for the 2 GHz fixed services bands.

Measurements for Denver in the 2300-2600 MHz ISM (Industrial, Scientific, and Medical) band provided information on the background emission levels generated by ISM devices (particularly, microwave ovens) in metropolitan areas. This information

is needed to assess compatibility requirements for proposed systems in this band and adjacent bands.

The DOD project determined the receivability of emissions in selected Fixed-Service microwave bands at several locations in the Washington, DC area. Those measurements were carried out with both the full RSMS configuration, mounted in a van, and with a suitcase system subset of the RSMS mounted at rooftop locations in the area.

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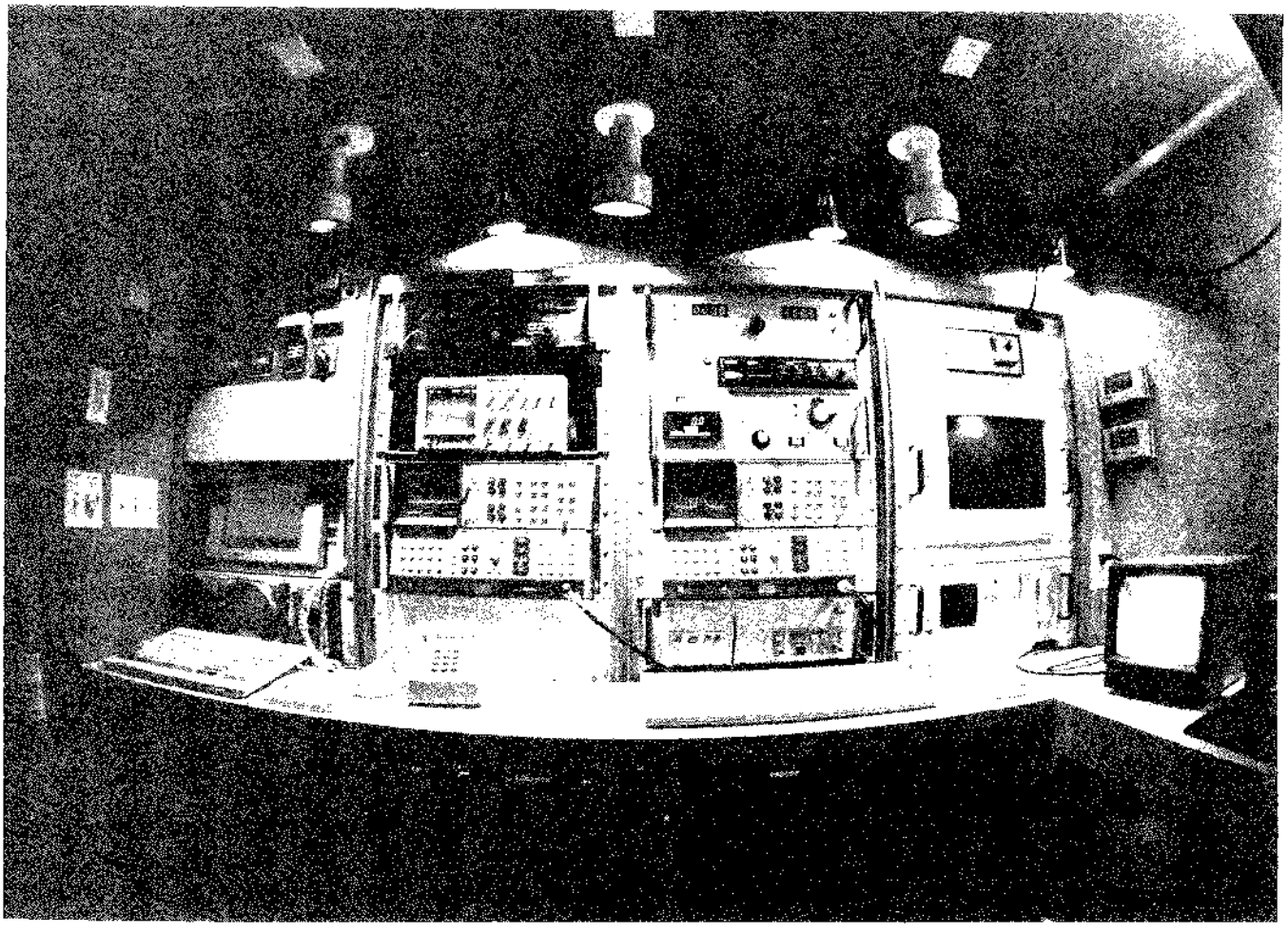


Console of the Radio Spectrum Measurement System (RSMS)

RSMS Mobile System Development

Outputs

- Frequency Management
- Spectrum Usage/Occupancy
- Interference Resolution
- Adaptable Software
- C-130 Mobility

Central to the RSMS enhancement activities this year was the procurement of a new vehicle to house the RSMS mobile system. The old system having been retired after 20 years of faithful service, needed a replacement to carry on the tradition of remote measurements. Planning of the new vehicle began in FY 91 with complete designs being drawn up that included all of the special features desired of the new system. Award of contract for the construction was made at the end of FY 91. The company that won the contract was especially well qualified for such a vehicle. Considerable time was spent in contract monitoring. The result was a support vehicle that will serve the RSMS program with excellent performance.

The foremost feature of the vehicle is roadability. Capabilities for climbing and descending steep grades are critical not only for program support but also for operator safety. The new vehicle has an extended gearing capability and heavy duty brakes for ascending and descending steep grades. Air-ride suspension affords the ultimate in equipment protection for long trips.

Creature comforts as well as equipment cooling are provided by an internally-mounted central air conditioning system. Two independent air conditioners provide a total of 28,000 BTU of cooling. They operate through a common plenum for environmental cooling with half of the air directed into the equipment racks to assure proper circulation. Separate electric heaters for the operator compartment compliment the cooling to keep the internal operating environment of the RSMS closely and automatically controlled.

Power for electronic and environmental systems is provided from an internally-mounted 10 KW generator. This extends the usability of the RSMS by providing stand-alone capability with a reliable over-rated independent power source.

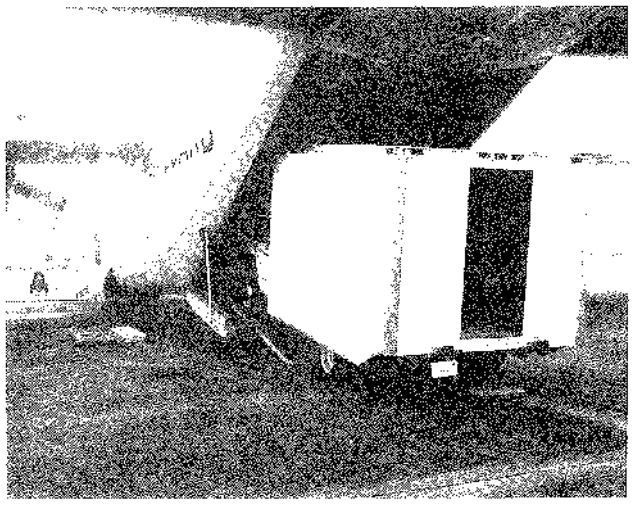
Special attention has been given to shielding the equipment compartment. Special materials were used to increase the shielding levels not only from external radiators but also for isolating the antenna system from the internally generated RF sources such as computer and other electronic noise.

Technical features include two telescoping pneumatic masts, a large (nine-inch diameter) telescoping mast to give selectable height for the main antenna platform, and a smaller (five-inch) mast for lighter weight antennas. A versatile and flexible design of the antenna interface and RF front end include enhanced serviceability and adaptability to differing measurement situations. A continuous-rotation capability along with computer control make the large-mast system a very capable feature of the new van system.

The large-mast system is easily configured to varying program requirements. A 'rack and stack' modular system design allows the most flexibility. Different modules can be added in a variety of modes to allow various antennas to be mounted singularly or simultaneously.

The main amplifier assembly is made up of octave-band filter/amplifier sets which cover frequencies from 1 to 18 GHz. These filters and amplifiers provide the best sensitivity for general measurements in the radar bands. Added to this is a selectable tracking YIG filter. This feature adds improved selectivity for measurements in a dense-emitter environment at the sacrifice of the best sensitivity. Five RF input connections are provided.

A feature that adds additional flexibility is a series of bypass relays that are not dedicated to any particular configuration but are fully programmable. To these relays may be added filters, amplifiers, or other devices when required for specialized measurements. These devices may then be switched into and out-of the RF path independently of the other amplifiers or filters.



RSMS being loaded on C-130

The main amplifier assembly is mounted in a drawer which is mounted on top of the large mast. The cover of this drawer contains all of the RF connectors to which the co-mounted antennas or other devices are connected. The drawer may be removed for service and configuration without mechanically disturbing the co-mounted antennas or other devices.

Also mounted with the main rf amplifier/filter assembly is a television camera. This unit with its zoom lens allows the operator to view the area being surveyed by the directional antennas during a measurement scenario.

A block down-converter assembly allows signal reception in the millimeter-wave bands of 18 to 26 GHz and 26 to 40 GHz. This module contains all of the necessary switching as well as horn antennas which are mounted behind a special window. This unit may be added atop the RF amplifier assembly and connected to two of the five input paths.

The antenna system was designed to handle parabolic dishes up to four feet in diameter. A mount is included that is adaptable to a variety of different sizes of dish antennas normally used by the RSMS. This mount is the top-most unit in the stackable RF system.

High-speed direction finding is a very usable feature of any measurement system. The RSMS design includes a six-antenna DF system operating on the amplitude-comparison computer algorithm which allows variable dwell time, sampling time, and other parameters to suit nearly any operating scenario.

A secondary capability of the RSMS is the ability to load the vehicle on a C-130 transport aircraft and take it to remote measurement sites. Previous attempts at measurements in places like Alaska or Hawaii required the largest transport aircraft or additional time for sea transport. This new capability is a welcome addition to the RSMS program and extends the service to many additional sponsoring agencies and tasks.

This new phase in the RSMS program will undoubtedly prove to be a significant step in mobile signal analysis and support for the spectrum monitoring objectives of ITS, NTIA, and other sponsoring organizations.

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Spectrum Surveillance System Development

Outputs

- Frequency Management
- Spectrum Surveillance
- Interference Resolution
- Remote Operation Data Base Management

The Yuma Proving Grounds needs a frequency management system to monitor their overall range activities. Due to a reduction in operation personnel as well as centralization of nationwide operations a greater need developed for more efficient frequency and spectrum management.

ITS was tasked to provide a system with a multi-faceted approach to the range frequency and spectrum management problem. Remotely located monitoring sites would provide directional information on radio activity at the range. Additionally a mobile system, dubbed the Desert Rat (DRAT), would be directed from a central station to venture out for a closer look at known and questionable radio sources.

Particular attention was given to the frequency coordination requirements. Monitoring of normal range radio activity as well as the intrusion of unknown and unauthorized emitters (transmitters) is a critical component of successful range operation.

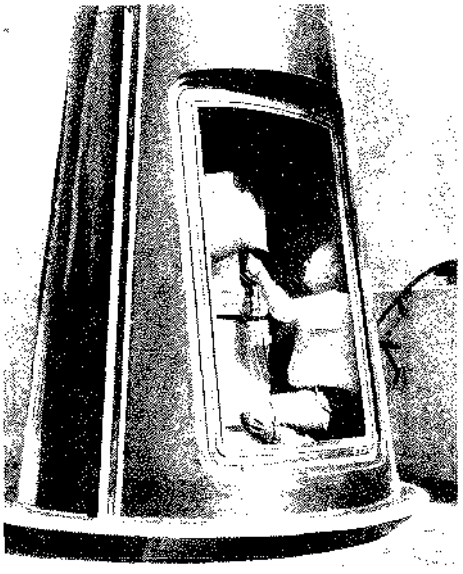
REMOTE DIRECTION FINDING STATIONS

Due to the mountainous nature of the range, coverage of the entire area appeared to be a difficult problem. After a tour by helicopter and some computer analysis of the geography a solution was soon apparent.

Deployed at remotely located and electronically quiet sites, remotely-controlled monitoring stations allow reception of signals and location of emitters using state-of-the-art direction finding techniques.

Operation and data transfer for the remote systems is in near real-time mode via a Local Area Network and microwave links from a central manned site.

Remote stations are housed in small enclosures for environmental control. These stations are unmanned and accessed only for periodic maintenance. Critical functions are monitored from the central control to assure proper and calibrated operation. Special features of the remote sites include battery/solar power, microwave control and data access over the LAN, and few moving parts.



Remote Direction Finding Station

The direction finding system for the remote stations provides basic coverage from 25 MHz to 1.3 GHz with receivability from 100 KHz to 2 GHz. Frequency extensions are added to the basic system using a small spectrum analyzer. This allows extension of DF capability up to 40 GHz.

MOBILE SYSTEM

The mobile arm of the system consists of a 1-ton van housing a computer controlled automated measurement system. Providing a wide range of automated

as well as manual controls, the system gives the operator a wide range of flexibility and speed for performing the needed measurements. Preset scenarios may be run or scheduled for automatic sequenced operation. A generator on board the vehicle provides on-the-fly measurement capability to the operating crew.

A direction finding subsystem will also be included in the mobile DRAT as well as additional antennas to allow detailed analysis of signals.

The DRAT system includes a pneumatic antenna mast with a tracking preselector to allow operation in areas with high energy signals that would overload a non-preselected system.

Communications with the DRAT mobile system will use a range radio that allows data transfer and data access to and from the base station via the base network.

The figures below are SHADOW plots using the geographic location and height above mean sea level for each of the two sites chosen as observation points. These locations proved to give almost complete coverage of the range leaving very few 'holes'. The SHADOW plots show that the two sites are line-of-site to each other, but neither provides coverage of all critical areas of the range.

For information, contact:
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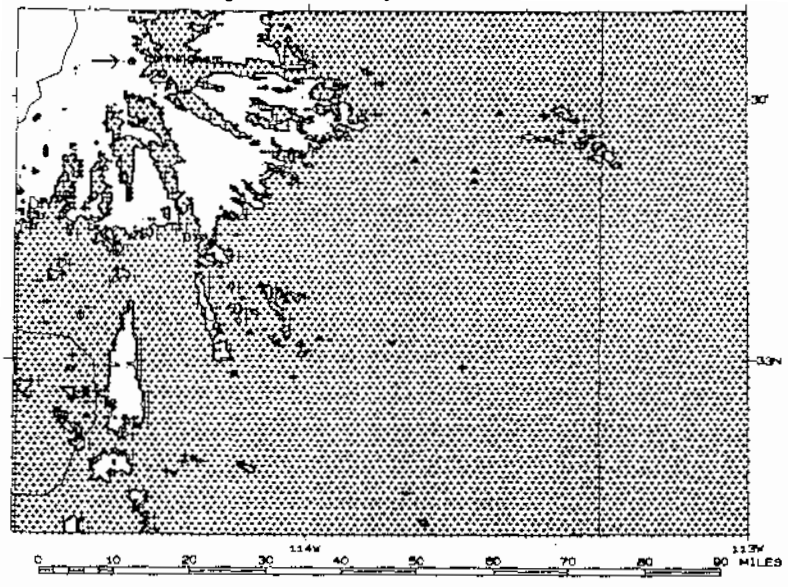
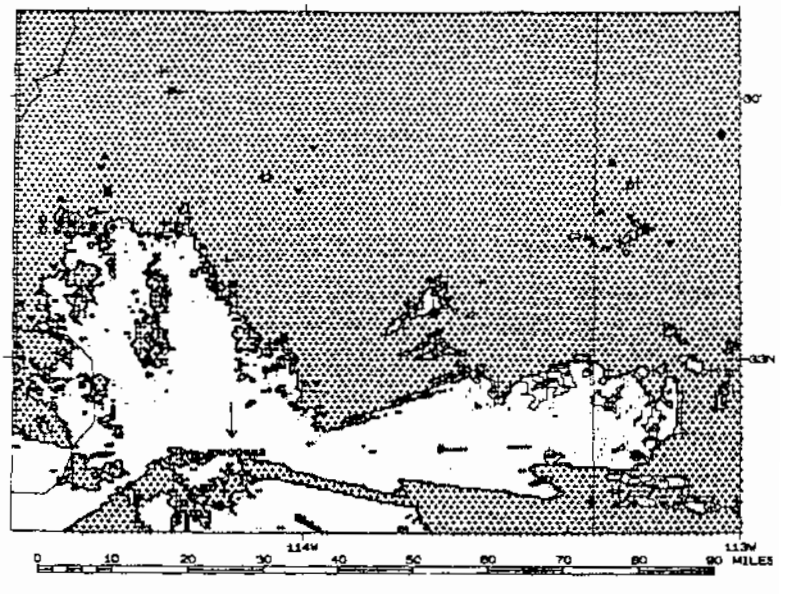


Cunningham

Muggans



Interference Assessment and Resolution

Outputs

- Measurements for NTIA on a prototype wind profiler radar to assess wind profiler radio frequency (RF) compatibility with other systems and to identify a band to accommodate U.S. wind profiler operations in the 400 MHz band
- Measurements for NTIA on a prototype impulse radar to assess that radar's RF compatibility with other systems and assess the feasibility of accommodating such impulse radar operations
- Measurements for the National Weather Service (NWS) to identify the source of suspected RF interference which had been reported at remote-data transmission systems at two NWS locations

One of the functions of the ITS Radio Spectrum Measurement System (RSMS) van-based capability and the Compact RSMS (CRSMS or suitcase) capability (Figure 1), is to assess and solve radio frequency (RF) interference problems. Spectrum measurements with these systems support NTIA's overall frequency management effort in the following areas:

Determination of Potential RF Interference Problems Between New and Existing Systems is accomplished through measurements on new or prototype equipment types. The measurements are devoted to understanding the RF impact of proposed systems on existing services and vice versa. The data may be used to determine equipment parameters, location considerations, or modifications which will mitigate potential RF interference. A prime use of the data is to help determine spectrum support for new or proposed equipment types.

Resolution of Suspected Ongoing RF Interference Between Systems is accomplished on a case-by-case basis. Typically, these problems are solved by performing measurements of the suspected interference directly through the RF front end of the victim system, as well as performing general background spectrum occupancy measurements. If a signal can be identified as causing interference, then the nature of the problem is assessed (e.g., whether the interference is in-band or out-of-band to the victim system) and an engineering solution is recommended. Depending upon the project, ITS personnel may also implement the proposed solution. Sometimes, ITS measurements show conclusively that there is in fact no RF interference present. In those cases, that knowledge is still useful in pinpointing the problem in the victim system, and in eliminating suspected interferers from further effort.

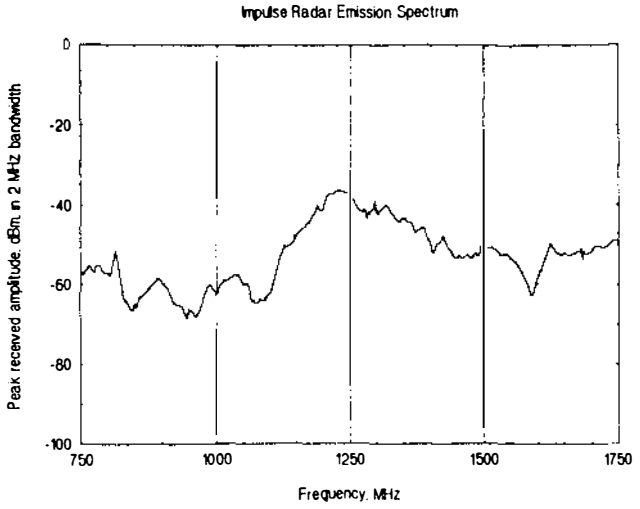
This year, two new systems were measured by ITS for NTIA, with the goal of determining spectrum support for those systems which would be compatible with existing RF systems. The systems under consideration were wind profiler radars and impulse radars. The largest effort was directed at the wind profilers. CRSMS measurements determined the following items:

- Wind profiler emission spectra
- Wind profiler radiated harmonic amplitudes
- Extent to which the profiler's antenna acts as a bandpass filter to reduce potential interference to the profiler from existing systems
- Wind profiler ground-level antenna gain pattern
- Wind profiler susceptibility to interference from

signal types that occur in the 400 MHz portion of the spectrum

- Effects of profiler emissions on land mobile types of receivers in the 400 MHz part of the spectrum.

These questions were answered by CRSMS measurements, and are soon to be released in an NTIA Technical Report. An emission spectrum is shown in Figure 2. A significant end result of this work was to provide the information that NTIA planners required to propose an operating frequency for U.S. 400 MHz wind profilers. This will in turn allow customers to order profilers, leading in turn to production of these systems. Such production has been halted until a suitable frequency assignment can be found.



A new impulse radar system was also measured for NTIA, with the object of determining possible portions of the spectrum for such radar operations. The radar transmits at low average power levels, but also utilizes short pulses, only a few nanoseconds long. As for wind profiler operations, the ITS measurements with the CRSMS were intended to answer questions relating to spectrum occupancy and compatibility with existing systems.

CRSMS measurements on the impulse radar determined the emission spectrum of the radar, as well as the impact of the radar on UHF television receivers. The amplitudes of interfering signals required to produce degradation of the radar's performance were also tested.

Measurement results indicate that it may be very difficult to allocate spectrum for impulse radar operations. Very wide emission bandwidths coupled with high peak power levels (even though average power levels are low) make it difficult to accommodate impulse radars under existing regulations.

The third interference project was devoted to resolving reports of ongoing RF interference at two different National Weather Service sites. Remote-data-transmission systems at these sites were experiencing frequency communication failures which built-in test equipment diagnosed as probable RF problems. The equipment manufacturer performed measurements at the sites, and observed what appeared to be an interfering signal at each location. At that point, the problem required the attention of a frequency management agency, and ITS was contracted to locate the interfering signal, identify it, and resolve the problem.

An automated, remote-controlled (via phone lines) CRSMS was positioned at each site. The CRSMS measurements ran 24 hours per day for approximately 5 days at each location. Measurements were made with both peak and average detectors, and the results were statistically accumulated to provide peak, average, and minimum activity with each detector at each site. The results indicated that no RF interference was present at either location.

Further ITS effort showed that a subtle artifact of the manufacturer's measurement arrangement had resulted in an unrelated signal being interpreted as RF interference. The ITS effort also demonstrated that the reported communication failures were generated within the data-transmission system. Corrections were recommended and implemented which reduced the system failure rate by about 80%. The negative RF interference finding helped prompt the manufacturer to search for additional system problems, and a software bug was discovered which was responsible for essentially the remaining 20% of communication system failures.

