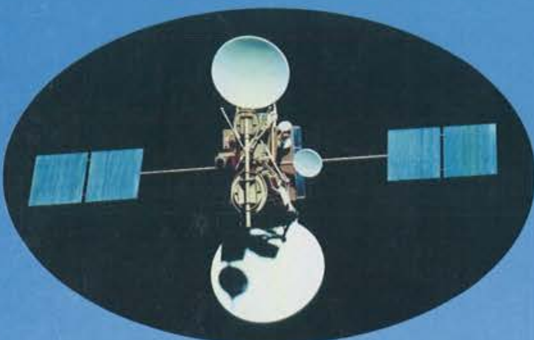
INSTITUTE FOR TELECOMMUNICATION SCIENCES

OF THE
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION




1993 TECHNICAL PROGRESS REPORT

For the Period October 1, 1992 through September 30, 1993

ITS

TECHNICAL PROGRESS REPORT

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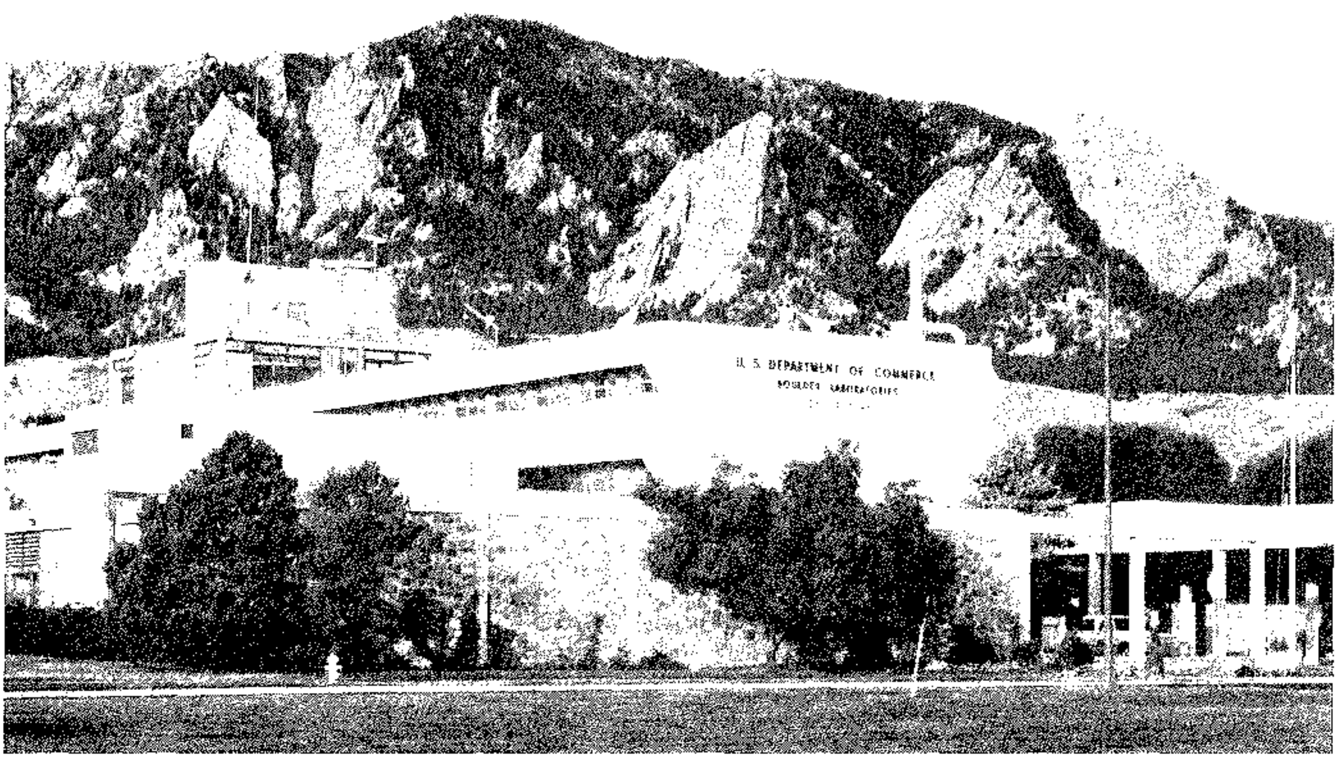
U.S. Department of Commerce
Ronald H. Brown, Secretary
Larry Irving, Assistant Secretary
for Communications and Information

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 promoting advanced telecommunications and information infrastructure development in the U.S., enhancing domestic competitiveness, improving foreign trade opportunities for U.S. telecommunication firms, and facilitiating 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 telecommunications technologies to aid in attaining commercialization of new products and services.



ITS

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ITS

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 120 permanent program staff. Many of these employees bring substantial engineering and scientific backgrounds and skills to our technically oriented programs. Indeed, 65% of our employees are electronics engineers, 8% are mathematicians, 2% are physicists, 6% are computer scientists, and 3% are computer programmers. During FY 93, ITS support consisted of $3.9M 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 Department of Defense (DoD) components provide the majority of ITS' other-agency funding. Non-DoD sponsors typically include the Department of Agriculture, the Department of Transportation, and the U.S. Information Agency. Cooperative research agreements with such companies as 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 FY93 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 adequeately describe the design and conduct of the research and experiments. 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.

Radio Spectrum Measurement System

ITS 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 ways that the U.S. can use the radio frequency spectrum. U.S. positions at these conferences also help determine the ways that frequencies are used worldwide, which affects U.S. export market opportunities, as well as the compatibility and interoperability of global systems.

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. Since these methods are useful to the private sector as well, ITS has established a computerized method of transferring this technology to all interested parties on a reimbursable basis.

Areas of Emphasis

ITU Radiocommunication Sector Activities

Includes projects funded by NTIA

Domestic Spectrum Analysis

Includes projects funded by NTIA

RSMS Spectrum Survey Measurements

Includes projects funded by the Department of Defense, NTIA, and the National Oceanographic and Atmospheric Administration.

Spectrum Measurement System Development

Includes projects funded by the Department of Defense and NTIA.

Interference Assessment and Resolution

Includes projects funded by NTIA

ITU Radiocommunication Sector Activities

Outputs

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

The Consultative Committee on International Radio (CCIR) is no more! In its place, following a major reorganization of the International Telecommunications Union (ITU), is the Radiocommunication Sector (ITU-R). The long-awaited change was approved at a 1992 Plenipotentiary Conference, and it became effective in March 1993. The same meeting also created the Telecommunications Standardization Sector (ITU-T) replacing the CCITT, and the Development Sector (ITU-D). The Development Sector is a new ITU division intended to assist lesser-developed countries in upgrading and improving their telecommunications expertise and infrastructures.

The reports and recommendations of the ITU 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 ITU-R 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 ITU-R at the national and international levels.

The ITU is one of the oldest standing committees of the United Nations. Its recent reorganization was driven by the requirements of a rapidly growing international telecommunications industry. Spectrum and standards need to be selected for new communication services, such as Personal Communication Services (PCS), low earth orbit (LEO) mobile satellite systems, high-definition television (HDTV), direct broadcast satellite (DBS), digital audio broadcasting (DAB), and more. Since many of these proposed services are inherently worldwide, users gain considerable benefit from international standards. Conformance with international standards, however, implies that many systems must delay widespread deployment until the standards process has been completed.

The new ITU organization has been streamlined to expedite the development of standards. It also recognizes a major trend in the merging of some aspects of the telephone network and radio systems and computer networks (e.g., cellular and PCS radio systems are seen as extensions of the switched network). Therefore, instead of the old separation into separate organizations for telephone and radio work, the new ITU is split into sections dealing with standardization and with radiocommunications. This separation more closely reflects the type of international oversight that is appropriate for the two major areas of telecommunications. The ITU-S covers all standards activities, including any radio systems where standardization and interoperability are particularly important. The ITU-R covers the technologies of radio systems, where adequate performance and non-interference are traditionally more important than interoperability.

The new split means that the standardization aspects of radio systems will be moved from the ITU-R to the ITU-S. These include the CMTT Group for standardization of TV and audio transmission formats. In addition, study groups concerned with the standardization of PCS and cellular systems may move to the ITU-T, because of their strong need to interoperate with the switched network.

The ITU-R uses international Study Groups that address a specific area of radio system technology.

In most cases, the U.S. has a corresponding set of national committees that prepare the U.S. input for consideration by the international committees. The particular topics treated by each Study Group change as necessary to meet the needs of the times and to reflect the topics that will be discussed by forthcoming radio conferences. The present ITU-R Study Groups include

SG1	Spectrum management techniques
SG4	Fixed-satellite service
SG5	Radio-wave propagation in nonionized media
SG6	Radio-wave propagation in ionized media
SG7	Science services
SG8	Mobile, radiodetermination, and amateur services
SG9	Fixed service
SG10	Broadcasting service (sound)
SG11	Broadcasting service (television)
SG12	Inter-service sharing and compatibility.

Most of the study groups will remain the same under the new ITU-R organization. Although the determination has not yet been made official, Study Groups 5 and 6 will probably be combined, putting all of the terrestrial propagation work within a single Study Group.

ITS personnel have been active in ITU-R Study Groups in the past year, including holding the office of chairman of U.S. Study Group 1. An ITS Staff member has been an international rapporteur for a draft recommendation on Spread Spectrum systems, and ITS personnel participated in the September 1993 working party meeting in Geneva.

An ITS staff member has recently been appointed as the new international chairman of Study Group 5B. This committee is undertaking major work in re-examining of VHF/UHF propagation models developed by many nations, including the terrain databases used in these models. These models will be compared against propagation measurements to determine which programs are most accurate and suitable for particular situations. The goal of this work is to create a series of PC-compatible propagation programs that will be standardized and made available inexpensively worldwide. Future work is expected to include short-range, urban, indoor, and outdoor propagation programs.

ITS personnel have also been active in Study Group 6, which considers HF propagation. Last year Study Group 6A created Recommendation 533, which included the code for an HF propagation program and associated databases similar to IONCAP. This year, ITS contributions will include adding a user-friendly interface to make the program in Recommendation 533 much easier to use. This will finally put a powerful PC-based HF propagation program in the hands of many international users. This capability is particularly important to many less-developed countries, where HF represents an important part of their communications infrastructure.

ITS continues to hold the position of International Chairman of Interim Working Party 6C. ITS personnel recently submitted an omnibus draft Recommendation on Noise, which will replace many earlier reports. This Recommendation was approved at the September 1993 meeting.

Even where ITS personnel have not been directly working in ITU-R committees, ITS measurements have sometimes played a major role. For example, ITS measurements on wind profilers were important in determining a suitable frequency band and realistic operating specifications for wind profilers in Study Group 12. ITS also provided much information on the causes of radar interference to point-to-point microwave and satellite downlinks, which has been incorporated in recommendations on the elimination of interference in Study Group 8.

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Domestic Spectrum Analysis

Outputs

- ITS Staff Study on spectrum requirements for the Fixed bands
- ITS contribution to Report on Spectrum Requirements NOI
- Theoretical analysis of spectrum efficiency of various mobile systems
- Meeting on joint State/Federal Colorado trunked radio system
- Presentation to Spectrum Planning Advisory Committee on Spectrum crowding

The Federal Government continues to undertake a comprehensive review of its spectrum management policies. This review has been prodded by a number of circumstances, especially a need to find frequencies for important new services [like Personal Communication Services (PCS)]. Congress has been active in encouraging NTIA to do some serious spectrum planning with numerous specific requests for action. One of these requests for FY93 was for a study of Federal mobile systems spectrum efficiency. Another bill requires the Federal Government to give up at least 200 MHz of spectrum to the private sector. Still another bill would allow the FCC to auction off sizable portions of spectrum to particular users, including much of the PCS spectrum near 2 GHz. Congress may also request reports on the additional cost of maintaining separate Federal Government frequency bands, require rapid action on PCS allocations, require joint frequency planning between the FCC and NTIA, and require the FCC to develop a plan for the Public Safety mobile radio.

The Spectrum Requirements Notice of Inquiry which was begun by NTIA last summer is moving towards culmination, with comments received from 63 parties. These comments have been analyzed by NTIA and are being incorporated in a report which will include estimates of future spectrum requirements for a wide range of services. ITS has prepared the Fixed Service portion of this report.

ITS has also continued to provide NTIA with Spectrum Resource Assessments (SRAs); studies of the uses of particular frequency bands or types of radio systems. ITS completed an SRA on all Fixed frequency bands between 406 MHz and 30 GHz. This SRA was begun in 1992 an was recently published as an ITS staff study. This staff study provided a description of 33 frequency bands above 400 MHz having Fixed services as a primary allocation. This study took a somewhat different approach from earlier SRAs, in attempting to understand the technological and economic factors affecting each band well enough to make a prediction of future growth in the use of band. This study included information on the geographic distribution of transmitters, trends in the number of licenses over the last 5 years, and major market and technology factors. The accompanying figure shows an example of a map of the geographic distribution of transmitters in the 3.7-4.2 GHz band. The overall conclusion from this study is that the total number of transmitters in the Fixed bands studied will decrease somewhat, with increases in the private operational bands not quite equaling the decreases in the common carrier bands and Cable TV bands. We intend to continue monitoring data on the Fixed bands over the next several years, updating the study and revising the predictions.

ITS also played a major role in the preparation of material for a report to Congress on the Federal Government mobile radio bands. Congress requested NTIA to compare the spectrum efficiency of commercial mobile systems with Federal Government mobile systems, and to prepare a plan and a schedule to improve Federal spectrum efficiency. Therefore, this report required a study of Federal and non-Federal mobile systems and their respective spectrum efficiencies, and the development of a plan for future Federal system deployment. (In essence, Congress requested NTIA to perform their own version of the FCC mobile radio "Re-farming" effort, which will completely revamp the regulations under which non-Federal mobile radio operates.) The

NTIA report recommendations have not been released to the public at this time.

Spectrum efficiency studies continue with an update of an internal white paper "Spectrum Conservation: Adjusting to an Age of Plenty." Presentations derived from this paper were given to three groups, including the January 1993 International Union of Radio Science (URSI) Conference, the NTIA Spectrum Planning Advisory Committee (SPAC), and the Transportation Research Board's Intelligent Vehicle Highway Systems Spectrum Workshop. This paper stressed the role of technology in alleviating spectrum crowding.

A Spectrum Resource Assessment concerning airborne video links was undertaken. This study investigated the possibility of converting existing Government airborne video links to compressed digital video links as a means to conserve spectrum. The current airborne video links require much bandwidth and provide the possibility of interfering with other systems over a very wide geographical area, because of the long line-of-sight distances associated with some airborne missions. The first phase of this SRA involved collection of data on the existing Government use of airborne video links. A second phase will investigate the problems and benefits associated with conversion to compressed digital transmission.

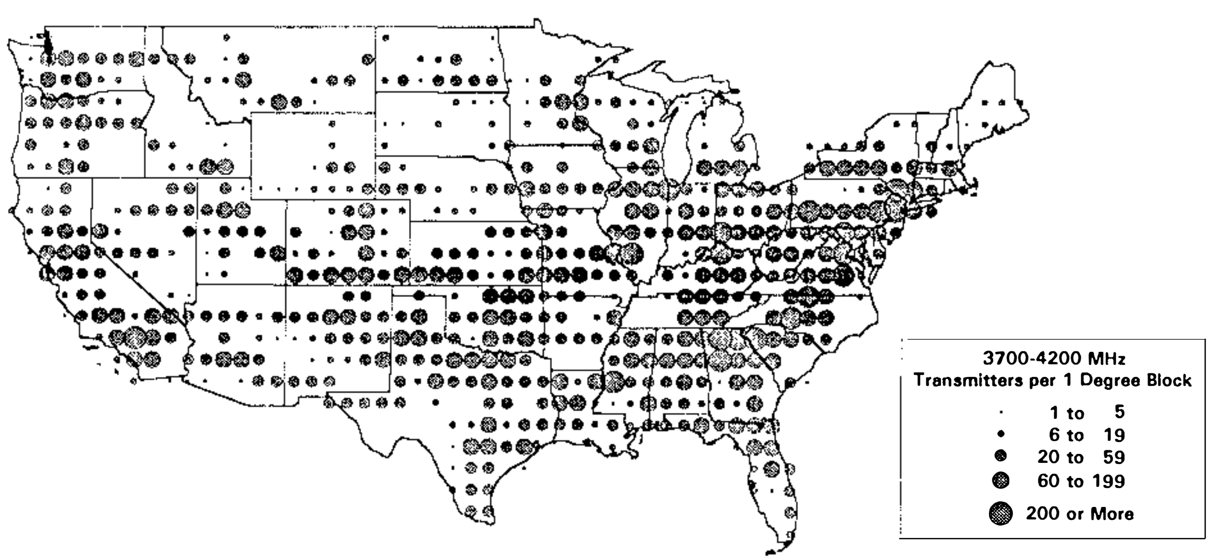
As part of our investigation of problems which might arise from sharing of mobile systems between Federal and non-Federal users, ITS hosted a meeting between the State of Colorado and several Federal agencies. The State of Colorado is planning to build a state-wide trunked, encrypted radio system compatible with APCO-25, and is soliciting for local governments and Federal agencies to share in the use of the system. Major points of discussion included control of the system and allocation of preemptive priorities under various emergency conditions.

Recent Publications

A preliminary look at spectrum requirements for the Fixed Services (by Matheson and Steele)

Mobile Spectrum Efficiency Plan—current title of a report to Congress, scheduled for October 1993 (by Cohen, Roosa, Matheson, Patrick, Hurt, and Kitzmiller)

Spectrum Conservation: Adjusting to an Age of Plenty (by Matheson)



RSMS Spectrum Measurements

Outputs

- Microwave oven emmission measurements

A key task in the RSMS measurement program this year was the characterization of microwave oven RF emissions. ITS received the cooperation of three microwave oven manufacturers who provided a variety of ovens on which to perform measurements of emission spectra, time waveforms, and spatial radiation patterns. The purpose of the measurements was threefold:

1) Develop useful measurement techniques and algorithms

2) Provide input for new emission standards and standard measurement techniques at frequencies above 1 GHz

3) Quantify microwave oven emissions for the purpose of maintaining compatibility between microwave oven emissions and other, proposed uses of the 2300-2600 MHz portion of the radio spectrum.

In the course of these measurements, much attention was focussed on the problem of producing measurements that could be widely used by standards groups, regulatory agencies, spectrum management organizations, and design engineers. In an effort to maximize effectiveness, the measurements were performed on a wide variety of ovens under a wide variety of conditions. The measurements were repeated in a range of bandwidths (30 kHz to 3 MHz), as seen in the figure on the facing page, and with various detection methods.

Among the accomplishments of this task were the development of a coherent set of techniques (including hardware and software) for making microwave oven emission measurements. These techniques will be recommended to standards groups for use in new emission assessments above 1 GHz.

The measurement outputs included broadband emission spectra, time waveforms, amplitude-probability distributions (APDs), inverse APDs, pulse duration statistics, and clear interval statistics. The effects of oven load and oven temperature were assessed. The effects of oven design and the design of individual components were also assessed for their effects on oven emission characteristics. It was determined that by far the most significant factor in microwave oven emissions is the design of the magnetron power output tube.

In addition to microwave oven measurements, 'suitcase' systems were used to perform measurements at Platteville, Colorado, in the 440-460 MHz range. The purpose of the measurements was to determine the RF environment in which wind profiler radars will typically operate when they begin to use 449 MHz as a center frequency. Suitcase systems were also to support Department of Defense HF systems testing in the midwestern U.S.

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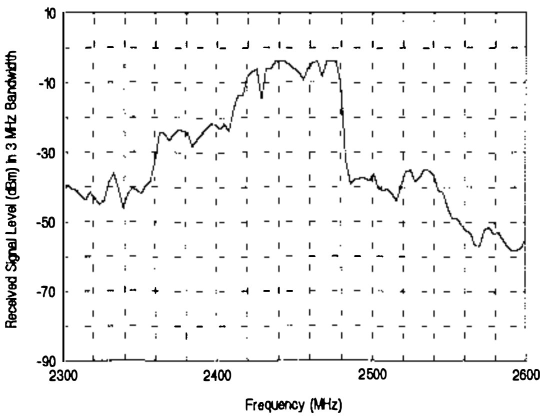
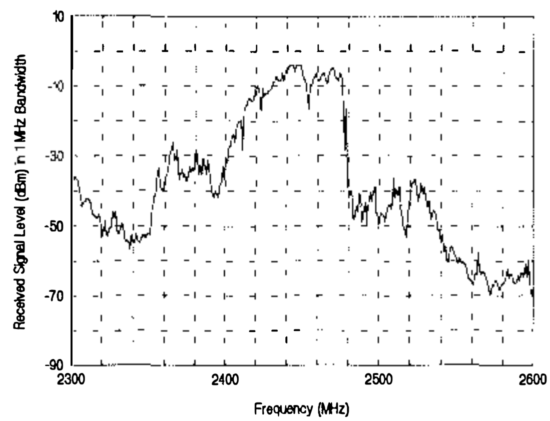
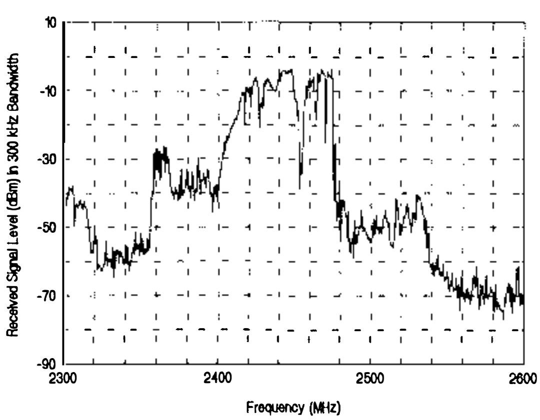


Microwave oven spectra in 3-MHz bandwidth.



Microwave oven spectra in 1-MHz bandwidth.



Microwave oven spectra in 300-kHZ bandwidth.

Microwave oven spectra measured with the ITS technique, in three different bandwidths.

Interference Assessment

Outputs

- Resolution of interference problems between high-power radars and ground-based satellite receive-only stations

Recently, numerous episodes of interference have occurred between radars operating in the 2900- to 3700-MHz part of the spectrum and terrestrial and satellite systems in the 3700- to 4200-MHz portion of the spectrum. NTIA has actively sought to better understand and quantify the mechanisms that have generated this compatibility problem, so that solutions may be implemented. ITS has supported this effort by providing measurements, analysis, and resolution proposals for known interference cases.

In FY92, the NTIA Office of Spectrum Management (OSM) became aware of an ongoing interference problem involving satellite receivers utilizing the 3700- to 4200-MHz band in south Florida. The interference had occurred sporadically for several years. The identification of the interference source was unknown, but it was suspected that either a radar or an electronic warfare system was involved. ITS and OSM developed a plan for capturing the electronic signature of the source(s), which would allow its identification. Once identified, coordinated tests would be performed to characterize the interference mechanism and to determine mitigation options.

In April 1993, the RSMS was deployed to a site in Florida that was known to be subject to frequent interference events. When an interference event occurred, the ITS/OSM RSMS crew obtained the center frequency, antenna pattern, pulse repetition rate, pulse width, emission spectrum, and direction of the interference source. The platform was observed electronically for a sufficiently long period of time to determine first that it was mobile, and second that it was airborne. The emission characteristics clearly established the identification of the source, and this was confirmed in real time through contact with FAA air traffic control in Washington, DC.

The source, a radar operating in the 2900- to 3700-MHz portion of the spectrum, was unequivocally correlated with the interference to the satellite system at the site. The radar beam rotation could be observed in the victim receiver. The victim receiver operated in the 3700- to 4200-MHz portion of the spectrum. However, the radar emission spectrum was suppressed to such an extent in the portion of the spectrum the receiver used that it was actually unmeasurable between 3700 and 4200 MHz. The suppression was in excess of 65 dBc. Subsequent RSMS measurements on this type of radar, made with a captive system radiating on the ground, confirmed that the radar presented excellent spectral conservation characteristics, and that not enough energy was present in the satellite band to produce interference due to spurious emissions at the satellite receiver frequencies. The radar emission also met the limits of the Radar Spectrum Engineering Criterion (RSEC) for extended spurious emissions.

The problem lay not in the radar transmission, but in the characteristics of the satellite receiver. ITS tests on the receiver system's first amplifier, performed both in Florida and later (and more extensively) at the ITS labs in Boulder, revealed that the first amplifier in the receiver had a broadband frequency response (Figure 1) which made it susceptible to overload *at the center frequency of the radar*. This meant that no mitigation option could be applied to the radar. Instead, the receiver would require a filter ahead of the first amplifier. The filter would have to pass energy in the 3700- to 4200-MHz band, and reject outside that band. Such a filter (Figure 2) was installed at satellite receive-only stations in Florida, and interference was suppressed.