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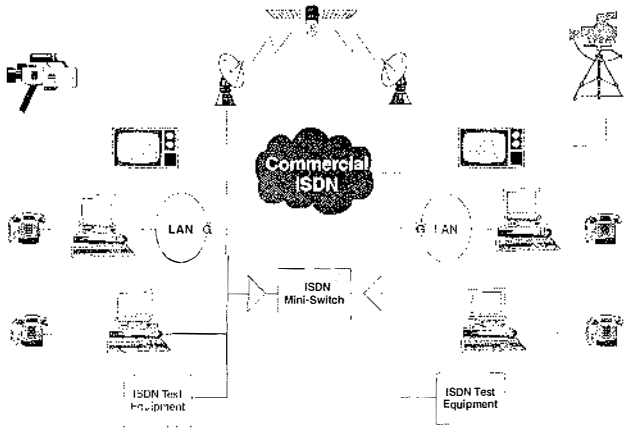
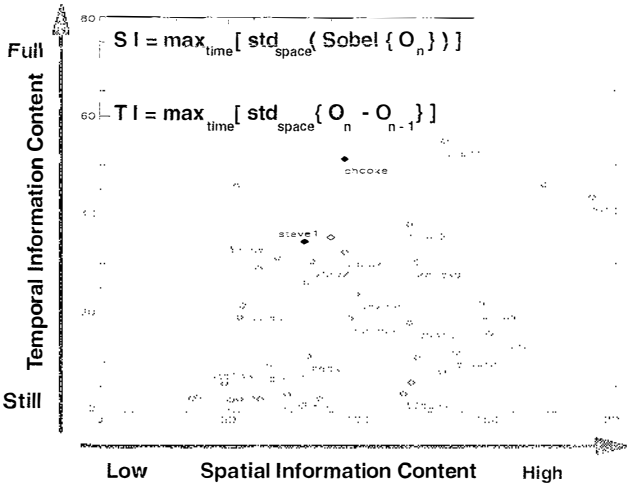
- Probability of Distortion D_m Given Parameter V_i

$$P(D_m|V_i) = \frac{P(V_i|D_m) \cdot P(D_m)}{\sum_k P(V_i|D_k) \cdot P(D_k)}$$

- Average over all Frames

$$P(D_m|\mathbf{V}) \approx \underset{i}{Ave}\{P(D_m|V_i)\}$$





Video, Voice, and Data Communications Assessment Activity

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 92, 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 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 Communications System, the Department of Defense and the National Telecommunications and Information Administration

Voice Quality Standards Development

Includes projects funded by the National Telecommunications and Information Administration

Digital Network Performance Standards Development

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

Radio System Interoperability Standards Development

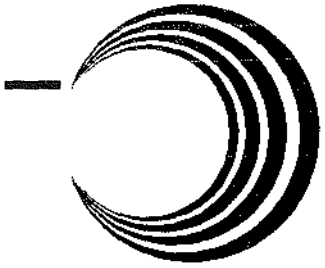
Includes projects funded by the U. S. Naval Underwater Systems Center, the Federal Emergency Management Agency and the National Communications System

Telecommunication Transmission Media Technology Studies

Includes projects funded by 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

The International Telegraph and Telephone Consultative Committee (CCITT) has become the principal forum for cooperative long-range planning of public telecommunication systems and services on a world-wide basis. 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. interest 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 92, Institute personnel served on the U.S. CCITT National Committee, which guides overall U.S. participation in CCITT activities, and provided leadership for 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), Personal Communication Service (PCS), and Intelligent Network (IN) technologies. B-ISDN will provide integrated video, voice, and data communications using an ultra high speed transmission backbone and innovative cell-based Asynchronous Transfer Mode (ATM) switching. Emerging PCS and IN technologies will ultimately enable subscribers to establish multi-media communications among cordless portable or fixed personal terminals located virtually anywhere in the world in a matter of seconds — and to establish custom-tailored communication profiles to meet their individual business and personal needs. CCITT Recommendations on B-ISDN, PCS, and IN services are expected to influence 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 92, the Institute provided international leadership for the Special Rapporteurs Group on Question 5 within CCITT Study Group XVIII; and provided national leadership for two key standards groups within the ANSI-accredited T1 (Telecommunications) Standards Committee: Technical Subcommittee T1S1 and Working Group T1A1.3. The Question 5/XVIII Rapporteurs Group has developed general Recommendations that will provide an overall technical basis for ISDN performance standardization, and is developing a specific Recommendation (I.35B) on B-ISDN performance. Technical 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 services. Working Group T1A1.3 (formerly T1Q1.3) develops American National Standards and contributes to CCITT Recommendations dealing with the performance of packet data networks and ISDNs.

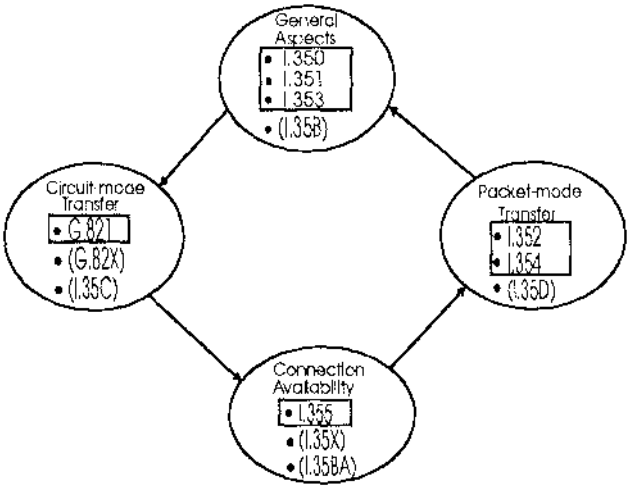
The Institute's technical contributions to Study Group XVIII during the 1989-92 CCITT Plenary Period played a strong role in the completion of four new CCITT Recommendations. Recommendation I.351 defines the overall structure for a related set of CCITT Recommendations that collectively provide a comprehensive basis for international ISDN performance specification. Recommendation I.353 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.354 specifies performance of ISDN packet mode bearer services. Recommendation I.355 specifies availability performance of ISDN 64 Kbit/s connection types. These four draft Recommendations were among those approved by Study Group XVIII at its June 1992 meeting for submission to the 10th CCITT Plenary Assembly to be held in March 1993. Institute staff members also participated strongly in developing U.S. contributions that were instrumental in enabling CCITT Study Group VII to complete another new Recommendation, X.138, which defines performance measurement methods for packet-switched data communication services.

A particular focus of the Institute's technical contributions to CCITT during FY 92 was draft Recommendation I.35B, which defines B-ISDN ATM cell transfer performance parameters and measurement methods. To advance this draft Recommendation, ITS personnel developed technical contributions on several B-ISDN performance issues, including the specification of performance parameters for describing cell delay variation (CDV) in ATM systems and the development of guidelines and algorithms for mapping performance values among the B-ISDN protocol layers. The CDV parameters are considered critical to the design and implementation of commercial ATM networks because of their strong influence on network transmission and switching capacity requirements. The active role played by Institute personnel in proposing and coordinating technical approaches for CDV specification in I.35B assisted the Question 5/XVIII Rapporteurs Group in reaching timely agreements on CDV parameter definitions and measurement methods. These agreements were instrumental in the completion of a closely related Recommendation (I.371) on ATM traffic control and resource management in B-ISDNs.

Institute staff members also play a significant role in achieving synergy between related national and international standards development efforts — and compatibility among the evolving national and international standards. During FY 92, Institute standards leaders contributed to development and successful T1 coordination of a new American National Standard, T1.504b, which specifies packet-switched data communication performance measurement methods. This new standard is completely compatible with CCITT Recommendation X.138. Collectively, T1.504 ("Packet-Switched Data Communication Service — Performance Parameters") and its supplements (T1.504a and T1.504b) define a comprehensive basis for the performance description and specification of packet-switched data services that is consistent with the corresponding X.130-series Recommendations.

Institute standards leaders also spearheaded a Project Proposal and technical plan for phased development of a new American National Standard, designated "T1.5FR," that will define performance parameters, measurement methods, and numerical performance objectives to be used in specifying and assessing public frame relay data communication services. Frame relay is a high-speed packet technology that is rapidly becoming important for the provision of public data communications among local area networks (LANs). The T1.5FR parameters will describe each of four principal data communication performance characteristics: speed, accuracy, dependability, and availability. The specified performance objectives are expected to be used by service providers in the planning, development, and assessment of frame relay services that meet user performance needs; by equipment manufacturers as minimum performance requirements and metrics that will affect equipment design; and by users as a common basis for evaluation of system performance and as information relevant to the matching of user needs with alternative provider offerings.



Relationship among completed and planned CCITT Recommendations on ISDN Performance

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

Video Quality Standards Development

Outputs

- Automated video quality measurement techniques and software
- Contributions to national and international standards committees
- Technical input to development of U.S. policies on advanced video technology

Telecommunication network and terminal designs must be based on the quality of service needs of end users. For video services, the truest and most fundamental quality measures are the viewers' subjective responses to the delivered images. Unfortunately, such direct subjective measures are time consuming and expensive to obtain. The practical alternative has been to identify electrical measures of video fidelity or transmission impairment that correlate reasonably well with the human responses. Such signal-based objective measures worked fairly well in the era of dedicated analog video distribution services, but they are not appropriate for use in assessing the quality of emerging video encoding and transmission systems.

Video signals are now commonly transmitted and stored in compressed digital form, with a potential loss of quality resulting from both the compression process itself and 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 compensation, adaptive transformations, adaptive pixel and/or frame prediction, and adaptive quantization, to name only a few. The resulting video impairments include edge busyness, blocking, image persistence (the presence of earlier image frames), and jerky motion. The original analog signal-based objective video measurements do not respond effectively to these new digital video impairments. Consequently, those measurements do not correlate well with quality as perceived by the end users of modern digital video systems. Video equipment designers, service providers, and end-users have an urgent need for new objective measures of video quality to replace them. The new measures must be independent of the coding algorithm and transport technology and must be applicable to a wide range of digital and analog video systems, both present and future. The current range of digital video systems includes videophone over the PSTN (<64 kbit/s), videoconferencing (using proprietary and H.261 algorithms <2 Mbit/s), MPEG1, MPEG2, contribution quality NTSC at 45 Mbit/s, and high definition television (HDTV).

Institute research engineers are working to fill the video quality measurement needs described above. The ITS research centers on the derivation of objective video quality measures that are technology independent and that emulate human perception. A family of very promising measurement techniques has been identified. This is a significant contribution to the field of video quality measurement.

The derivation process ITS has used to design the perception-based video quality measures is illustrated in Figure 1.

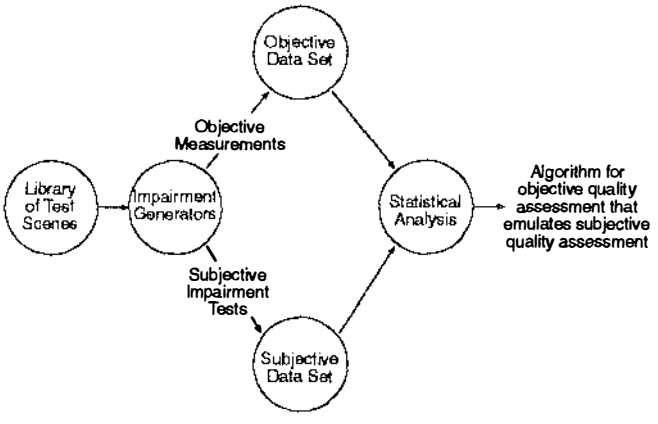


Figure 1. Development Process used to Design Video Quality Measures

Of utmost importance here is that the objective video measures be designed to reflect the subjective (or viewer panel) quality ratings. Since digital video system performance is dependent upon the input scene or program material, selection of the library of test scenes is critical. Test scenes have been developed to span a wide range of spatial and temporal information content in order to produce various amounts of coding and transmission difficulty for systems under test. Since the goal is to produce quality measures that work well across a wide range of video technologies, a broad family of impairments have been tested. These impairments include digital video compression systems operating at line rates from 56 Kbits/s to 45 Mbits/s with controlled error rates, NTSC encode/decode cycles, VHS and S-VHS record/play cycles, and VHF transmission. Institute staff members have obtained subjective quality assessments of impaired test scenes by conducting viewing tests according to CCIR Recommendation 500-3. Objective measurements of video quality have been made and statistical analysis techniques used to select the most effective set of objective video quality measures. The selected measures have been combined in an objective quality assessment algorithm.

The specified algorithm — a linear combination of one objective spatial distortion measurement and two objective temporal distortion measurements — has been shown to give an overall objective quality measurement that accurately tracks subjective quality ratings across the very wide range of test scenes and impairments studied at ITS. The objective measure of spatial distortion quantifies the percent change in edge energy (calculated by determining edge density and sharpness) and provides a measurement of the amount of image blurring. The objective measures of temporal distortion quantify the degree to which the video system distorts the flow of motion in the video scene.

Figure 2 compares the performance of the ITS-developed objective video quality measurement algorithm with the subjective viewer panel scores. If only one 9-second test scene is used (upper left), the objective algorithm has an average RMS error of 0.51 quality units (on a scale of 1 to 5, where 5 is the highest quality). This error is reduced if more test scenes are used to evaluate the performance of the video system. If 5 test scenes are used (lower right), the objective algorithm has an average RMS error of 0.27 quality units. The reduction in error appears to follow the standard 1 over the square root of n rule, where n is the number of test scenes used. This method of averaging multiple measurements to reduce error is a common technique used by engineers in many disciplines. In all but the last case (n=5), the video scenes used to test the performance of the objective video quality algorithm were not used to train or design the system. Some training scenes (about 30%) were included for n=5 to increase the number of test points for the plot (there are 13 test points for the n=5 case).

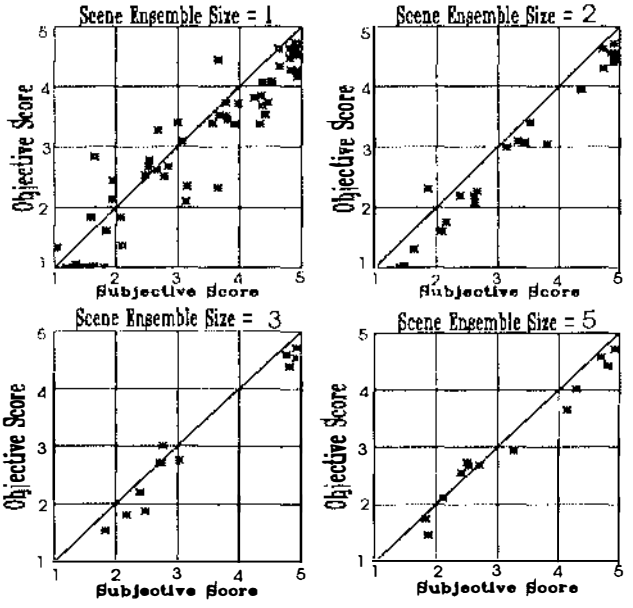
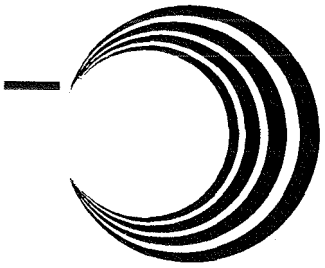


Figure 2. Convergence of the Objective and Subjective Scores as the Scene Ensemble Size Grows

The work described here directly supports the American National Standards Institute (ANSI) Accredited Standards Committee T1, Working Group T1A1.5, in their development of American National Standards on video performance. The ITS-developed video quality measurement algorithm has been accepted by T1A1.5 for inclusion in a set of candidate techniques being evaluated for possible inclusion in a draft ANS on video conferencing/video telephony performance. Institute staff members are implementing the algorithm in a personal-computer based real-time video quality test instrument that will be used in field demonstrations and measurements.

For information, contact:
Stephen Wolf (303) 497-3771



Voice Quality Standards Development

Outputs

- ◆ Contributions to standards organizations
- ◆ Prototype voice quality assessment system
- ◆ Objective evaluation of speech coding techniques

Gauging quality is an important element in the design and operation of modern voice communication systems. Accurate quality measures are particularly important in assessing the performance of systems that employ digital compression techniques or highly variable transmission media — for example, systems being developed to provide the innovative wireless personal communication service (PCS) of the future. Unfortunately, it is just such systems for which conventional analog voice transmission performance measures, such as loss, noise, and talker echo, are least satisfactory. Accurate quality assessment (and comparison) of these advanced systems is currently possible only through the use of human listener panels.

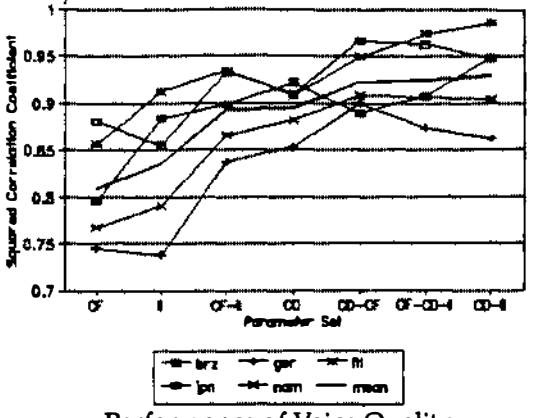
Although human listeners provide the most dependable ground truth assessment of voice communication quality, the time and dollar costs of listener panels often make them impractical. An automatic, computer-based system for objective assessment of voice quality would offer many advantages. It would provide near real-time estimates of voice quality, compared with days or weeks required for listener panel results. It would produce assessments that are consistent and repeatable. Finally, a computer-based system would be relatively inexpensive. 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.

In prior work, the Institute has developed a computerized system for objective voice quality assessment. The system compares measurements of input and (degraded) output voice signals with training data using Bayes estimation techniques to produce an accurate prediction of subjective listener panel scores for a broad range of impairments. Output of the system includes an estimate of mean opinion score (MOS), which ranges between 1 and 5 where 1 is "unacceptable" and 5 is "excellent". Additional information includes estimated MOS probabilities and types of degradation likely to be present in the speech. During FY 92, Institute staff members initiated work aimed at developing a portable version of the voice quality assessment system that will be used to make measurements in the field.

In addition to conducting research in objective voice quality assessment techniques, the Institute is strongly promoting national and international standards development in this area. During FY 92, Institute personnel continued to lead a Study Project, within the ANSI accredited T1A1 Technical Subcommittee, to determine the feasibility of a national standard for voice quality assessment technique. In prior work, on the international level, ITS has advanced its voice quality program goals and contributed to related multi-national research by participating in a CCITT SG XV subjective and objective test of 16 kbit/s speech coding techniques. During FY 92, ITS was involved in planning a similar 8 kbit/s test, which will include an evaluation of objective quality assessment methods being considered by CCITT. Techniques to be tested include the ITS Bayes classifier system and component algorithms proposed in contributions from France (Information Index, II), Japan (Cepstral Distance, CD), and Canada (Coherence Function, CF).

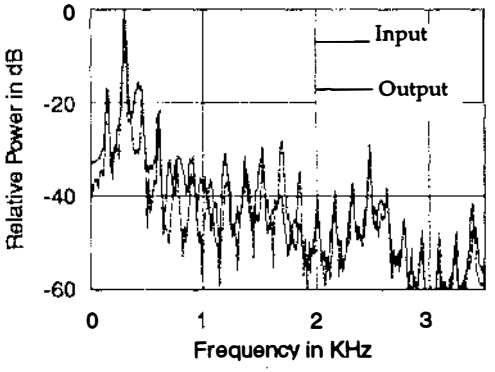
As one of the host laboratories participating in the international tests, ITS has implemented all of the proposed objective assessment algorithms and applied them to a speech database developed by CCITT. The database consists of over 1.2 Gbytes of speech data representing numerous types of codec-related distortions. Included languages are North American English (NAM), Italian (ITL), Japanese (JPN), Brazilian (BRZ), and German (GER), with

both male and female talkers. Example results of tests conducted in FY 92 are shown in the figure below. This graph shows the performance of each assessment method for each language contained in the database. Combinations of assessment methods (e.g., Coherence Function and Information Index, CF-II) are implemented using the ITS Bayesian Classifier technique. The vertical axis of the graph corresponds to the squared correlation coefficient for the assessment methods as compared to actual subjective results for the speech samples used. A squared correlation coefficient value of 1.0 would indicate perfect correspondence between the quality estimated by the assessment method and the quality actually measured in a previously conducted subjective test. The horizontal axis lists the various assessment method combinations that were tested. Plotted points are provided for each language. Notice that, generally, combinations of the CF, CD, and II assessment methods performed better than any of the methods did alone. In part based on the ITS evaluation results, these complementary techniques were specified in a Supplement to a CCITT Recommendation, P.11, that was approved by CCITT Study Group XII for forwarding to the March 1993 CCITT Plenary Assembly.

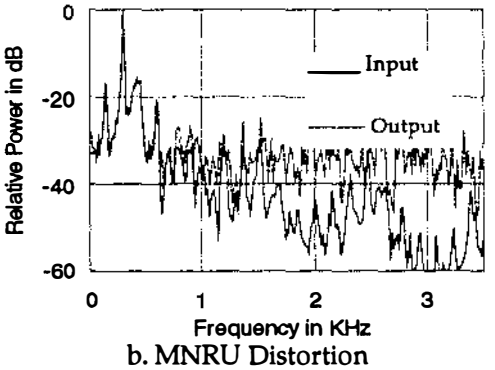


Performance of Voice Quality Assessment Measures

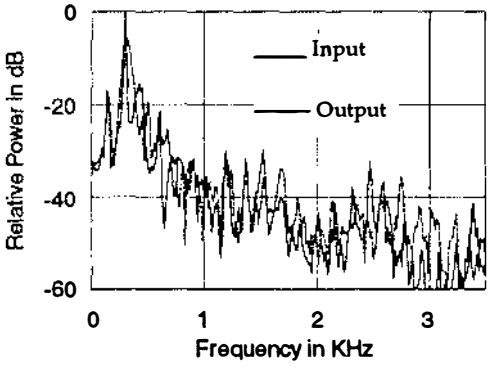
In related research, the Institute contributed to a Committee T1 Working Group assessment of reference distortion signals for speech codec evaluation. Industry participants had proposed an algorithm, called the "T-Reference," for generating temporally-correlated signal distortions characteristic of those observed at the outputs of low-bit rate speech decoders. Informal subjective assessment indicated that the T-Reference was more effective in replicating the impairments introduced by real codecs than a previously-used reference distortion standard, the modulated noise reference unit (MNRU). An ITS analysis of representative speech signals using fast Fourier transforms provided an objective corroboration and explanation for these informal assessment results, as illustrated in the figures below. These results gave the Working Group a quantitative basis for comparing the MNRU and T-Reference distortion signals for potential use in new standards.



a. Low Bit Rate Voice Coder



b. MNRU Distortion



c. T-Reference Distortion
Input and (distorted) Output Spectra

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Digital Network Performance Standards Development

Outputs

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

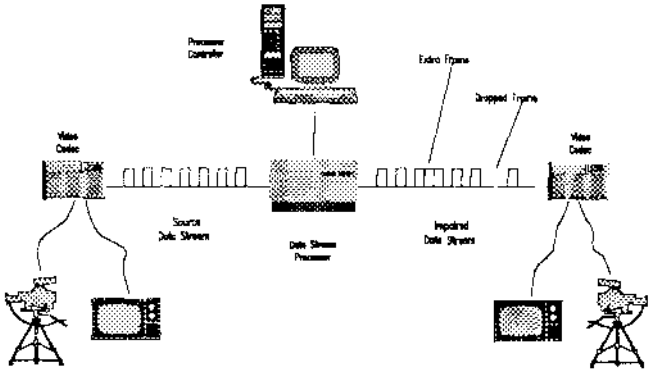
The Institute has been involved in the development, experimental validation, and practical application of digital network performance standards for many years. In prior work, Institute staff members have defined comprehensive methods of specifying and measuring the performance of data communication systems 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. The ITS-developed performance standards are now widely used in Federal procurement of data communications equipment and services, and ITS-developed data communication measurement technologies have been implemented in commercial data communication test equipment. The Institute has assisted several other agencies in using the performance specification and measurement standards to assess their data communication needs. In FY 92, the Institute upgraded its digital network performance test facility with new ISDN measurement capabilities and planned new measurements of high-speed ISDN services to support national and international performance standards development.