ITS currently maintains a log of other interference cases, many involving radars and terrestrial and satellite microwave links. The log and the case histories and interference resolutions which have been developed and applied are being used to produce an NTIA Report on the general problem of compatibility between radars and microwave links which operate in adjacent bands.

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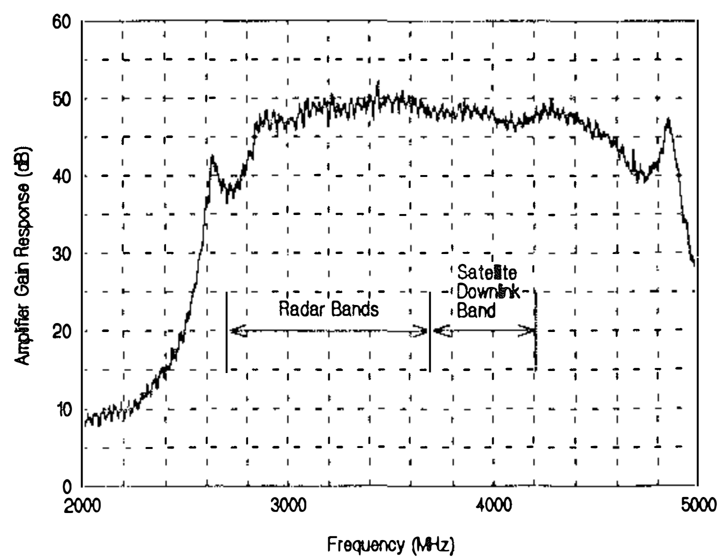


Figure 1. Front-end amplifier gain response of the satellite receiver, shown in relation to adjacent radar bands. Overload can occur because the amplifier responds to radar energy in bands adjacent to the receiver band.

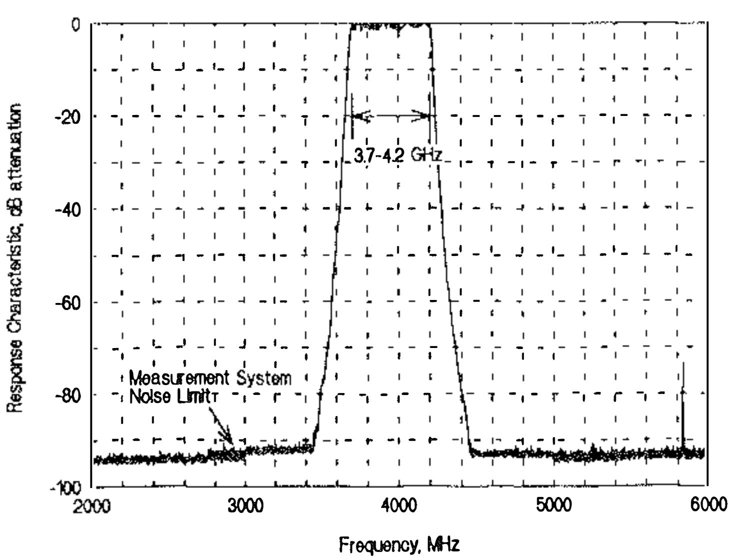
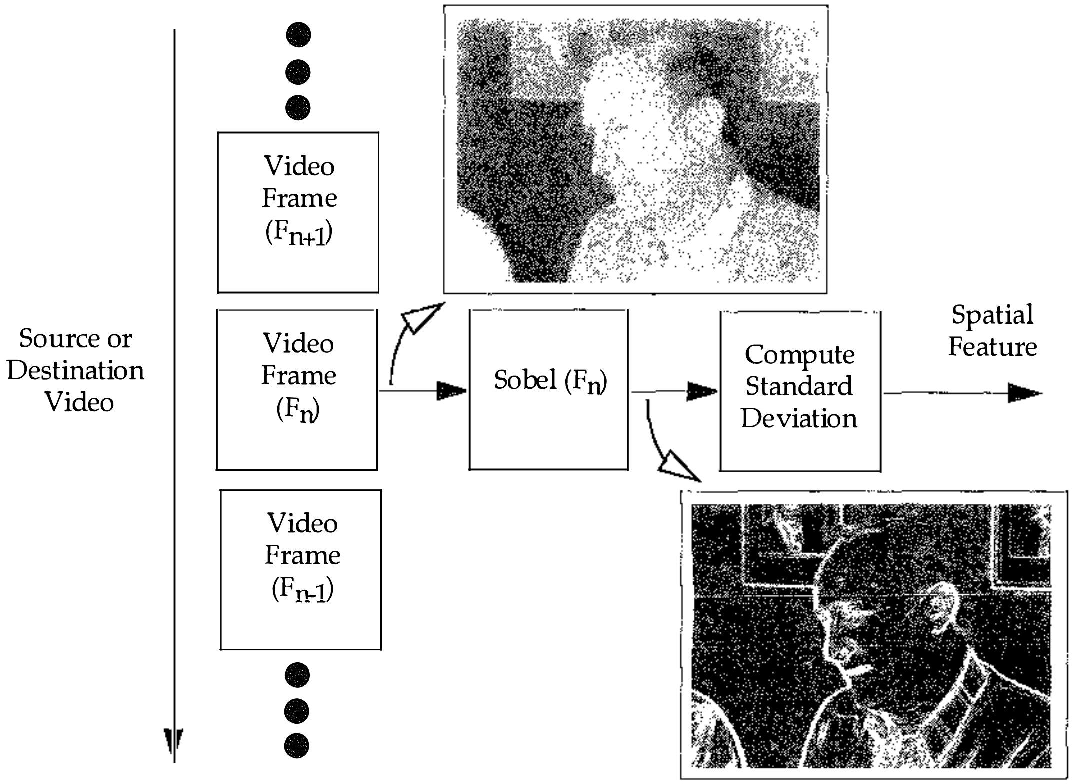
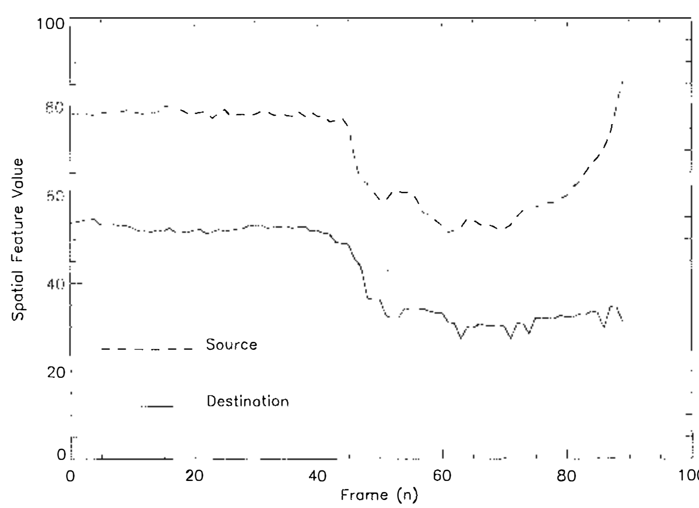


Figure 2. Measured response characteristics of a bandpass filter installed on a satellite receiver to mitigate interference from radars outside the receiver band.



Perception-based Spatial Video Feature



Example Time History

Perception-based Video Quality Measurement

ITS

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 FY93, ITS placed special emphasis on developing 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 in 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 principal standardization body of the International Telecommunications Union (ITU), the Telecommunication Standardization Sector (formerly known as the CCITT). The technical standards and Recommendations developed in these forums are becoming the blueprints for future telecommunications technology development.

Areas of Emphasis

ITU-T Activities
Includes projects funded by NTIA

Video Quality Standards Development
Includes projects funded by NTIA and the National Communications System

Voice Quality Standards Development
Includes projects funded by NTIA and the National Communications System

Digital Network Performance Standards Development
Includes projects funded by NTIA and the National Communications System

Radio System Interoperability Standards Development
Includes projects funded by the National Communications Systems and the Federal Emergency Management Agency

Telecommunication Transmission Media Technology Studies
Includes projects funded by the National Communications System

ITU Telecommunications Standardization Sector Activities

Outputs

- U.S. and International ITU-T leadership
- Technical contributions
- Proposed ITU-T Recommendations

The International Telecommunication Union's Telecommunications Standardization Sector (ITU-T), recently formed by consolidating standardization activities of the International Telegraph and Telephone Consultative Committee (CCITT) and International Radio Consultative Committee (CCIR), is expected to continue the preeminent international role of its predecessor organizations in the cooperative long-range planning of public telecommunication systems and services. The technical standards ("Recommendations") being developed by the ITU-T have 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 ITU-T activities by leading U.S. preparatory committees and international work groups, preparing technical contributions supporting key ITU-T standards development projects, and drafting proposed ITU-T Recommendations on topics of particular importance to U.S. interests and needs.

The Institute provides strong support to the U.S. Department of State in leadership of the U.S. Organization for the ITU-T. During FY93, Institute personnel served on the U.S. ITU-T National Committee, which guides overall U.S. participation in ITU-T activities, and provided leadership for U.S. ITU-T Study Group B, which approves and presents U.S. Contributions to the ITU-T on emerging Broadband Integrated Services Digital Networks (B-ISDNs), Personal Communication Services (PCS), and Intelligent Network (IN) capabilities. Broadband ISDNs will provide integrated video, voice, and data communications using ultra-high-speed transmission systems and innovative cell-based Asynchronous Transfer Mode (ATM) switching. Personal Communication Services and IN capabilities will ultimately enable subscribers to establish multimedia 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. ITU-T 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's ITU-T Study Group B responsibilities include organization and conduct of U.S. ITU-T preparatory meetings and leadership of the U.S. Delegations to meetings of ITU-T Study Group 13 (General Network Aspects).

The Institute also provides leadership in ITU-T and ANSI-accredited standards committees whose work is particularly relevant to Commerce goals. During FY93, Institute representatives completed a four-year term of international leadership in the CCITT Study Group XVIII Special Rapporteurs Group on Question 5; assumed an expanded role in leadership of the newly-formed ITU-T Working Party 13/4; and provided national leadership for Working Group T1A1.3 within the ANSI-accredited T1 (Telecommunications) Standards Committee. The Question 5/XVIII Rapporteurs Group produced a group of Recommendations that will provide a technical basis for ISDN performance standardization. Working Party 13/4 is responsible for continuing performance studies required to implement emerging technologies (e.g., B-ISDN, IN) in global public networks. Working Group T1A1.3 develops American National Standards and contributes to ITU-T Recommendations dealing with the performance of packet data networks and ISDNs.

The Institute's technical contributions to Study Group XVIII during the four-year Study Period leading up to the February 1993 World Telecommunication Standardization Conference played a strong role in the approval of four new ITU-T network performance Recommendations at that conference. Recommendation I.351 defines the overall structure for a related set of ITU-T Recommendations that collectively provide a comprehensive basis for international ISDN performance specification. Recommendation I.353 defines ISDN performance apportionment boundaries and a set of reference events that are used in defining specific ISDN performance parameters. Recommendation I.354 specifies speed of service performance objectives for ISDN packet mode bearer services. Recommendation I.355 specifies availability performance objectives for ISDN 64 kbit/s connection types. The Institute also contributed strongly to the successful development and coordination of a highly significant new Recommendation, I.356, that defines performance parameters and measurement methods for ATM cell transfer in B-ISDNs. Recommendation I.356 was approved at the first (July, 1993) meeting of ITU-T Study Group 13.

A particular focus of the Institute's technical contributions to the ITU-T during FY93 was the specification of cell delay variation (CDV) in ATM systems. Two CDV parameters were defined (see figure). The first parameter, 1-point CDV, describes variability in the pattern of cell arrivals at a boundary with respect to a negotiated peak cell rate. The second parameter, 2-point CDV, describes variability in the pattern of cells exiting a network portion with reference to the corresponding pattern of cell arrivals at the portion input. Careful specification of CDV is essential to enable ATM networks to efficiently multiplex video, voice, and data communication streams, which have fundamentally different (and highly variable) traffic characteristics.

Institute staff members play a significant role in achieving synergy between related national and international standards development efforts—and compatibility among the evolving national and international standards. For example, Institute standards leaders are spearheading phased development of two new American National Standards, designated "T1.5I" and "T1.5ATM" that will define performance parameters, measurement methods, and numerical performance objectives for narrowband and broadband ISDN services. T1.5I and T1.5ATM are being developed to achieve technical compatibility with the corresponding ITU-T Recommendations (I.352-I.356). Institute personnel are leading and contributing to the development of a new American National Standard for performance specification of frame relay services. This work is being closely coordinated with a related project in ITU-T Study Group 7 to promote compatibility among national and international performance standards for this innovative high-speed packet technology.

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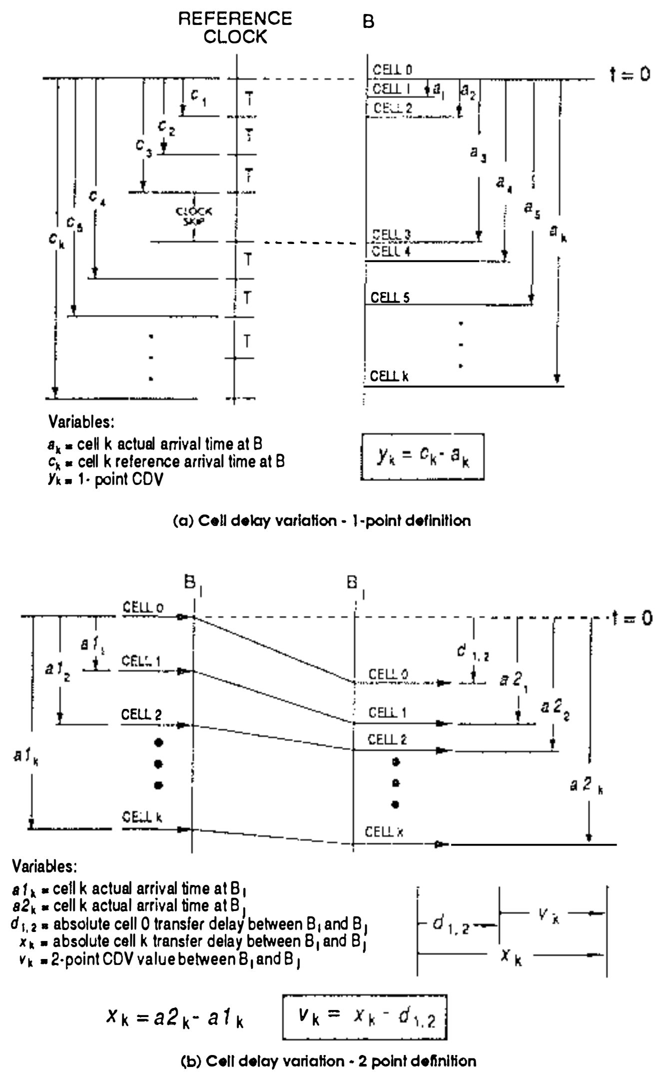

Cell delay variation parameter definitions.

ITS

Voice Quality Standards Development

Outputs

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

Widespread implementation of digital encoding and compression technology has made the assessment of audio communication quality increasingly important -- and increasingly complex. Systems for transmitting audio over digital networks range from 4-kHz voice systems with bit rates as low as 2.4 kbit/s, through 7-kHz voice systems with bit rates up to 64-kbit/s, to 20-kHz multi-channel music and entertainment systems using bit rates in the neighborhood of 128 kbit/s per channel. The digital bit streams for these systems may be carried by radio, wire, or optical fiber, and may be multiplexed with video and data bit streams in Integrated Services Digital Networks (ISDNs). Given the complex interactions among signal content, source coding, channel coding, and channel conditions, it is not surprising that the voice transmission quality measurement techniques developed for wired analog telephony do not adequately characterize the voice transmission quality of emerging digital systems.

In light of this proliferation of new communications technologies, an accurate and reliable way to assess the audio transmission quality of proposed systems and services is essential. The most fundamental and "correct" measures of transmission quality are the subjective responses of listeners to the sounds actually delivered by the system under test. Unfortunately, subjective tests are both costly and time consuming to perform. The Institute is working to develop practical and cost-effective alternatives: objective digital signal processing algorithms that characterize delivered audio quality in the same way it would be characterized by a human listener panel.

Historically, telecommunications networks have been used primarily for the transmission of 4-kHz voice signals, and the focus of the objective audio quality assessment algorithms has been on these signals. In previous years, the Institute developed an algorithm that uses a 5-point mean opinion score scale to provide indications of quality for voice transmissions utilizing 64-kbit/s pulse code modulation (PCM), 32-kbit/s adaptive differential pulse code modulation (ADPCM), and 16-kbit/s code excited linear prediction (CELP). During FY93, standardization activities continued and prototype voice quality test instruments were designed, constructed, and demonstrated. Research was conducted to determine how best to extend the scope of assessment algorithms to include wideband voice, general audio, and a wide variety of coding schemes.

Throughout FY93, the Institute continued its participation in the ANSI-accredited standards working group T1A1.6. This group works towards the standardization of specialized signal processing techniques. A T1A1 Technical Report, authored at the Institute, describes and analyzes a family of objective voice quality measurement techniques and a combining technique developed at the Institute. In the ITU-T, the Institute has taken a leadership role in the form of the associate rapporteurship for Question 13/12. This Question addresses methods of modeling and measuring non-linear processes in voice transmission. The Institute also participates in the Federal Telecommunications Standards Committee and chairs its subcommittee on Digital Telecommunications Quality. In addition to fulfilling these leadership responsibilities, the Institute prepared and presented numerous technical contributions, demonstrations of research results, and a study project proposal to standards committees during FY93.

To aid in the transfer of audio quality assessment technologies, the Institute designed, constructed, and demonstrated a pair of prototype voice quality test instruments during FY93. These instruments may lead the industry to develop commercial products that would allow field technicians to use the Institute's objective audio quality assessment algorithms. The instruments were constructed by adding analog conversion and interface hardware and customized software to fast, portable, personal computers. The prototype instruments are capable of performing basic measurements and have been used to measure voice transmission quality over local telephone loops and long-distance connections. The knowledge gained from the design, construction and testing of these prototype instruments has led to new test instrument designs with greatly enhanced flexibilities. Work towards this next generation of instruments continues.

To date, most objective audio quality measurements have stemmed more from theories of voice coding and transmission techniques than from an understanding of human auditory perception and judgment. The Institute is conducting research to establish how best to incorporate more complete models for human auditory perception and judgment into objective audio quality assessment techniques. This work should yield objective audio quality measurements that come closer to the desired goals of breadth of applicability and correlation with subjective assessments. Key elements of perceptual models are the limited frequency and temporal resolution of the human auditory system and its nonlinear transfer characteristics.

An example of a model for the limited frequency resolution of the human hearing process follows. It has been established that a person's ability to resolve neighboring frequencies is nearly constant for frequencies below 500 Hz and decreases markedly for frequencies above that point. This effect can be modeled by a nonuniform bank of overlapping band-pass filters, known as critical band filters. The figure shows the response of a set of 16 such filters covering the interval from DC to 4 kHz. On the psychoacoustic frequency scale known as the Bark scale, the filter centers are uniformly spaced at one Bark intervals and each filter has a bandwidth of one Bark. If the energy of an audio signal that passes through each of these filters is accumulated over an appropriate time interval, the resulting set of 16 values provides an approximation to the auditory neurological stimulation that is generated by that signal at that time. Separate sets of values can be calculated for the audio signals that are input to and output from an audio system under test. The distance between these two "perceptual stimulus vectors" must then be defined in a meaningful way. This is an area of continuing research at the Institute.

The psychoacoustic literature contains perceptual models that extend out to 20 kHz. The incorporation of these models into new objective audio quality assessment tools could allow for reliable objective assessment of wideband speech and music transmission systems. Already, these wideband perceptual models are being used to encode high-quality music at a minimal bit rate by exploiting the masking properties of the human ear. These areas are currently under study at the Institute. Many low-bit-rate digital voice coders have been designed to operate over radio channels which can introduce a significant number of bit errors. Depending on how many and which bits are errored, these voice coders can create some rather unusual sounds. Research is under way to determine how perceptual models might be used to design audio quality assessment tools that more accurately characterize the perceptual impact of these bit errors and the bursts of sound that they create.

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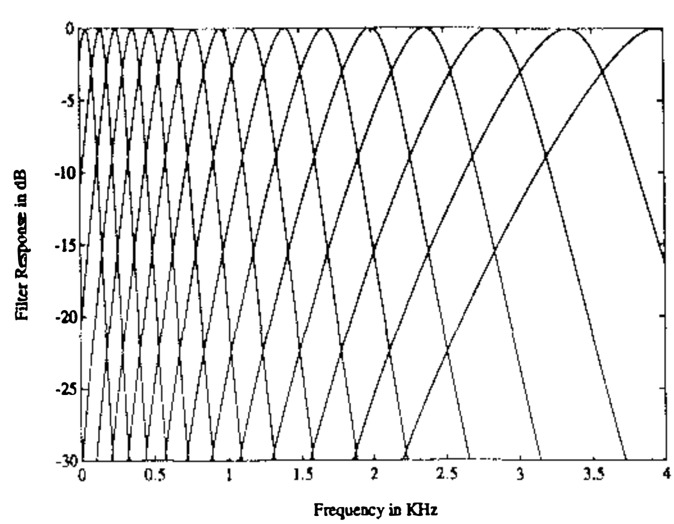

Response of 16 critical band filters, from DC to 4 kHz.

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 technologies

Video terminals and communication systems must be designed on the basis of the quality-of-service needs of end users. The most "user-oriented" video quality measures are the viewers' subjective responses to the delivered images, but such *direct subjective* measures are difficult and expensive to obtain. For conventional analog video systems, a practical alternative has been to identify electrical measures of signal reproduction fidelity that correlate reasonably well with the human responses. Unfortunately, these conventional analog measures are inapplicable to advanced digital video services (e.g., videophone, videoconferencing, video on demand, and HDTV). Digital compression and transmission introduce impairments fundamentally different from those introduced in conventional signal reproduction. Examples of compression-related impairments are blocking, image persistence, and jerky motion. Compressed digital video systems are also extremely sensitive to variations in scene content. Thus, in general, the user-perceived quality of a digital video system is a function of both the system and the input signal.

The need for in-service measurements that correlate with the end user's perception of video transmission quality has led ITS to develop new, fundamentally different video performance measures that are objective but *perception-based*. Such measures are derived from electrical and mathematical properties of the digitized input and output signals, and thus are implementable in automated test equipment; but they are chosen on the basis of their correlation with the subjective video quality assessments of viewer panels. They achieve technology independence by, in effect, mimicking human perception—and human reactions to imperfections in received visual information. These new perception-based video quality measures will give standards bodies, equipment manufacturers, service providers, and end users an accurate and uniform means for objectively assessing and comparing the performance of advanced video systems.

ITS has been working closely with video communication service providers, test equipment manufacturers, and participants in ANSI-accredited Telecommunications Working Group T1A1.5 (Audio-Visual Communications Coding and Performance) to optimize and standardize this promising measurement technology. A primary focus of this technology transfer effort during FY93 was implementation of the video quality measures in a real-time PC-based measurement system. Figure 1 presents a block diagram of the in-service perception-based video quality measurement system ITS has developed. The measurement system is composed of two sub-systems: a source instrument and a destination instrument. The source instrument attaches non-intrusively to the source video and extracts a set of source features that can be used as a reference to quantify perceptual video quality changes. The destination instrument attaches non-intrusively to the destination video and extracts an identical set of destination features. An objective estimate of video quality can be obtained by comparing the source features with the corresponding destination features.

Two kinds of features have proven useful for measuring video quality. The first measures spatial distortions in the video (e.g., blurring); the second measures temporal distortions (e.g., jerky motion). Experiments have shown that these perception-based video quality features can be communicated with a very low bit rate, and can thus be easily and economically transferred between the source and destination video ends, which may be separated by many thousands of miles. The low bit-rate features that quantify the quality of the video scene can also be used to measure one-way video delay.

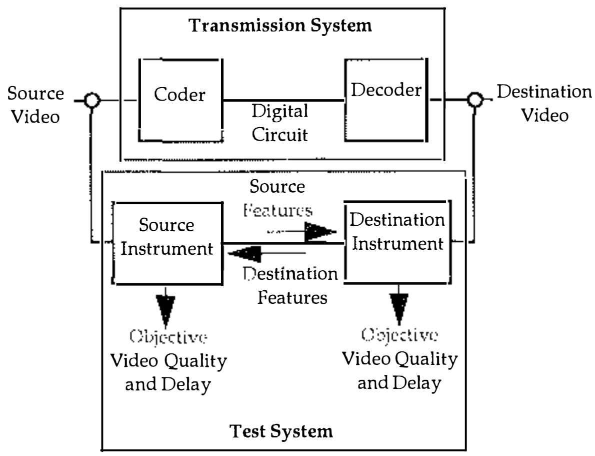

Figure 1. Real-time PC-based video quality measurement system.