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, and promotes the rapid commercialization of Federally developed technology for private-sector use. Toward the latter goal, Institute personnel have begun the construction of a Digital Network Performance field test unit. This device will provide a practical implementation of the NTIA-developed performance measurement standards and will give ITS engineers an easy-to-use laboratory and field-portable measurement tool for high-speed network assessment. The system is being constructed of off-the-shelf, readily available hardware to minimize implementation cost. In conjunction with this work, much of the previously written data communication performance measurement software is being updated to be more user friendly and more portable to a variety of computer systems.

Engineers Tim Butler and D.J. Atkinson
Conduct ISDN Performance Experiments

Telecommunications Standards Development. One of the Institute's objectives is to develop new and relevant telecommunication standards based on

emerging technology and perceived need. The Digital Networks program supports the development of these standards through a parallel process that involves the implementation of standards as they are developed to prove that the standards are both feasible and useful. A current example of this process is the validation of performance parameters proposed in Draft American National Standard T1.I ("Specification and Allocation of Performance for ISDN"), which is currently under development by Technical Subcommittee T1A1. In order to validate the parameters proposed by T1.I, the Institute has used previously written Data Reduction and Data Analysis software modules to minimize implementation time. ITS engineers developed and validated a new Extraction Software module specifically tailored to the newly defined ISDN performance parameters. The performance measurement system, which includes software, terminal equipment and protocol analysis equipment, has been implemented in the ITS digital network test facility. As new parameters are defined, the software will be updated to validate those parameters. This allows the parameters to be thoroughly tested on basic rate and primary rate ISDN connections established using the laboratory's ISDN mini-switch. Once the standard, and therefore the test system, is complete, the mini-switch will be supplemented by operational network capabilities, including one or more commercial ISDN services and a satellite-based ISDN transmission and switching system.



ATM Simulator Concept

Integrated Broadband Networks Performance. Institute engineers have exploited similarities among several cooperative programs to enable the development of new measurement techniques and tools for integrated voice/video/data performance measurement. ITS interests in performance standards for new technologies have been combined with NCS interests in performance impacts on National Security and Emergency Preparedness (NS/EP) to facilitate the development of these capabilities. A major focus of this program is development of performance specifications and measurement capabilities for integrated broadband networks. The laboratory support for the Integrated Broadband Networks Performance program will be provided by an Asynchronous Transfer Mode (ATM) simulator currently under development. ATM is an advanced, cell-based transmission and switching technology that has been accepted by the American National Standards Institute (ANSI) and International Telegraph and Telephone Consultative Committee (CCITT) as the data transport protocol for use in Broadband Integrated Services Digital Networks (B-ISDNs). The Institute is implementing a real-time ATM simulator that can introduce impairments, typical of those expected to be found in an ATM network, into a high-speed data stream. Examples of these impairments include cell transfer delay, cell delay variation, errored cells, lost cells, and mis-inserted cells.

In addition to its ATM capabilities, the simulator will have the ability to simulate impairments introduced by the B-ISDN physical layer. It is currently expected that the physical channel protocol used in ATM networks will be either the U.S.-defined Synchronous Optical Network (SONET) or its international counterpart, the Synchronous Digital Hierarchy (SDH). Impairments that might be introduced by the physical channel include errored seconds, severely errored seconds, and background block errors.

The ITS ATM simulator will provide a valuable and unique capability to support the B-ISDN performance standards development process by facilitating the collection of empirically derived data. An example of the utility of this is the determination of how physical layer performance (SONET/SDH) affects the performance of the ATM layer. In addition, the simulator can be used to create realistic impairments in live data streams. That could be useful, for example, in assessing the impact of lost cells in the user-perceived quality of a connection transmitting compressed video data.

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Radio System Interoperability Standards Development

Outputs

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

Effective technical standards provide cost savings in the procurement of Federal radio systems and improve Federal operations by promoting interoperability among systems used by different agencies. Improved interoperability in turn benefits providers by increasing aggregate markets for radio system 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.

HF Radio Standards. A long-term goal of the ITS/NCS radio systems interoperability program is to promote the development and implementation of advanced communication protocols and signal processing technologies in practical HF radio systems. The resulting improvements in HF system performance are substantially enhancing 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 92, the Institute promoted the development and standardization of advanced HF radio system concepts through its leadership in joint industry/Government HF radio technical committees. This work resulted in the development of Federal Standards (FS) 1045A, 1046, and 1049 Section 1.

Enhanced Interoperability Test Facility. The Institute's proof-of-concept test operations have demonstrated the benefits of testing early in the standards development process. Institute staff members performed verification testing of the concepts developed for pFS-1046 and -1049 utilizing the Enhanced Interoperability Test 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 Automatic Link Establishment (ALE) family of adaptive HF radio standards. The EITF provides an environment for proof-of-concept testing prior to the release of proposed standards and assists Federal Government agencies and manufacturers of radio systems in assessing the interoperability of products manufactured to the new standards. 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. Programs are ongoing to evaluate new ALE protocols and frequency hopping systems.

Assessment of Antarctic HF Radio Communications Link. Based on successful ITS involvement in the development and testing of HF radio ALE standards, the Naval Underwater Warfare Center tasked the Institute to assist them and the National Science Foundation in a unique HF radio link assessment. ITS provided over-the-air testing expertise, staff, and equipment to conduct an assessment of the primary HF radio link between Christchurch, New Zealand and McMurdo, Antarctica. Health and welfare traffic as well as scientific data are passed over this HF link on a continuous basis as propagation conditions allow. The Institute performed two weeks of over-the-air testing which demonstrated that ALE technology could substantially improve the availability and quality of communications over this critical link.

Operational and Technical Analysis of HF Antennas. The Institute provides an HF antenna testing capability for support of the NCS-sponsored SHAred RESources (SHARES) HF radio program. Fully illustrated test reports are furnished to the test sponsor for dissemination to all interested and concerned parties. 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 network consists of "pop-up" vertical telescoping monopole antennas designed for below-surface installation in a steel and concrete silo. Twenty-four of these systems are currently installed at ten sites. These aged antennas have experienced some deployment and operational problems and some may 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; (2) development of propagation path profiles, (3) 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 (4) final recommendations to the sponsor.

Land Mobile Radio Interoperability Standards. The Institute serves as the Secretariat and provides technical support to the FTSC Land Mobile Radio (LMR) 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 LMR interoperability among Federal and civilian law enforcement agencies.

Meteor-Burst Standards Development. The Institute has provided technical support to NCS in the development of three Federal interoperability standards related to meteor burst communications. Proposed FS-1055 defines the basic interoperability requirements and technical characteristics for communications between master and remote stations. PFS-1057 defines interoperability requirements for communications between gateway master stations located in different networks. A companion document, pFS-1056, defines standard methods of encryption for sensitive or classified data transported via meteor-burst systems. During FY 92, the Institute prepared coordination drafts of all three standards for review by Federal agencies, industry, and the public. ITS also developed a Technological and Economic Impact Assessment for these proposed standards.

Recent Publications

U.S. Standardization in HF Radio Automatic Link Establishment and Network Control (by Adair)

A Family of Federal Standards for HF ALE Radios (by Adair and Bodson)

From Manual to Automated to Adaptive High Frequency Radios (by McMillian)

The Application of Automatic Link Establishment Techniques with HF Radio Communication Links at High Latitudes (by Peach, Adair, and Katan)

Linking Protection for HF Radio Automatic Link Establishment (by Redding and Johnson)

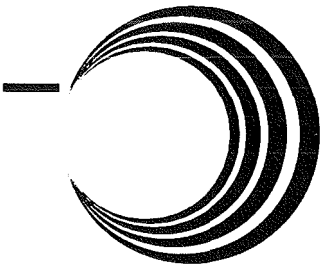
Adaptive HF Radio Performance Evaluation Using Automated Instrumentation (by Wortendyke and Riddle)

EMI Regulations and Standards, Chapter 14, Radio Frequency Interference: How to Find it and Fix it (by Bodson, Peach, and Cass)

Automatic Link Establishment, Shared Resources (SHARES) HF Radio Program Information Bulletin (by Peach)

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

HF Radio Testing



Telecommunication Transmission Media Technology Studies

Outputs

- ANSI standards for on-premises telecommunication wiring, grounding and bonding, 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 organizations 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 industry standards-development process. During FY 92, 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 contributions involved telecommunication standards on (1) optical fiber and metallic transmission media used in on-premises applications; (2) grounding and bonding of metallic transmission lines; and (3) 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.

Telecommunication Wiring 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 has resulted in publication of three industry standards. The first is ANSI/EIA/TIA-568, Commercial Building Wiring Standard. This voluntary industry standard was adopted in 1992 as Federal Information Processing Standard (FIPS) 174, which is a mandatory Federal standard for use by all Federal agencies in the wiring of new office buildings. 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 (adopted as FIPS-PUB-159), authored by ITS staff. The second is a companion standard, ANSI/EIA/TIA-569, Commercial Building Standard for Telecommunications Pathways and Spaces. This industry standard was adopted as FIPS 175. The standard defines 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, Residential and Light Commercial Telecommunications Wiring Standard, which defines a generic telecommunication wiring system for small buildings. This industry standard has been adopted as FIPS 176. Two additional allied standards are being developed to address administration of commercial building wiring (to be published as ANSI/TIA/EIA-606) and separately, bonding and grounding requirements for telecommunications. The latter standard defines a bonding and grounding infrastructure that supports a multivendor, multiproduct environment and specifies grounding practices for various systems that may be installed on customer premises (to be

published as ANSI/TIA/EIA-607). They also are planned for adoption as FIPS.

The first nine of a family of optical-fiber cable standards in the hierarchical TIA/EIA-472-series have been developed with the participation of Institute staff members. The Detail Specifications (the TIA/EIA 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 FIPS. This will be the first time that performance standards for optical-fiber cables have been available to the user community.

These Detail Specifications form a part of a set of TIA/EIA standards that systematically specify performance requirements for optical-fiber cable. This hierarchical specification system comprises four tiers: The singular **Generic Specification**, TIA/EIA-4720000-A, is the umbrella document for all optical fiber cables. It delineates minimum requirements that are common to all optical cable types, as well as providing a "shopping list" of test requirements and test methods that may be applied to families of cables targeted toward various applications, and to specific groups of cable designs. Each of several **Sectional Specifications** defines requirements for a cable family, ordered by primary applications (e.g., indoor or outside use). They set forth minimum testing requirements applicable to all cables of the cable family. **Blank Detail Specifications** are prepared for each of a limited series of cable designs (e.g., optical fibers with metallic elements) that fall within the family of the relevant Sectional Specification. They give specific editorial directions for writing Detail Specifications and may introduce additional requirements that are not addressed in the higher-order documents. **Detail Specifications** follow the applicable Blank Detail Specification and provide detailed requirements, including performance requirements, for specific applications. They also may introduce additional requirements not addressed in the higher-order documents.

Survivability Standard for Optical Fiber Links. Institute staff members have been assisting the National Communications System in developing a proposal for a series of standards for protection of optical-fiber links. The protection would provide an enhancement of durability 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 been approved by the ANSI-accredited standards development Subcommittee T1E1. Two levels of standards will be developed. A **Baseline Standard** will 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. An **Above-Baseline Standard** will set forth various levels of physical stress and radiation protection over and above the typical levels addressed by the baseline standard. The estimated completion date for the Baseline Standard is the beginning of calendar year 1993; the estimated completion date for the Above-Baseline Standard is the end of calendar year 1993.

For information, contact:
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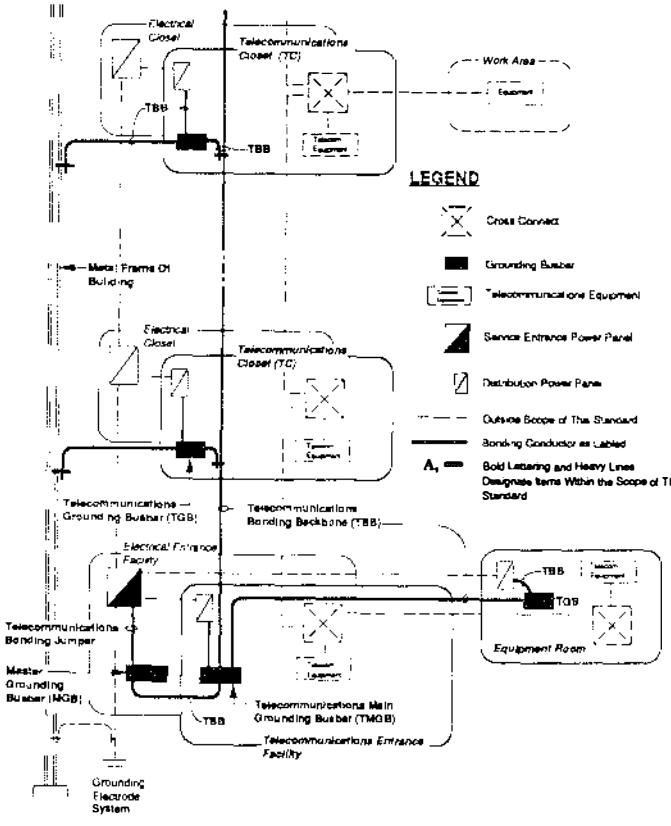
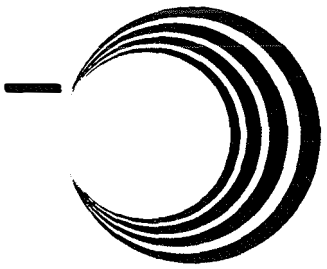


Scope of the Grounding and Bonding Standard



Telecommunications Terminology and Standards Information

Outputs

- U.S. Contributions to ISO-2382, Information Systems Vocabulary
- Support of ANSI Accredited Technical Committee X3K5 in development of ANSDIS, American National Dictionary for Information Processing
- Compilation of U.S. Army comments on FED-STD-1037B, Glossary of Telecommunication Terms
- Prototype acquisition-oriented database service on telecommunication standards

Through active participation 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. Institute staff members and programs promote interoperability and support the FTSC in several ways. Among these are contributions to private-sector work in telecommunication terminology standardization and the development of an acquisitions-oriented database of telecommunication standards. Both efforts are motivated by the need for interoperability. Telecommunication glossaries promote interoperability through the achievement of consensus on standardized language for evolving technologies; the standards database will promote interoperability by facilitating access to standards in procurement specification and system design.

U.S. Contributions to National and International Vocabulary Standards. The Institute provides a Vice Chair for the ANSI Accredited Technical Committee X3K5, which develops vocabulary standards for information systems. During FY 92, the X3K5 Committee refined and updated definitions on information systems vocabulary for such fields as E-mail, text processing, programming languages, and OSI architecture. The ITS Vice Chair had also participated in the FTSC Subcommittee for FED-STD-1037B, and was therefore able to promote convergence of definitions in these related terminology standards.

The ITS Vice Chair of X3K5 also serves as convener for ISO/IEC SC 1 Working Group 7 on Data Communications. That international working group, which meets twice a year, develops standard vocabulary for the six parts of ISO-2382 dealing with local area networks, OSI, E-mail, and data communications. The Institute's participation in WG7 is an extension of ITS efforts in X3K5. Both programs promote standardized language to enhance interoperability and compatibility — two aspects of equipment and systems operation that are fundamental to strengthening U.S. competition in the world market.

Also in 1992, the ITS staff member on X3K5 and WG7 participated in reviewing the glossary portion of a U.S./Canadian international standard on pathways for telecommunications wiring in "smart" buildings.

Army Comments on FED-STD-1037B. The Institute was funded separately to assist the Department of the Army in developing — and coordinating within the DoD — 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 Federal Standards. In addition to its active participation in the development of all the predecessor documents (MIL-STD-188-120; FED-STD-1037, and 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. In DoD working group meetings last year, the Institute compiled the Army comments along with new DoD definitions on network management and video teleconferencing. The resulting definitions, with documented rationale, were printed on ballot pages for coordination.

Database service on telecommunication standards. This project, which continues preliminary FY 91 work, addresses the need for a readily accessible and user-friendly computer database service on telecommunication standards. The service is targeted toward requirements of persons involved in acquisition (both technical staff and procurement personnel). Other perceived applications include telecommunication system design and the writing of telecommunication standards. Agencies participating in the FTSC Standards Database Subcommittee (chaired by ITS) have made recommendations on design of the database, i.e., on what information it should contain and how this information should be structured to provide a useful tool to the user. Foremost among these recommendations was the requirement that the database provide extensive indexing/cross-referencing (through key words and other means of grouping related documents) to access information on all standards pertinent to a subject area (e.g., facsimile). Thorough abstracts are also required to provide information adequate for the user to make decisions on applicability of standards germane to a given subject area. This latter requirement is virtually unique, because abstracts are rarely provided within the text of national or international telecommunication standards, and must be written for this database.

Based on these primary prerequisites, ITS selected relational database management system (RDBMS) software that will be structured to provide a variety of menu-driven document search options and the ability to display related families of standards that deal with a common area of technology. Using this software, ITS has designed a prototype database that includes the following elements as distinct fields:

- Title
- Document number
- Document source (preparing activity)
- Ordering information
- Publication date & revision date
- Adoption of/superceded by [another standard]
- Key words
- Abstract
- Cross references to other related standards, including listing of other standards in the pertinent "family"
- Status of the standard (final or draft)
- Category (e.g., telecommunications, software)

The technical content of the prototype database was deliberately limited in FY 92 to approximately 300 standards, concentrating on Federal Telecommunication Standards and selected Federal Information Processing Standards (FIPS). A limited number of other national and international standards were added to extend the cross-referencing, to give the initial users a more comprehensive idea of how this cross-referencing works. This relatively small volume of data has made it possible to concentrate on refinement of the database methodology. This has facilitated reprogramming in response to comments from user trials.

The prototype database was programmed using DOS-based RDBMS software to permit utilization of existing DOS hardware, which has limited the prototype to single-user remote access via dial-up modem. Following successful beta trials by members of the FTSC Subcommittee and a demonstration to the FTSC during their August 1992 monthly meeting, ITS has begun transporting the database to the UNIX environment. This will be completed in FY 93, and the database will be installed on a UNIX platform that will provide multiple-user simultaneous access. Plans are underway to provide access via both Internet and X.25 circuits as well as dial-up modem. The data content of the prototype will be expanded in FY 93 to include a broader spectrum of national and international telecommunication standards.

For information, contact:

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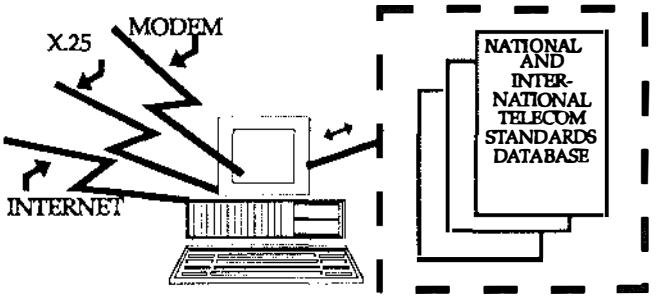
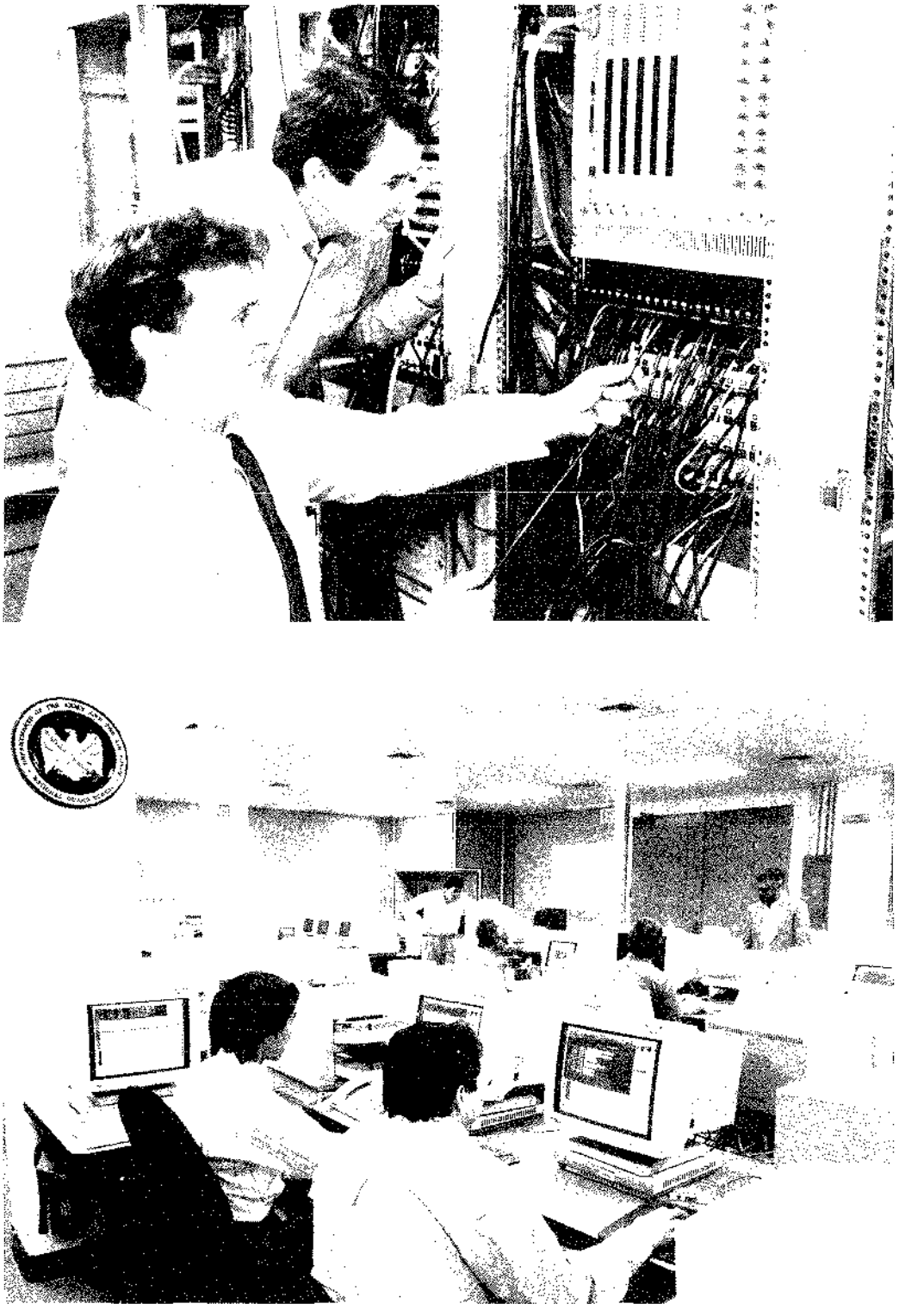
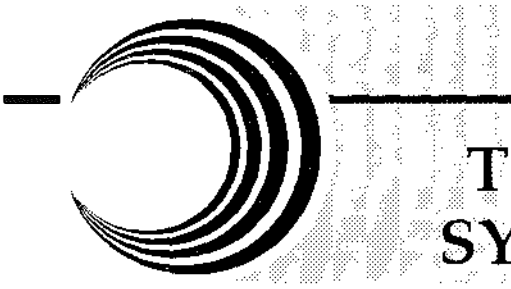


Planned access methods for the Standards Database Service



Reserve Component Automation System Test Laboratory and Communications Center



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

Army Reserve Component Automation System Testing and Evaluation

Includes projects funded by the U.S. Army Reserves

HF Systems Assessment

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

Radio System Design and Performance Software

Includes projects funded by the Department of Defense, the U. S. Army Information Systems-Engineering Command and the U.S. Army Foreign Science and Technology Center

High Definition Television Coverage Analysis

Outputs

- Initial development of interference model for allocation of new HDTV channels for TA Services
- Consultation on development of ATTC (Advanced Television Test Center) field tests
- A statistical model of multipath derived from data collected in Denver and San Francisco

High Definition Television (HDTV) is being developed in the U.S. (and in Europe and Japan) as a means of providing greatly improved picture quality to television customers. 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. U.S. capability in digital signal processing and video compression technology is creating the first digital HDTV standard that will displace existing Japanese and European analog technology.

In the U.S., several proposed systems using different modulation, encoding, channel equalization, and data compression techniques are being developed. These will be tested by ATTC in a laboratory environment. A system of industry/government advisory committees have 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. ITS 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 coverage and interference models for allocation and assignments for the new HDTV stations.

The planning model uses the Communication System Performance Model (CSPM) to predict the impact of adding an HDTV transmitter into an already crowded TV spectrum. By utilizing the irregular terrain model (ITM) available in CSPM, it is possible to predict with greater accuracy where interference will occur thus minimizing the impact on existing NTSC television stations and maximizing coverage of new HDTV stations.

As an example, consider the task of predicting the impact of adding an HDTV station in San Diego, CA on the same UHF channel as an existing UHF station in Huntington, CA (serving the Los Angeles area). First, a prediction is made showing the predicted grade A and B coverage of channel 50 in Huntington, CA. A prediction is also made for an HDTV transmitter of approximately 240 kW ERP located at an existing antenna site near San Diego. Using preliminary data from one of the proposed HDTV systems, a plot can be made of where the HDTV signal causes objectionable interference to the NTSC signal (For this example, a signal to interference ratio of 30 dB of available power was used. Final data of this type will be available from the laboratory tests being conducted by ATTC.). Figure 1 shows the region where the existing station is not affected.

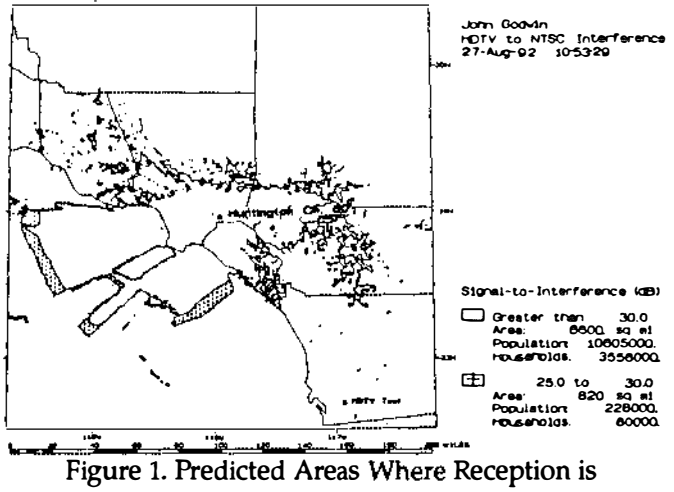


Figure 1. Predicted Areas Where Reception is Unaffected and Where Interference Occurs.

This plot can be produced as an overlay for the coverage map to allow easy determination of what areas will experience interference from the new HDTV transmitter. In this example, most of the interference occurs over the ocean where it is not a problem. If the FCC propagation curves are used for these predictions, much more interference is predicted because they do not take into account the beneficial effect of terrain blocking the undesired signal from the Los Angeles area.

In the design of HDTV systems it is useful to know what problems one will find in the environment. Last year ITS measured the multipath on actual television broadcast links that might connect a transmitting station to a home user. Using an operating commercial station and one of the off-screen horizontal lines that are often used for such tests, we transmitted a special signal that allowed us to record the channel impulse response — the response of the receiver not only to the signal as sent but also to delayed copies of the signal that arrive after reflecting off such things as buildings, trees, or mountains. Examining such a measurement, one sees first a large pulse which represents the directly received signal. Then come a jumble of smaller pulses which tail off into the receiver noise floor. These are the multipath components. In present-day television they cause the 'ghosts' that can spoil a picture. In the suggested HDTV systems, if they are ignored they might render the picture useless.

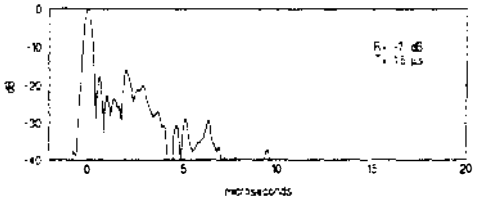
To describe our results in engineering terms we have developed a 'model' which pictures the 'multipath tail' as a noise-like random process with an exponentially decaying amplitude. Using this model we may summarize the measurements. To provide statistical sample sets we lump measurement sites together into 'archetypal regions.' These are fairly small regions where the buildings and vegetation are similar — a 'wooded residential area,' for example, or an 'urban area with low buildings.' At the sites of such a region we would expect multipath components to have the same mixture of amplitudes and delays, and therefore the impulse responses to have the same sort of appearance.

The table shows the results for two widely separated wooded residential areas in and near Denver, both in the summer when the trees were in full leaf, and in the winter when there was snow on the ground and the trees were bare. At each site there were four measurements involving two transmitters and two kinds of antennas — an omnidirectional antenna and a directional log-periodic antenna. The value R measures the ratio of the energy in the multipath tail to that in the direct signal while T is the time in which the average power in the tail decays by 4.3 dB. Note that the season does not seem to have affected the results, nor has the distance from the transmitters. The directional antennas have reduced the multipath by about 3 dB, and the UHF signals have perhaps 4 dB more multipath than do the VHF signals. These general remarks seem to hold in other archetypal areas.

Multipath characteristics for two wooded residential areas, measured in both Summer and Winter. The columns describe the multipath strength R and the delay spread T.

	Summer		Winter	
	R (dB)	T (μs)	R (dB)	T (μs)
Denver (25 km)				
VHF/Omni	−14.8	3.43	−12.0	1.11
VHF/LPA	−18.0	8.37	−16.6	4.37
UHF/Omni	−10.0	.93	−15.4	3.63
UHF/LPA	−13.5	6.92	−16.5	6.24
Longmont (54 km)				
VHF/Omni	−14.6	.91	−12.1	.66
VHF/LPA	−17.8	2.68	−17.4	3.15
UHF/Omni	−11.2	3.44	−12.1	3.43
UHF/LPA	−14.5	7.03	−12.0	7.38

Perhaps another use for our model is in the simulation of channel characteristics — such as we have done in Figure 2. While there exist areas with a definitely different pattern of multipath components, we feel that our model fits a great many areas very satisfactorily.



A simulated response function using parameters that might describe the function in Figure 1.

Recent Publications:

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

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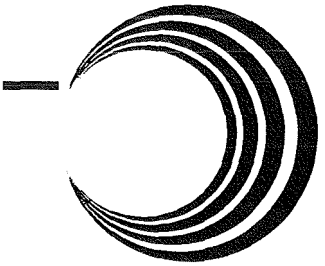

Army Reserve Component Automation System Testing and Evaluation

Outputs

- Test Design Plans
- Test Analysis Reports
- Independent Evaluation Report

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 its Reserve Component, which comprises the Army National Guard and U.S. Army Reserve. The RCAS is an automated information system that will support the decision-making needs of all commanders, staffs, and functional managers responsible for Reserve Component forces. The RCAS is being implemented using state-of-the-art office automation, telecommunications, data base management, and information processing capabilities to provide timely and accurate information needed to efficiently accomplish routine administrative tasks and to plan, prepare, and execute mobilization. It will be self-sufficient but capable of exchanging data with related information systems used by the Active and Reserve Components. Office automation capabilities provided by RCAS will include word processing, spreadsheets, E-mail, desktop organizer, presentation graphics, personal data base, and desktop publisher. Mobilization support capabilities provided by RCAS will include mobilization command and control, management of human resources, force authorization, logistics, and training. The Army has defined the following specific objectives for the RCAS program:

- 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.
- 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 Institute is supporting the RCAS Program Management Office (PMO) by serving as the technical tester and evaluator for the RCAS. This responsibility involves developing technical test plans, establishing a technical test bed, and conducting a series of technical tests to evaluate the functionality and performance of the RCAS as it is developed and deployed.

Technical Test and Evaluation Planning. The Institute has developed a series of related test and evaluation plans as they apply to the first releases of the RCAS system. The Independent Evaluation Plan (IEP) is the highest level planning document. It defines general requirements and objectives for the overall system evaluation. It is intended to be a stand-alone document that both sets the framework for the formal RCAS test and evaluation process, and establishes specific rules and guidelines for conducting the tests and evaluating the test results. Since technical testing is performed by the contractor and the (ITS) Government technical tester, the IEP governs the production of test data from both of these organizations.

The next-highest-level planning document is the Test Design Plan (TDP). While the IEP outlines a

general set of RCAS evaluation functions, the TDP defines specific, comprehensive testing functions. The test exercises given in the TDP are aimed at obtaining the data needed to conduct the independent evaluation. The test exercises of the TDP extend across all technical testing — both contractor and government.

The lowest level and most detailed plans associated with the RCAS T&E program are the Detailed Test Plans (DTPs). Unlike the IEP and TDP, which are written by the technical independent evaluation team on behalf of the RCAS PMO, the DTPs are developed by the technical testers (contractor and ITS). The plans fulfill the requirements of the IEP and TDP by describing in detail the actual tests, exercises, and exercise sets that will be preformed to assess the functionality and performance of each delivered RCAS configuration.

Test Bed Implementation. With the participation of the RCAS contractor, the Institute has established a comprehensive RCAS test bed at the Boulder Laboratories. The RCAS test bed is capable of simulating any two Army Reserve or National Guard echelon system configurations. It includes representative data base servers, office automation servers, mail servers, X-terminals, local area networks, FTS-2000 services, communication routers, a network management system, and encryption devices. Test equipment includes network simulators, network analyzers, a remote terminal emulation system, traffic generators, and test software. The test bed was installed and successfully used in initial RCAS testing during FY 92.

Technical Testing. The RCAS is being implemented and fielded in a series of increments called blocks. During FY 92, the first RCAS block was submitted to the technical test facility for test and evaluation. This block ("Block X") consists of commercial off-the-shelf (COTS) equipment and software providing office automation capabilities. The Institute's technical testing of the integrated set of COTS hardware and software was accomplished during the second and third quarters of FY 92. The testing was performed at the system level to validate system engineering and design as required by the specifications and to establish the system performance limits. Following testing, a technical evaluation based on both the contractor and Government-supplied test data was performed. A technical evaluation report was developed and presented to the RCAS Program Management Office.

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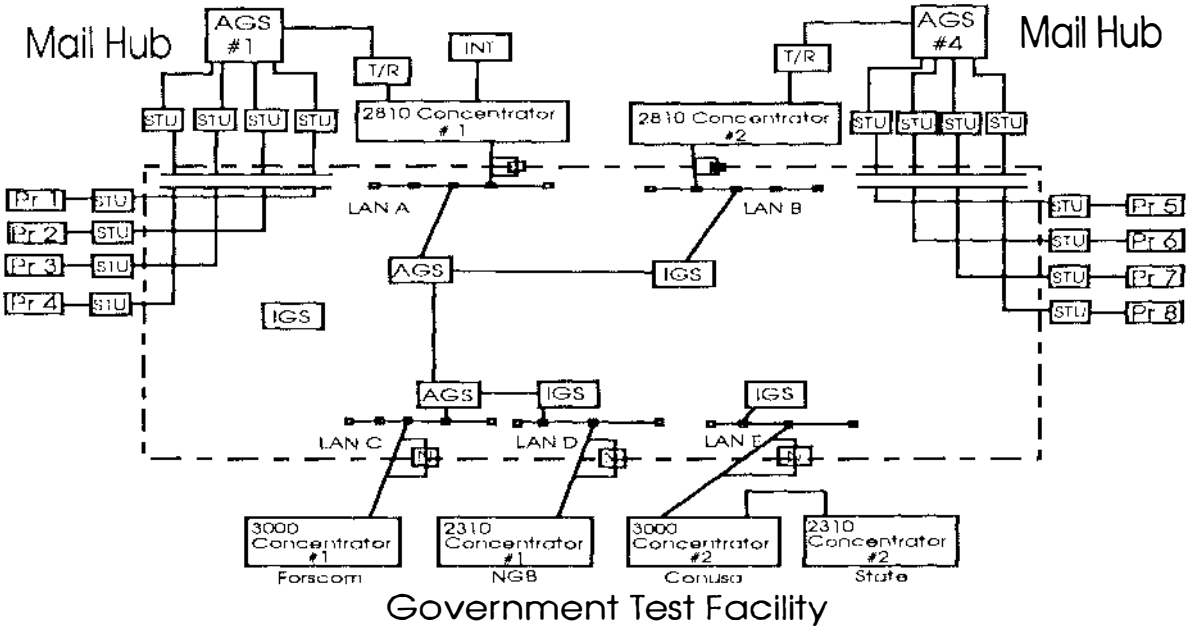

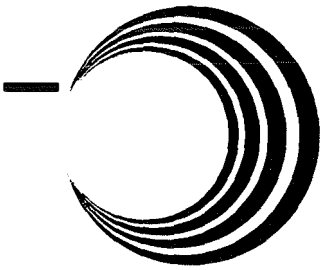

HF Systems Assessment

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 prediction 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 impul-

sive 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 (PC) 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 a PC 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 specifying values on a screen that are then used to construct the IONCAP input file.

A specialized processor has been developed to manage an external antenna data base file for specific applications. For example, a subset of an external antenna file data base can be extracted for tactical use.

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 called 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 polar path; therefore, the predictions are somewhat different.

The propagation program (ICEPAC) has also been modified to reflect the latest improvements in the Electron Density Profile Model (ICED) in the polar region. The URSI 88 set of foF2 coefficients for sunspot 0 and 100 have been incorporated into the ICEPAC program. The antenna routines from the HFMUFS (high frequency predictions program) have been modified and made as an option on the ICEPAC program.

A program has been developed that uses the foF2 coefficients to evaluate the partial derivatives with respect to latitude, longitude and height for the use in full ray trace programs and for studies using more than three control point locations on a path for HF communications. This study is continuing with the objective being a program that will do a partial or full ray trace depending on the users choice.

For Information, contact:
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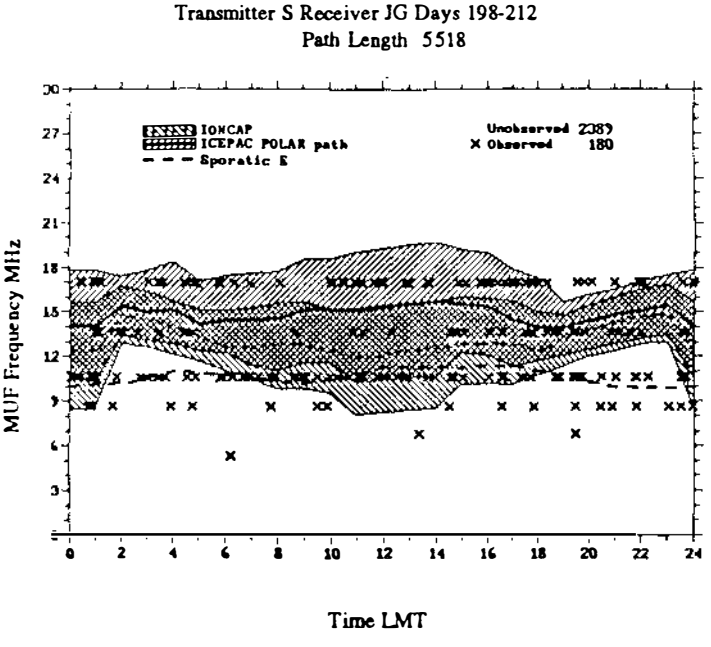


Radio System Design and Performance Software

Outputs

- Public version of AMOS model called 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 1992 with the improvement of the AMOS (Analysis of Microwave Operational Scenarios) software, MOSES (Microwave Operational Scenario Evaluation Software), JEM (Jammer Effectiveness Model), 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 been limited to mainframe computers.

AMOS/MOSES/ROSES/JEM Models

The AMOS/MOSES/ROSES family of models continue to serve as development and analysis tools for Government and private industry. The JEM software model is under development and primarily used by the US Army to evaluate Electronic Warfare scenarios. All of these models 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.

The MOSES software performs analyses in the microwave frequency range (1-300 GHz). The newest version of MOSES is ROSES (radio operational system evaluation software). 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 extending the 1-300 GHz range presently covered by MOSES. These frequencies were included 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 which 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 thirteen modules which use state-of-the-art programming interfaces and the newest engineering models developed by ITS, industry, and CCIR. The program provides a complete design and documentation of terrestrial radio links operating in the frequency range of 1 to 30 GHz. 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 which must be input by the user.

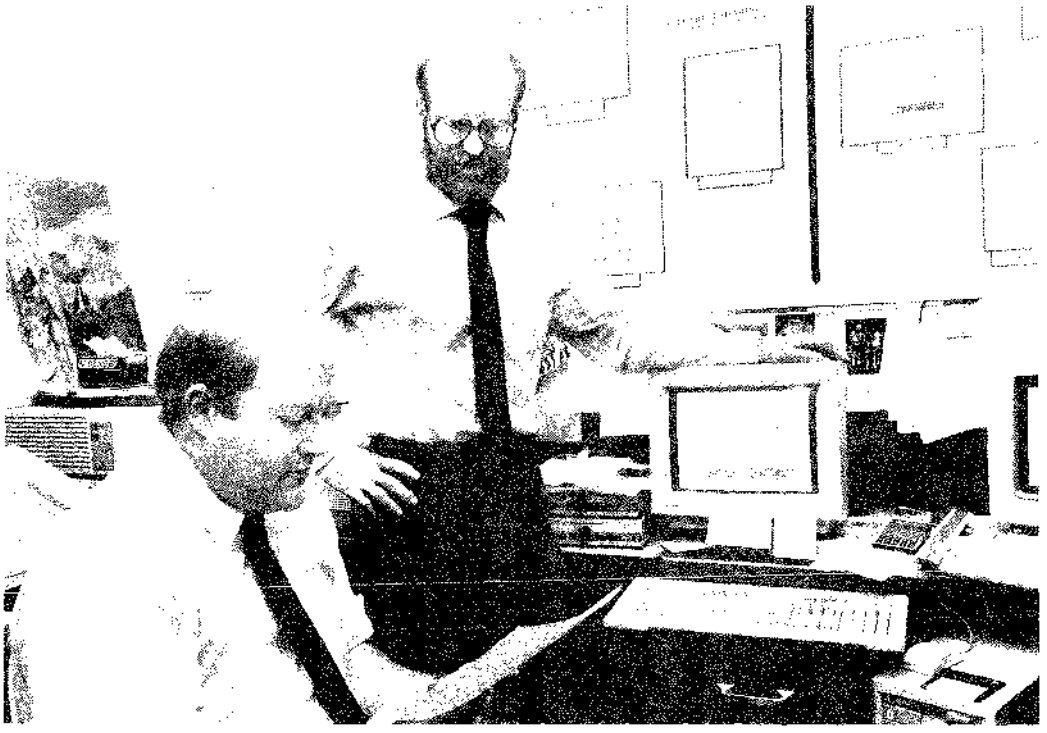
Initially, the user must input the site coordinates and path profile. The path profile can be input manually or can be obtained automatically from the Defense Mapping Agency's CD ROM Digital Terrain Elevation Data (DTED). RAIDER then determines the clearance for the link. It calculates whether the path 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. The program then calculates the system performance parameters for the line-of-sight paths and the basic transmission loss values for diffraction and scatter paths. 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. This data is presented in both tabular and graphical output and may be saved as hard copy.

Recent ITS Publications

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

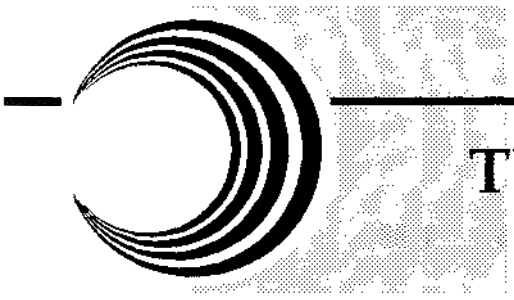
Software for the Analysis of Microwave Operational Scenarios (by Allen)

For information, contact:
Nicholas DeMinco (303) 497-3660
AMOS/MOSES/ROSES/JEM
Timothy Riley (303) 497-5735
RAIDER



ITS Video Quality Laboratory Environment

PCS Radio Channel Probe Performance Examination



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 Modeling

Includes projects funded by the National Telecommunications and Information Administration

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 many commercial and government agencies

Advanced Systems Planning

Includes a project funded by the U. S. Department of Agriculture-Forest Service

Network Engineering and Installation

Includes a project funded by the U.S. Naval Research Laboratory

Assessment of Telecommunications Dependence on Foreign Sources

Includes a project funded by the U.S. Army Defense Information Systems Agency

Personal Communication Services Modeling

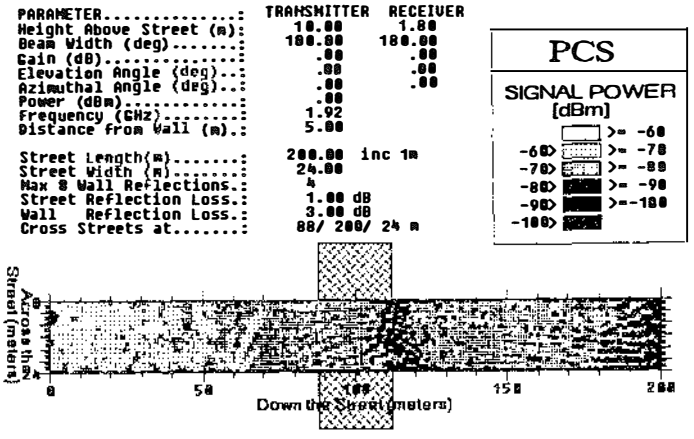
Outputs

- Development of Area Coverage Model
- Development of Spectrum Sharing Model
- Development of PCS Simulation Plans

Personal Communications Services (PCS), a class of telecommunications services including a wide range of capabilities such as telephony, data services, paging, voice mail, electronic messaging, and future advanced technologies are making communication independent of time, distance, and location. The decisions of the limited reallocations World Administrative Radio Conference (WARC) held in early 1992 determined spectrum usage impacting development of PCS systems. The bands reallocated by the WARC for low earth-orbit satellite systems, and both terrestrial and satellite mobile services, including future public land mobile telecommunications systems (FPLMTS), will be used by the emerging PCS technologies. Within the United States the Federal Communications Commission will establish frequency band allocations for PCS providers/users through the rule making process.