Tests of correlation between objective measures and subjective responses have been conducted in a number of video experiments. Standard industry procedures have been used for the collection of the subjective viewing responses. From these subjective viewing responses, a subjective mean opinion score was computed, where a rating of 5 represents excellent quality (or imperceptible distortions) and a rating of 1 represents bad quality (or very annoying distortions). The perception-based features were measured using the same source and destination video as the subjective tests. Objective quality parameters, derived from the perception-based features, were then used to predict the subjective viewer responses. Correlation results for two recent experiments are summarized in Figure 2. The first video experiment, depicted in Figure 2a, utilized a very wide range of source video and transmission system impairments. Figure 2a plots the average subjective and objective scores for the 28 transmission systems used in the test, where the average was computed using the scores of approximately 5 test scenes passed through each transmission system. The coefficient of correlation between the subjective and objective scores was .98 and the RMS error was 0.25 quality units. The second video experiment, depicted in Figure 2b, was performed to test contribubution-quality (i.e., studio-to-studio) 45-Mbps transmission systems. These high-end video transmission systems are typically used by broadcasters. Figure 2b plots the average subjective and objective scores for the 38 transmission systems used in the test, where the average was computed using the scores of approximately 3 test scenes passed through each transmission system. The coefficient of correlation between the subjective and objective scores was .97 and the RMS error was 0.23 quality units. These excellent results suggest that the perception-based video quality features are measuring fundamental perceptual quantities and thus are applicable to a wide range of video services and transmission systems.

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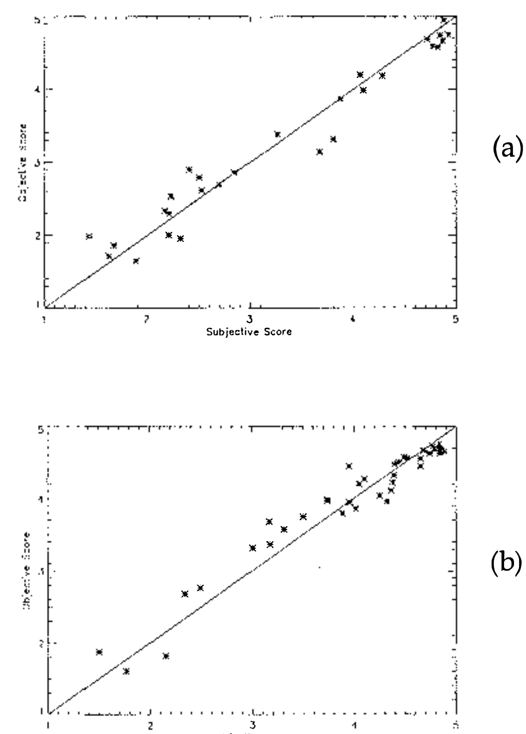

Figure 2. Objective to subjective correlation results.

Digital Network Performance Standards

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 FY93, the Institute upgraded its digital network performance test facility with new Integrated Services Digital Networks (ISDN) measurement capabilities and planned new measurements of high-speed, broadband ISDN (B-ISDN) services to support national and international performance standards development.

The major goal of the Institute's digital network performance program in FY93 was to develop and validate a B-ISDN/asynchronous transfer mode (B-ISDN/ATM) network emulator. The emulator will be used experimentally to determine quantitative relationships among performance measures observed at various layers in the B-ISDN/ATM protocol hierarchy. Performance objectives will profoundly influence the capacity and economy of B-ISDN/ATM systems because these systems achieve much of their economic advantage through the use of statistical multiplexing. As described in other sections of this report, Institute staff members are assisting national and international standards committees in developing performance measures and numerical performance values (objectives) to characterize and limit the impairments that may occur at each B-ISDN/ATM protocol layer. The interdependencies among performance values at the physical and ATM layers, the ATM adaptation layer (AAL), and higher protocol layers in B-ISDN/ATM systems are currently not well understood. Basic performance parameters have been defined for the physical and ATM layers in ITU-T Recommendations G.826 and I.356, but appropriate parameters for the AAL and higher layers are yet to be determined. Numerical performance values have thus far been defined only for the physical layer— in the absence of detailed quantitative information on the higher-layer impacts of those values. The B-ISDN/ATM emulator will assist B-ISDN standards and technology developers in defining the higher-layer performance parameters—and specifying appropriate performance values for all layers—on the basis of comprehensive, correlated multi-layer experimental data.

The key role of the ATM emulator in the conduct of correlated, multi-layer B-ISDN/ATM performance assessment experiments is illustrated in the accompanying figure. The emulator will accept synchronous or asynchronous digital streams from external codecs supporting independent or integrated video, voice, and data communications; will embed these digital streams in ATM cells and Synchronous Optical Network or Synchronous Digital Hierarchy (SONET/SDH) frames; will communicate these frames at standardized SONET/SDH rates over an experimental optical communications link; will introduce transmission errors, slips, and other physical layer impairments (and corresponding cell error, loss, or misinsertion events) in accordance with experiment objectives; and will distribute the resulting digital streams through external codecs to end users for quality of service evaluation. End-to-end quality will be evaluated both subjectively, by human viewers and listeners, and objectively, through use of the perception-based parameters being developed in the Institute's Video Quality and Voice Quality programs. The completed B-ISDN/ATM emulator will make it possible to directly and quantitatively correlate impairments observed at any protocol layer with the quality of service assessments and needs of human users.

The B-ISDN/ATM emulator capabilities are being developed in three phases. The Institute's FY93 work in Phase 1 produced a device that can be used to emulate a SONET channel and to introduce controlled errors into that channel. Phase 2 added ATM emulation capabilities. The third phase, currently in progress, will establish interfaces needed to connect the emulator to external data streams. All elements of the emulator are integrated in a single card cage with the exception of an external computer that controls the error generator. That computer, a DOS-based PC, communicates with the components of the emulator via a general purpose instrumentation bus (GP-IB) interface. It provides a means of extracting performance data and calculating values for the associated performance parameters in addition to controlling the error generator.

The error generator element of the emulator produces a Poisson distribution of errors with ratios selectable in decades between 10^{-9} and 10^{-2}. The use of computer control enables the experimenter to change the error generation state at intervals of approximately 18 ms. This capability will be used in the development of error models that can emulate real world B-ISDNs. One error model being considered for use in emulating real world network performance is the Markov state model. Three states (error free, some errors, severely errored) will be required for a minimally useful model; however, it is likely that a four or five state model will be used to provide a more realistic representation of broadband network characteristics. Selection of the final error model and application of the emulator in B-ISDN/ATM and SONET performance under a variety of error conditions is planned for FY94.

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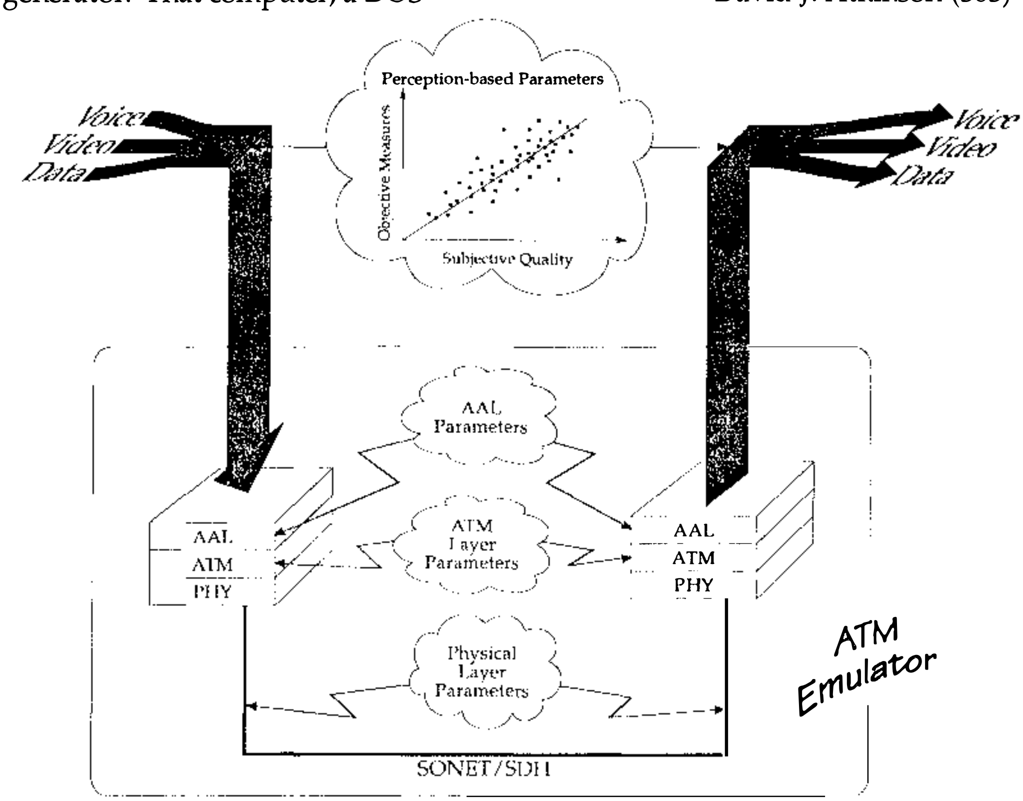

Radio System Interoperability Standards Development

Outputs

- HF radio standards
- Proof of concept test reports
- Simulation analysis results
- Audio CD for ALE interoperability testing

The development and implementation of Federal Standard 1045 (FED-STD-1045) "HF Radio Automatic Link Establishment" has revolutionized HF radio communications by embedding computer-controlled sounding, polling, and adaptive channel selection techniques in advanced HF transceivers. FED-STD-1045 has become the foundation for a number of additional Federal standards that specify, in functional terms, an array of more advanced HF radio networking and message handling capabilities. When fully developed and implemented, these HF automatic link establishment (ALE) standards will substantially improve radio communications efficiency and interoperability within and among civilian Federal agencies, emergency preparedness organizations, U.S. military departments, and the U.S. amateur radio community. The HF ALE standards will enhance competition and promote new product development in the U.S. telecommunications industry and will afford U.S. radio equipment manufacturers new opportunities for international trade. Federal standardization will also lower the cost of advanced HF radios, making them more accessible to users.

During FY93, Institute staff members authored a series of technical articles describing the development and testing of the HF ALE standards. These articles were published in six consecutive issues of the Amateur Radio Relay League (ARRL) publication QEX. The general contents of each article are summarized in the table.

QEX Article Series:
The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)

Part I:	The National Communications System, the Federal Standards Development Process, and the Basic Definition of Federal Standards 1045 through 1054
Part II:	A Compact Disc for Testing HF ALE Radios
Part III:	Where are the Federal Standards for HF ALE Radio Networking Going?
Part IV:	Network Simulation for the Radio Amateur
Part V:	An Amateur's Practical Approach to HF ALE Systems
Part VI:	Federal Standard 1049: The Future of HF ALE Operation in Stressed Environments

All ALE radios procured by the U.S. Government must be able to perform the mandatory features defined in FED-STD-1045. This assures that regardless of vendor, all ALE radios will interoperate successfully. Each radio system must be tested to verify its feature-by-feature interoperability. The interoperability tests are best done with clean, strong signals in the laboratory. A primary output of the Institute's FY93 work in this area was a digital audio compact disc (CD) which provides the strong, clean signals required for such laboratory HF ALE interoperability testing. The disc will be widely distributed to industry and Government users of HF ALE radios. Based on initial demonstration of the audio CD, it is expected that the Government will approve a version of the CD as the primary standard for ALE radio interoperability testing. As an extension of the audio CD concept for testing ALE radios, ITS plans to develop an additional set of CDs in FY94 containing degraded, noisy, weak tones to support laboratory testing of radio performance.

Interoperability testing has been costly to both the Government and industry in the past. Some testing will always have to be done by the Government to verify that the equipment Federal Agencies purchase meets their specifications. ITS has worked closely with the HF industry to assure that emerging Federal standards are realistic and provide users with all needed functions. The HF industry has realized that a Government-produced, highly-accurate test tape or audio disc that exercises all the mandatory features of a Federal Standard will be a very useful and unbiased technique for the quick evaluation of the interoperability of ALE HF radio systems. This approach makes use of the most cost effective and accurate technology available today for reproducing sounds—the home digital compact disc player. Measurements have indicated that frequencies and timing can be better than 10 ppm on good quality disc players. Other advantages of choosing optical discs are low cost and the fact that the disc cannot be altered, thus assuring consistency among tests conducted by different users.

The technique for producing the all digital audio was developed using C Language programs on a desktop personal computer (PC). Algorithms developed (under NTIA contract) at New Mexico State University were adapted to encode an ASCII text protocol file describing the unique ALE calls and addresses. The output of the encoder is a sequence of the 8-ms ALE 8-ary tones described in FED-STD-1045. These "software" tones are sampled at 44,100 Hz to produce a true 16-bit, stereo, digital audio data file. ITS developed a method to describe all the basic ALE mandatory calls with printable ASCII characters. Different types of ALE calls are recorded on different tracks of the CD, very similar to selections of music which are on separate tracks of any commercial CD.

<u>Recent ITS Publication</u>

A Compact Disc for testing HF ALE Radios (by Wortendyke and Riddle)

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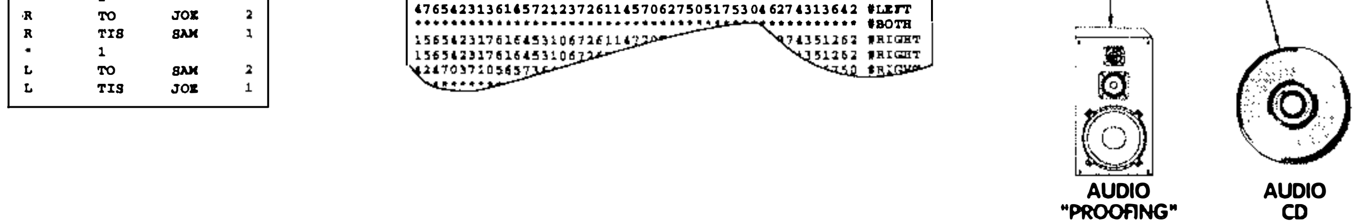


Generation of ALE tones for interoperability testing of FED-STD-1045 radios.

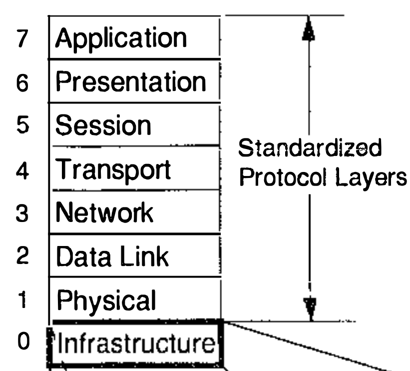
Telecommunications Transmission Media Technology Studies

Outputs

- ANSI/TIA/EIA standards for on-premises telecommunication cabling, grounding and bonding, optical fibers, and optical-fiber cables
- Federal Standards and Federal Information Processing 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 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.

During FY93, the Institute's contributions to transmission media standardization were focused in three committees: Telecommunications Industry Association (TIA) TR-41 on User Premises Telecomm Requirements; TIA FO-6 on Fiber Optics; and American National Standards Institute (ANSI) accredited Subcommittee T1E1 on network interfaces. The first effort involved support of the TIA TR-41 committee in the development of on-premises telecommunications "infrastructure" standards. Infrastructure for on-premises telecommunications can be defined as those components of a building that do not change often: namely, the pathways for telecommunications media (e.g., conduits), the spaces for equipment (e.g., telecommunications closets), the telecommunication portion of the grounding system, and the longer-term portions of the cable plant. These infrastructure standards may be thought of as "Layer 0" with respect to the familiar Open Systems Interconnection (OSI) Reference Model. The infrastructure standards include both TIA/EIA standards and their Federal Telecommunications and Federal Information Processing Standards counterparts, as illustrated in Figure 1.



TIA/EIA Standard	Federal Standard
TIA/EIA-568 -1991	FIPS PUB 174
TIA/EIA-569 -1990	FIPS PUB 175
TIA/EIA-570 -1991	FIPS PUB 176
TIA/EIA-606 -1992	To Be Determined
TIA/EIA-PN-2327 (Proposed TIA/EIA-607)	To Be Determined

Figure 1. "Layer 0" infrastructure standards and their relationship to the OSI Reference Model.

The first two EIA/TIA standards in the building-cabling family (ANSI/EIA/TIA-568-1991, on building cabling, and ANSI/EIA/TIA-569-1990, on pathways and spaces) were revised and updated during the FY93 time frame. Institute staff members coordinated and presented many Federal Agency comments on these standards for consideration by the industry working groups during this revision cycle.

With ITS technical support, the TIA Fiber Optics (FO) Division published two significant standards during FY93. These are ANSI/TIA/EIA-472CAAA, Detail Specification for All Dielectric (Construction 1) Fiber Optic Communications Cable for Indoor Plenum Use, Containing Class Ia, 62.5-μm Core Diameter/125-μm Cladding Diameter Optical Fiber(s) and ANSI/TIA/EIA-472DAAA, Detail Specification for All Dielectric Fiber Optic Communications Cable for Outside Plant Use, Containing Class Ia, 62.5-μm Core Diameter/125-μm Cladding Diameter/250-μm Coating Diameter Optical Fiber(s). These standards will be recommended for adoption as FIPS PUBs, which will make them mandatory for Federal use. Both standards adopt by reference the multimode optical-fiber performance specifications of FIPS PUB 159, which was authored by Institute staff members.

Institute staff members also made significant contributions to the TIA/EIA-607-199x standard on Telecommunications Grounding and Bonding during FY93. Scope of this standard is illustrated in Figure 2. The standard specifies the requirements for a uniform telecommunications grounding and bonding infrastructure for commercial office buildings, intended to support a multivendor, multiproduct telecommunications environment. The intended use of the standard is in the manufacturing of telecommunications equipment, in the installation of such equipment, and in commercial building design (both new and retrofit). It is anticipated that the industry standard will be published during the first quarter of 1994, and that the companion Federal standard (FIPS PUB) will be published during the second quarter of the same year.

Finally, the Institute has assisted the NCS in stimulating T1E1 working groups to develop "baseline" and "above baseline" survivability standards for telecommunication links. During FY93, ITS staff members assisted the NCS in preparing the statement of work (SOW) for a contract to industry to develop survivability recommendations for consideration by several T1E1 working groups. ITS reviewed the "baseline" standard, proposed by industry, which reflects "Bell System Practices" for plant installation. ITS also reviewed the SOW for the "above baseline standard" to be proposed by industry. This standard will contain recommendations developed by the Institute for survivability of optical fiber links, contained in an earlier ITS report entitled "Multitier Specification, Background and Technical Support Information" — Volume II. ITS will review the inputs presented to T1E1 and will contribute to refinement and coordination of their content. These efforts continue the Institute's contributions to the evolution of more survivable public network facilities—a key goal maintaining Government effectiveness and promoting the public interest in an era of increasing dependence on telecommunications.

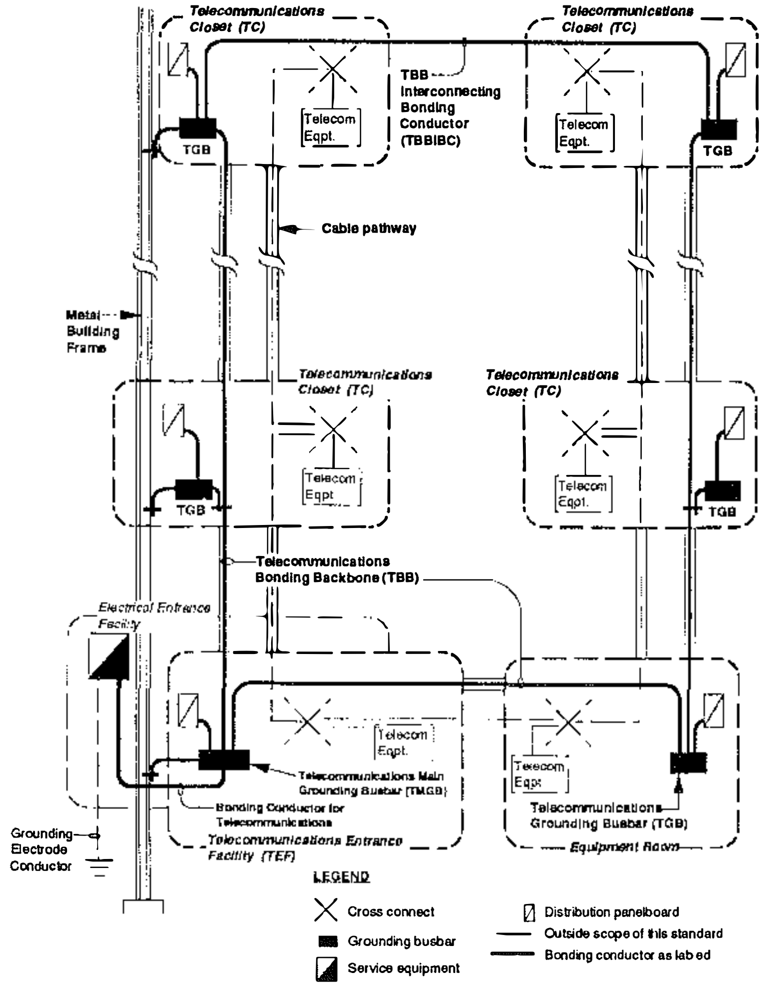


Figure 2. Scope of the Bonding and Grounding Standard.

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Federal Database of Telecommunications Standards

Outputs

- Operational, network-accessible database system
- Expansion of database contents from 150 to 350 entries
- New user tracking and event monitoring capabilities

```
"I want to find all standards that contain
         the phrase: radio
 AND     the phrase:
 AND     those that contain
         the phrase:                                               ."
"Further, I want the search restricted to the following fields:
         All 'wordy' fields (slower searching).                    ."



            Start Search: ESC 5  Clear Word: ESC 7  Delete Char: ESC d
    Change Search Fields: ESC 0   Key Words: ESC 3
     Change Search Logic: ESC 9      Redraw: CTRL/R       Help: ESC 1
        Search by Family: ESC 4    Snapshot: CTRL/P       Exit: ESC 8

Database Design 1991-3: Bill Ingram. Additional Programming: Keith Junker
```

1. The Search Parameters Screen.

The Institute's Federal Telecommunications Standards Database project, which continues FY91 and FY92 work, addresses the need for a readily accessible and user-friendly computer database service to provide key information on standards used in Federal telecommunications procurement. The service is targeted towards two primary user communities: persons involved in Government acquisition of telecommunications equipment and services and the writers of future telecommunication standards.

The prototype system implemented in FY92 resided on a DOS-based computer and used DOS-based relational database management system (RDBMS) software. During FY93, ITS purchased a UNIX-based workstation capable of sorting data approximately four times faster than its predecessor. As the prototype DOS system was disassembled, ITS evaluated the performance of the DOS-based RDBMS software to determine whether the UNIX version of this software should be purchased or whether other RDBMS software should be used. One motivation for the former approach was the fact that database users had become quite proficient at using the original DOS-based RDBMS software, and most of the learned techniques were usable with the UNIX version. Also, the database was designed to be completely portable to the UNIX RDBMS

```
Std Number              Title
FED STD  --  HF Radio Modem
 1052
FED-STD  --  Analog to Digital Conversion of Radio Voice by 4800 bit/second
 1016          Code Excited Linear Prediction (CELP)
FED-STD  --  Interoperability Requirements for Encrypted, Digitized Voice
 1023          Utilized with 25 KHz Channel FM Radios Operating above 30 MHz
FED-STD  --  Encryption & Modulation Methods Within 4,800 Bit/s Digitized
 1024          Voice VHF & UHF Mobile Radios
FED-STD  --  Coding, Modulation & Transmission Requirements for Single
 1035A         Channel Medium and High Frequency Radiotelegraph Systems Used
FED-STD  --  Interoperability Requirements for Trunked Land Mobile Radio
 1044          Systems Operating with Analog & 25 KHZ Channel Digital Radios
FED-STD  --  High Frequency (HF) Radio Automatic Link Establishment
 1045
FED-STD  --  HF Radio Automatic Networking
 1046
FED-STD      HF Radio Automatic Message Store-and-Forward
 1047

.QP Rel Stds: ESC 7 QP Key Wds: ESC 6 Prev Page: ESC 3 Help: ESC 1 Exit: ESC 8.
```

2. The Matching Standards Screen.

```
------------------------------------------ (16   standards found)
| "I want to find all standards that contain
|            the phrase: radio
|  AND       the phrase:
|  AND       those that contain
------------------------------------------------------------------------------
Record Number: 29     Standard Type: FED-STD
               Standard Number: 1045                Authority: NCS
Standard -High Frequency (HF) Radio Automatic Link Establishment
   Title



    Families:  Radio
Publish Date: 1990          Superseded by: (none)
  Reaffirmed: 0                Adopted as: (none)
      Status: Final          Adoption of: (none)
  Order Info: GSA                  Category: Telecommunications

                Help: ESC 1           View Stds related to this one: ESC 0
Prev Matching Standard: ESC 3              Restore Previous Listing: ESC 5
Next Matching Standard: ESC 2         Redraw: CTRL/R   View Families: ESC 4
   Move Between Fields: TAB, U-Arrow  Snapshot: CTRL/P            Exit: ESC 8
------------------------------------------------------------------------------
```

3. The Information Screen.

software. After comparing several different RDBMS software systems, ITS decided to purchase the UNIX version of the original RDBMS system. The database was successfully integrated with the new RDBMS on the UNIX-based workstation in the second quarter of FY93. Figures 1-3 show three of the database screens, as seen by a user.

ITS staff members also devoted considerable FY93 effort to the collection and development of information related to the standards listed in the database. While some of this information was available from an examination of the standards themselves, abstracts, applicability statements, cross references, and standards family groupings often had to be created from scratch. There are now 350 mostly complete standards data entries provided in the database. ITS expects to at least double this number in FY94.

ITS achieved a major improvement in the utilization of the standards database during FY93 by making it accessible via Internet. Users can now employ the Telnet program to connect to the database at Internet address **sneffels.its.bldrdoc.gov**. Three high-speed (up to 14,400 bits per second) modems were also interfaced with the database computer during FY93 to allow several users to connect to the database via conventional telephone lines. The telephone number of the modem bank is (303) 497-5452.

In other FY93 work, ITS staff members added audit trails to the database. A registration system now prompts users to enter their name and address when they access the system. This information will later be used by ITS staff to create a mailing list of database users. Event monitoring has also been added to record, on the hard disk, significant events as a user navigates the database. Examples of such events are starting and quitting the database and viewing a particular record. This information will be useful in isolating problems reported by users and in assembling usage data.

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

```
-----------------------------------------
|Select a Family Name from the list.      |
|DTE/DCE Interface                        |
|Modems                                   |
|ASCII                                    |
|Optical Char. Recog. (OCR)               |
|Encryption                               |
|Computer Output Microfilm/form           |
|Computer Languages                       |
|Radio                                    |
|Audiovisual Teleservices                 |
|Building Telecomm. Cabling/Wiring        |
|Geographical, Time, & Date Codes         |
|Computer Graphics                        |
|FAX/Telematic Services                   |
|High-Level Data Link Control (HDLC) Proc |
|OSI Reference Model                      |  ----------------------------
|Packet Switching                         |  Press TAB  or U-Arrow to move |
|                                         |  between selections.           |
|                                         |                   Help: ESC 1  |
|                                         |Select Family: ESC 5 Exit: ESC 8|
-----------------------------------------------------------------------------
```

4. The Family Groupings Screen.

Telecommunications Terminology Standards

Outputs

- U.S. Contributions to ISO-2382, Information Systems Vocabulary
- Support of ANSI-accredited Technical Committee X3K5 in development of ANSDIS, *American National Standard Dictionary for Information Systems*
- Compilation of U.S. Army comments on FED-STD-1037B, *Glossary of Telecommunication Terms*

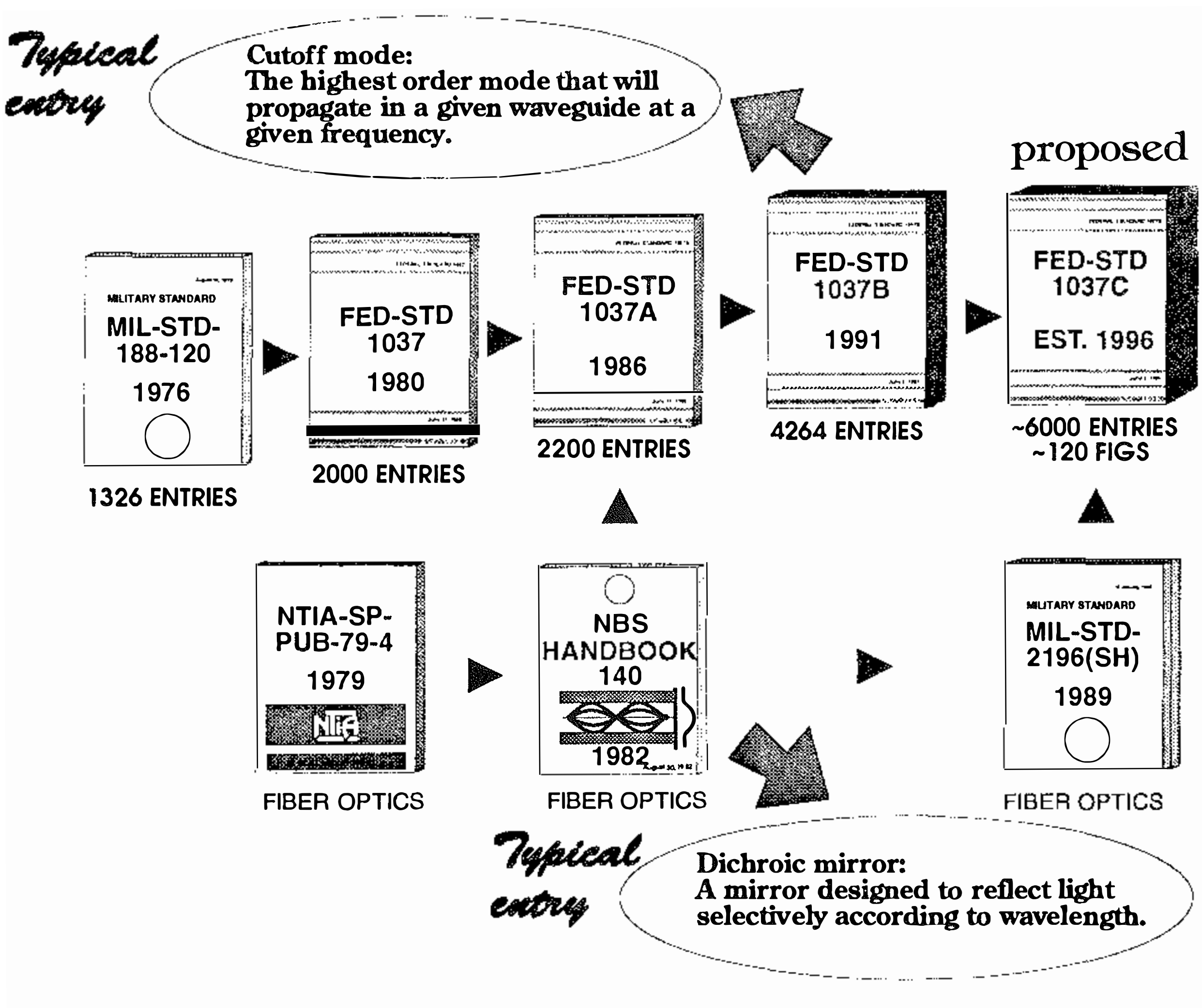
Through active participation in telecommunications standards committees, the ITS staff assists the Federal Telecommunication Standards Committee (FTSC)—chaired by the National Communications System (NCS)—in establishing Federal standards to promote end-to-end interoperability of telecommunications systems owned or leased by the Federal Government. Institute programs promote interoperability and support the FTSC in several ways. Among these are contributions to telecommunications terminology standards—an effort motivated by the need for interoperability. Telecommunications glossaries promote interoperability through the achievement of consensus on standard language for evolving technologies. The benefits of vocabulary standards accrue to everyone from procurement officials to installers, to maintenance personnel, to instructors, and to end users in the field.

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 FY93, the X3K5 Committee refined and updated definitions on information systems vocabulary for such fields as computer graphics, computer security, data communications, E-mail, and programming languages.

The ITS Vice Chair of X3K5 also serves as convener for the Joint International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Subcommittee 1 Working Group 7 on Data Communications. That international working group, which meets twice a year, develops standard vocabulary for several parts of ISO-2382 dealing with local area networks, OSI, E-mail, and data communications. The Institute's participation in WG 7 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. competitiveness in world markets.

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 (as co-author, editor, or committee chair) in the development of the 1037-series of Federal Standards (see figure). In addition to its active participation in the development of all of the predecessor documents, the Institute developed two editions of a pioneering fiber optics glossary, published as NTIA Special Publication 79-4 and NBS Handbook 140. This fiber optics glossary was also published internationally as IEEE-814 and IEC-812, and in an expanded form, as a U.S. Military Standard. In DoD working group meetings last year, the Institute compiled and edited Army comments along with new DoD definitions on network management and video teleconferencing. The resulting definitions, with documented rationale, were printed on ballot pages and submitted to the FTSC for Government-wide coordination in the preparation of a revised Federal telecommunications glossary, 1037C.

For information, contact:
Evelyn M. Gray (303) 497-3307



Federal standards in the 1037 series that ITS has contributed to.

Personal Communication Services Standards Support

Outputs

- Leadership in PCS standards organizations
- Technical contributions on PCS standardization issues

Personal Communication Services (PCS) is a revolutionary and integrating telecommunications service concept that promises to provide wireless access, terminal mobility, personal mobility, and service profile management to voice and data subscribers on a worldwide basis, using low-power, handheld terminals. Telocator, the Personal Communications Industry Association, predicts that PCS providers may have as many as 23 million subscribers by the year 1997—and 56 million by 2002. National and international standards bodies are actively addressing the numerous and complex technical issues that must be solved to ensure that the enormous market potential of PCS is realized—and that PCS subscribers receive the highest quality service at the lowest possible price.

National and international organizations addressing PCS and related technology issues include ANSI Committee T1 (Telecommunications), the Telecommunications Industry Association (TIA), and the Standardization and Radiocommunication Sectors of the International Telecommunications Union (ITU). The T1 and TIA standards activities are focused on PCS systems that may be made available to the public as early as 1995, while the ITU bodies are focused on systems that will be developed in the post-2000 timeframe. The implementation of U.S. PCS systems is dependent on Federal Communications Commission (FCC) decisions regarding spectrum allocation and licensing.

In the U.S., the TIA and ANSI T1 have defined a functional PCS architecture as shown in Figure 1. The letters in the figure identify the principal interfaces between PCS system components. Some level of standardization is required for each of these interfaces. The interface receiving the most attention at the present time is the so-called "A" interface, which is usually referred to as the "common air interface" or CAI (Figure 2).

The T1 Subcommittee T1P1 and the TIA Subcommittee TR46 have formed a Joint Technical Committee (JTC) for Wireless Access to develop a common air interface standard. During FY93, Institute personnel chaired *ad hoc* groups on Channel Characterization and Testing within the JTC. Because of ITS work on related projects (see the sections on PCS Measurements and PCS Modeling), the Institute has been able to make strong technical contributions to the JTC in addition to chairing the *ad hoc* groups. Agreement on standards at the physical or air interface level is critical to ensure PCS system interoperability. It is the goal of the FCC to ensure that each region of the country can have multiple PCS providers, and that providers can mix and match equipment from several manufacturers. The Institute's work in the JTC will help realize this goal.

The Institute has organized and will be chairing and hosting a PCS forum for the purpose of facilitating information exchange among Federal Government users, standards organizations, manufacturers, potential PCS service providers, and other user groups.

<u>Recent ITS Publications</u>

Personal Communication Services Channel Modeling and Simulation with Application to Telecommunication Standards (by Lemmon, Vogler, and Hoffmeyer)

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

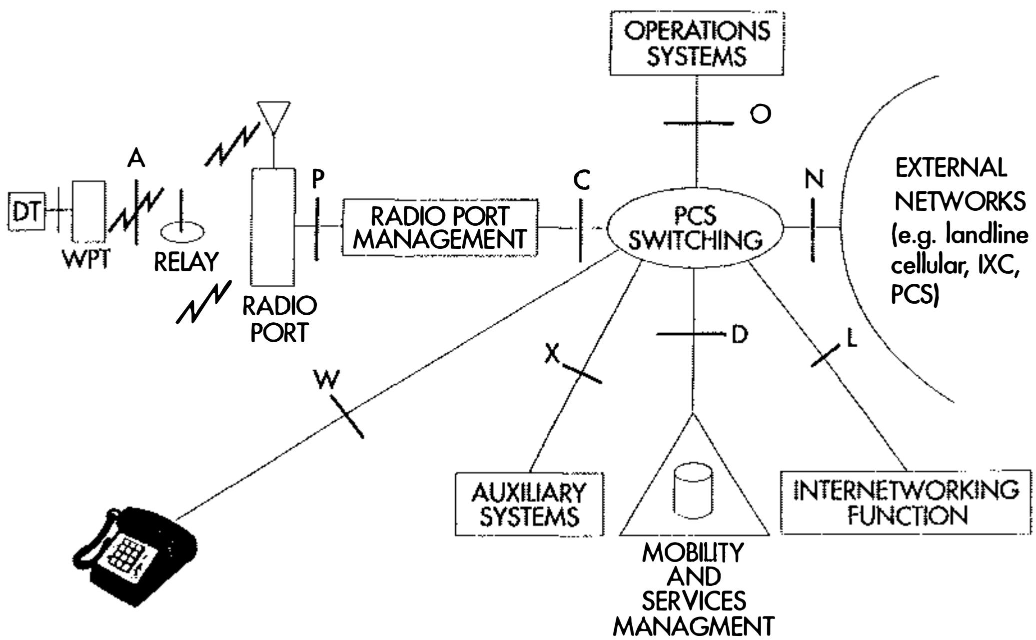


Figure 1. Functional PCS network architecture.

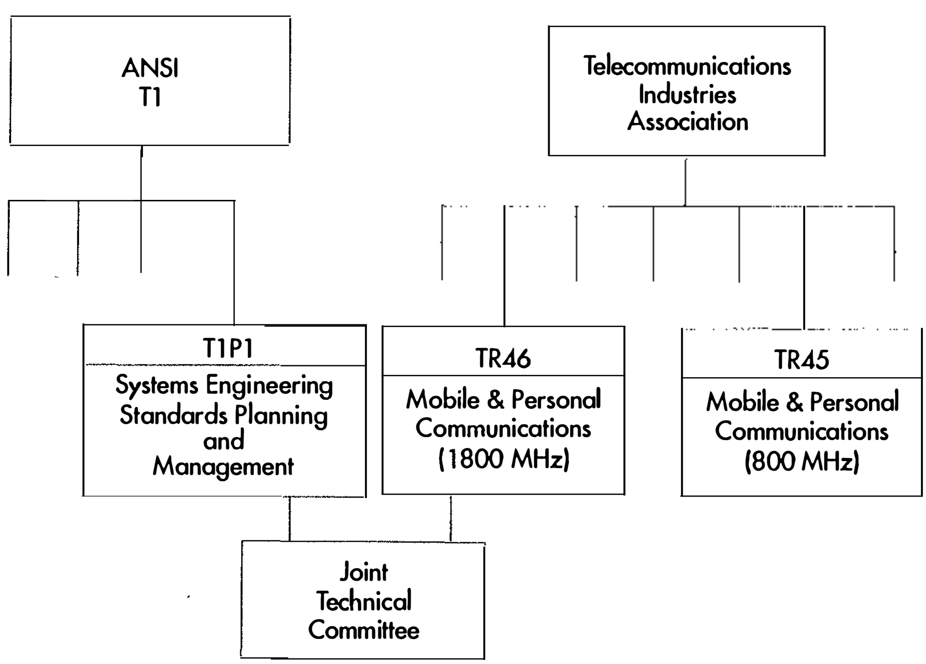
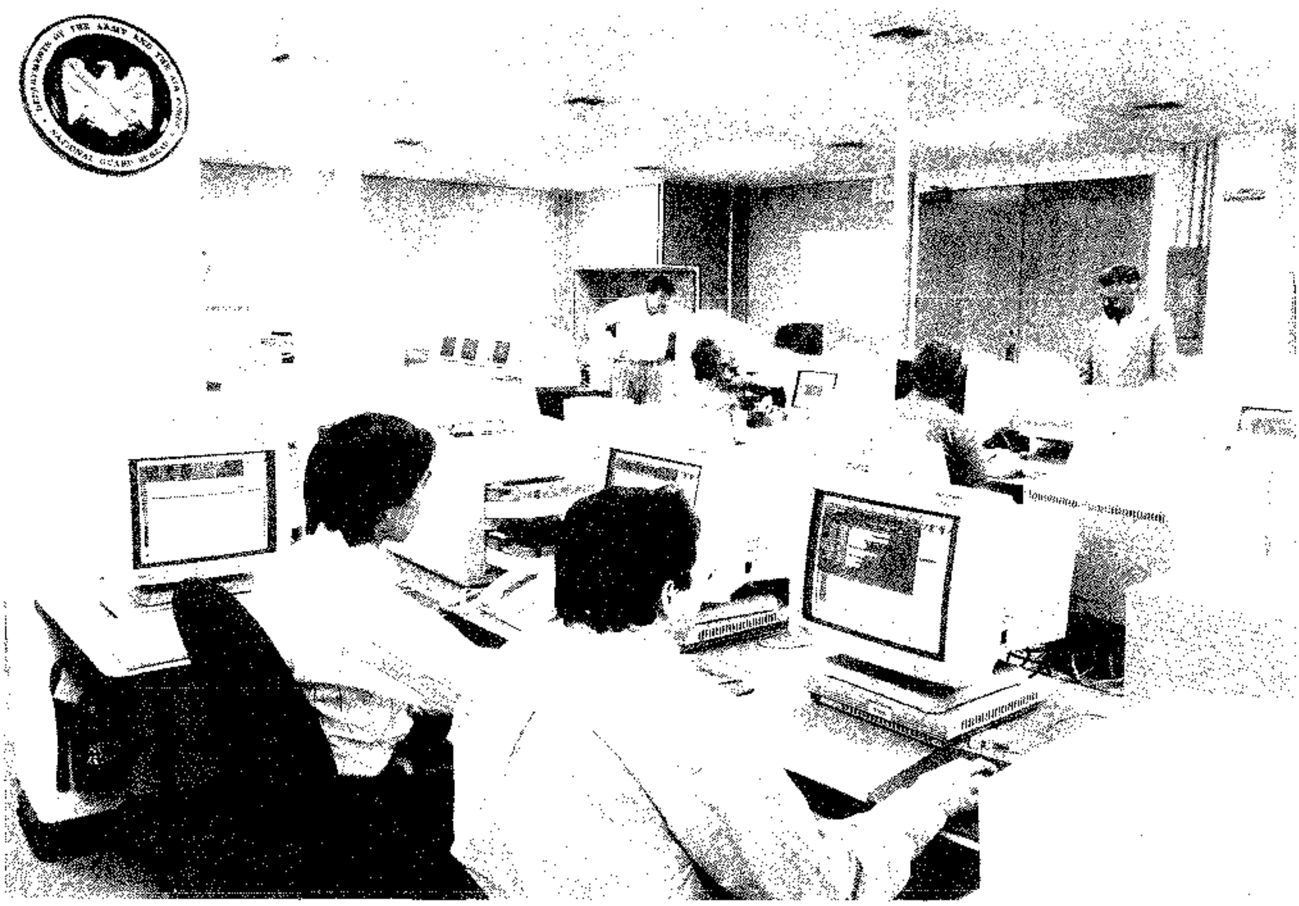


Figure 2. Common air interface standards development.



Reserve Component Automation System Test Laboratory

TELECOMMUNICATION SYSTEMS PERFORMANCE

The Institute conducts a variety of programs for assessing the performance of communications networks and transmission systems. The tools developed by the Institute for assessing telecommunication systems performance include techniques to be used during the system design process for predicting the performance of a telecommunication system in any specified operating environment. The set of tools also include hardware/software test and measurement systems used for evaluating the performance of either prototype or operational networks or transmission systems.

These tools are applied to the performance evaluation of a variety of voice, data, or video telecommunications systems. These systems may be either entire networks or specific transmission links.

In systems performance evaluation programs at the Institute, emphasis is placed on performance as perceived by the user of the system. Thus, user-oriented parameters are defined and utilized for the system evaluation rather than system-oriented performance parameters. The former tend to be system independent, while the latter tend to be system dependent meaning that they would need to be changed for each system under test.

Areas of Emphasis

High Definition Television

Includes projects funded by NTIA.

Digital Audio Broadcasting

Includes projects funded by NTIA.

Radio System Design and Performance Software

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

Reserve Component Automation System Testing

Includes projects funded by the U.S. Army Reserve Component Automation System Program Management Office.

Advanced Broadcasting Support

Outputs:

- Simulation of COFDM (Coded Orthogonal Frequency Division Multiplex) modulation for use in DAB (Digital Audio Broadcasting)
- 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.

Coded Orthogonal Frequency Division Multiplex (COFDM) modulation is a multi-carrier modulation technique that can offer superior performance in multipath and frequency selective fading environments. Its use is being considered in Europe for High-Definition Television (HDTV) (the Scandinavian HD-Divine system) and DAB (the Eureka system) and in the U.S. for DAB. ITS has begun to develop computer models to simulate COFDM and estimate its performance under different impairments. An example of a COFDM signal is shown in Figure 1. Figure 2 shows the performance of a type of COFDM in noise.

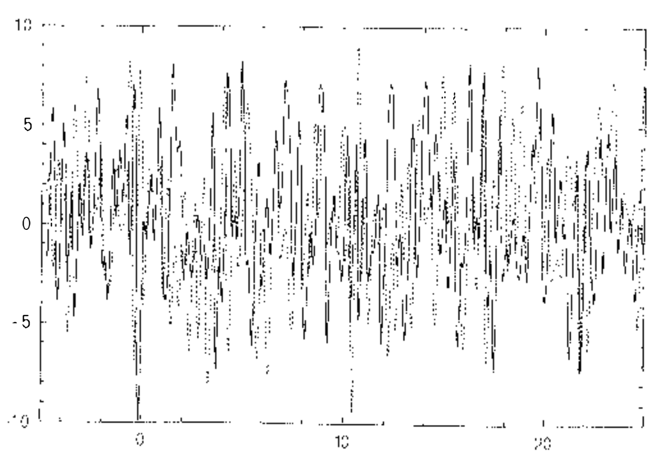


Figure 1. Impulse and quadrature components of a COFDM signal.

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.

A set of industry/Government advisory committees have been set up under the auspices of the Federal Communications Commission (FCC), Advisory Committee on Advanced Television Systems (ACATS) to advise and oversee various aspects of HDTV planning, development, testing, and deployment. ITS is currently involved in providing equipment to measure multipath propagation distortion in Charlotte, NC, where the field tests of the 'grand alliance' HDTV system will be tested.

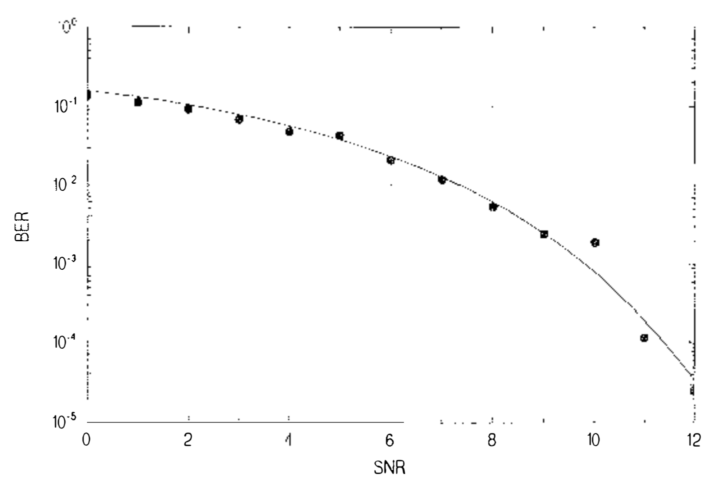


Figure 2. Theoretical and simulated error rates for a COFDM signal in noise.

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 that represents the directly received signal. Then come a jumble of smaller pulses that 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' that 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 does 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.

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.

Recent Publications

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

A Characterization of the Multipath in the HDTV Channel (by Hufford)

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

Army Reserve Component Automation System Testing and Evaluation

Outputs

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

The U.S. 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 (ANG) and U.S. Army Reserve (USAR). The RCAS is a state-of-the-art automated information system that supports the decision-making needs of the commanders, staffs, and functional managers responsible for the operational readiness of the Reserve Component. The RCAS combines office automation, telecommunications, distributed database, and distribution processing capabilities to accomplish day-to-day administrative tasks and to provide timely and accurate information to prepare and execute mobilization. It is a self-sufficient system capable of exchanging data with related information systems in the Active and Reserve Components.