The Institute has been active in the development of computer models to assess system losses in typical PCS operational environments for the proposed frequency bands. Specifically, models are being developed for urban outdoor microcells and within building environments, and to assess the sharing potential of PCS systems with each other and incumbents in the proposed PCS bands within the U.S. To further the PCS interests of Government and Industry the Institute is participating in the U.S. CCIR Study Group 8 Task Group 8/1 (FPLMTS), the Joint Technical Committee of ANSI T1E1 and TIA TR45.4 (air-interface standard), and 802.11 (wireless LANs standards committee) of the IEEE. This will contribute to the establishment of international standards for the emerging technologies with respect to common air-interface protocols, interoperability, network interfaces and compatibility, validation and registration, intersystem handoff, and performance specifications.

The outdoor urban microcell area coverage model as well as the spectrum sharing model are nearing completion. Their intent is to assist PCS system planners and designers in determining how well a proposed system works within specified environmental boundaries. To help PCS system planners and designers account for the effects of operating a PCS system microcell in an outdoor core urban environment in the proposed bands, the Institute has taken a first step in developing an area coverage model for operation using these bands. To help planners and designers determine the effects of providing PCS in an environment where incumbent services exist the Institute has developed a spectrum sharing model based on several possible scenarios. The next figure is an example of an area coverage for a PCS microcell for an urban canyon showing the effects of propagation losses due to reflections from the street and canyon walls, and diffractions from building edges at the cross street.



Example of Area Coverage for a PCS Microcell in an Urban Canyon

For future work the Institute plans to 1) expand the area coverage model to the non-line-of-sight case for outdoor urban environments as well as to closed

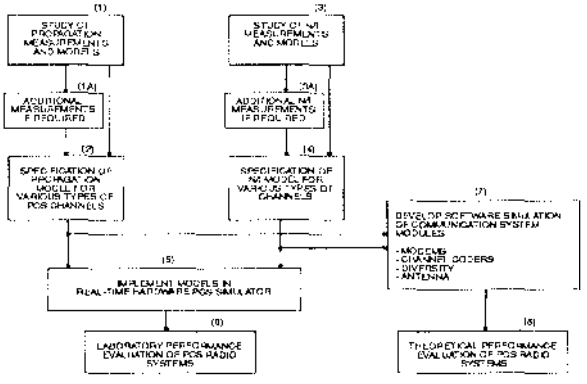
environments with reflection and diffraction losses from obstructions within the coverage area (e.g., buildings, vehicles, terrain features, trees), 2) work closely with internal groups conducting PCS measurements to corroborate the models' predictions, 3) develop a software simulator to simulate digital PCS system performance using a library of impulse responses, and 4) develop a hardware channel simulator for link performance assessment. The models mentioned above will be installed on TA Services computers able to be accessed by system designers/planners via modems or the INTERNET.

The above activities are part of a program plan that the Institute, realizing that an investigation into PCS technology for present and future applications is a multi-year effort, has tentatively established to provide a detailed list of tasks necessary to address the technically challenging issues of PCS. The major goal of such a program plan is to provide leadership concerning the PCS issues of interoperability, spectrum efficiency, frequency reuse, standardization of propagation and noise/interference models, simulation criteria, testing methodologies, and potential cooperative research and development agreements (CRADA) with industry for testing proposed PCS radio systems.

The major elements of the program plan are 1) link performance assessment using a channel simulator (hardware), and modeling/simulation of channel characteristics for a suite of modulation and coding techniques, diversity, and antennas (software); 2)software simulation of PCS subsystems; and 3)program products relevant to assisting Government and Industry in the development, maintenance, and operation of PCS systems. The program products include contributions towards the establishment of standards, testing methodologies, and channel environment modeling/simulation.

The link performance assessment element of the program plan consists of several components which include 1) a survey of propagation measurement results and available models, 2) specifications of propagation models for PCS channels for a variety of environments, 3) a survey of noise/interference models for PCS channels, 4) the specification of noise/interference models for a variety of PCS channels, 5) the development of a PCS link simulation system, 6) laboratory performance evaluations of PCS radio systems, 7) the development of software simulation of communication system modules, and 8) the theoretical performance evaluation of PCS radio systems. The next figure shows a flow chart of these specific proposed tasks.

The above PCS link performance assessment tasks are a first step in the comparison of radio systems performance. An expanded program is required to provide a detailed theoretical analyses of system performance, a development of system/subsystem level simulation, or a combination of analysis and simulation be used to assess system performance. Protocol concerns for PCS at higher OSI levels could benefit from network or subsystem software simulation.



PCS Performance Assessment Tasks

There are 5 major tasks associated with the simulation of PCS subsystems. The first task is to develop a detailed definition of the simulation system requirements and objectives incorporating relevant open questions from PCS standards bodies. The proposed software simulation can assist in resolving these questions. The second task consists of the definition of performance measures to be used to assess differing PCS subsystem architectures and implementation. The third task is an application of an error statistics model to the PCS channel to assess the performance of various types of modulations, channel access schemes, and coding techniques on system performance. The fourth task is a study to define calling rates, services, user density for various PCS environments, traffic levels and patterns, and other aspects of the PCS user environment. The fifth task is the actual development of the PCS subsystem simulation software.

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Satellite Studies

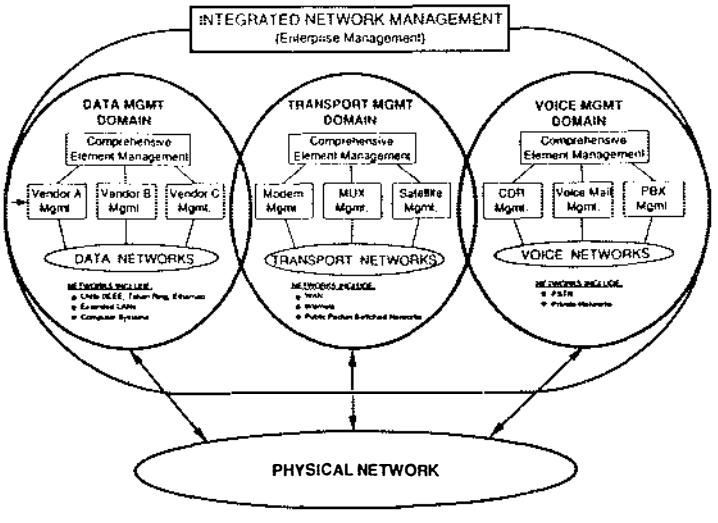
Outputs

- Expanded simulation model for advanced hybrid network performance evaluation
- Description of system interfaces and standards requirements for hybrid network management
- Enhanced test-sets for conducting advanced satellite system performance measurements
- Contributions to a National Science Foundation panel report on worldwide satellite communications technology

During FY 92, the Institute continued to combine resources and facilities from several projects in a comprehensive and objective study of possible roles for advanced communication satellite systems in future Broadband Integrated Services Digital Networks (B-ISDNs). A number of separate, but highly synergistic, ITS projects in this area are described below.

Simulation of Hybrid Satellite/Terrestrial ISDN Designs. The Institute is examining alternative roles for advanced communication satellites in the ISDN telecommunication environment of the future as part of NASA's Satellite Communications Application Research (SCAR) program. The goal is to identify the most effective uses for satellite-based transmission and switching capabilities in a hybrid terrestrial-satellite network, and to determine engineering bounds on the requirements for ISDN-embedded satellites. The work began in FY 91 with the development of a theoretical network model describing a hybrid, circuit-switched network employing both terrestrial and satellite technologies. This work also identified performance characteristics and techniques which could be applied in simulating a hybrid network. During FY 92, the theoretical model was translated into a computer-based network model using the techniques of object-oriented analysis and design. Simulations have been developed using this model to study the effectiveness of an advanced communications satellite, with on-board processing and switching, in maintaining and enhancing the performance of a long-distance, circuit-switched terrestrial network by providing adaptive restoration and load-sharing functions. Future simulations are planned to model packet-switched and Broadband ISDN traffic on large-scale networks. The OPtimized Network Engineering Tools (OPNET) program has provided the development environment and simulation engine for this work. The simulations are being developed and run on two high-speed RISC workstations connected by local area network.

Network Management Studies. The Institute is conducting studies of network management technology to develop a background and basis for planning network interface and management standards to accommodate advanced hybrid terrestrial/satellite networks. The accompanying figure illustrates the separate-domain and element-specific character of network management as it exists today. Users are



expressing an urgent need for more effective means of managing networks comprised of heterogeneous, independently-operated telecommunication facilities. Such integrated network management capabilities are particularly important in realizing the

benefits of hybrid networks. The realization of efficient hybrid ISDN and B-ISDN topologies will require integrated network management capabilities that are adapted to the special characteristics of satellite systems. The Institute's network management studies will define the required capabilities and provide specific proposals for their implementation in emerging national and international standards.

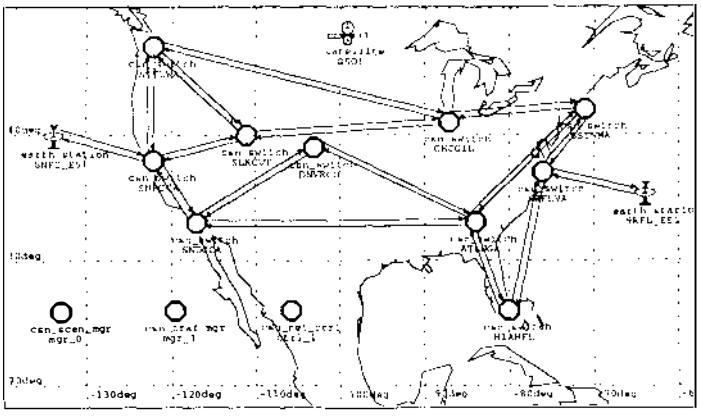
Advanced Satellite Communication Performance Measurements. The next generation of satellites will use advanced technologies such as demand assigned multiple access, scanning local (versus global or regional) beams (as illustrated in the figure), and on-board demodulation and processing of baseband signals. Currently, network planners do not receive (or need) much more information about the performance of a satellite link or channel than the availability and throughput of the transmission medium and the bit error rate. However, with the advanced technologies available on the next generation of satellites, planners will require much more information. ITS has designed tests to be performed on a prototype of the next generation of communication satellites, the Advanced Communication Technology Satellite (ACTS) being developed by NASA, that will measure performance of the satellite system comprehensively, addressing both transmission and switching capabilities. These tests are based on two data communication performance standards developed at ITS and adopted by ANSI: X3.102 — "User-Oriented Performance Parameters" and X3.141 — "Measurement Methods for User-Oriented Performance Evaluation". As one of NASA's approved experimenters, ITS will begin characterization tests on ACTS soon after the satellite is launched in the third quarter of 1993. In addition to performing tests on ACTS, ITS will assist NASA by serving as host site for an ACTS Earth station that will be used extensively by other ACTS experimenters in the Rocky Mountain region.

Satellite Communications Technology Evaluation. An eleven-member panel of experts was organized by the National Science Foundation to perform a comprehensive evaluation of satellite communications technology world-wide. The Institute was asked to provide a member to the panel with responsibility for evaluating terrestrial/satellite network interface technology. The panel members visited technology centers throughout Europe in June and plan to make similar visits in Japan during October, 1992. Other visits to selected locations are planned. The panel's report for the European visits has been prepared. The final report, covering information obtained during all visits, will be published in 1993 following an open workshop scheduled for January.

Recent ITS Publications

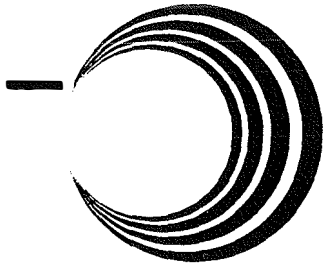
Simulation of Hybrid Terrestrial-Satellite Networks for Service Restoral and Performance Efficiency (by Nesenbergs)

Contribution to the WTEC Evaluation Report on Satellite Communication Technology — European Portion (by Jennings)



Video monitor image of the computer simulation model for a 10-node, hybrid, circuit-switched, network.

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



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

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 past year the TAServices computer system was be replaced with a state-of-the-art computer providing greatly increased data base and user services. The current on-line terrain data base has a resolution of 3-arc-seconds (90 meters), the 1990 census data is incorporated. 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.

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.

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.

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 resolution is 3

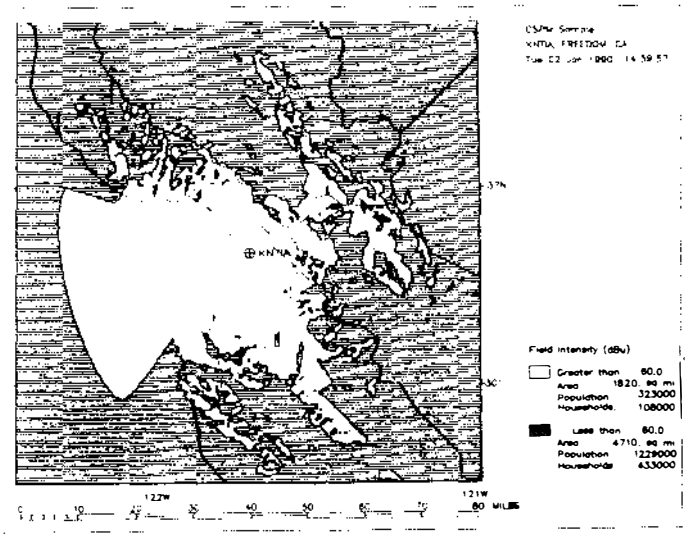
arcseconds (90 meters), and is generally derived from scaled maps of the Defense Mapping Agency. This program extracts path profiles according to user specified input parameters of location, bearing, etc. After the data are extracted, either the individual elevations or an average elevation along the 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 user defined intervals of bearing around the transmitter. The program lists the contours of signal coverage of the transmitter along each radial and lists distances to user specified contours for each radial. 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 produces plotted outputs which can be either FAXed directly to the user or be 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. The FCC rules as well as other widely available models can also be chosen. New models are placed on-line within CSPM as they become available. CSPM 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.

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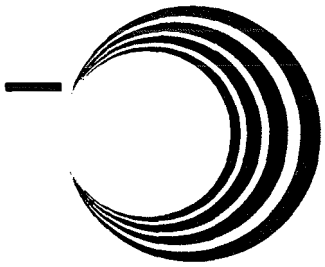

Advanced Systems Planning

Outputs

- Technical Planning Support for Eastern Region, U.S. Forest Service
- Technical Planning Support for Washington Office, U.S. Forest Service

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.

U.S. Forest Service Eastern Region Telecommunications Planning. The Institute is assisting the Eastern Region of the Forest Service to develop telecommunications plans to serve the 14 national forests of the Region. The work is being conducted in three steps: 1) assess communications requirements and constraints; 2) develop a regional strategic plan; and 3) produce tactical plans for each forest.

To take advantage of geographical similarities, the 14 national forests were divided into two groups of seven forests each. The first group to be addressed is known as the Lake States Forests because they are located near the Great Lakes in the states of Minnesota, Wisconsin, and Michigan. An ITS team visited each of these forests to conduct interviews with telecommunications system users to determine their requirements for voice, data, video, and radio communications, and their ideas for using telecommunications to improve the way they do business. A report detailing telecommunications requirements was prepared.

Applicable policy, regulatory, and technological constraints, both short-term and long-term, are being identified and evaluated in preparation for the development of a ten-year Regional Strategic Telecommunications Plan. ITS will develop this plan for the Eastern Region in concert with the development of a Forest Service National Strategic Telecommunications Plan, another ongoing ITS project described in the following section. The purpose of strategic planning is to provide a framework for incremental action that will move systems and services closer to meeting evolving user requirements. As choices are made among the alternatives, those choices become the basis for future decisions. With the extremely rapid changes in telecommunications technology, the strategic plan must be dynamic and will be reviewed for updating each year.

Work has also begun on tactical plans for each of the Lake States Forests. These short-term plans will address the next two to three years but will be consistent with the long-range direction of the Regional Strategic Plan. The tactical plans will identify equipment and services to purchase or lease, and how to configure and manage the telecommunications system.

U.S. Forest Service National Strategic Telecommunications Plan. In August of 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. Key ITS tasks in developing the Plan are the following.

Task 1. Establish the baseline for all subsequent tasks — a "Vision" of future Forest Service telecommunications based on current business needs and those projected for the upcoming years.

Task 2. Define internally-established social, economic, regulatory, policy, and other constraints that affect telecommunications planning.

Task 3. Define outside influences that may limit or direct the Plan — e.g., Department of Agriculture, Congress, and General Services Administration guidance and regulations. For example, with the advent of FTS 2000 as the national network for Government telecommunications, the Forest Service is required to use its services wherever possible.

Task 4. Review existing systems to establish a baseline understanding of USFS "reality" today. Radio, voice telephone, and data communications equipment and architectures currently being used at all echelons are described.

Task 5. Describe and assess the new telecommunications technologies that may provide the means for the transition from the present to the future "Vision". In addition to advanced communications schemes like Broadband Integrated Services Digital Network (B-ISDN), low orbit satellites, and Personal Communication Service (PCS), more stable technologies with useful capabilities have also been examined. An example of one such "older" technique is Adaptive HF Radio, which uses automatic link establishment to establish calls quickly and reliably.

Task 6. Formulate issues and alternative national strategies. This task uses the results of all previous tasks in formulating potential strategies for satisfying the Forest Service's requirements for the next 10 years. These alternatives are presented to the Forest Service for review, and for selection of the best alternative(s).

Task 7. Develop a detailed description of 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 change (or be changing) across the telecommunication planning elements.

During FY 92, ITS personnel performed work on all of the above project tasks except Task 7. Drafts of Task Reports for Tasks 1 through 6 were completed and forwarded to the Forest Service for review and comment. Task 7 work will commence once the Forest Service reviews the final Task 6 Report and selects the approach for the National Strategy. The final report is scheduled to be completed during the second quarter of Fiscal Year 1993.

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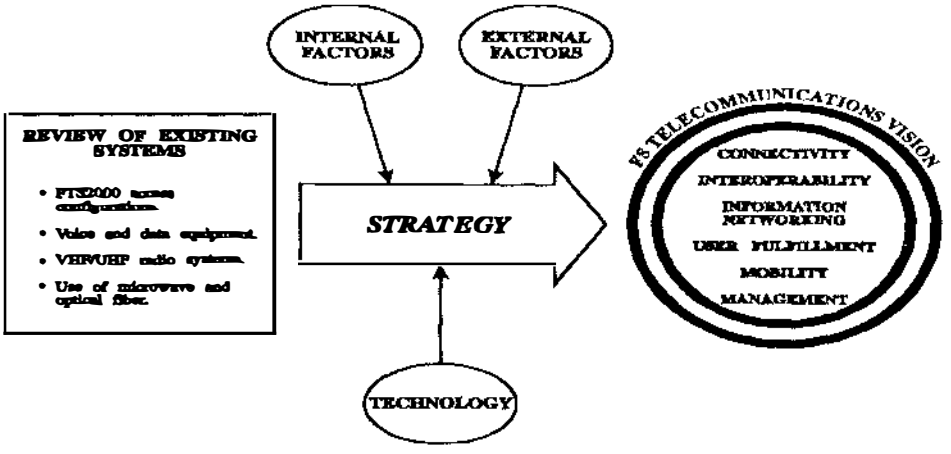

Network Engineering and Installation

Outputs

- Technical consulting
- WAN/LAN prototype testing
- Network troubleshooting
- Technical briefings

Department of Defense Intelligence Information System Implementation. Dramatic changes worldwide over the last two years have impacted U.S. military plans and policies. The down-sizing of the U.S. military and a shrinking defense budget dictate the restructuring of U.S. forces and assets to optimize efficiency and effectiveness through increased consolidation and integration. With the decrease in resources, greater emphasis is placed on cooperation with allies for common defense needs.

There is a critical need for intelligence analysts to exchange information securely across system boundaries in order to provide a fused, multi-source intelligence product, with a commensurate reduction in resources for development and operations. One vehicle by which the intelligence applications can be developed and operated securely with a minimum of duplicate functionality, a maximum of shared resources, and interoperability of information and functions is the Department of Defense Intelligence Information System (DODIIS) standards architecture.

The DODIIS community is striving to build interoperable intelligence capabilities at reduced costs by defining and implementing an open-systems, standards-based architecture that crosses all Service channels and uses commercial-off-the-shelf (COTS) hardware and software. To achieve this objective, the DODIIS community has developed and published open systems standards, a network reference model, and a client-server environment specification for use in implementing the network architecture throughout the Defense intelligence community. The U.S. Pacific Command (PACOM) ADP Server Sites program (PASS) represents the Pacific theater's effort to optimally implement the evolving DODIIS standard architecture throughout the Pacific theater.

During FY 92, ITS provided technical support to the United States Commander in Chief of the Pacific (USCINCPAC) in the development of the PASS concept, architecture, and implementation plan through active participation as a technical advisory member to the Pacific Intelligence Architecture Committee (PIAC). ITS provided technical briefings to the PIAC on advanced communications technologies and services (e.g., SONET, ATM, BISDN) and other subject areas requiring a technical perspective. ITS was active in developing and reviewing technical documents used for implementing PASS in the Pacific theater, and published a technical information guide on the existing DODIIS network.

ITS aided in the design of the local and wide area communications architecture in support of PASS. ITS performed laboratory prototype testing of various network and equipment configurations as well as technical evaluation and technical support, system and network testing, debugging, and documentation of field installations of DODIIS local area networks (LANs) at military sites throughout the Pacific. The figure below depicts DODIIS LANs and their interconnectivity via the Defense Secure Network (DSNET-3).

ITS LAN Design and Implementation. The Institute's implementation of a new, state-of-the-art, ITS-wide local area network during FY 92 culminated over a year's work in planning and design. This new data communications infrastructure was developed by an in-house, cross-functional team of engineers and managers. Benefits of the new LAN will include universal connectivity inside ITS for E-Mail; client-server computing services provided by high-speed UNIX RISC servers; and wide-area network (WAN) communications with NTIA, project sponsors, other

Federal agencies, and university and industry researchers.

Requirements and significant design factors for this LAN included: reliability, manageability, flexibility, upgradability, standards compliance, and interoperability in a heterogeneous, open systems environment. ITS has over 100 full-time personnel and over 140 computers, including IBM-compatible PCs, IBM PS/2s, Apple Macintoshes, and UNIX workstations from several manufacturers. Evolving project needs and new technologies create a rapid replacement rate in computers, with a completely new set of computers every three to four years. Adds, moves, and changes occur frequently, as new projects are undertaken and personnel are moved from one work area to another. These were additional factors influencing the LAN design decisions.

The most significant FY 92 accomplishment in the LAN project was the installation of new network cable throughout ITS. Over 45,000 feet of hybrid copper/optical fiber cabling now interconnects ITS facilities in a physical star topology. Nearly 160 LAN wall outlets connect to one of two central wiring closets, which are interconnected with redundant fiber optic backbone cables. This arrangement allows easy reconfiguration of the network, and the delivery of new high-speed services to any part of the Institute as requirements arise.

The node cabling is custom-designed and compliant with the ITS-developed *Federal Standard 1090 (ANSI/EIA/TIA-568-1991) Federal Building Telecommunications Wiring Standard,* and the *ANSI X3T9.5 Fiber Distributed Data Interface (FDDI) Standard* specifications. Each cable is a siamese design with both copper and optical components in the same sheath. The copper portion is rated for 100 MHz performance (EIA Category 5). It has four 22 AWG twisted-pairs, with an overall foil shield and drain wire. The 62.5/125 micrometer, multimode, optical fiber supports data rates of 150 MHz-km at 850 nanometers or 500 MHz-km at 1300 nanometers. There are four fiber strands in each node cable. This cabling provides ITS several options at each wallplate, including 10Base-T or optical ethernet, and single or dual-attached FDDI (or CDDI) workstations. The same fiber may also be used for special applications such as an experimental SONET/ATM network.