Key RCAS elements include commercial off-the-shelf X-stations and PC-based terminal servers; reduced instruction set computer (RISC) processors; commercial office automation software including word processing, E-mail, spreadsheet, graphics, and desktop publishing packages; specialized UNIX-based Ada application software; and a fully integrated relational database for every unit. The RCAS hardware will be installed on local area networks (LANs) at approximately 9,800 ANG and USAR units throughout the United States. The individual LANs will be interconnected by an FTS 2000-based multilevel, secure, wide area network (WAN) covering the entire U.S. and selected overseas locations.

The RCAS is designed to meet the following standards:

- Open Systems Environment (OSE)
- Portable Operating System Interface for Computing Environment (POSIX)
- Government Open System Interconnection Profile (GOSIP)
- Multi-level Security (DoD 5200.28)
- Structured Query Language (SQL)
- Standard Data Elements (AR 25-9)
- X-Window System
- Ada Programming Language
- Software Documented for Reuse.

The Institute is supporting the RCAS Program Management Office (PMO) in the technical testing and independent evaluation of the RCAS. The technical testing responsibility involves maintaining (and incrementally upgrading) an extensive RCAS Technical Test Bed at the Boulder Laboratories; developing detailed test plans for each increment (or "Block") of RCAS functionality; conducting tests to assess the system's performance in accomplishing required functions under realistic usage and traffic conditions; and summarizing the test results for each Block in a Test Analysis Report. The independent evaluation responsibility includes the establishment of overall test objectives and criteria, general oversight and direction of the test conduct, and interpretation of the technical and practical implications of the test results.

During FY93, ITS received the first of several increments of the RCAS system solution. The first increment ("Block X") consisted primarily of commercial off-the-shelf hardware and software products integrated to provide an office automation capability and a mail transfer network. The ITS Block X technical testing focused on stress and performance assessment of the office automation server and the mail distribution network.

At each echelon, the office automation environment consists of an Intel 486 processor, a multilevel, secure, trusted UNIX operating system, and supporting peripherals. Each 486 processor serves a number of X-station graphic terminals.

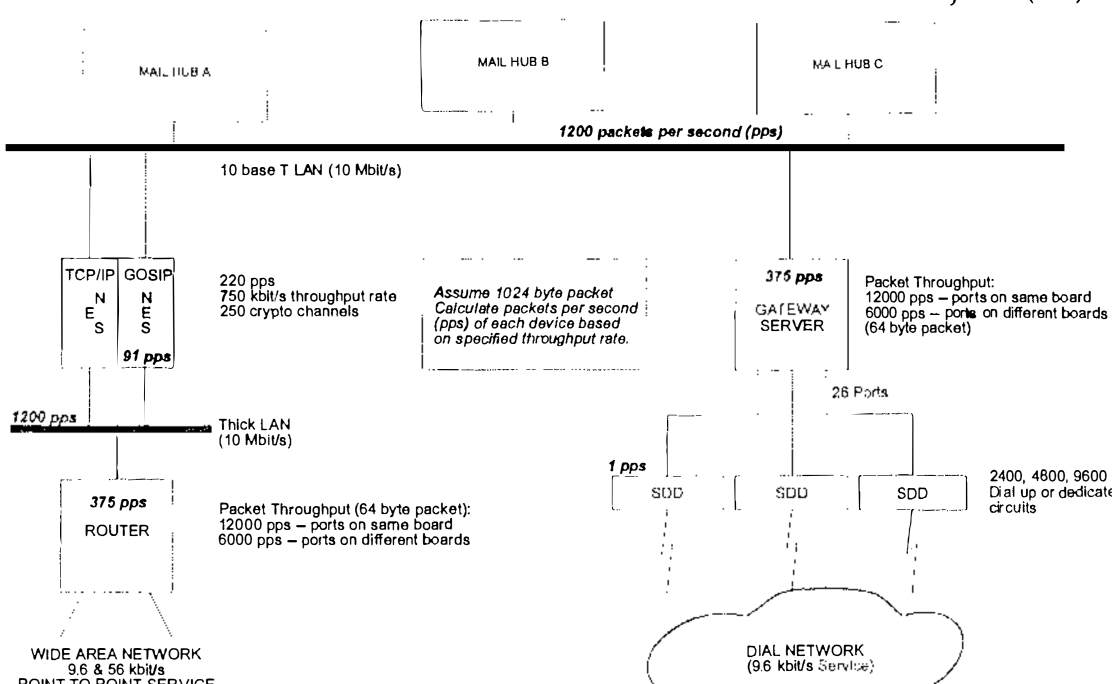
The Block X performance tests measured the server's response time to transactions requested within the system's various office automation products. The primary test element is a remote terminal emulator that captures and reproduces the user X-station transactions. Multiple copies of typical user work scripts are offered to the server as though multiple users were concurrently (but independently) working on the server. The terminal emulator software time stamps all transactions from each user. This process collects a large sample of transaction times and provides a distribution of the results. Performance data were collected on the office automation server for an increasing number of simulated X-station users, to provide a general estimate of the performance of the server as function of the number of active X-stations.

Tests were also performed to exercise the E-mail functions in a TCP/IP protocol environment. The purpose of these tests was to validate the system's ability to accept and correctly forward all options and combinations of mail formats and sizes and to assess the system's timeliness in the delivery of messages. The RCAS network will be supported by five mail hubs at various locations in the United States. These hubs will store and forward all messages passed from one geographic location to another. The core of the mail hub consists of three RISC-based computers. A block diagram of the mail hub components is shown below. The RISC machines and the network components share a common LAN. Access to the LAN from the wide area network is through two routes. Direct-connect or dedicated circuits from external locations to the hub enter through a router and a network encryption system (NES). A second access, by way of dial-up circuits, is through encrypting modems and a gateway server.

To support planned tests of the mail distribution functions, ITS is developing a network traffic model to estimate the message rates through each of the RISC machines.

Current efforts are focused on the preparation of plans and tools to test the next RCAS release. This release will include a substantial amount of Ada application code and a large database to support that application code. Major efforts will include the development of test databases, the expansion of the terminal emulation technique to support transaction timing of the applications, and the development of stressed network tests.

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



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 radio wave propagation modeling have continued at ITS in FY93 with the improvement of the AMOS (Analysis of Microwave Operational Scenarios), 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 latest version of JEM runs in Windows™ 3.1 as a Windows™ application. The extensive analysis and design capability of these codes have previously been limited to mainframe computers.

AMOS/MOSES/ROSES/JEM Models. The AMOS/MOSES/ROSES 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 U.S. Army to evaluate electronic warfare scenarios. All of these models are highly structured and modular in design, which allows for greater flexibility and expandability. 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 database 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 developmental 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- to 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- to 30-MHz range will include propagation models for both the ground wave and the sky wave. An irregular terrain model for the 20-MHz to 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 activities. The Radio Analysis and Integrated Design for Engineering Requirements (RAIDER) program is an integrated, user-friendly set of software modules that automates the calculations for the design and prediction of line-of-sight and beyond-the-horizon path terrestrial links that had previously required extensive hand calculations and mainframe computers. RAIDER can be used easily and efficiently, both in the field and in the office, by users who are familiar with radio systems.

RAIDER currently consists of 13 modules that use state-of-the-art programming interfaces and the newest engineering models developed by ITS, industry, and ITU-R. 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 that 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. These data are presented in both tabular and graphical output and may be saved as hard copy.

<u>Recent ITS Publications</u>

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

HF Radio ALE Network Simulation Modeling

Outputs

- Simulation of sounding effects on HF radio ALE network performance
- Support to HF radio ALE Federal Standards development
- Support to Federal Agencies operating HF radio ALE networks

The ITS is developing an HF radio Automatic Link Establishment (ALE) network simulation modeling capability. A conceptual model of an HF radio ALE network has been developed based on Federal Standard 1045A, "Telecommunications: HF Radio Automatic Link Establishment." The basic elements include models of the HF propagation channels, the operation of the individual radio sets, the digital and voice traffic offered to the network, overhead traffic for the operation of the network, and the interoperation among the radio sets on the network. The HF propagation model is determined by the channel reliability outputs of ITS' Ionospheric Communication Analysis and Prediction Program (IONCAP).

The conceptual model is the basis for the design of the simulation programs. The computer programs incorporate the models either deterministically or stochastically. The deterministic models reflect details that are static, or never changing. The stochastic models contain random components and are used to simplify and to speed up the execution of the simulation programs, as well as to simplify detail that is of relatively minor importance to the present purpose of the simulation. Thus, not every detail is directly programmed, but may be mathematically simulated instead.

Desktop personal computers or workstations are used to run the simulation programs. Thus many simulation runs can be made in a short period of time. For example, up to 100 runs of 48 hours of simulated network time can be accomplished in 30 minutes. Many simulation runs may be necessary since the stochastic nature of elements of the simulation imply that the performance results are also of a random nature. The numerical results must be analyzed by statistical methods.

The network simulation is dynamic in that it models the changing conditions of the radio communications network over time. The simulation is a discrete event simulation program. The major events, which drive the simulation clock, are attempts by the radio stations to link with one another to pass digital or voice traffic. The traffic itself is modeled by the time it takes to actually pass the traffic. The digital bits (or the actual voice transmissions) are not tracked or considered directly, but are handled as a data aggregation.

Network simulations are validated by statistical comparison of simulated performance to the known performance of existing networks and to the existing Federal Standards. Validation is necessary since simulations are at best an approximation to the system being modeled.

The network simulation is generally used to study network performance. Such performance can be easily studied by simulation when direct testing of an existing radio network is impossible or economically unfeasible, or when the network itself exists only at the design level. Network simulation is considered by ITS not to be a substitute for direct testing and study of networks but as testing in support of actual over-the-air network tests.

It is a requirement that proposed features to Federal HF Radio Standards undergo over-the-air testing before being included in the standards. The basic FS-1045A radio is designed to handle up to 100 programmed addresses for other stations and may operate on up to 100 HF radio frequencies. Testing of the full capabilities of the radio sets will be costly and time consuming. Network simulation modeling will be used as a preliminary evaluation of proposed standards features. This will allow standards development to proceed without the delay caused by the necessary over-the-air testing.

Several Federal agencies are operating HF radio ALE networks. One of the goals of network simulation at ITS is to provide these agencies with the capability to model expanded or alternative configurations of their networks. The characteristics of theses existing networks will be investigated, determined, and specifically modeled. Changes in network configuration, network operation, network control, and alternative implementation of the federal standards can be studied without actually making the changes on the operating network. This will keep downtime of the real networks to a minimum.

During FY93, ITS conducted a simulation study to determine the effects of sounding on a ten-station network operating on ten HF frequencies. Sounding is the periodic broadcast, by a radio station, of self-identification information that may be monitored and automatically evaluated by other radio stations in the network. A radio station will sound on each of the available frequencies in turn. The evaluation of sounds by listening stations provides information on the state of HF radio propagation. The radio sets will then be able to automatically select the propagation channel with the highest probability of providing an HF radio link to the desired destination station. The problem is that network and station overhead due to sounding can be detrimental to network performance.

The simulation study indicated that sounding did not improve performance of the network under most operating conditions. However, with a low traffic rate under poor general HF propagation conditions, sounding was found to significantly enhance the performance of the simulated network. This was due to the identification of the few HF channels that were able to support communications. Example simulation results are shown below.

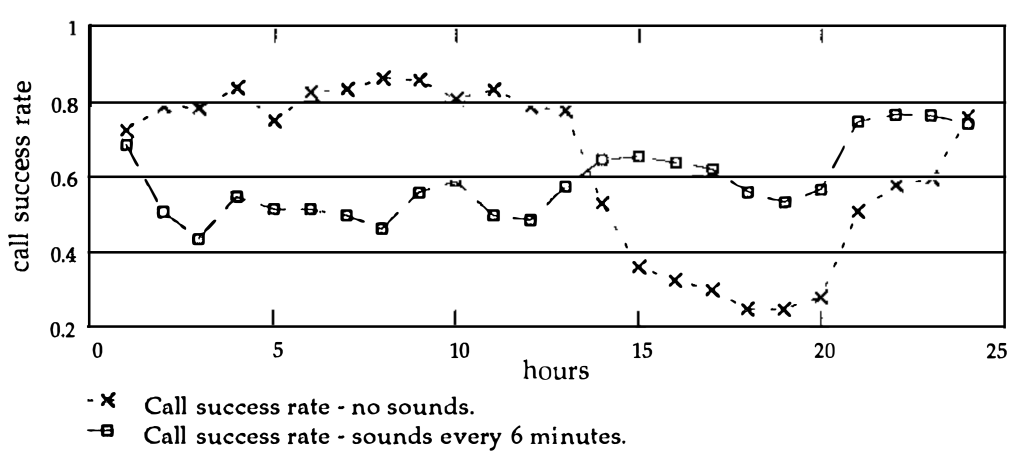
This small-scale simulation also demonstrated the efficacy of discrete event simulation in studying HF radio ALE networks.

The Institute has proposed the development of an HF ALE simulation test bed for large (≤ 100 node) networks. The proposed test bed will allow the study of ALE networks utilizing the full capabilities of the radio sets. The simulation test bed will be used to conduct research on network design and control, to test network configuration alternatives, to improve methods of propagation data collection, to study and predict the performance of specific ALE networks, and to study efficient methods of discrete event network simulation.

<u>Recent ITS Publication</u>

Simulated Effects of Sounding on Automatic Link Establishment HF Radio Network Performance (by Sutherland).

For information, contact:
David A. Sutherland (303) 497-5161



Example simulation results. Simulated network performance by hour for 24 hours measured by the radio call success rate for 5 messages per hour and network sounds heard every 6 minutes. The two traces compare the network performance with and without sounding.

The Advanced Communications Technology Satellite (ACTS)

ITS

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

Assessment of Emerging Technologies
Includes a project funded by the National Security Agency

Personal Communication Services Modeling
Includes projects funded by NTIA

Intelligent Vehicle Highway Systems
Incudes projects funded by the Department of Transportation

Satellite Studies
Includes projects funded by NTIA 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

The DoD Intelligence Information System Implementation
Includes a project funded by the Department of Defense

Assessment of Telecommunications Dependence on Foreign Sources
Includes a project funded by the U.S. Army Defense Information Systems Agency

Telecommunications Assessment

Outputs

- Study of telecommunications trends
- Assessment of the impact of new telecommunications products and services on secure telecommunications
- Survey of advanced technology security features and vulnerabilities

The world's telecommunications capabilities are rapidly evolving toward all-digital systems and networks using transmission media supporting very high data rates. Voice, data, and video communications are being integrated into these modern architectures, so that all services co-exist simultaneously and share broadband transmission channel capacity. The many advanced telecommunications products and services and the wide variety of efficient protocols available and operating on these systems create the need to establish complimentary capabilities to protect selected communications channels. Traditional schemes for providing required security may not be directly applicable or sufficient for the new and rapidly changing telecommunications environment. The Institute is conducting studies, looking into the future, to define the security requirements and risks of these new telecommunications technologies.

An essential aspect of the ITS mission lies in tracking evolving telecommunications and assessing the impact of these evolutionary trends on the future telecommunications infrastructure. This assessment includes a recognition of the security implications of these new and evolving technologies. Two security related aspects of telecommunications decision-making influenced by the Institute's assessments and future capabilities projections are the protection of information and the procurement of interoperable systems.

Information protection has been a key thrust of the Institute's efforts in the past year. ITS has assisted the Department of Defense (DoD) in the identification of key technologies likely to be transferred from the commercial sector into the DoD community. Identification of these key technologies is critical for making judicious decisions in the allocation of scarce financial and personnel resources.

ITS has performed a detailed study assessing the security implications of emerging technologies including Personal Communication Services (PCS), wireless Local Area Networks (LANs) and wireless Private Branch Exchanges (PBXs). This study has covered the operation of the air interface, the wireless to wireline network interface, and the database interaction for each of these systems. The study identifies general mechanisms for wireless system protection and makes specific recommendations for protection of the candidate PCS interfaces proposed by vendors.

The security risk analysis performed on these three technologies involves the assessment of physical threats (denial of service), threats to the information itself (interception, masquerading and modification) and indirect threats (traffic flow analysis). Potential mitigation techniques are being addressed.

Figure 1 illustrates typical results of an analysis of some of the vulnerabilities of a particular implementation of PCS. A geographical coverage area for the system cell is typically about 2 km in diameter. Each microcell contains a base station that includes a radio transmitter, receiver, antenna and computer. Calls may be transmitted to users via radio links using FDMA, TDMA, CDMA or a combination of techniques. Mobile users are tracked by computers as they move from cell to cell. The Mobile Switching Center (MSC) maintains the database that identifies each subscriber's location and service profile and provides required security information. The MSC is also the PCS gateway to the wireline network that supports calls to subscribers outside the local PCS area. The "lock" symbols in the figure indicate areas that require protection. Areas of particular vulnerability are the air interface, the base stations, and the MSC and its associated databases. All of these areas are being considered in detail in the Institute's analysis.

Figure 2 shows the complexity in the evolving telecommunications infrastructure that drives many of the concerns about security, privacy and authentication. The many public interexchange carriers, local exchange carriers, and private networks all add to the complexity of providing the level of security users have become accustomed to, as well as the levels required for national security. Researchers at the Institute are in contact with service and equipment providers to keep abreast of technological developments. Institute representatives also serve in leadership roles in the development of performance and interoperability standards. It is from this depth of experience and contacts that ITS undertakes to assess and predict future telecommunications services and systems and associated security and interoperability implications.

<u>Recent ITS Publications</u>

Present Status and Future Trends in Telecommunications (by Linfield)

For information, contact:
Timothy H. Cole (303) 497-7578

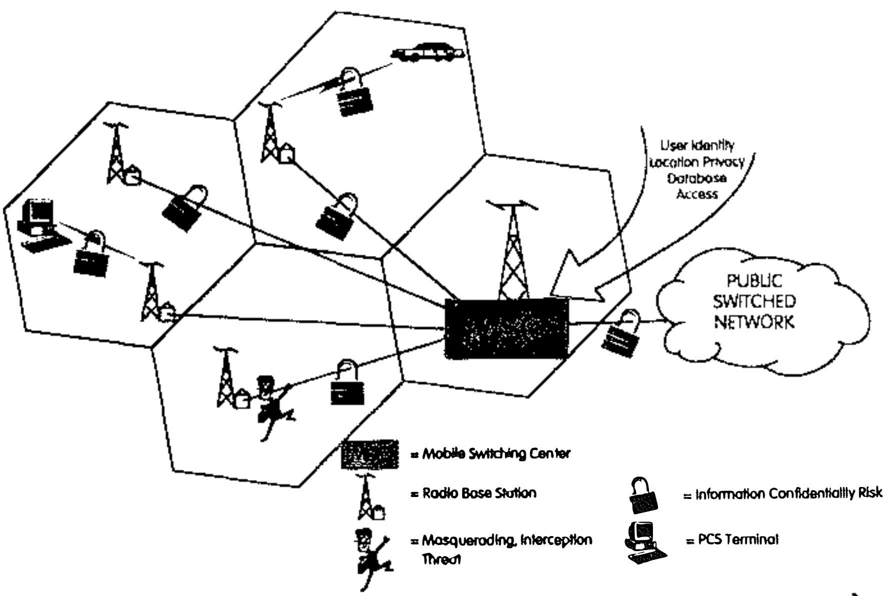


Figure 1. Typical security risk analysis results.

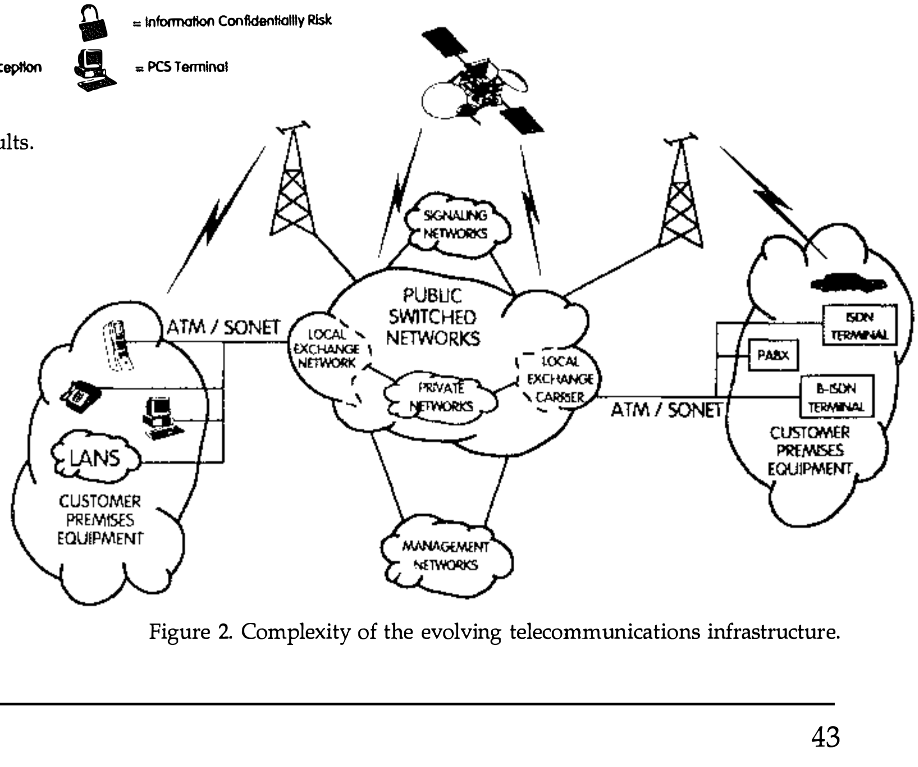


Figure 2. Complexity of the evolving telecommunications infrastructure.

Personal Communication Services Modeling

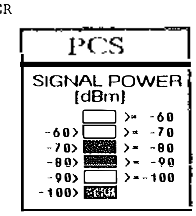
Outputs

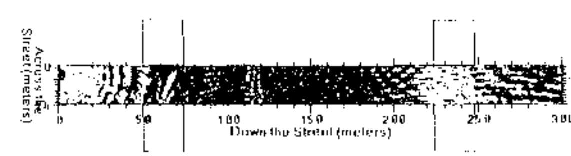
- Development and enhancement of Geometric Optics Model
- Enhancement of Spectrum Sharing Model
- Coordination distance analysis
- Development of PCS simulation plans

ITS has been active in the development of computer propagation models for typical PCS operational environments in the allocated PCS frequency bands. Specifically, models have been developed for urban outdoor microcells and indoor (building) environments, and to assess the spectrum sharing potential of PCS systems with each other and with incumbents in the allocated PCS bands. In addition, an analysis was performed to evaluate proposed coordination distances between the incumbents and PCS in the 1850-1970 MHz band. ITS has been active in the creation of such computer models in order to help support the development of the emerging PCS technologies. In addition, ITS's participation in national and international standards bodies will contribute to the development of compatible PCS products.

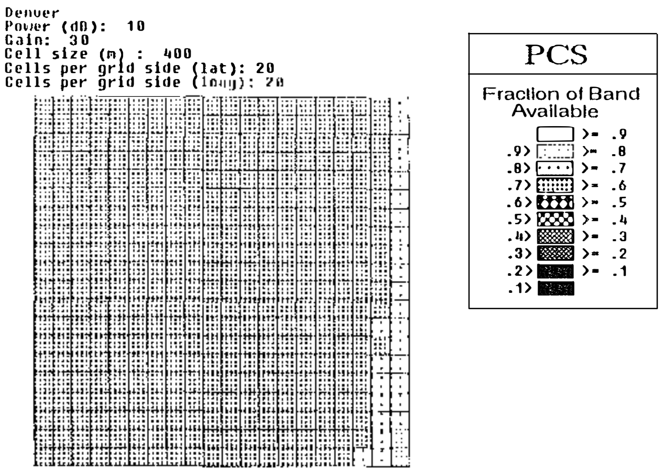
The intent of the Geometric Optics model to help PCS system planners and designers account for the effects of operating a microcell in an outdoor urban environment. This model can be used as a tool by system planners and can be used to predict system performance. The model provides a virtually complete description of the radio channel including delay time, signal arrival angles, polarizations, etc. Because the signal at the receiver can be completely described, different systems can be modeled/simulated regardless of system parameters (i.e., whether the system uses TDMA, CDMA, antenna diversity, etc.) Future plans include 1) expanding the model to include the non-line-of-sight case for outdoor urban environments, as well as for closed environments, with reflection and diffraction losses from obstructions within the coverage area (e.g., buildings, vehicles, terrain features, trees); and 2) working closely with internal groups conducting PCS measurements to corroborate the models' predictions. The following figure is an example of an area coverage plot for a PCS microcell in 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.

PARAMETER.............:	TRANSMITTER	RECEIVER
Height Above Street (m):	10.00	1.80
Beam Width (deg).......:	180.00	180.00
Gain (dB).............:	.00	.00
Elevation Angle (deg)..:	.00	.00
Azimuthal Angle (deg)..:	.00	.00
Power (dBm)............:	.00	
Frequency (GHz)........:	1.92	
Distance From Wall (m).:	5.00	
Street Length (m)......:	300.00 inc 1m	
Street Width (m).......:	24.00	
Max # Wall Reflections.:	10.00	
Street Reflection Loss.:	3.00 dB	
Wall Reflection Loss...:	6.00 dB	
Cross Streets at.......:	50/ 150/ 24 m	



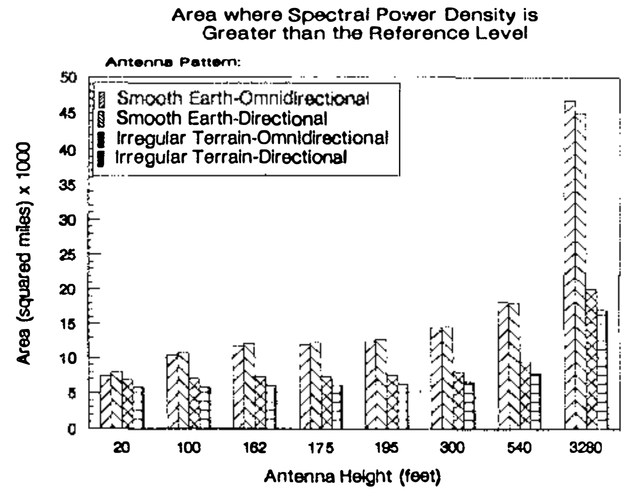


To assist planners and designers determine the effects of providing PCS in an environment where incumbent services exist, the Institute has developed a spectrum sharing model, also nearing completion, based upon optimizing desired design parameters (i.e., number of PCS base stations, antenna heights, revenue from operations, etc.). This model currently optimizes or maximizes the number of PCS base stations that can operate on a given frequency in the 1850-1970 MHz band without interfering with any of the incumbent microwave receivers. Plans for expansion of the model include allowing for base station power reduction dynamics and adding the capability to activate/deactivate specific cells within a grid of base stations to more closely model actual microwave/PCS use. The next figure shows an example output from the Spectrum Sharing Model. It depicts a grid of base stations, with one PCS base station per square, overlying part of the city of Denver. The area over which the grid lies includes 63 incumbent microwave links. The shading in each square indicates the percentage of the 1850-1970 MHz band that is available to the base station in that location. The percentages are determined by maximizing the number of PCS basestations that can operate on a given frequency without interfering with the microwave receivers.



The purpose of the coordination distance analysis was to determine if different criterion could be used to reduce the FCC proposed coordination distance, which was based upon maximum effective isotropic radiated power and maximum transmit and receive antenna heights, while maintaining a desired level of microwave interference protection. It is desirable to reduce the number of coordinations that must be performed by potential PCS providers since performing the required coordinations can be both costly and time consuming. The analysis consisted of evaluating the effect of real antenna heights and patterns, and smooth earth and irregular terrain propagation on the area over which coordination would be required. The results of the analysis are being incorporated into an Institute paper.

The analysis was based upon incumbent links in the Denver region. The next figure shows the coordination distance area produced for a number of criteria. The greatest coordination area, approximately 50,000 sq. miles, is that determined by the FCC criteria. Use of the smooth earth propagation model reduced the areas significantly from the area proposed by the FCC. Accounting for the directionallity of the microwave antennas did not significantly reduce the coordination area, but changed the shape of the area to reflect where coordination would more realistically be desirable. The use of an irregular terrain propagation model would be expected to have the same result. For all cases, the use of lower antenna heights resulted in reduced coordination areas.



The activities described below are part of a program plan that the Institute has established 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/interface models, simulation criteria, and testing methodologies.

To further the PCS interests of Government and industry the Institute is participating in the ITU-R study Group 8 Task Group 8/1 (FPLMTS), the Joint Technical Committee of ANSI T1P1.4 and TIA TR46.3.3 (air-interface standard), and 802.11 (wireless LANs standards committee) of the IEEE. Contributions toward the establishment of national and international standards for the emerging technologies for common air-interface protocols, interoperability, network interfaces and compatibility, authentication and registration, intersystem handoff, and performance specifications are anticipated.

Future work of the Institute includes plans to 1) develop a software simulator to simulate digital PCS system performance using a library of impulse responses; and 2) develop a hardware channel simulator for link performance assessment. The models mentioned above will be installed on TAServices computers which will be accessible to system designers/planners via modems or through the INTERNET.

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Intelligent Vehicle Highway Systems (IVHS)

OUTPUTS

- Characterization of the roadway electromagnetic environment
- Propagation modeling for the roadway environment
- Electromagnetic compatibility analysis of IVHS systems/subsystems
- Electromagnetic compatibility standards committee support for IVHS systems/subsystem

Surface transportation in the United States is becoming more of a problem as congestion continues to increase. The conventional approach of building more roads will not work in many areas of the country, for both financial and environmental reasons. The traffic congestion causes the inefficient movement of traffic and takes its toll in lost productivity, accidents, wasted energy, and increased vehicle emissions. Safety on the Nation's highways is also of prime concern.

Recognition of these problems led to the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. The purpose of the ISTEA is to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner.

A group of technologies collectively known as Intelligent Vehicle Highway Systems (IVHS) is one way to meet the goals of the ISTEA. The IVHS technologies include: information processing, navigation, communications, control, and electronics. IVHS can improve safety, reduce congestion, enhance mobility, minimize environmental impact, save energy, and promote economic productivity in our transportation system. The highway applications of emerging navigation, communications, and vehicle identification and control technologies can contribute to the solution of congestion, safety, and other highway problems.

IVHS utilizes computer and communications technologies to provide information to travelers about road and transit travel conditions and to monitor, guide, and control the operation of vehicles. It can enable travelers to make more informed choices about routes, times, and modes of travel; allow authorities to manage transportation systems and control traffic more efficiently; and in the future, through automation of vehicle control, assist drivers and reduce accidents.

IVHS will enable a range of transportation strategies to be implemented more effectively than they are today. These include rapid response to road accidents to restore traffic flow, directing traffic away from the most congested routes, ride sharing, traffic control at intersections and on street networks, ramp metering on freeways, reserved lanes for buses and high-occupancy vehicles, and toll collection. Some of these measures might be employed only in extreme contingencies, such as major accidents, disasters, environmental emergencies, or fuel shortages, which have low probability of occurrence but high costs if they do occur.

Electromagnetic compatibility (EMC) is a primary consideration in IVHS system design. The performance of the communication, radar, navigation and electronic control systems and subsystems are increasingly dependent upon the compatible coexistence of all of these electronic systems/subsystems. Unintended interactions can occur between these systems. The signals associated with these system functions occupy a wide range of the electromagnetic spectrum. There is a need for carefully designed control measures to confine these signals and their total spectra within the spatial, spectral, and temporal limits to avoid disruptive interference.

ITS will address the EMC of IVHS by participating in many activities during the initial conception, design, development, and testing of IVHS and follow them through the entire life cycle of updates and modifications. Activities of ITS will include, but not be limited to: characterize the electromagnetic environment, plan spectrum use, and develop propagation models; determine suitability of new and emerging communications technology for IVHS; predict radio coverage for communication systems (see figure); select/establish an EMC requirement standard for IVHS; create an EMC control plan; select/develop an EMC testing standard for IVHS; and create an EMC test plan. ITS will also follow good EMC design practices by being involved in system architecture evaluation in the concept and design phases and ensuring EMC for demonstration projects during the course of IVHS development.

EMC analysis and design is important in the early stages of system development. It has the potential to reduce overall costs in the development of the entire system. The cost of EMC fixes to the system increases as the system development progresses, and EMC fixes added later to the system have the potential to cause performance degradation.

EMC areas of consideration will include any equipment, subsystem, or system that is part of the IVHS and its intended operational environment. EMC must be considered for: within the vehicle between different IVHS equipments/subsystems, intervehicle between IVHS equipments on different vehicles, between vehicles and other elements of the IVHS infrastructure, and between the IVHS and the total environment. Vehicles include private vehicles, buses, commercial freight transports, and transport vehicles such as trucks.

It is anticipated that the FM subcarriers of FM broadcast bands will be used to provide traveler information services in some demonstration projects, and possibly in the final IVHS architecture. ITS is currently using computer prediction techniques to predict coverage areas of FM radio subcarrier broadcasts in specific regions of the United States.

For information contact:
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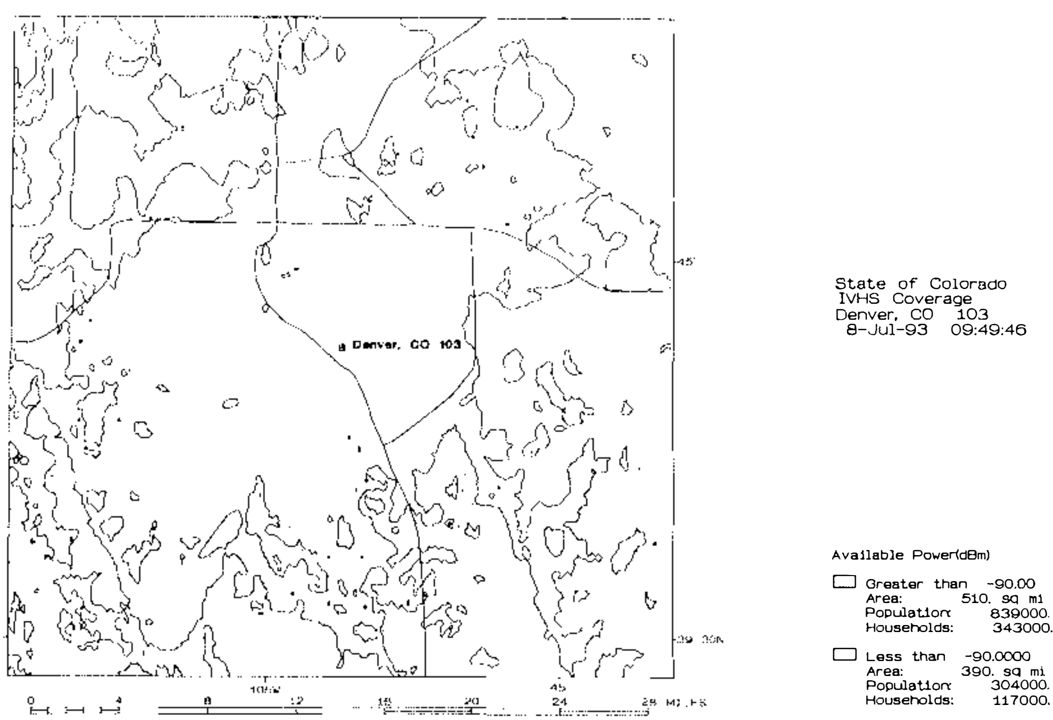

FM Radio Subcarrier Coverage of one station in Denver, Colorado

Satellite Studies

Outputs

- Simulation model for hybrid satellite/terrestrial network performance
- ACTS system performance measurement plan
- Survey of network management concepts, standards, and products
- Conference presentation and report section on satellite/terrestrial interface technology

The Institute conducts satellite studies in several related areas. An integrating objective of this work is to define the role advanced satellite systems should play in future Broadband Integrated Services Digital Networks (B-ISDNs).

Hybrid Satellite/Terrestrial Broadband Network Simulation. The Institute has developed a computer simulation model to be used in promoting effective integration of advanced satellite systems with high-capacity terrestrial systems in future broadband ISDNs. Unique features of the model include the ability to simulate networks with many nodes and to aggregate traffic (individual calls) in order to maintain reasonable computer run times. FY93 work focused on documenting the simulation model and exercising it in trial applications. Staff members developed a user guide and a detailed description of the model's software implementation; defined topologies representative of traffic patterns for simulated 10- and 20-node network configurations; and computed blocking grade of service (BGOS) values in several simulations of each configuration. BGOS values were calculated for the network and time-averaged as illustrated in Figure 1. Simulations also were developed to test performance of the call aggregation technique. The Optimized Network Engineering Tools (OPNET) software package has provided the development environment and simulation engine for this work. This object-oriented approach utilizes finite-state-machine process models to provide a high degree of flexibility in modeling. Example process models generating traffic and routing traffic are shown in Figure 2.

Network Management Studies. As telecommunications technology enters the era of broadband multimedia services, users and providers require much more flexible and powerful capabilities for service selection and facilities control. Network management is the technology that provides these capabilities. During FY93, the Institute completed a survey report that presents a general explanation of network management technology, describes the many organizations that participate in the development of network management standards, and examines the functional characteristics of representative network management products. It is expected that this survey will become the basis for future work to define and develop network interface and management standards to accommodate advanced, hybrid networks.

Advanced Satellite Communication Performance Measurements. The National Aeronautics and Space Administration (NASA) has developed the Advanced Communications Technology Satellite (ACTS) to maintain and enhance U.S. leadership in satellite communications. The ACTS technologies include demand assigned multiple access (DAMA), scanning and hopping spot-beam antennas, on-board baseband processing, and adaptive forward error correction to mitigate atmospheric and rain attenuation. The satellite was successfully launched by NASA's Space Shuttle in September of 1993; it will be used in various demonstrations and experiments throughout FY94 and FY95. The Institute hosts one of several regional ACTS earth stations and is a principal ACTS experimenter. During FY93, Institute staff members installed the NASA-supplied low bit rate (LBR) earth station at the Boulder Laboratories and completed plans and equipment development for a comprehensive ACTS system performance assessment experiment. The Institute is using two ITS-developed American National Standards as the basis for its performance assessment experiment: ANS X3.102 (User-Oriented Performance Parameters) and ANS X3.141 (Measurement Methods for User-Oriented Performance Evaluation). Figure 3

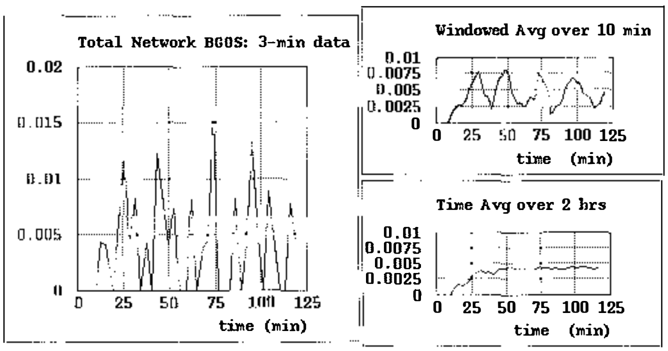

Figure 1. Blocking grade of service (BGOS) for a 10-node network showing 3-min, 10-min, and 2-hr average results.

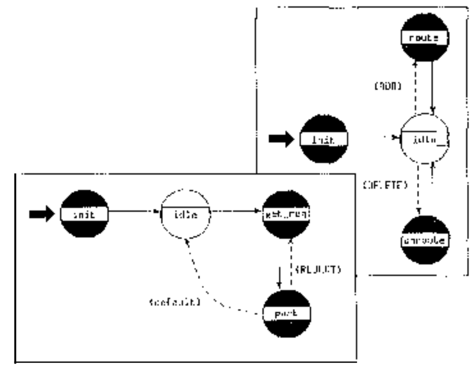

Figure 2. Process models for the traffic manager (left) and network controller (right); parts of the aggregate traffic computer simulation for circuit-switched networks.

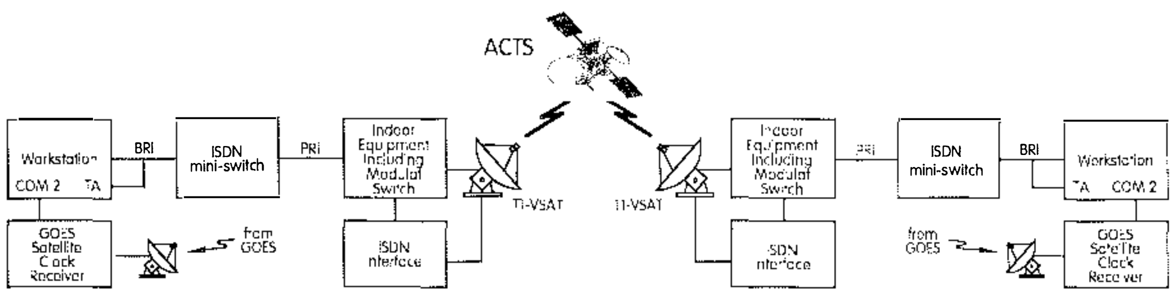

Figure 3. Equipment required to measure performance parameters for ACTS.

shows the equipment configuration that will be used in our ACTS performance assessment experiment.

Satellite Communications Technology Evaluation. A twelve-member panel of experts was organized by the National Science Foundation (NSF) to perform a comprehensive evaluation of satellite communications technology world-wide. The Institute was invited to participate in the panel with responsibility for evaluating terrestrial/satellite network interface technology. The panel members visited technology centers throughout the World in FY92. The Panel's conclusions were presented at a public conference in February 1993; the Final Report was issued in July 1993. Conclusions covered nearly 20 key communications satellite technologies. The Panel's subjective assessment is that the U.S. leads in five of these technologies, but lags in another nine. The technology of particular interest to the Institute's satellite studies is the satellite/terrestrial interface. Based on the Institute's studies, it appears that very little work is currently being conducted anywhere in the world to ensure timely development of interface capabilities for broadband, hybrid networks. Institute research will be directed towards fulfilling this need.

Recent ITS Publications

Contribution to JTEC/WTEC Report on Satellite Communications Systems and Technology World-wide (co-authored by Jennings)

Network Management: A Review of Emerging Concepts, Standards, and Products (by Jennings, Linfield, and Meister)

Characterizing ACTS for the User (by Weibel)

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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 databases are updated as new data and methodologies are developed by the Institute's engineering and research programs.

The current on-line terrain data base has a resolution of 3 arc-seconds (90 meters); the 1990 census data is incorporated. Other Government databases 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 send 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 database according to user-specified search parameters of location and search distance.

TVFIND, AMFIND, and TOWERFIND - These programs are similar to FMFIND in that they return the parameters for the respective TV, AM, or tower assignments/data according to the user- specified search locations and distances.

INMOD - This is a comprehensive 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 database of terrain elevations in various parts of the world. The data resolution is 3 arc-seconds (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 U.S. using the digitized topographic data. It is generally used for sighting of satellite terminals and radars so that 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 U.S. using the digitized topographic data. It shows clear areas that are line-of-sight to the base of the antenna, grey areas that are line-of-sight to the top of the antenna, and black 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 - The 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 that can either be FAXed directly to the user or be plotted in brilliant colors on clear plastic to a specified scale for overlying 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 U.S. and determining the population covered by at least one of these stations.

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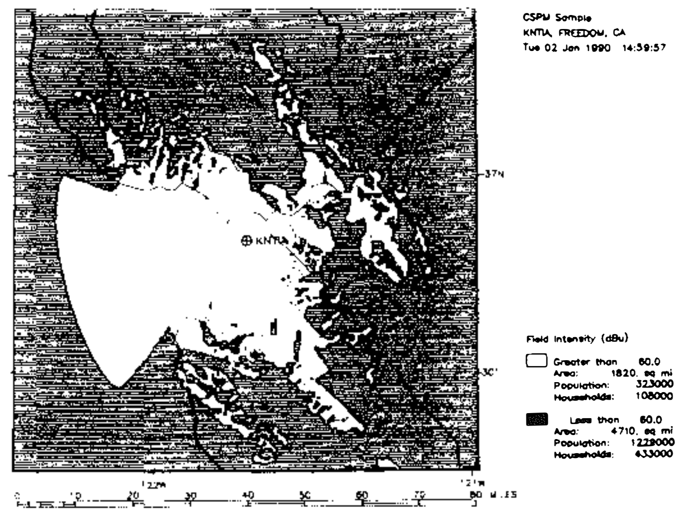

Example of TV Station Coverage Calculated Using CSPM

Advanced Systems Planning

Outputs

- Telecommunication Planning Support for Eastern Region, U.S. Forest Service
- Telecommunication 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. ITS provides advanced systems planning services to assist user organizations in analyzing their telecommunications needs -- and selecting systems that will meet those needs within budgetary and policy constraints.

Examples of the telecommunication system planning activity are two ongoing projects for the USDA Forest Service. The first project, described below, will develop a national strategic telecommunications plan for the entire organization. The second project uses the guidance formed by the national plan to develop a regional strategic telecommunications plan and individual tactical telecommunications plans for each National Forest within the region. The purpose of strategic planning is to provide a framework for incremental action (the tactical planning) 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.

U.S. Forest Service National Strategic Telecommunications Plan In 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 a 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 ensure that the selected telecommunications 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 National 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.

Task 4 Review existing systems to establish a baseline understanding of Forest Service "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."

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.

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.

The process began with a visit by an ITS team to each of these Forests. They conducted interviews with telecommunications system users to determine their requirements for voice, data, video, and radio communications, and to gather their ideas for using telecommunications to improve the way they do business. The team also inventoried the present Forest radio network, telephone system, and data network equipment. Interviews of the users on the quality of their telecommunications service and measurements of the radio equipment performance were also conducted.

From the visits, ITS will develop the a 10-year Regional Strategic Telecommunications Plan in concert with the development of the Forest Service National Strategic Telecommunications Plan. Work has also begun on tactical plans for each of the Eastern Region 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.

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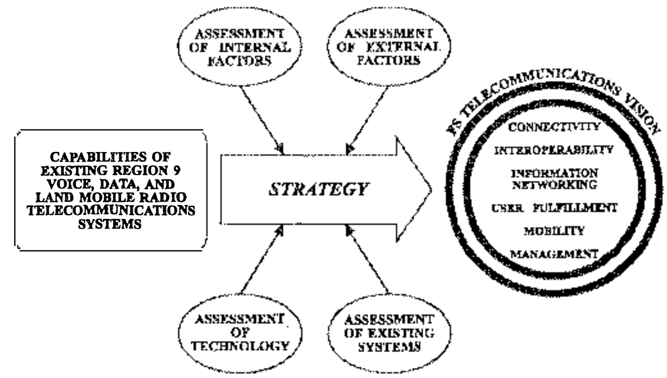

A systematic approach to telecommunications planning and realizing an agency's telecommunications goals.

Assessment of Telecommunications Dependence on Foreign Sources

Outputs

- Evaluation of Class 5 switching equipment
- Identification of component and material vulnerabilities
- Analysis of factors that affect U.S. dependence on foreign sources

The telecommunication industry plays a critical role in assuring the Nation's ability to maintain continuity of Government and essential private sector functions in the face of National Security or Emergency Preparedness (NS/EP) challenges. The National Communications System (NCS) is the Federal Government's primary agent for developing and executing the Nation's NS/EP plans. In support of NCS, the Institute is studying the extent and nature of U.S. dependence on foreign sources for telecommunications systems and components that could affect U.S. telecommunications capabilities in an NS/EP scenario. The work involves both identifying current system and component dependencies and developing mechanisms for assessing ongoing and long-term dependence.

The Institute's FY93 efforts focused on assessing U.S. dependence on foreign components, assemblies, subassemblies, and raw materials used in the manufacture of Class 5 telecommunications switches. The study methodology involved analysis of published data and interviews with representatives from a number of U.S. companies. (The interview results are not identified with particular companies to enable a more complete presentation of the findings.) The study distinguished two general categories of dependencies for consideration: dependencies on foreign suppliers for switch components themselves, and dependencies on foreign suppliers for raw materials and technology used in the manufacturing of such components. In each category, a product was identified as dependent if over 50 percent of the product was obtained from foreign sources by at least one U.S. company. The identified components and materials are listed below in descending order of percent of product obtained from foreign sources.

Category 1. Dependence on foreign sources for Class 5 switch equipment components.

a. Printed circuit board (PCB) mounted transformers
b. Plastic-coated relays
c. PCB assemblies
d. Ceramic packages used for ruggedized semiconductor components
e. Bare PCBs (fiberglass substrate)
f. Ferrite products
g. Semiconductors (high-capacity memory chips and microcontrollers).

Category 2. Dependence on foreign sources for materials and technology used in the manufacture of Class 5 switches.

a. Consumables (petrochemical-based items such as solvents, solder paste, adhesives, etc.)
b. Raw silicon (silicon ingots or wafers)
c. Manufacturing process equipment (primarily for the microelectronic manufacturing process)
d. Photolithography equipment and technology
e. Metals (such as copper, aluminum, gold, silver, and zinc).

A global source analysis, derived from data collected during this study, is shown in the figure on the facing page. The actual proportion for each segment of the graph varies company by company. The foreign sources examined in this study are concentrated in the 'Pacific Rim' area.

Foreign source dependencies in the areas discussed in this study are generally a result of a U.S. company's inability to compete with foreign companies. A conspectus of the reasons why U.S. companies are not able to compete follows.