Each central wiring hub connects 80 of these node cables to a combination copper punch-down block/patch panel and fiber optic patch panel. The cables are patched directly into the modular premises hub concentrator. The hub concentrators will support ethernet, token ring, or FDDI networks, but only 10Base-T is installed currently. Repeaters are used to connect the hub to the existing 10Base2 thin coaxial ethernet.

ITS has employed an open systems approach in software, by using TCP/IP applications on all platforms. Future improvements will provide OSI applications such as X.400 E-Mail and FTAM as well.

As the LAN continues to evolve, it will provide the means for implementing new services such as desktop publishing. By adhering to standards wherever possible, and always providing an upgrade path, ITS expects a long lifetime for this important investment.

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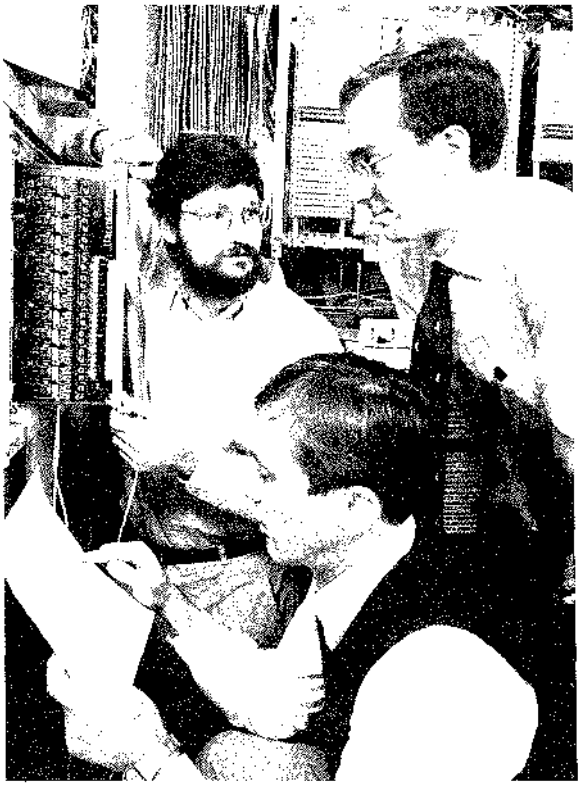


Tim Butler, Darren Smith, and Rob Debolt
Check ITS LAN Connections

Assessment of Telecommunications Dependence on Foreign Sources

Outputs

- Evaluation of current U.S. telecommunications dependence on foreign sources
- Ongoing and long-term dependence assessment plans

The telecommunication industry plays a critical role in assuring the Nation's ability to maintain continuity of Government and essential private sector functions when faced with national security or emergency preparedness (NS/EP) challenges. The National Communications System (NCS) is the Federal Government's primary agent for planning and coordinating the Nation's NS/EP telecommunication activities. The NCS NS/EP Telecommunications Plan of Action (NTPA) calls for:

- The identification of possible impediments to effective telecommunications industry mobilization and mobilization planning and the recommendation of corrective actions, and
- The identification and recommendation of any Federal Government actions needed to support telecommunications industry mobilization planning activities.

The Institute for Telecommunication Sciences (ITS) is supporting NCS in fulfilling this NS/EP responsibility by conducting a study to determine the extent and nature of U.S. dependence on foreign sources for telecommunications systems and components that could be of particular importance in a NS/EP scenario. The work involves both evaluating current system and component dependence and developing mechanisms for assessing ongoing and long term dependence.

BACKGROUND

According to a 1987 Government report, the extent of the telecommunication industry's dependence on foreign sources for raw materials, components, parts, and equipment is a key area of concern in evaluating the industry's ability to maintain service and production capabilities and accommodate increased service and equipment demands under mobilization conditions. The Joint Industry-Government Telecommunications Industry Mobilization (TIM) Group was established by the President's National Security Telecommunications Advisory Committee (NSTAC) and the National Communications System (NCS) Committee of Principals (COP) to identify possible impediments to effective telecommunications industry mobilization and assist in the development of corrective actions to overcome any identified impediments.

On the basis of its collective assessment of the responses to a NSTAC-wide Dependence on Foreign Sources survey, and other information obtained from the literature, briefings, and consultation with experts in the Federal Government and the private sector, the Joint TIM Group formulated several recommendations including:

(a) The Government, in conjunction with NSTAC, should establish a mechanism to periodically assess industry dependence on foreign sources in light of identified Government mobilization needs.

(b) The NCS and NSTAC should jointly keep the Executive Office of the President (EOP) apprised of any specific foreign dependence issues relating to telecommunications, and identify, if necessary, possible measures for reducing or mitigating these foreign dependencies.

STUDY METHODOLOGY

The ITS study was undertaken in response to the Joint TIM Group recommendations. ITS proposed a three-phase approach:

Phase I — Systems Level Analysis. Analyze each major telecommunications system or group of

systems to determine the amount of production within the U.S., the imported quantities, the exported quantities, and U.S. consumption.

Phase II — Component Level Analysis. Identify specific components of those Phase I systems that came primarily from foreign sources.

Phase III — Identification of Vulnerabilities. Investigate the vulnerabilities to the U.S. telecommunications infrastructure due to dependence on the identified systems and components.

The Institute's FY 92 activities and accomplishments in Phase I and Phase II of the study are summarized in the following. After evaluating the available data and data sources, ITS and NCS decided to limit the initial scope of the study to the area of telephone switching equipment (specifically, class-5 switches); to develop a detailed study methodology and preliminary conclusions focused on that study area; and then to apply the approach to other areas as appropriate. The class-5 telephone switch was selected because of its widespread use and its significant importance in the U.S. telecommunications infrastructure.

At the component level of the analysis, the goal is to identify components of the class-5 switch that are wholly or primarily obtained from foreign sources. Information on the class-5 switch components and their sources were obtained from the switch manufacturers via a questionnaire and on-site visits. Some preliminary results from the collected data reveal that:

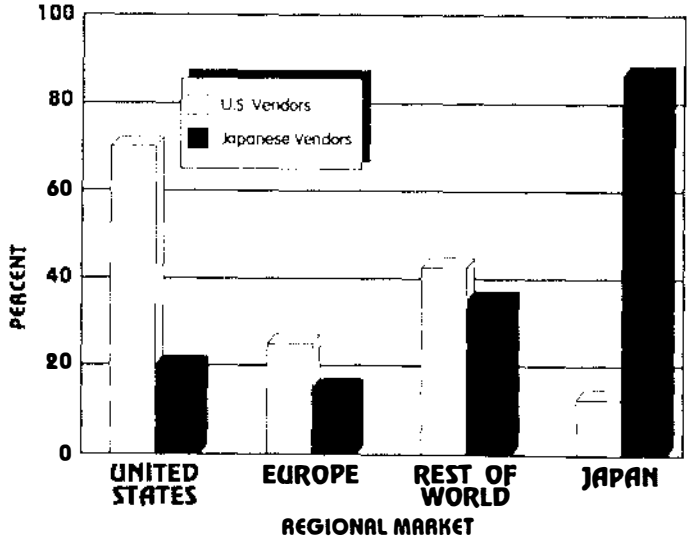
(a) Industrial base data collection and reporting should follow a more efficient and organized approach so trend analysis can emerge. Surveys do not identify specific component level problems. At this time to evaluate foreign source vulnerability a research oriented approach is necessary. A technical understanding of the technology is important to fully understand many dependence issues.

(b) Some of the significant technology-related foreign source dependencies identified appear common to most systems that utilize substantial micro-electronic components, include commodity memory semiconductors, plastic coated relays, and ferrite cores. The graph below shows a comparison of the 1991 regional semiconductor markets.

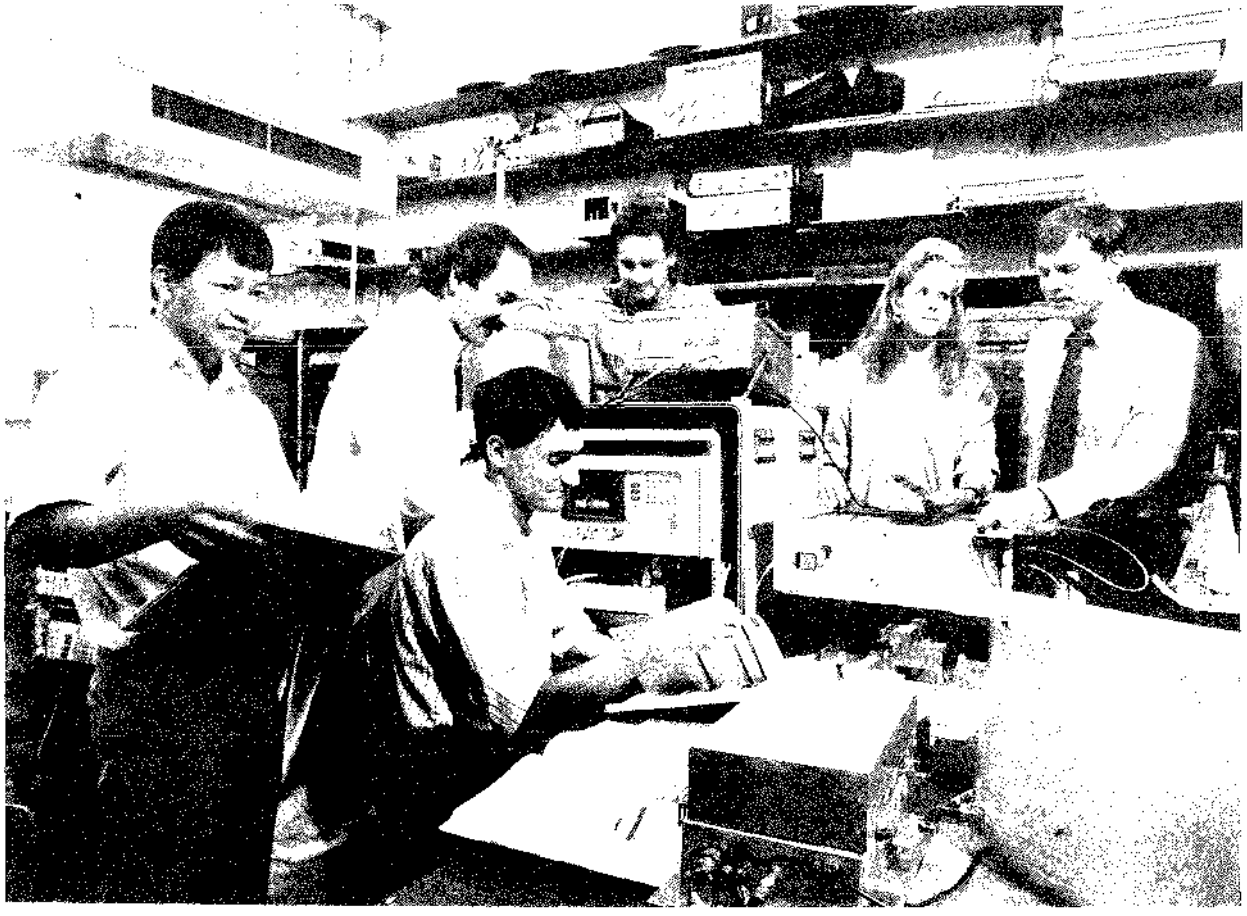
(c) U.S. firms are generally well-positioned in terms of technology and innovation. However, some handicaps commonly cited by U.S. manufacturers are capital costs, and unfavorable economic and international trade policies and practices. Although analysis of these concerns is beyond the scope of this study, ITS has identified their impact on specific dependence issues.

A final on this project will be provided to the National Communications System by the end of the 1992 calendar year.

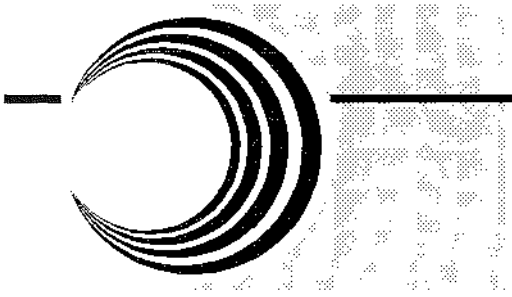
For more information contact:
David F. Peach (303) 497-5309
Michael D. Meister (303) 497-6571



1991 Regional Semiconductor Market



Millimeter-Wave Radio Channel Impulse Response Probe Testing



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 affected 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 Studies

Includes projects funded by the National Telecommunications and Information Administration, the U.S. Army Communications-Electronics Command, the U.S. Army Missile Command, the U.S. Army Atmospheric Science Laboratory, and the Department of Defense

PCS Measurements

Includes projects funded by Telesis Technologies Laboratory and US West Advanced Technologies, Inc.

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

Indoor Propagation Measurements

Includes projects funded by the National Telecommunications and Information Administration

Cooperative Research with Industry

Includes projects funded by Telesis Technologies Laboratory and US West Advanced Technologies, Inc.

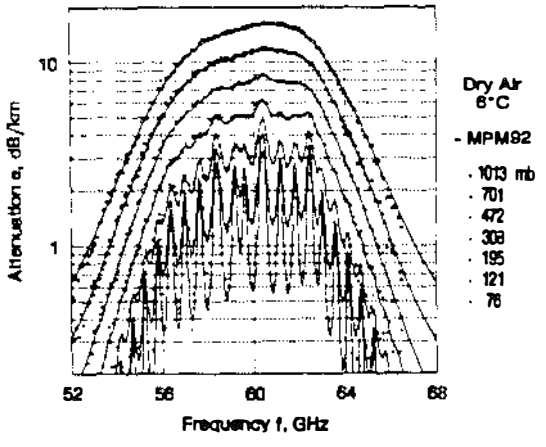
Millimeter-Wave Propagation Studies

Outputs

- Wideband Propagation Measurements in Conifer Trees
- Model MPM92 (1 - 1000 GHz)
- Model ZPM92 (50 - 120 GHz)

MPM is a Millimeter-wave Propagation Model, which computes the spectral properties of air, water vapor, suspended water/ice particles, and rain for frequencies up to 1000 GHz in terms of a complex refractivity or of related path-specific attenuation and delay rates. The variables describing the atmospheric state are pressure, temperature, relative humidity, suspended particle density, and rain rate. The parametric nature of MPM makes it convenient to convert readily available meteorological data from different climatic zones into system performance predictions. Three model modules (D, V, WI) have been updated for MPM92.

The dry air module D is supported by extensive 60 GHz laboratory measurements of the pressure-broadened O2 spectrum. Molecular oxygen dominates the absorption properties of air between 50 and 70 GHz. ITS studied the O2 spectrum of dry air under laboratory conditions with a resonance spectrometer. The detection sensitivity was 0.02 dB/km. Over 5,000

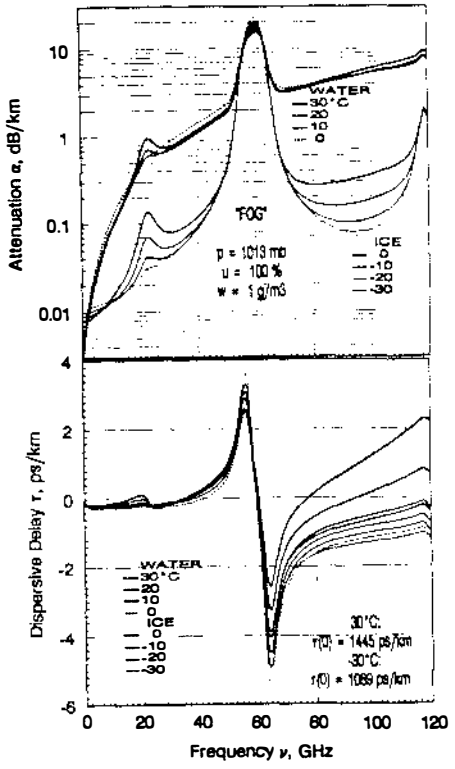


Attenuation Data of Dry Air between 50 and 68 GHz at Various Pressures, 10113 to 76 mb.

values of the attenuation rate α(dB/km) were measured over the frequency range from 49.5 to 67.2 GHz at eleven pressure levels (13 - 1013 mb) and three temperatures (6, 30, 54°C). Rosenkranz's overlap theory was applied to the data sets to minimize the residuals, and a best fit led to revised overlap (line mixing) coefficients. A graphical comparison between measured data groups and model predictions is shown here.

The water-vapor module V considers contributions of 30 local H_2O lines, which are supplemented by an empirical continuum term based on fitting laboratory measurements. Experimental millimeter-wave attenuation of moist air exhibits more water-vapor absorption than results from the summation of H_2O rotational lines. A continuum term was added to the contributions of 30 local ($\leq$ 1 THz) lines to furnish an empirical correction. The formulation of the excess was based on matching ITS laboratory measurements at 138 GHz. These measurements were extended by a French group (Bauer et al.) into the 183.7 to 213.5 GHz range, and their data are close to MPM predictions. A Far-wing contribution of allowed H_2O lines is the accepted theoretical interpretation of the continuum.

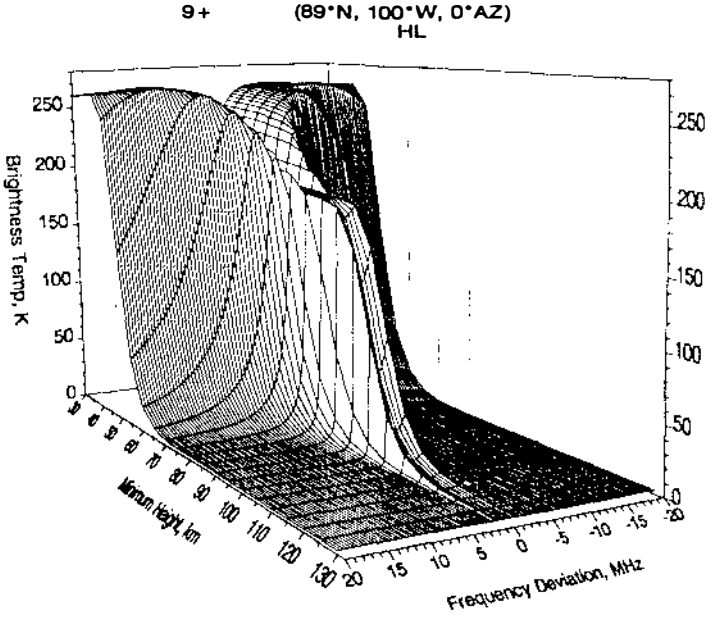
The suspended-particle module WI employs revised formulations for the complex permittivities of water and ice up to 1000 GHz which, however, above 300 GHz provides only minimum estimates due to the Rayleigh approximation. Dielectric properties of water plays a key role in computations of propagation effects caused by droplets 'suspended' (radii $\leq 50\mu m$) in fog/cloud conditions or by 'falling' ($r \geq 100\mu m$) rain drops. Complex refractivity spectra for a heavy fog (1 g/m^3) in saturated sea-level air are depicted.



Complex Refractivity Spectra of Saturated Air Containing Sea Level Fog Droplets with $1 g/m^3$ Water Density.

ZPM is a "Zeeman"-effect Propagation Model, which computes for the middle atmosphere (25 - 120 km, U.S. Std. Atm.) transmission and emission behavior of isolated spectral O_2 lines near 60 and 119 GHz. The earth's magnetic field (22 and 65 μTesla, depending on geodetic location and altitude) influences mesospheric line properties: The Zeeman effect splits each line into sublines; and how these sublines react to an electromagnetic field depends on the polarization of that field. Over the band of ± 2 MHz around a center frequency, the medium is anisotropic so that radio waves are subjected to polarization discrimination and Faraday rotation. The program ZPM allows the user to display many aspects of how polarized radio waves propagate through this medium and study the consequent effects.

The complex refractivity tensor, specific attenuation, Faraday rotation, polarization state (Stokes parameters), path transmission and the emitted thermal radiation are computed for ray-path geometries within or through the spherical shell model (25 - 120 km). These results are important for atmospheric limb sounding experiments from space-based platforms such as UARS-MLS (2 MHz) and ATLAS-MAS (0.2 MHz channel resolution). Circular (RC, LC) and linear (HL, VL) polarizations of the received thermal emission are considered in the example shown for tangential path-heights of 65, 90, and 100 km. FORTRAN programs for MPM and ZPM run efficiently on desk-top microcomputer, and current diskettes may be requested from ITS.



Polarized Thermal Radiation Emitted from the 9+ Line at 61.150 GHz for Equatorial and Polar Limb Paths with Minimum Tangential Heights of 65, 90, and 100 km.

Recent ITS Publications

Atmospheric spectral properties: 10 - 350 GHz, Proc. Microwave Radiation Conf. 92 (by Liebe).

The 60-GHz oxygen spectrum: New laboratory measurements and line parameters, J. Quant. Spectr. Rad. Transf. (by Liebe, Rosenkranz, and Hufford).

Models for atmospheric refractivity and radio-wave propagation below 1000 GHz, Int. J. IR & MM Waves, Part I: MPM (by Liebe, Hufford, and Cotton); Part II: ZPM (by Hufford, Liebe, and Cotton).

Wideband Propagation Measurements at 30.3 GHz through a Pecan Orchard in Texas (by Papazian, Jones, and Espeland)

For information, contact
Hans J. Liebe (303) 497-3310.

PCS Measurements

Outputs

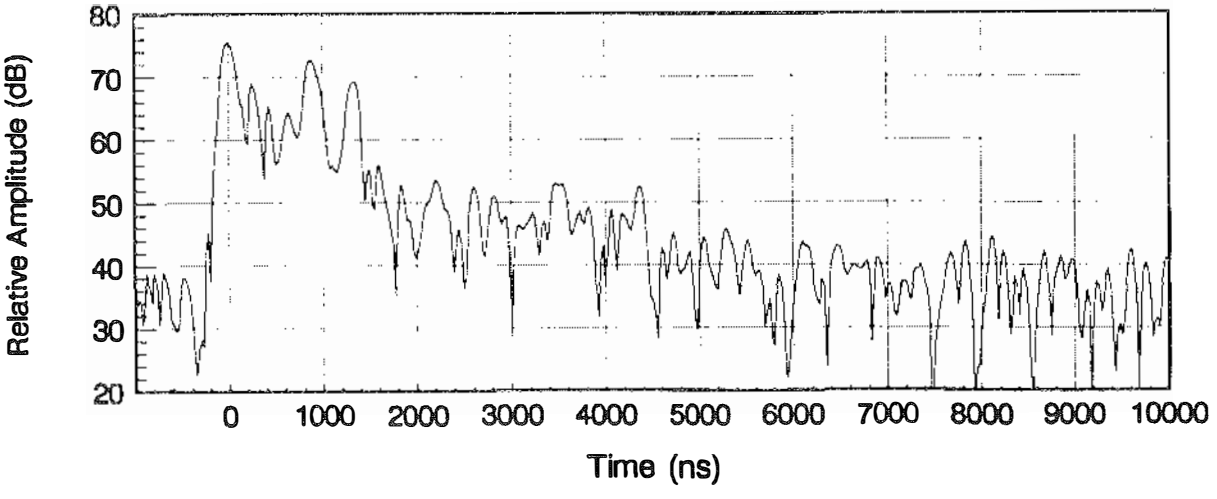
- Development of a system to simultaneously measure signal amplitude and phase variations of two transmitted CW signals
- Mobile propagation measurements of signal amplitude and phase in urban/suburban microcells
- Development of an innovative digital impulse response measurement system
- Impulse response measurements in the 1850-1990 MHz band in urban macrocells

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 they will accept voice messaging from all callers except selected numbers which they will answer immediately and personally.