Technology outflow. This is commonly referred to as "technology giveaway." A number of examples can be cited illustrating the acquisition of key U.S. technologies by organizations outside the U.S., leading to subsequent U.S. dependencies on these organizations for manufacturing materials.

Environmental concerns. Many of the countries that are competing successfully (offering components at lower cost) do not have the same restrictions for toxic waste disposal, disposal of solvents and other chemicals, safety of employees, etc. that increase the cost of doing business in the U.S. The additional costs must be reflected in the price of the product.

Tax laws. Most companies operating in countries outside the U.S. are subject to more favorable tax depreciation policies than companies in the U.S.

The "hot toy" problem. Commercial products have become increasingly more "high-tech," and frequently use the same type of electronic devices (e.g., microprocessors, memory chips, digital signal processors, and displays) that are used in the latest technology telecommunications equipment. The increased demand for these electronic devices can result in shortages in materials needed for telecommunications equipment manufacturing.

Some of the foreign-sourced items, discussed previously, (e.g., some types of consumables, raw materials, and precious metals) can be critical to the manufacturing process of other items within the telecommunications infrastructure. For example, components such as copper wire, aluminum cable sheath, telephone poles, dies used to color parts within cable, and the polyethylene used for the cable sheath, all require foreign-sourced raw materials.

The manufacturing process of many of the components listed above are dependent on raw materials that are petrochemical based. For example, petrochemicals are used to formulate the creosote used to treat telephone poles (to retard decay of the wood). Zinc is an important raw material required in the process of galvanizing the mounting hardware for supporting utility cables on the pole.

An item as simple as a telephone pole can be a "show stopper." A recent example illustrates this point: the Regional Bell Operating Companies (RBOCs) providing service in the geographic area affected during Hurricane Hugo (along the East Coast in 1990) experienced shortages of telephone poles and the associated hardware. The hurricane traversed through three RBOCs as it passed up the coast. The first RBOC affected placed replenishment orders for telephone poles, depleting the supply. Subsequent orders to suppliers required production of more poles, resulting in a depletion of the creosote used to treat the poles. As the chain of events progressed, the resulting shortage was that of petrochemicals to manufacture the creosote. This story illustrates the complexity of the supply chain and the difficulty in identifying possible foreign source problems.

A final report for this project was delivered to the sponsor in January 1993 and published by NCS as a Technical Information Bulletin (TIB 93-5).

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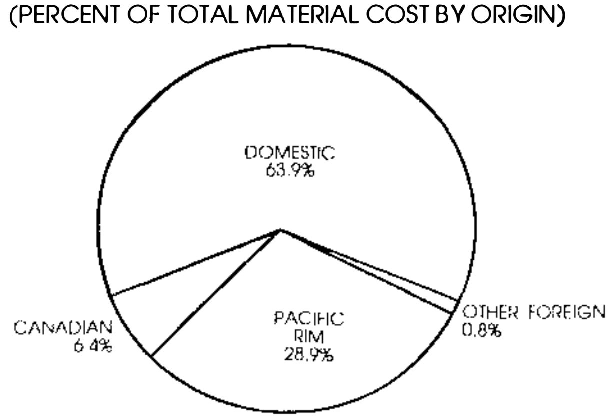
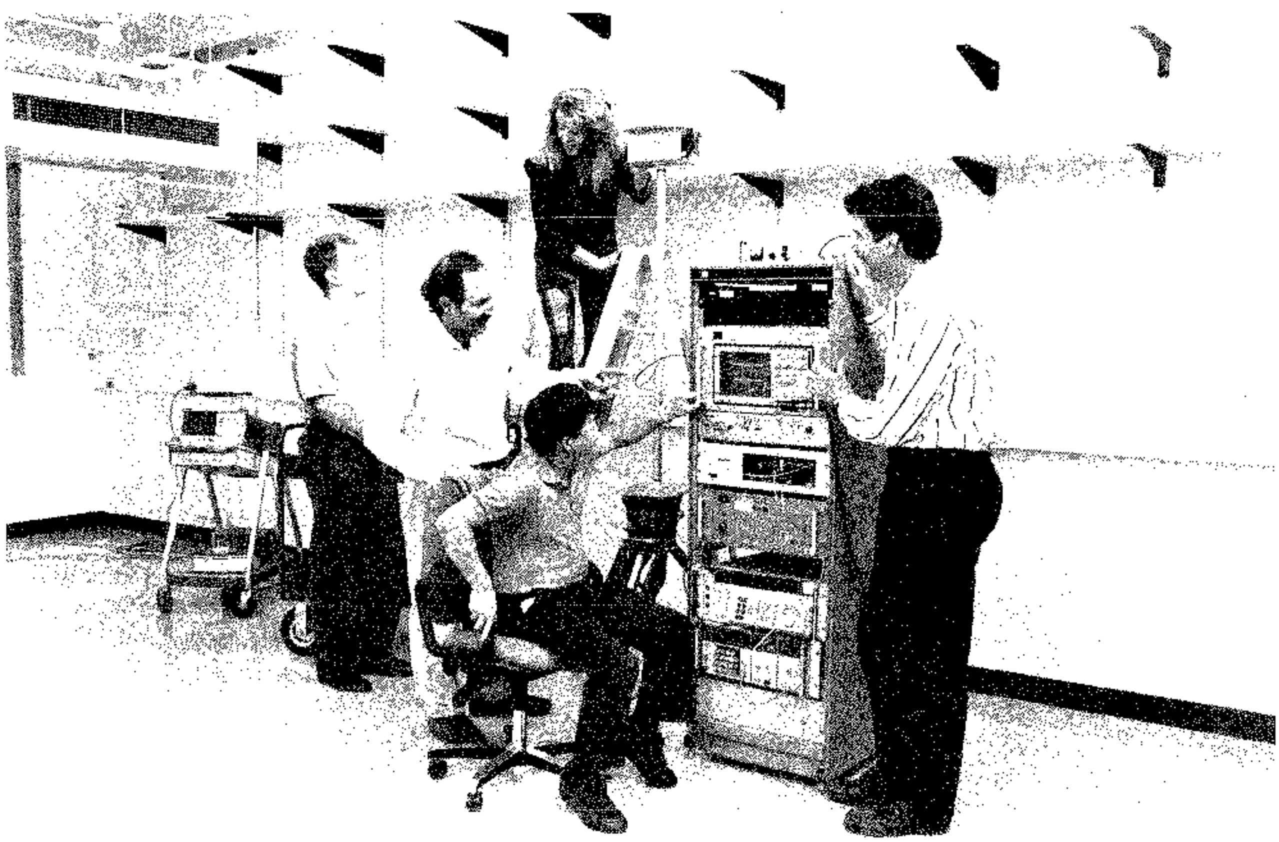
GLOBAL COMPONENT SOURCING - SWITCHING
(PERCENT OF TOTAL MATERIAL COST BY ORIGIN)





Millimeter-Wave Radio Channel Impulse Response Probe Testing

APPLIED RESEARCH

The rapid growth of telecommunications over the last 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 on the lowest frequencies (LF noise measurements) to the highest frequencies in use (millimeter-wave modeling).

This work extends ITS' expert understanding of the ways that propagation of radio signals is affected by the propagation medium, made up of the earth's surface, the atmosphere, and the ionosphere. It is resulting in new propagation models for the broadband signals used in some of the new radio systems. Other efforts are increasing our understanding of the 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 NTIA, the U.S. Army Communications-Electronics Command, the U.S. Army Atmospheric Science Laboratory, the Federal Highway Administration, and the Department of Defense.

PCS Measurements

Includes projects funded by NTIA, US West Advanced Technologies, Inc., and Bell Atlantic Mobile Systems.

Radio Channel Modeling and Simulation

Includes projects funded by NTIA, U.S.Information Agency-Voice of America, and the Department of Defense.

Wireless Local Area Network Research

Includes projects funded by NTIA.

Cooperative Research with Industry

Includes projects funded by US West Advanced Technologies, Inc., and Bell Atlantic Mobile Systems.

Millimeter-Wave Propagation Models

Outputs

- Millimeter-wave Propagation Model, MP
- Radio Path Model, RPM
- Zeeman Propagation Model, ZPM

The increasing sophistication and complexity of modern millimeter-wave systems requires an accurate and comprehensive description of the propagation medium. Depending on the functional system principle (active, passive), propagation phenomena affect and often limit the overall performance.

The Millimeter-wave Propagation Model, MPM, predicts the propagation characteristics (attenuation and delay rates) of a nonprecipitating atmosphere for frequencies below 1000 GHz. Central to MPM predictions are complex refractivity spectra **N** of the main natural absorbers (i.e., oxygen, water-vapor, suspended droplets). They are computed from known meteorological data; i.e., barometric pressure (10^{-5} to 1013 mb), ambient temperature (-100 to 50 °C), relative humidity (0 - 100%), and water droplet or ice particle density (0 - 5 g/m^3). Spectra of 44 O_2 , 34 H_2O lines, and of nonresonant spectra are considered. All have been updated with new spectroscopic information. Continuum contributions from the H_2O line spectrum above 1000 GHz are approximated by the wing response of a strong pseudo-line centered at 1800 GHz. Typical examples of the attenuation rate for saturated air at sea level are plotted in Figure 1. Cloud/fog effects are treated with the Rayleigh approximation employing revised formulations for the permittivities of water and ice.

A spherically stratified atmosphere serves as the Radio Path Model, RPM, to evaluate cumulative transmission and emission properties. The model atmosphere consists of concentric layers extending in 1-km increments from 0 to 130 km. Values for **N** are enumerated via height profiles of air and water vapor densities. The U.S. Standard Atmosphere and a mid-latitude mean water-vapor profile are the defaults for RPM. Figure 2 illustrates for various zenith paths (default case) the attenuation behavior up to 340 GHz.

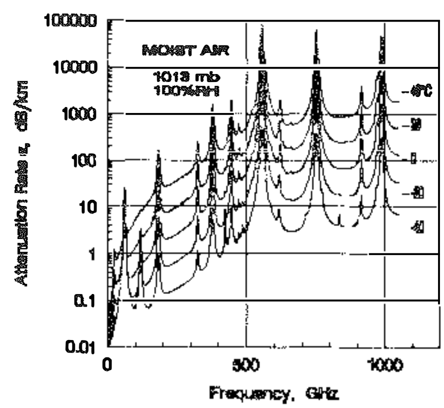


Figure 1. Attenuation rate of saturated air at sea level pressure (MPM).

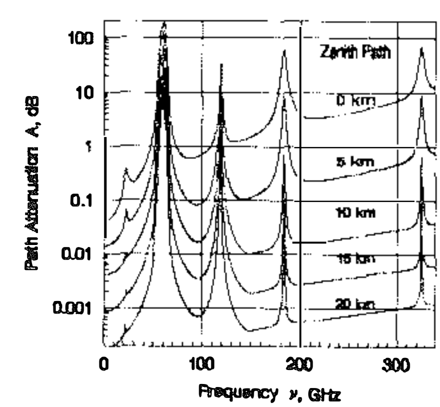


Figure 2. Zenith path attenuation for U.S. Standard Atmosphere from 0, 5, 10, 15, and 20 km (RPM + MPM).

The absorbing atmosphere emits noise radiation at the equivalent blackbody temperature, T_B, which is computed by means of numerical integration over the specified path. Decreasing transmission leads to increasing emission.

The Zeeman propagation model, ZPM, considers the influence of the Earth's magnetic field (20 - 65 μT) on O_2 absorption lines below 120 GHz. Anisotropic medium properties exist at altitudes between 30 and 120 km. To model those, more variables have to be introduced to

a) mark the coordinates of the starting point for a ray path:

height above sea level	h	≤ 1000 km (satellite or shuttle orbit) (absorbing atmosphere from 0 to 130 km)
latitude	L	90° (north pole)→ 0° (equator)→ -90° (south pole)
longitude	LO	0° (Greenwich), +180° (east), -180° (west);

and b) describe the radiowave polarization and its propagation direction:

initial polarization	POL	HL, VL (linear) and RC, LC (circular)
azimuth	AZ	0°(north)→ 90°(east)→ 180°(south)→ 270°(west)
elevation	EL	>0°: ↑ (up), 0°: → (horizontal), <0°: ↓ (down).

The elements of a complex refractivity tensor are evaluated in the vicinity (±10 MHz) of the O_2 line centers for their effects on the propagation of plane waves. ZPM predicts polarization- and direction-dependent effects through the mesosphere. Cumulative attenuation near a 61-GHz O_2 line is shown in Figure 3 for two limb path geometries looking down from h = 300 km at the equator and at 57°N.

Emission spectra of the 9^+ line (61150 ± 3 MHz) for paths with tangential heights ranging from 20 to 125 km are consistent with data measured by the shuttle-based millimeter-wave limb sounder MAS flown in March 1992 on the ATLAS I mission. Their analysis is an ongoing cooperative effort with the Max-Planck-Institute for Aeronomy, Germany.

Recent ITS Publications

Atmospheric 60-GHz Oxygen Spectrum: New Laboratory Measurements and Line Parameters, (by Liebe, Rosenkranz, and Hufford).

Progress in Atmospheric Propagation Modeling at Frequencies Below 1000 GHz, (by Liebe, Hufford, and Cotton).

Propagation Modeling of Moist Air and Suspended Water/Ice Particles at Frequencies Below 1000 GHz, (by Liebe, Hufford, and Cotton).

For information, contact:
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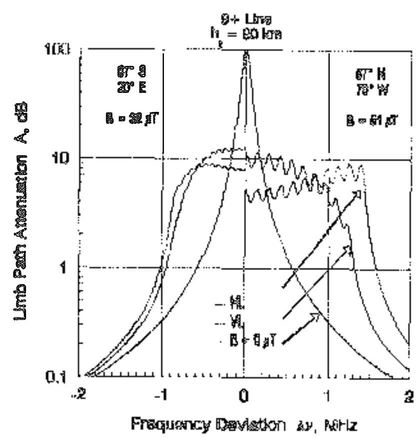


Figure 3. Path attenuation of linearly polarized waves near the 9^+ O_2 line.

Personal Communication Services Measurements

Outputs

- Utilization of a newly developed digital sampling channel probe for impulse response measurements
- Impulse response measurements in the 902-928 and 1850-1990 MHz bands in various macrocellular environments
- Narrowband building penetration measurements at 912, 1920, and 5990 MHz

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. PCS measurements play an important role in providing much of this information.

The primary work in PCS measurements at the Institute this year has been the utilization of a newly developed digital sampling channel probe in performing impulse response measurements. This probe was developed as a joint effort between ITS and Telesis Technology Laboratories, Inc. (TTL) and consists of a separate transmitter and receiver section. A patent is currently pending on this system. The probe is ideal for making outdoor impulse response measurements to characterize wideband propagation in the radio channel. The system currently has the capability of transmitting two different PN codes at a 10-Mbit/s rate. These codes can be transmitted on different carrier frequencies, with different antenna polarizations, or with different antenna spacings. The resulting signal bandwidth of each code is 20 MHz with a delay resolution of 100 ns. The maximum measurable delay is 51 μs.

A personal computer is used to control the dual-channel receiver. The dual-channel design allows different carrier frequencies, different antenna spacings, or different antenna polarizations to be implemented at the receiver as well as at the transmitter. The system has a processing gain of 27 dB with a receiver noise figure of approximately 8 dB. Impulse responses are measured simultaneously on each channel.

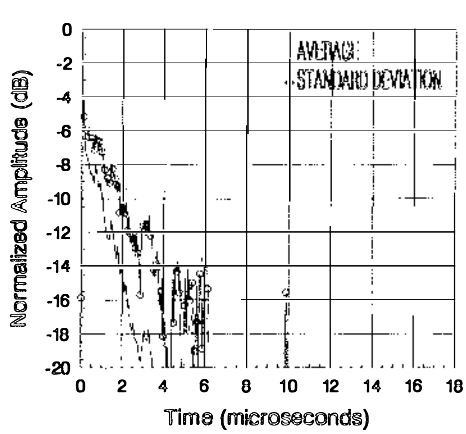
A PCS propagation experiment using the digital sampling channel probe was conducted to measure impulse responses in the 902-928 and 1850-1990 MHz bands simultaneously. The measurements were taken in four different macrocells (with radii ranging from 3 to 11 km) in the Philadelphia, PA area. The cells were chosen to represent typical semi-rural, suburban, urban, and urban high-rise environments. Measurements were taken in all four cells using vertically polarized transmit and receive antennas. In the suburban and urban high-rise cells, measurements also were taken using circularly polarized transmit antennas (the receive antennas were vertically polarized).

The measurements were made with the transmitter placed at existing cellular base station sites and the receiver located in a measurement van. Several different types of calibration and system verification procedures were performed to ensure optimal system operation. Impulse response data were recorded in the 902-928 and 1850-1990 MHz bands simultaneously as the measurement van travelled along predetermined routes within each cell. The routes were chosen to provide a representative characterization of the propagation behavior in each cell.

The impulse response data were analyzed to provide RMS delay spread (see table), correlation bandwidth, and various other multipath power statistics (see figure). The results of this data analysis provided a comparison of wideband propagation between the two frequency bands, the two transmit antenna polarizations, and between the different cell types. Major differences in the propagation behavior between the two frequency bands were not seen. The urban high-rise cell exhibited the most multipath, showing higher power and more delayed signals with longer delays than in the other cells. Propagation behavior in the suburban and urban cells was very similar. The semi-rural cell, however, displayed more multipath than the suburban and urban cells, probably due to hilly terrain (in the semi-rural cell). An improvement in propagation (less multipath) was seen when using the circularly polarized transmit antennas instead of the vertically polarized ones for 1920 MHz. This trend was not apparent for 915 MHz. These results suggest that the detrimental effects of multipath propagation may be reduced by using circular polarization in place of vertical polarization in the transmit antennas of a PCS system operating in various macrocellular environments. Additionally, the results suggest that these benefits obtained by changing the transmit antenna polarization may be more significant for 1920 MHz than for 915 MHz. Further polarization studies are recommended to investigate these possible benefits.

Comparison of RMS Delay Spread Values Exceeded (in μs) for 1920 MHz

Cell Type/Antenna Polarization	Probability of Exceeding RMS Delay Spread		
	0.5	0.2	0.1
Semi-Rural/ Vertical	0.14	0.30	0.50
Suburban/ Vertical	0.12	0.25	0.35
Suburban/ Circular	0.09	0.19	0.27
Urban/ Vertical	0.14	0.31	0.41
Urban High-Rise/ Vertical	0.65	1.00	1.21
Urban High-Rise/ Circular	0.53	0.78	1.01



Average and standard deviation of multipath power in an urban high-rise cell for 1920 MHz

A series of narrowband building penetration measurements were recently completed. These measurements were made in and around buildings in residential and urban high-rise environments. The transmitter was set up outside of the buildings and the receiver moved to various locations inside and around the outside of the buildings. Vertically polarized omnidirectional antennas were used at the transmitter and receiver. Received signal levels were recorded simultaneously for 912, 1920, and 5990 MHz. These data will be analyzed to provide a characterization of building attenuation for the different building types at the different frequencies. The results of the data analysis will be used to determine if, and to what extent, outdoor base stations can provide PCS coverage inside buildings.

Recent ITS Publications

Inpulse Response Measurements in the 902-928 and 1850-1990 MHz Bands in Macrocellular Environments (by Wepman, Hoffman, Loew, Tanis[Bell Atlantic Mobile], and Hughes[Bell Atlantic Mobile])

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

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

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HF Channel Modeling and Simulation

Outputs

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

Advanced high-frequency (HF) communication systems that operate over wide bandwidths (on the order of 1 MHz or more) are being developed, motivated by the application of spread spectrum technology to HF systems and by the development of new digital signal processing techniques. Many uncertainties exist concerning the performance of wideband HF systems. Channel simulation enables one to evaluate the performance of communication equipment without the time and cost of extensive field testing. However, the development of a channel simulator requires a model that accurately describes the real-world communication conditions.

Laboratory testing of HF radios in the past has employed channel simulators that implement a narrowband model of the HF channel. This model has only been verified for narrowband (less than 12 kHz) stable channels. The Institute has developed a wideband (1 MHz) HF channel model that overcomes many of these restrictions. 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.

A significant recent addition to the channel model has been the development of a model of the atmospheric noise waveform. Atmospheric noise is often characterized by the amplitude probability distribution (APD), which is a cumulative distribution of the received noise envelope. Figure 1 shows a family of APD's for atmospheric noise that has been specified by the International Radio Consultive Committee (CCIR), now the ITU-R, based upon measured data. The different curves correspond to different values of the voltage deviation parameter, which is the ratio of the root-mean-square and the average values of the noise envelope. Figure 2 shows a family of APD's generated from simulated waveforms using the atmospheric noise model. The in-phase component of the voltage of a simulated waveform, sampled once per millisecond over a time interval of 16 seconds, is plotted in Figure 3. The waveform shows the clustering of noise pulses that is characteristic of atmospheric noise. It is consistent with measured data.

A real-time hardward channel simulator that implements the new HF channel model has been developed by the Institute. This has been achieved by custom circuitry designed and built by Institute personnel, and state-of-the-art digital signal processing hardware. The simulator is being used by private industry to test 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 HF communication systems and networks. A second-generation simulation system is currently being developed to operate over larger bandwidths (on the order of 4 MHz) to simulate Personal Communication Services channels.

Recent ITS Publications

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

A New Atmospheric Noise Model and its Implementation in a Real-Time Signal Processing System (by Mastrangelo)

For information, contact:
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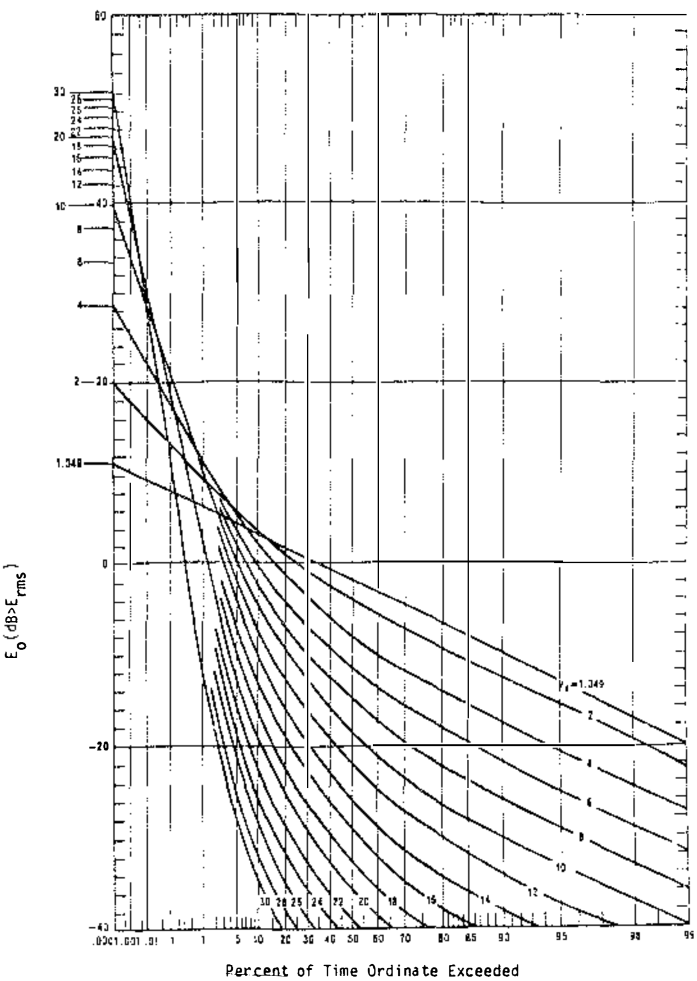


Figure 1. CCIR Report 322 set of amplitude probability distributions of atmospheric radio noise for various V_d values.

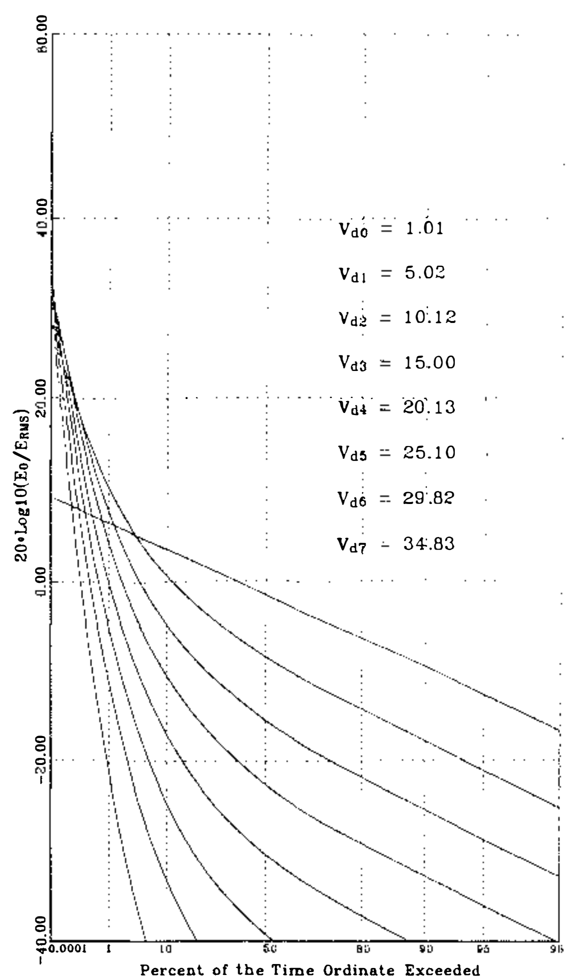


Figure 2. Set of amplitude probability distributions of simulated atmospheric radio noise for various V_d values.