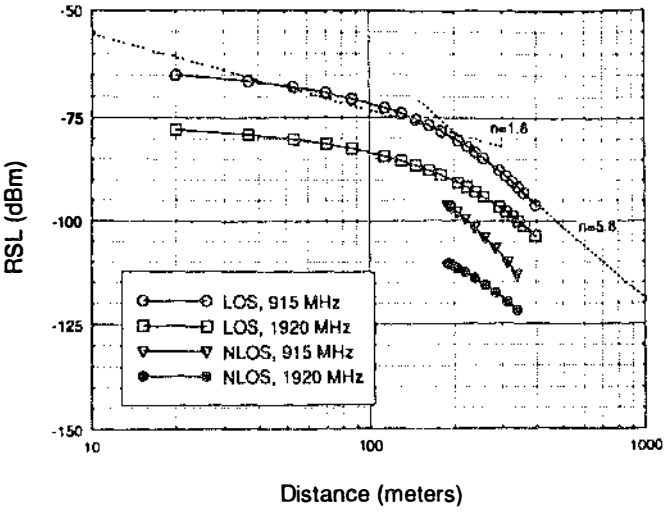
Traditional radio systems have involved well designed links over longer distances. Little is known about providing reliable radio links over short distances to arbitrary locations within man-made environments. Knowledge of noise, potential interferers, signal strength, and delay spread is needed before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

Part of the work in PCS measurements at the Institute has been accomplished through Cooperative Research and Development Agreements with private industry. Under one such Agreement, with US West Advanced Technologies, Inc., ITS developed a narrowband mobile measurement system to measure signal amplitude and phase variations of two simultaneously transmitted CW signals in outdoor microcells. This measurement system consists of a transmitter and receiver pair. The transmitter uses two frequency synthesizers locked to a stable reference oscillator to generate two CW signals. These signals are then amplified, combined, and transmitted through an appropriate antenna.

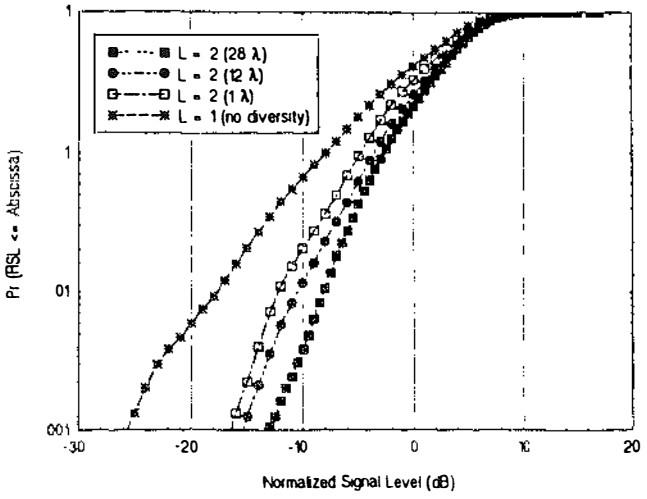
At the receiver, a matching antenna is used. The received signal is split into two signals. These signals are then bandpass filtered, amplified, and down-converted to audio signals. Signals are then digitized and recorded on digital audio tape (DAT).



Impulse Response in an Urban High-Rise Environment



Mean Received Signal Level vs. Distance in Microcell



Link Improvement via Space Diversity for a LOS Path in a Microcell

Mobile measurements were taken using this system at 915 and 1920 MHz in Albuquerque, NM and Boulder, CO. The transmitter was mounted on a cart that was moved at a pedestrian speed while the receiver was fixed in location. Measurements were made along line-of-sight (LOS) and non- LOS paths for cell sizes of approximately 300 meters in radius within residential, business, and downtown environments. The raw data is presented as received signal level and phase vs. distance. The data analysis included computation of mean path losses, signal level quantiles, and excess path losses as well as decomposition of fading processes into "fast" and "slow" components, and analysis of spatial diversity in a LOS link. An important result of the analysis showed that differential mean path losses between 915 and 1920 MHz typically ranged from 8 dB to 15 dB.

In addition to the work conducted under cooperative research with private industry, ITS has developed an innovative digital impulse response measurement system. This measurement system is comprised of a separate transmitter and receiver. The transmitter uses a pseudo-random noise (PN) code generator whose clock frequency is controlled by a signal generator. The PN code generator produces a maximal length code and can be set to any rate up to 50 Mbits per second. The PN code is used to modulate an RF carrier to produce a binary phase shift keyed (BPSK) signal. This signal is then amplified to a desired power level and transmitted through an antenna.

The receiver utilizes an antenna to receive the BPSK signal. This signal is then filtered, amplified, down-converted to an IF signal, and digitized. A unique software detection and correlation process is then used to provide the impulse response characterizing the propagation between the transmitter and receiver.

Impulse response measurements in the 1850-1990 MHz band have recently been completed using the digital impulse response measurement system. These measurements were made within an urban low-rise cell and an urban high-rise cell in the Boulder/Denver area. The receiver was placed in a fixed location while the transmitter was installed in a measurement van. Measurements were made at fixed locations within each cell along a line-of-sight, diagonal, and zigzag path. The impulse response data will be analyzed for delay spread and correlation bandwidth with the results published as an NTIA report.

Recent ITS Publications

Signal Strength Measurements at 915 MHz and 1920 MHz in an Outdoor Microcell Environment (Aguirre [US West], Allen, and Laflin) Spectrum Usage Measurements in Potential PCS Frequency Bands (Wepman, Matheson, Allen, and Achatz)

For information, contact:
Jeffery A. Wepman (303) 497-3644

HF Channel Modeling and Simulation

Outputs

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

Interest in HF communication systems, particularly those using wide bandwidths (on the order of 1 MHz or more), has been revitalized in recent years. This interest has been driven by the development of advanced digital signal processing and spread spectrum technologies. Digital spread spectrum systems offer the potential for improved performance and immunity to signal detection, interference, and jamming. Nevertheless, many uncertainties exist concerning the performance of these systems. Channel simulation enables designers to evaluate the performance of HF radio equipment in a repeatable, objective fashion without the cost of extensive field tests. For these reasons, the Institute has undertaken the development of a wideband HF channel simulator.

A channel model that accurately describes the real-world conditions encountered on communication links is required for the development of a channel simulator. Previous HF channel simulators have been based on a channel model developed circa 1970, and 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 HF paths.

The Institute has developed a wideband HF channel model that will overcome many of these restrictions. The objective has been to develop a model that is accurate over bandwidths of 1 MHz or more (as well as narrow bandwidths); that can be validated with measured data; and that is suitable for implementation in a real-time channel simulator. The model describes the characteristics of ionospheric skywave propagation, as well as a waveform for wideband HF noise and interference. Comparisons between outputs of the new channel model and measured data have shown good agreement. Outputs of the propagation model have been compared with propagation data collected by the Naval Research Laboratory on a variety of different paths, and outputs of the noise/interference model have been compared with data collected by the MITRE Corporation.

A real-time hardware channel simulator that implements the new HF channel model has been developed by the Institute. The simulator incorporates custom circuitry designed and built by Institute personnel and state-of-the-art digital signal processing hardware. A simplified block diagram of the simulator and a photograph of the simulator hardware are shown in Figures 1 and 2, respectively. Briefly, the transmitted signal from the radio under test is downconverted to baseband and digitized. The signal is then Fourier transformed to the frequency domain, and the resulting spectrum is multiplied by the channel transfer function in the first array processor. In the second array processor, jamming signals and narrowband interference are added to the transmitted signal, and the result is inverse Fourier transformed back to the time domain. The digital signal processor adds Gaussian noise and impulsive noise (both man-made and atmospheric) to the signals and interference. The result is converted to an analog signal and upconverted.

The simulator is currently being used by private industry for the testing of wideband equipment being developed as part of a large military communication system procurement. It will also be used for the final Government testing of this equipment. The simulator will later be used for the testing associated with the development of a family of Federal Standards for (narrowband) HF communication systems and networks.

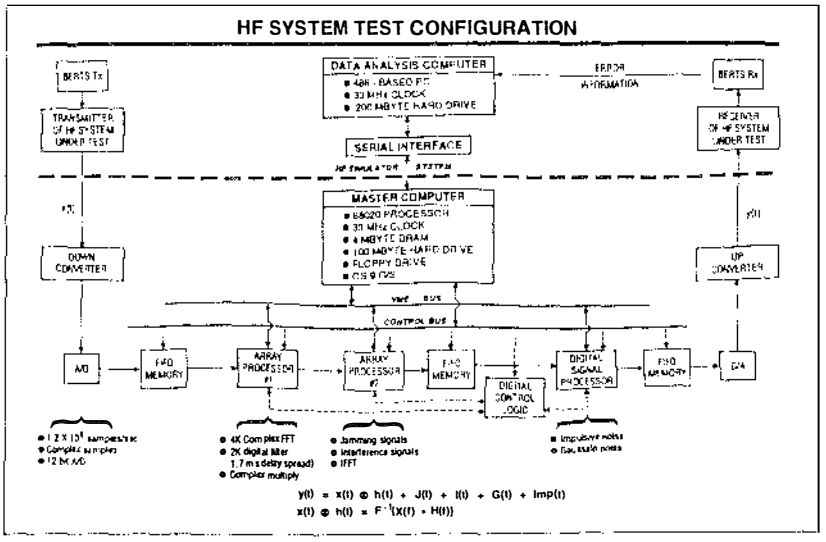


Figure 1. Wideband HF Channel Simmulator Block Diagram

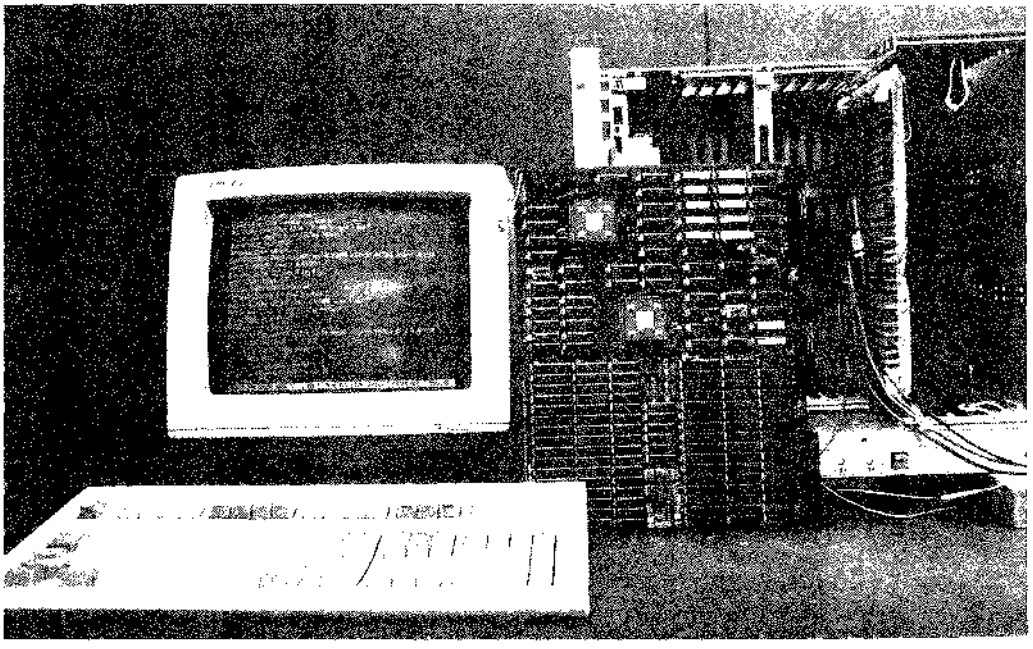


Figure 2. Wideband HF Channel Simulator Hardware

Recent ITS Publications

A New Approach to HF Channel Modeling and Simulation — Part III: Transfer Function (by Vogler and Hoffmeyer)

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

For information, contact:

James A. Hoffmeyer (303) 497-3140

Indoor Propagation Measurements

Outputs

- Indoor impulse response measurement data
- Indoor radio channel models
- Indoor digital transceiver performance prediction software

Many new emerging radio technologies promise convenience and increased productivity in the work place. Many of these technologies will involve radio links that are wholly indoors, for example digital cordless telephones, wireless private branch exchanges (WPBX), and wireless local area networks (WLAN). The performance of these systems will be limited by the indoor radio channel. Therefore, it is necessary to understand the indoor radio channel in order for these systems to be effectively developed and regulated. ITS has undertaken research in indoor radio propagation in order to provide the fundamental knowledge required.

The indoor radio channel exists in a complicated environment and displays complicated behavior. In addition, this environment is highly variable because of the diversity of building types and furnishings. Finally, little knowledge currently exists regarding radio propagation indoors.

Walls, floors and ceilings limit radio performance by reducing radio coverage and introducing dispersion. Radio coverage can be increased by boosting transmitted power or adjusting gain factors in the radio link budget. Dispersive effects caused by multipath include frequency selective fading in the frequency domain and delay spread in the time domain. Narrowband transceivers operated in dispersive radio channels suffer power fading due to the frequency selective fading. Methods such as direct sequence spread spectrum can be used to mitigate this fading by spreading the signal energy in the frequency domain. Angular and/or spatial antenna diversity can also be used to mitigate fading. Wideband digital signals suffer intersymbol interference (caused by the delay spread) resulting in bit errors. Intersymbol interference is not mitigated by increasing the transceiver's signal-to-noise ratio.

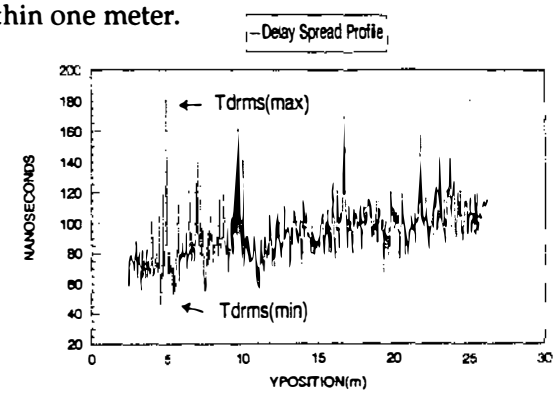
Accurate models and measurements are needed for indoor radio links in order to predict the impact of these effects and to better plan, design, and deploy indoor systems. In fiscal year 1992, ITS completed an initial set of indoor radio propagation measurements. Wideband measurements of the channel impulse response were made in three indoor environments, a long hallway, an auditorium, and an open, soft-partitioned office space.

The ITS wideband channel probe uses the pseudo-random noise, sliding correlator technique providing excellent signal-to-noise ratio for the impulse response measurements. The dispersive properties of the indoor environment require measurement bandwidths exceeding 50 MHz in order to resolve the various multipath components of the signal. The ITS probe is unique in the industry, in that it provides impulse response measurement bandwidths from 200 to 1000 MHz. These bandwidths provide excellent time delay resolution of the channel. The 200 MHz bandwidth allows the measurement of multipath signals delayed from 10 to 635 nanoseconds (ns) with a resolution of 10 ns while the 1000 MHz bandwidth allows the measurement of signals delayed from 2 to 127 ns with a resolution of 2 ns. All measurements are stored in complex valued form to represent the inphase and quadrature components of the complex impulse response.

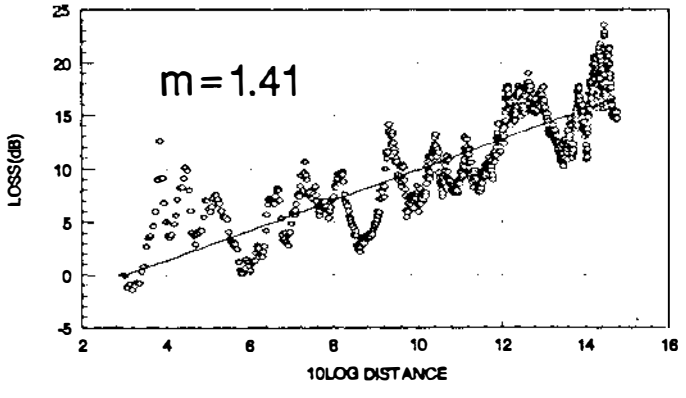
The channel measurements were made using a 1500 MHz carrier with biphase shift keying. To simulate typical operating conditions for an indoor system, the measurements were taken with a corner-mounted, stationary terminal and a mobile terminal that was moved within the measurement area.

The data were separated into cases where unobstructed line-of-sight (LOS) conditions existed between the transmitter and receiver and cases with obstructed line-of- sight (OLOS). The data naturally separates into these two classifications and significant changes in the channel were noticed as the path changed from LOS to OLOS. Multipath conditions were typically less severe for LOS paths.

More detailed results for the soft-partitioned office space include the following. The median value of the root- mean-square (rms) delay spread was 20 ns for the LOS conditions and was 70 ns for the OLOS conditions. The OLOS rms delay spread was observed to increase with distance. For OLOS paths, the components in the impulse response were found to change radically with small changes in transceiver position. This was due to the resolution limit of the measurement system resulting in several multipath signals adding together in one signal component of the measured impulse response. These multipaths interfered with each other, sometimes cancelling each other, so that even strong components in the impulse response faded significantly. Thus, over short distances, on the order of a wavelength, the power distribution in the impulse response changed radically. The figure below shows a change in rms delay spread from 44 to 181 ns within one meter.



The decrease of signal level with distance is often described by a power law, i.e. an exponent applied to the distance. For free space the exponent is 2. The power law exponent for indoor LOS paths was experimentally found to range from .93 to 1.7. Results from one measurement is shown in the figure below. OLOS links had exponents ranging from 2.6 to 7.8 depending upon the number of office partitions in the path.



The IEEE 802.11 (WLAN) standards committee is developing a standard for WLANs. ITS is actively participating with contributions directed towards the development of the physical layer standard. The initial indoor radio channel measurements and modeling activities at ITS have been contributed to the 802.11 committee.

Future work at ITS for indoor systems will include studies of the effect of antenna placement, antenna diversity, and depolarization on the indoor channel. Measurements will be made in various building types including industrial since one of the important applications for WLANs is robotic manufacturing.

In addition to measurements, ITS will continue its modeling efforts for the radio channel. The indoor channel will be modeled geometrically and statistically. A geometric model must take into account building architecture and reflection, refraction, and diffraction phenomenon. The geometric model is useful for studying the dynamics of the radio channel and understanding the fundamental principals of indoor propagation. Statistical models provide a well defined description of the radio channel that can be used for theoretical studies and simulation tests. The model must be parameterized based on building type or characteristics. Practical implementation of geometrical and statistical models for the indoor radio channel are currently being studied at ITS.

Both geometrical and statistical models, as well as measured data, can be used for simulation testing. Software simulation is useful for assisting in planning and initial system design such as the selection of a modulation type. Hardware simulation is useful for testing prototype designs or for selecting among various vendor products. In fiscal year 1993, ITS will be developing an initial software simulator for testing the performance of various digital modulation techniques for the indoor radio channel. In addition, an initial investigation into the development of a hardware simulator will be undertaken.

Recent ITS Publications

ITS Wideband Measurement and Prediction Efforts (by Achatz and Papazian)

Wideband Propagation Measurements for Wireless Indoor Communication (by Papazian and Achatz)

For Information, contact:
Robert J. Achatz (303) 497-3498

Cooperative Research with Industry

Outputs

- Measurements of spectrum usage in the 600 MHz to 2.5 GHz range in five cities
- Mobile propagation measurements of signal amplitude and phase in urban/suburban microcells
- Development of an innovative digital impulse response measurement system

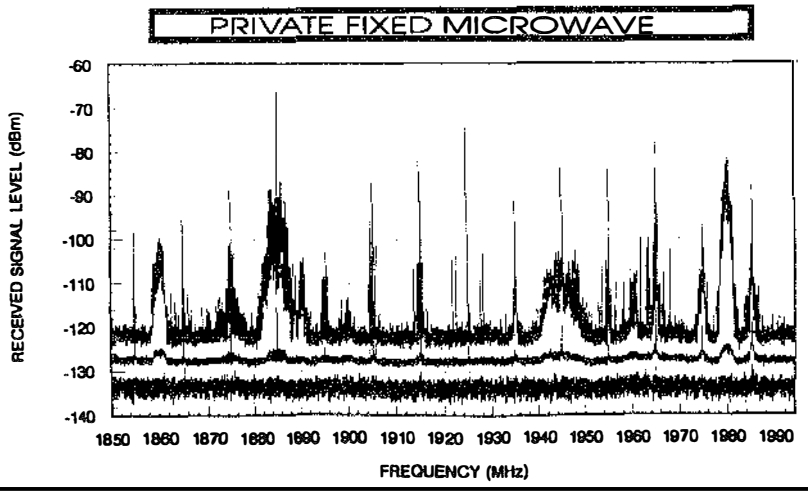
As part of the Federal Government's efforts to promote technology advancement through the transfer of technology from Federal laboratories to the private sector, ITS has participated in five Cooperative Research and Development Agreements (CRADAs) with private sector organizations. Research was conducted under agreements with Bell South Enterprises, Telesis Technologies Laboratory, and U S West Advanced Technologies. Research is currently being conducted under two other CRADAs.

The Federal Technology Transfer Act of 1986 as amended allows ITS to enter into CRADAs and provides for the protection of proprietary information. The CRADAs also allow for the control of the dissemination of research results so that both the private partner's and ITS's interests are protected. The CRADA also provides protection for inventions and allows the private partner to hold an exclusive license on a government owned patent.

Much of the Institute's work in PCS has been accomplished through CRADAs. So not only does the private industry partner benefit, but the Institute is able to undertake research in commercially important areas that it would not otherwise have been able to do. As an example, of the mutual benefits obtained under a CRADA, ITS was able to study spectrum resources and the availability of propagation models for PCS in a cooperative effort with Bell-South Enterprises before Federal funding was available for such work.

Another example is the opportunity that ITS has had to share in and contribute to a comprehensive technology development program with Telesis Technologies Laboratory (TTL), a Pacific Telesis subsidiary. The Institute assisted TTL in the development of an experimental plan for spectrum usage, signal strength, noise, and delay spread measurements.

As part of the agreement with TTL, ITS developed a mobile, computer-controlled, RF measurement system that was installed in a mini-van. Spectrum usage measurements were then conducted using this system at 37 locations in each of five cities: Dallas, Chicago, New York, Los Angeles, and San Francisco. The measurements were taken in the 614-806 MHz, 824-944 MHz, 1850-1994 MHz, 2110-2182 MHz, and 2400-2600 MHz bands.



The results of these measurements have been published as a NTIA Technical Report. They show the amount of spectrum used by other services that would be observed by potential PCS systems operating in these bands. These measurements were reported in an NTIA report. An example of the spectrum measurements made in Los Angeles, CA is shown on the previous page.

The Institute also made significant contributions to the development of TTL's signal strength measurement system which TTL has used extensively in the development of its PCS strategy. More recently, ITS has delivered to TTL an innovative impulse response measurement system. This system allows the complete measurement of the radio channel impulse response in less than 50 μs. A patent application on this instrument is in preparation.

Under a CRADA with U S West Advanced Technologies, Inc., ITS developed a narrowband mobile measurement system to measure signal amplitude and phase variations of two simultaneously transmitted CW signals in outdoor microcells. These measurements were made at 915 and 1920 MHz along line-of-sight (LOS) and non-line-of-sight (NLOS) paths in Albuquerque, NM and Boulder, CO. A detailed analysis of received signal level and Doppler effects was preformed. The results of this analysis were published in the proceedings of the 1st International Conference on Universal Personal Communications.

Cooperative research with private industry has helped ITS accomplish its mission to support U. S. industry and competitiveness by providing insight into industry needs. This has lead to adjustments in the focus and direction of other Institute programs to improve their effectiveness and value.

To date, all of the cooperative research has addressed the development of radio technology for Personnel Communication Services (PCS). However, ITS is interested in assisting private industry in other areas of telecommunication technology as appropriate. The pages of this technical progress report reveal many technological capabilities that may be of value to various private sector organizations. Such organizations are encouraged to contact ITS if they believe that ITS may have technology that would be useful to them.

Because of the great commercial importance of many new emerging telecommunication technologies including PCS, wireless local area networks, digital broadcasting, and intelligent vehicle-highway systems, ITS plans to vigorously pursue technology transfer to the private sector through CRADAs and thereby contribute to the rapid commercialization of these new technologies. In addition, ITS plans to commit substantial resources of its own to contribute to the development of these new technologies and standards.

Recent ITS Publications

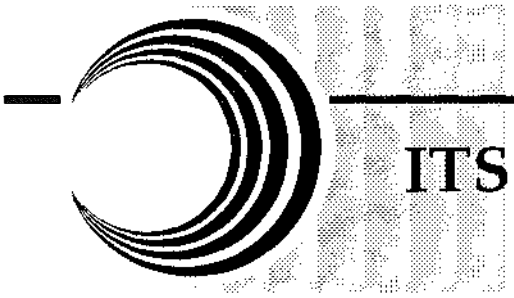
Signal Strength Measurements at 915 MHz and 1920 MHz in an Outdoor Microcell Environment (Aguirre [U S West], Allen, Laflin)

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

For information contact:
Ken Allen (303) 497-5474

ITS Video Quality Laboratory Environment

PCS Radio Channel Probe Performance Examination



ITS TOOLS AND FACILITIES

Data Communication Laboratory Test Bed

This ITS test facility is used as a tool for:

1. 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.

2. 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.

3. 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.

Digital Networks Laboratory

ITS established the Digital Networks Laboratory to support the Institute's leadership in developing national and international telecommunication performance standards and to facilitate the transfer of telecommunications technology to industry and Government. This laboratory was designed to support the emulation of many modern telecommunication networks, including ISDN's and Broadband ISDN's. Capabilities exist that allow proposed performance measures for new and existing networks to be validated in a controlled environment. The Laboratory can also be used for testing of new ISDN and B-ISDN services and, in the future, for performance evaluation of multimedia systems that include integrated audio, video and data transport and presentation. Equipment that is part of the Laboratory includes personal computers equipped with ISDN interfaces, ISDN telephones, ISDN Terminal Adapters, an ISDN mini-switch, a video codec (with CCITT H.261 capabilities), a sophisticated ISDN protocol test instrument, and a new real-time B-ISDN Asynchronous Transfer Mode (ATM) simulator. Laboratory ISDN equipment allows basic rate (2B+D) bearer service to be delivered to various types of terminal equipment, while protocols used to provide this service are monitored by the ISDN protocol analyzer. The new ATM simulator can introduce impairments, typical of those expected to be found in an ATM network, into a high-speed data stream. In addition to the ATM simulation capability, this device has the ability to simulate the impairments introduced by the B-ISDN physical layer (SONET in this case although SDH capabilities are possible). Because the Digital Networks Laboratory is integrated with the ITS Voice and Video Quality Laboratories, ITS has the capability to measure simulated performance of networks simultaneously transporting voice, video, and data information.

HF ALE Radio Network Simulation

ITS has developed an HF Automatic Link Establishment (ALE) Radio Network Simulation computer program. The purpose of this discrete event simulation and the supporting computer programs is to study the effects of various network protocols on the performance of ALE radio networks. Network simulation allows the study and testing of networking protocols for the upcoming series of HF radio Federal standards on ALE. Simulation of the effects of these networking protocols allows standards development to proceed in lieu of over-the-air radio testing which may not be practical or cost effective. Simulation results will also be useful to ALE HF radio users, network designers, manufacturers, and

vendors. The simulation is conducted on a fast-disk-caching, 50 MHz 486 computer with EISA bus.

HF and PCS Channel Simulator

ITS has developed a new real-time HF channel simulator for testing advanced HF radio systems. The simulator consists of the hardware implementation of new propagation and noise/interference models developed at the Institute. Unlike existing narrowband HF models and simulators, the new simulator is capable of emulating the wide bandwidths needed for testing wideband spread-spectrum HF radios and can simulate propagation conditions typical of disturbed channels. Because of the architectural design of the simulator and the use of state-of-the-art signal processing systems, the simulator has the flexibility for future use simulating other types of channels such as channels typical of Personal Communication Services networks.

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.

Integrated Networks Simulation Environment

Computer-based modeling and simulation is a research tool that is rapidly growing in acceptance in telecommunications engineering. ITS maintains a model development and simulation environment for creating communications network simulations. This system is currently hosted on two Silicon Graphics high-speed RISC workstations. These computers are connected by an ethernet local area network using NFS and TCP/IP to share resources. Each workstation has a complete software development environment. This includes the object-oriented OPtimized Network Engineering Tools (OPNET) program from MIL 3, Inc. for developing, executing, debugging, and analyzing simulation models. The Empress relational database management system (RDBMS) stores the input scenario database information. Revision control tools provide the means to make multiple versions of the same model, and add or subtract features as needed. A standard library of models provides the capability of simulating ethernet and FDDI LANs, packet-switched networks, satellites and other systems. This environment is currently being used to develop models for evaluating the performance of advanced hybrid (terrestrial-satellite) networks, featuring futuristic satellite designs.

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 103 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'
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.

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Local Area Network

ITS' new state-of-the art local area network (LAN) will help the Institute to more-quickly respond to new programs and new technologies. This LAN interconnects every office and laboratory within ITS, and provides access to sponsors, research collaborators, and other agencies through wide area network (WAN) connections.

The LAN began with efforts to improve the infrastructure for internal data communications, and provides electronic mail, client-server computing, and peer-to-peer services for all ITS personnel. Currently, the LAN operates as an IEEE 802.3 10Base-T ethernet. This ethernet supports heterogeneous computers from IBM PCs, to Macintoshes, to Hewlett-Packard, Sun, Silicon Graphics, and Data General RISC workstations. TCP/IP applications software is used to provide the multi-vendor interoperability.

Over 45,000 feet of hybrid copper/optical fiber cabling integrates ITS' facilities in a physical star topology. Nearly 160 LAN wall outlets connect to one of two central wiring closets, which are interconnected with redundant fiber optic backbone cables. This arrangement allows easy reconfiguration of the network, and the delivery of new high-speed services to any part of the Institute as the requirement arises.

The node cabling is a custom-designed hybrid of 100 MHz, shielded, twisted-pairs, and FDDI-compliant 62.5/125 micrometer, multimode, optical fiber supporting data rates of 150 MHz-km to 500 MHz-km. This cabling provides ITS the advantage of being able to deploy single or dual-attached FDDI (or CDDI) workstations from any wallplate location. The same fiber may also be used for special applications such as an experimental SONET/ATM network.

Wide area connections with the Internet allow ITS personnel to exchange information with NTIA, NASA, the National Communications System, and other federal agencies, universities, and industry.

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 interoperability and performance of a variety of networks under many conditions. The network incorporates Local Area Networks (LANs), Metropolitan Area Networks (MANs), and Wide Area

Networks (WANs) to carry CAD/CAM, voice, video, and high-resolution graphics to teleconferencing data. ITS designed the network so that data paths between any two nodes can span any scale of network (from LAN to WAN) or cross diverse transmission media. ITS has also developed software that measures ANSI X3.102 user-oriented performance parameters at various layers in the TCP/IP protocol stack. The network consists of IEEE 802.3 coaxial Ethernet (10 Mbps), 10 Mbps fiber optic Ethernet, a 14/12 GHz (Ku-band) satellite transmit/receive earth station, and a satellite network simulator. The Network Laboratory provides the Video Quality 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 wavelengths. ITS makes measurements using this facility to improve and validate computer models that provide system designers and users with performance prediction capabilities.

Radio Spectrum Measurement System

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

Standards Database Service

The Institute has developed the prototype of a specialized computer-based information source on telecommunication standards for support of telecommunications equipment and services acquisition by Federal Government agencies and departments. This project is targeted toward the enhancement of Federal agency/departmental applications-unique procurement of interoperable telecommunications equipment and services in terms of national security or emergency preparedness (NS/EP) communications requirements. Additional applications include use by writers of telecommunication standards.

The goal has been to provide a customized on-line, user-friendly relational database that will permit the user, without intensive specialized training, to identify all telecommunication standards that may be pertinent to a specific procurement requirement. To facilitate this, standards have been grouped into "families" comprising documents relating to various disciplines. Key words, abstracts, and cross references are also provided, to further assist the user in locating pertinent standards.

Under FY 92 funding by the National Communications System (NCS), ITS has developed the prototype database, comprising a limited data content, and refined the conceptual approach as the result of beta trials by Federal users via dial-up modem access. In FY 93, the data contents will be expanded in preparation for access by other means, such as Internet, as well as by modem.

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 and test automated techniques for assessing the quality of video and image data. This laboratory consists of a distributed, workstation-based system for implementing and testing a large set of video and image parameters, a real-time PC-based system that can perform video quality measurements in the field, and a viewing room (built to CCIR Recommendation 500 specifications) that is used to view and subjectively grade video data. The viewing room provides a means for validating the objective video and image parameters from the computer based systems. Since most of the newer video systems being used by the telecommunications industry are digital, the video quality laboratory hardware and software has been specifically designed to address this difficult measurement problem. Integration of the ITS Video Quality Laboratory with the ITS Voice Quality Laboratory, and the Digital Networks Quality Laboratory enables ITS to conduct multimedia performance testing.

Laboratory hardware consists of an ensemble of broadcast quality cameras, video recorders and players, image capture/display equipment, image processing workstations, digital video systems, and video test equipment. Computer hardware includes 486-based systems with broadcast quality (756 x 486 pixel) frame capture/display capability with real-time image processing boards, 2 high speed RISC workstations with high resolution monitors (1280 x 1024 pixels), a high speed RISC server, over 3 GBytes of hard disk space for storing images, and a 1.3 GByte tape drive. A high resolution color printer may be used to obtain video prints or transparencies of processed imagery. Video equipment includes a broadcast quality camera, 3 monitors, a Betacam SP video recorder and player, VHS and S-VHS video cassette recorders, video format converters, a wideband video switcher, a programmable video signal generator, a video waveform monitor, an NTSC vectorscope, and a high speed digital oscilloscope. Video teleconferencing codecs may be used to generate distorted video teleconferencing data.

Voice Quality Laboratory

The ITS Voice Quality Laboratory is used to study the effects of transmission impairments on the perceived quality of voice signals and provides facilities that allow the development and testing of voice quality assessment techniques. Equipment available in the laboratory includes a pair of 80386-based workstations having precision analog input and output interfaces that allow processing of CD-quality audio, a computer controlled DAT recorder/player, and appropriate amplifiers and signal generators. The computer systems are also used to manage extensive databases of subjectively rated voice signals obtained from CCITT, COMSAT, the NSA and others. These databases are employed as a source of test signals for the evaluation of existing and proposed voice quality measurement techniques. A testing program is ongoing, in cooperation with the CCITT and with industry and Government research laboratories, to evaluate and validate measures of voice quality that are proposed as national and international standards and to measure the performance of voice coders and voice coding algorithms. Voice Quality Laboratory systems are interconnected with equipment in the Video Quality and Digital Networks Laboratories allowing integrated testing of telecommunication systems that simultaneously transport voice, video, and data information. Such testing capabilities have become more important with the advent of modern multimedia systems and services. Currently, Voice Quality Project staff members are developing a

portable version of the ITS Voice Quality Assessment System that will be used in field testing as well as in the laboratory. This system will make use of a version of the Voice Quality Assessment Software that has been designed to have maximum portability to a variety of computer systems including those using the MS-DOS, Microsoft Windows, and Unix environments.

ITS PROJECTS — FY 1992

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 (ACTS) — Raymond D. Jennings (497-3233). Design experiments, that will be conducted in FY 93 using ACTS, to characterize system performance (end-to-end) for the next generation of communication satellites that will use scanning, spot-beam antennas and on-board signal processing. Investigate appropriate roles for advanced communication satellites in providing B-ISDN.

Broadband Networks — William R. Hughes (497-3728). Build infrastructure necessary for ITS to take a leading role in developing Broadband research community by expanding and enhancing ITS's Broadband Networks performance measurement capabilities.

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 implementation of advanced broadcasting techniques including high-definition television.

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.

Fuzzy Logic Research — Timothy W. Butler (497-3606). Study fuzzy logic and systems theory in the context of telecommunications system performance measurement work.

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-in dependent 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 models applicable to frequencies up to 300GHz that will be useful in assessing millimeter-wave telecommunication system performance.

PCS Studies - James S. Washburn (497-3109). Provide a computer prediction model for area coverage of personal communications services' (PCS) base-stations and for sharing between PCS and fixed services; analysis of sharing in the 1850-1990 MHz band; and participation in standards committee work for mobile radio.

PCS-92: Modeling and Simulation - James A. Hoffmeyer (497-3140). Conduct study of propagation and noise/interference models and feasibility of adapting WBHF simulator for PCS channel simulation.

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(s) of advanced communication satellite systems in providing broadband ISDNs. Interface and management standards for networks composed of both advanced terrestrial and satellite resources (hybrid networks) are factors of particular interest in this research.

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 — Steve Voran (497-3839). Develop objective voice quality assessment techniques and standards contributions in support of advanced voice coding and ISDN standards within T1 and CCITT.

Wavelets — David A. Sutherland Jr. (497-5161). Review scientific, engineering, and mathematics literature on emerging theory of Wavelets. Report on fundamentals of Wavelet Theory and possible applications to telecommunication projects and research at ITS.

National Institute of Standards and Technology

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.

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 measurements of millimeter-wave propagation in the evaporation duct. Polarization dependence and depolarization are studied.

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)

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.

Radio Link Integrated performance Predictions - Susan L. Rothschild (497-3411). Provide services to update and enhance the programs written by ITS to predict the performance of line-of-sight, marginal line-of-site, and beyond the horizon radio links.

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 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. 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 Independent Testing Evaluation - Val J. Pietrasiewicz (497-5132). Establish a comprehensive testing evaluation program for RCAS contractor and technical testing, independently evaluate testing methodology and results, and report on the findings.

ASL

ITS Model for EOSAEL - Hans J. Liebe (497-3310). Update the ASL's Electro-Optics Systems Atmospheric Effects Library (EOSAEL) with ITS-developed millimeter wave models.

Yuma Information Systems Command

Desert Rat SMS - Brent L. Bedford (497-5288). Design, procure and configure a mobile frequency monitoring system for the Yuma Information Systems Command.

Yuma Remote System - David A. Clingerman (497-3820). Design, develop and configure a fixed-location directional spectrum analysis system for the Yuma Information Systems Command.

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)

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.

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.

Foreign Dependence Information Assessment — David F. Peach (497-5309). Determine U.S. dependence on foreign sources for telecommunications systems and components that could affect telecommunication within the U.S. in a national security/emergency preparedness (NS/EP) scenario. The work requires identification of system and component dependencies and identification of a mechanism to monitor ongoing and long term assessment of foreign dependence in telecommunications. The work performed in FY 92 is a pilot project from which to gain expertise and insight in developing a research strategy on a larger scale.

HF Simulation System Specification Development - John J. Lemmon (497-3414). Analyze noise/interference data, develop operational control software, develop full user's documentation, hardware upgrades to simulator, and conduct feasibility study for design of a frequency hopping interface.

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 inter-operation 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 —— Chris Redding (497-3104). Evaluate concepts, prototypes and 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 Undersea Warfare Center (NUWC)/ National Science Foundation (NSF)

Assessment of the NSF Department of Polar Programs HF Radio Link — David F. Peach (497-5309). Assess the HF radio link between Christchurch, NZ and McMurdo, Antarctica and provide recommendations for improvement of voice and data quality and HF link availability.

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.

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.

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 G ·1 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 onboard 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.

Oxygen Absorption Measurements — Hans J. Liebe (497-3310). Measure oxygen 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 communication satellite systems with terrestrial, fiber-based ISDNs to enhance overall network survivability and efficiency, and to support broadcast, mobile, and thin-route applications. A computer-based simulation model with which to estimate the performance of circuit-switched, hybrid networks has been developed.

NOAA-FSL

Profiler Site Survey - Frank H. Sanders (497-5727). Measure existing spectrum occupancy in the 445-455 MHz band at the Platteville, CO wind profiler site, and demonstrate for Forecast Systems Laboratory (FSL) personnel the techniques and capabilities for remotely controlled rf measurements that FSL may want to utilize at other wind profiler sites.

National Security Agency

Impact of New Communications Technologies - William J. Pomper (497-3730). Assess the impact that emerging and future telecommunications technologies will have on information systems security.

NWS

RFI Investigation - Frank H. Sanders (497-5727). Determine sources of radio frequency interference experienced by the National Weather Service Automated Surface Observing System.

TELESIS TECHNOLOGIES LABORATORY

PCS Impulse Response Probe— Jeffrey A. Wepman (497-3644). Provide an innovative radio channel impulse response probe for studying propagation in the 2 GHz band for PCS Planning.

Bell Atlantic Mobile Systems

PCS Impulse Response Measurements -- Jeffrey A. Wepman (497-3644). Measurements of the radio channel impulse response for urban/suburban environments.

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)

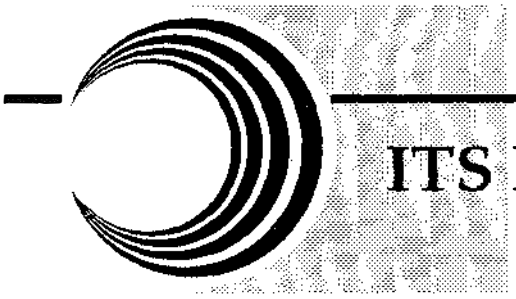
Support for USIA HF Conference Activities — James S. Washburn (497-3109). Provide VOA with the capability to assess the impact of the decisions taken at WARC-87 on U.S. high-frequency (HF) broadcasting interests, the determination of the validity of broadcast service quality predictions and a plan for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

U S West

PCS Measurements - J. Randy Hoffman (497-3582). Conduct signal strength measurements to help U S West install an experimental PCS system.



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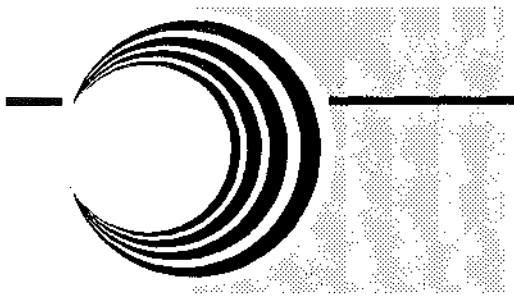
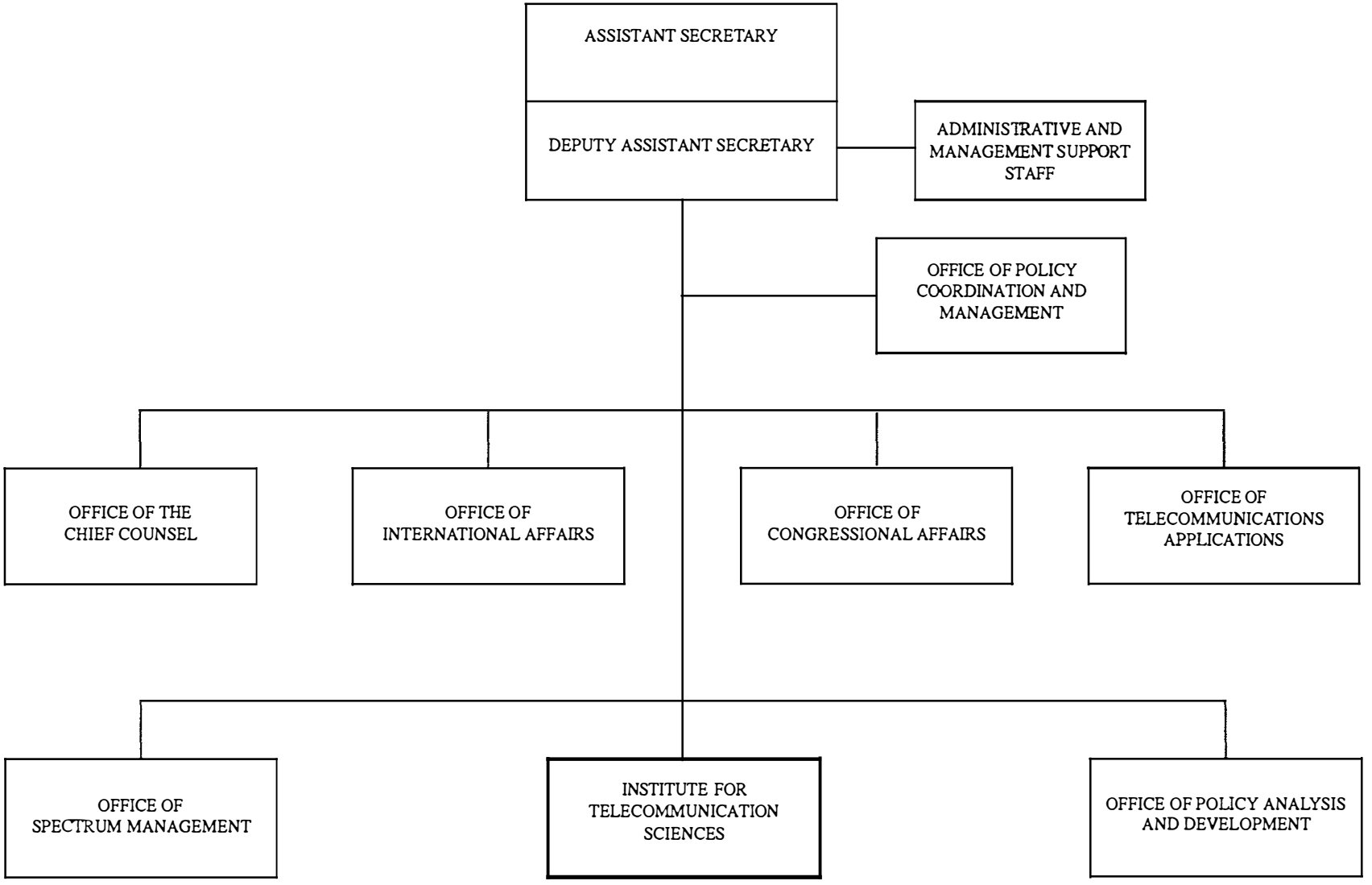


ACRONYMS AND ABBREVIATIONS

ACTS	Advanced Communications Technology Satellite
ALE	Automatic Link Establishment
AMOS	Analysis of Microwave Operational Scenarios
ANSI	American National Standards Institute
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
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	MillimeterWave
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 Scenario 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

NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION



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