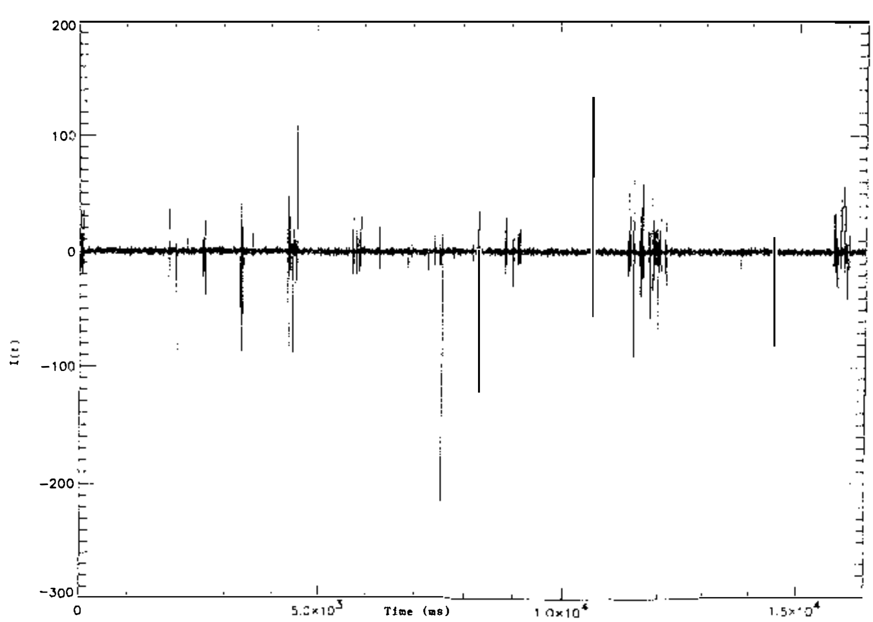


Figure 3. Sixteen seconds of the in-phase component of a simulated atmospheric noise waveform.

Indoor Propagation Measurements

Outputs

- Indoor impulse response measurements
- Indoor radio channel models
- Indoor digital modem hardware and software simulation

Many new emerging radio technologies promise convenience and increased productivity in the workplace. 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, which is highly variable because of the diversity of building types and furnishings. It is necessary to understand the indoor radio channel in order for these systems to be effectively developed and regulated. ITS has undertaken research on indoor radio propagation in order to provide this fundamental knowledge.

Walls, floors, and ceilings limit radio performance by reducing radio coverage and introducing dispersion. Radio coverage can be increased by boosting the signal-to-noise ratio (SNR). 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. Wideband digital signals suffer intersymbol interference (caused by the delay spread) resulting in bit errors. Methods such as direct sequence spread spectrum, frequency hopping, angular and/or spatial antenna diversity, and channel equalization are used to mitigate the frequency selective fading and intersymbol interference of the indoor radio channel.

Accurate models and measurements of the indoor channel are needed in order to predict the impact of multipath and to better plan, design, and deploy indoor systems. At ITS, indoor channel multipath is measured with a wideband channel probe. The channel probe uses the pseudo-random-noise, sliding correlator technique, providing an excellent SNR 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.

In FY92, ITS completed an initial set of indoor radio propagation measurements. Measurements of the channel impulse response were made with a wideband channel probe in three indoor environments: a long hallway, an auditorium, and an open, soft-partitioned office space. The center frequency of the measurements was 1.5 GHz. In FY93, ITS made additional measurements in a warehouse environment with roughly the same dimensions as the soft-partitioned office area. This allows a comparison of the channel between similar-sized indoor environments with different furnishings. Measurements of the warehouse were conducted at frequencies of 1.5 and 5.8 GHz. A frequency of 5.8 GHz was chosen to support the movement to higher frequencies and to provide support for U.S. companies that would like to enter the European "HIPERLAN" market.

The warehouse was measured two distinctly different ways. For the first method, the measurements were taken with a corner-mounted, stationary terminal and a mobile terminal that was pushed through the measurement area. Impulse response measurements were made every fifth of a wavelength over 8 paths that were evenly distributed over the 70- by 70-foot warehouse room. The second method adds angle of arrival and polarization information to the channel impulse response measurement. This new technique uses a corner-mounted, vertically polarized receiver antenna and a directional antenna mounted on the mobile transmitter. At selective points throughout the room, 12 impulse response measurements are made at six distinct azimuths (0, 60, 120, 180, 240, and 300 degrees) with both horizontal and vertical polarizations. These data will be directly useful for simulations studying the effects of angle and polarization diversity.

The indoor channel measurements are used to support modeling and simulation efforts at ITS. The indoor channel can be modeled geometrically or statistically. A geometric model must take into account building architecture and reflection, refraction, and diffraction phenomenon. The geometric model is useful in understanding the fundamental principles of indoor propagation. It also provides repeatable results and allows the user to easily study the effects of different antenna types and placement. Channel measurements are used to verify results of the geometrical model.

Statistical models provide a well-defined description of the radio channel that can be used for analytic studies of the wireless system. The probability densities of random variables such as time delay, phase, and gain of the paths can be used to derive bit and frame error rates. Channel measurements taken by ITS can be used to construct the statistical models.

Software simulation is useful for studying complex systems that are difficult to subject to analysis. Software simulation is generally used in initial system design and debugging. At ITS, engineers are using off-the-shelf simulation packages to predict the performance of various common air interfaces in the indoor multipath channel. Performance prediction is also being performed with custom software written in Fortran and C languages. In both cases, the indoor channel measurements are used to provide realistic channel information. In FY93, the measurement results from the soft-partitioned office environment were used to predict the performance of direct-sequence spread spectrum modems using Binary Phase Shift Keying for data rates from 0.9 to 14 Mbps. The figure below shows the probability of bit error (Pe) as a function of position over a 25-meter-long office isle.

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 ITS channel measurements are being used to compare various common air interface proposals. These channel measurements are also available to the public on magnetic media.

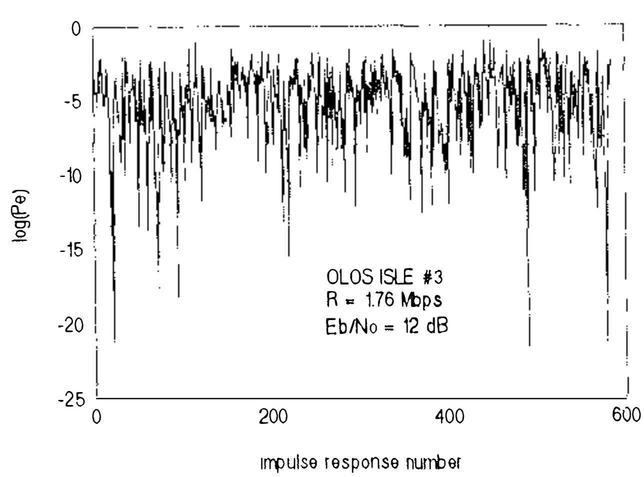
<u>Recent ITS Publications</u>

Modeling the Wideband Channel Impulse Response (by Achatz)

Indoor Wideband Propagation Data (by Achatz, Papazian, and Roadifer)

Complex Impulse Response Measurements of a Warehouse (by Achatz, Lo, and Koverman)

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



Probability of bit error (Pe).

Cooperative Research with Industry

Outputs

- Patent application for the Digital Sampling Channel Probe
- Simultaneous measurements of the channel impulse response at 900 and 1900 MHz for urban/suburban macrocells
- Simultaneous measurements of building penetration loss at 912, 1920, and 5990 MHz
- Broadband propagation measurements at 30 GHz for Local Multipoint Distribution Services

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 for a number of years in Cooperative Research and Development Agreements (CRADA) with private sector organizations. Research has been conducted under agreements with Bell South Enterprises, Telesis Technology Laboratories, US WEST Advanced Technologies, and Bell Atlantic Mobile Systems.

The 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 interests are protected. CRADAs also provide protection for inventions and allow the private partner to hold an exclusive license on a Government-owned patent.

Much of the Institute's work in Personal Communication Services (PCS) has been accomplished through CRADAs. 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 in earlier years, ITS was able to study spectrum resources and the availability of propagation models for PCS in a cooperative effort with BellSouth Enterprises before Federal funding was available for such work.

Another example from earlier years is the opportunity that ITS has had to share in and contribute to a comprehensive PCS technology development program with Telesis Technology Laboratories, Inc. (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 an innovative impulse response measurement system called a Digital Sampling Channel Probe. This system allows the measurement of the complex valued radio channel impulse response in less than 51 µs. A portion of a measured impulse response is shown here. Repeated measurements can be spaced as closely in time as every 51 µs. The maximum measurable delay spread is 51 µs. The impulse resolution is 100 ns and the interval of discrimination (the difference in signal level from the peak impulse value to the correlation noise floor) is better than 50 dB. The bandwidth is 20 MHz and the noise figure is 8 dB. A joint patent application has been filled as a result of this work.

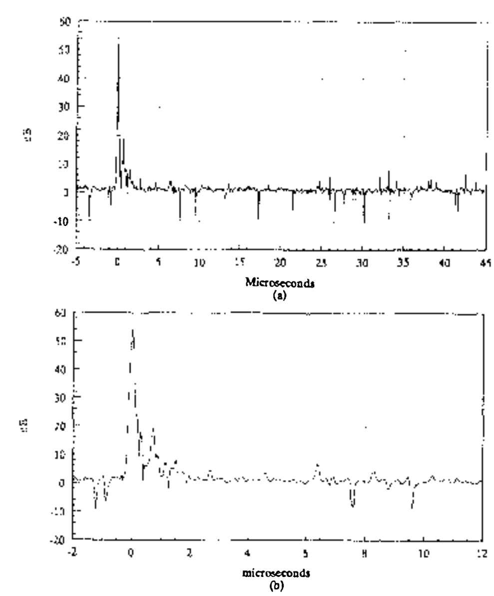


Figure 1. ADP of cell 44 (a) -5 to 45 microseconds, (b) -2 to 12 microseconds.

This year, Bell Atlantic Mobile Systems and ITS cooperatively measured channel impulse responses in the 902-928 and 1850-1990 MHz bands. Simultaneous measurements were made using a dual channel version of the Digital Sampling Channel Probe. Mobile measurements were made along streets, roads, and highways in four different macrocells (radii from 3 to 11 km) in the Philadelphia, PA, area. The cells were chosen to represent typical semi-rural, suburban, urban, and urban high-rise environments. The transmitter was placed at existing cellular base stations and the receiver was located in a van.

The data were analyzed to provide RMS delay spread, correlation bandwidth, and various other multipath power statistics. The results of this analysis were used to compare wideband propagation characteristics between the two frequency bands, two transmit antenna polarizations, and the different cell types.

Also in cooperation this year, US WEST Advanced Technologies and ITS measured the penetration loss into buildings from street microcells at 912, 1920, and 5990 MHz. The purpose of these measurements is to determine if, and to what extent, outdoor base stations can provide PCS coverage inside buildings. Measurements were made at eight private residences and four commercial urban high-rise buildings.

ITS has been a premier laboratory in millimeter-wave research for two decades. This year, ITS was able to apply this unique expertise in support of the development of commercial services using millimeter waves. Under the CRADA with US WEST Advanced Technologies, ITS made broadband measurements at 30.3 GHz to investigate the propagation characteristics important for Local Multipoint Distribution Services (LMDS). Channel impulse response measurements were made using a sliding correlator, pseudo-random noise channel probe with a 1-GHz bandwidth (500 Mb/s) and a delay resolution of 2 ns. The signal spectrum was computed from the complex valued impulse response and the frequency selective fading was examined. The amplitude of the channel transfer function showing fading across the band centered at 30.3 GHz is shown on this page.

Cooperative research with private industry has helped ITS accomplish its mission to support U.S. industry's productivity 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.

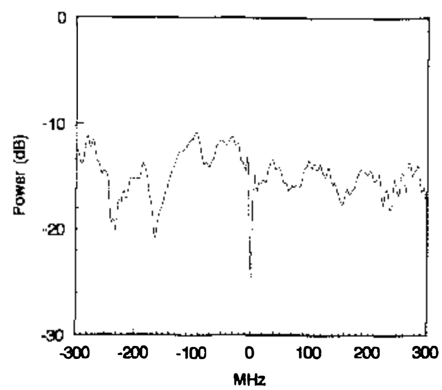


Figure 2. Transfer function of 30.3-GHz propagation channel.

To date, the cooperative research has addressed the development of radio technology for PCS or LMDS. 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, LMDS, 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.

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

PCS Radio Channel Probe Performance Examination

ITS TOOLS AND FACILITIES

Advanced Communications Technology Satellite Test Facility

ITS installed the Advanced Communications Technology Satellite (ACTS) test facility this fiscal year. Through a Memorandum of Understanding with NASA, ITS received an experimental Ka-band Earth station (ES) capable of a 1.8-Mbps data rate, ISDN communications, and full mesh connectivity with every other ACTS ES. The ACTS Test Facility also includes equipment to characterize the performance of the ACTS. The equipment includes 486-based computers, an ISDN mini-switch, ISDN Terminal Adapters, satellite clocks and modems. The ITS-supplied equipment will be used to perform a unique experiment to characterize the digital communication service provided by ACTS from the user's perspective. In addition to ITS performing its own set of experiments, the facility is also supporting other ACTS experimenters, is open for demonstrations, and is available for Government, industry, and university use given approval by the NASA ACTS Experiment Office.

An Audio Compact Disc for Testing HF Radio ALE Interoperability

Federal Standard 1045 defines sophisticated protocols and techniques for Adaptive HF radios that can perform Automatic Link Establishment (ALE). All ALE radios procured by the U.S. Government must be able to perform the mandatory features defined in this standard. This assures that regardless of vendor, all ALE radios will interoperate successfully. Each radio system must be tested to verify its feature by feature interoperability. ITS has developed a Beta test digital audio compact disc (CD) which provides the strong, clean signals needed for interoperability testing in the laboratory. The disc will be distributed to industry and Government in the first quarter of FY94. ITS will evaluate user's comments on both the concept and initial implementation of the Beta test disc in FY94. If the results are favorable, this reference interpretation and implementation of FED-STD-1045 will be widely distributed to industry and Government users as an aid to ALE radio interoperability testing. As an extension of the audio CD concept for testing ALE radios, ITS plans to provide a set of CDs in FY94 with the degraded, noisy, weak tones for performance testing. This approach makes use of the most cost-effective and accurate technology available today for reproducing sounds—the home digital compact disc player. Measurements have indicated that frequencies and timing can be better than 10 ppm on good quality disc players. Other advantages of choosing optical discs are low cost and the fact that the disc cannot be altered, thus assuring consistency among tests conducted by different users.

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 ITU-T 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 INTERNET, NREN, 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 Sampling Channel Probe for PCS

ITS, in a joint effort with Telesis Technology Laboratories, Inc. (TTL), has developed an innovative dual-channel digital sampling channel probe. The probe consists of a separate transmitter and receiver section. A patent is currently pending on this system. The probe is ideal for making outdoor impulse response measurements to characterize wideband propagation in the radio channel. The system currently has the capability of transmitting two different PN codes at a 10-Mbit/s rate. These codes can be transmitted on different carrier frequencies, with different antenna polarizations, or with different antenna spacings. The resulting signal bandwidth of each code is 20 MHz with a delay resolution of 100 ns. The maximum measurable delay is 51 μs.

A personal computer is used to control the dual-channel receiver. The dual-channel design allows different antenna spacings or different antenna polarizations to be implemented at the receiver as well as at the transmitter. The system has a processing gain of 27 dB with a receiver noise figure of approximately 8 dB. Impulse responses are measured simultaneously on each channel.

HF ALE Radio Network Simulation and Radio Simulators

ITS has developed an HF Radio Automatic Link Establishment (ALE) Radio Network simulation system. The purpose of this discrete event simulation and the supporting software is to support Federal HF Radio Standards development, to conduct research on efficient ALE network configurations, designs, and operations, to study and predict radio network performance, and to study efficient methods of network simulation. Simulation of ALE radio networks is intended to support over-the-air (OTA) tests since OTA network testing may not always be practical or cost effective. Results of network simulation studies will also be useful to HF ALE radio users, standards developers, network designers, radio manufacturers and vendors.

ITS has also developed a package of software simulators of the ALE system that correspond to the ISO OSI model. The simulators include an HF Channel simulator and an ALE Model simulator which represent the OSI Physical Layer, an ALE Forward Error Correction simulator and an ALE Protocol simulator which represent the OSI Data Link Layer, and a network protocol simulator at the network layer of the ISO OSI model. The advantage of software simulation is that each of these modules may be directly linked with other software simulation modules. The alternative is a complex and rather expensive hardware simulator which causes an increase in complexity of necessary equipment and the servicing software as well as interfaces to other software and hardware. These simulators are being used actively in developing test methodology for ALE radio systems and to test advanced ALE concepts and protocols.

HF Interoperability Test Facility

The ITS Interoperability Test Facility (ITF) was developed in FY89-90 through funding from the National Communications System (NCS). This facility continues to serve the Federal community in a dual capacity: firstly, to assist in the development of a family of Federal Standards relating to adaptive HF radio systems; and secondly, 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 between vendors.

The ITF is equipped with three portable HF channel simulators based on the internationally accepted Watterson model, several HF transceivers with FED-STD-1045 Automatic Link Establishment (ALE) modem/controllers, several broadband HF antenna systems and a suite of modern test and measurement equipment. During the past year a conical monopole and a rotatable log periodic dipole array have been installed at the ITF's Green Mountain Mesa transmitter site. The ITF possesses numerous test frequencies across the HF band and is licensed to transmit not only from the local area but from anywhere in the continental U.S. under a mobile authorization. The ITF is continuing to expand its capabilities and is adding interfaces to other transmission modes to create a multiple media test facility.

HF and PCS Channel Simulator

ITS has developed a unique capability for simulating the channel conditions encountered on high frequency (HF) communication links in order to evaluate the performance of HF radios under a variety of repeatable, controllable conditions. The channel simulator employs state-of-the-art digital signal processing technology to implement new mathematical models of the propagation, noise, and interference environments. Unlike past HF channel simulators that are only valid over narrowband (several kHz bandwidth) stable channels, the new simulator is based on a fundamentally new approach that enables the simulation of wideband (on the order of 1-MHz bandwidth) as well as narrowband channels, both disturbed and nondisturbed. ITS personnel are in the process of developing and implementing channel models relevant to personal communication services (PCS) in order to evaluate the performance of PCS radio systems currently under development.

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's surface to 120 km. This latter height provides a realistic basis to conduct experiments that are representative of satellite heights for most applications. This tool is available for use by private parties on a reimbursable basis.

Local Area Network

ITS' state-of-the art local area network (LAN) allows 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 provides electronic mail, client-server computing, and peer-to-peer services for all ITS personnel, using TCP/IP and NFS applications. Currently, the LAN operates as an IEEE 802.3 10Base-T ethernet. This ethernet supports over 160 heterogeneous computers including PCs, Macintoshes, and Hewlett-Packard, Sun Microsystems, Silicon Graphics, and Data General RISC workstations.

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. All outlets are capable of supporting 100-MHz data rates either via twisted pair, or the fiber. 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 combination of flexibility and available bandwidth allows ITS to extend its laboratory capabilities by interconnecting separate labs and equipment as needed for a particular research or test capability. For larger programs, a distributed testbed may be rapidly assembled.

Wide area connections with the ARPA Internet allow ITS personnel to exchange information with NTIA, NASA, the National Communications System, and other federal agencies, universities, and industry. If you require dial-up access, an account, or other information, please contact Darren Smith at (303) 497-3960, or dsmith@its.bldrdoc.gov.

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 microwave radios under identical conditions. This simulator was developed to perform evaluations for the Department of Defense; however, it could also be used for testing microwave radios used in the private sector.

Microwave Line-of-Sight (LOS) and Troposcatter Channel Probes

ITS uses these instruments for measuring the amount of multipath on either line-of-sight or troposcatter communication links. Multipath is the result of reflections, scattering, or 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 multipath, which is a dynamically changing quantity, 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.

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.

Radio Spectrum Measurement System

The Radio Spectrum Measurement System (RSMS) is an ITS asset which makes available broadband (0-18 GHz) measurement capabilities in a self-contained, vehicularly mounted configuration. The RSMS is used to support Federal spectrum management tasks, and as such is utilized by NTIA, other agencies, and private industry on a cost-reimbursed basis. The system capabilities are defined by a unique complement of hardware, software, and operations personnel.

RSMS measurement hardware consists of a pair of 0-18 GHz measurement systems. The systems include frequency domain, time domain, and modulation domain analyzers. Key to the system's usefulness are preselected, low noise RF front ends. The systems can be operated in fully automatic (computer-controlled), semi-automatic, and fully manual modes. Control and analysis software has been written by ITS to provide maximum usefulness for spectrum management tasks, including specialized algorithms for acquisition of emitter (e.g., radar, LMR) signatures. Remote control via telephone lines is possible. The entire system is mounted in a C-130-transportable vehicle, along with a generator, air conditioning, and a pair of 30-foot telescoping masts.

The most important RSMS capability is the expertise of the operations personnel who use the system to make measurements. A common problem with highly automated and sophisticated measurement systems is an inability to determine the quality of a measurement while it is in progress. RSMS personnel bring decades of experience to the problems of determining what measurements are required to fulfill a goal, setting up a measurement configuration which will successfully acquire those measurements, and finally assessing the quality of the measurements as they are being conducted.

Standards Database Service

ITS has developed and placed on-line a database service on telecommunication standards, available on a UNIX-based minicomputer via Internet and dial-up modem. The database uses relational database management system (DBMS) software to provide various information fields for the standards, including abstracts, key words, standards-developing authority, and ordering information. A unique feature of the database is the ability to not only search the contents to find standards by key words and titles, but also to locate closely related "families" of standards. Each family of standards addresses a common discipline, application, or type of equipment. Inter-related standards are also mutually cross-referenced to indicate, for example, that an international standard has been adopted as an American National Standard or a Federal Standard.

Following refinement of the DBMS software, the prototype database has been placed on-line with preliminary data contents of some 360 standards for user beta trials. The contents will be expanded to include a broad spectrum of telecommunication standards. The primary targeted users are those involved in acquisition. Standards-developing organizations and individuals have also expressed considerable interest in the service.

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 ITU-R 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 GB of hard disk space for storing images, and a 1.3-GB 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 system impairments on the perceived quality of voice signals. The laboratory provides facilities for the development and testing of voice quality assessment techniques. Laboratory equipment includes 80386-based workstations equipped with 16-bit analog-to-digital and digital-to-analog converters. These computer workstations provide the interface between digital signal processing algorithms and high-quality analog audio signals. A computer-controlled DAT recorder is available, as well as are an assortment of mixers, amplifiers, headphones, microphones, and monitor speakers. Computer systems are used to manage databases of subjectively rated voice signals obtained from ITU-T, COMSAT, and other industry sources. These databases are used for the development and evaluation of new objective voice quality measurement techniques. An ongoing testing program evaluates measures of voice quality that are proposed as national and international standards. Another major laboratory activity is the design and construction of specialized portable voice quality test instruments. These instruments are constructed by adding customized hardware and software to fast portable personal computers. The Voice Quality Laboratory is interconnected with the Video Quality and Digital Networks Laboratories. These connections enable the integrated testing of telecommunication systems that transport voice, video, and data.

ITS PROJECTS — FY 1993

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 — Wayne R. Rust (497-5572). 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) — Marjorie L. Weibel (497-3967). Design experiments, that will be conducted in FY94 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.

Broadband Radio Systems — Ronald L. Ketchum (497-7600). Support the development of broadband radio technologies and applications, especially high-data-ratio, digital communications. Measure and model millimeter wave propagation. Measure and model broadband indoor propagation and support wireless local area network standards development.

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.

International Standards — Neal B. Seitz (497-3106). Provide leadership to T1 and U.S. ITU-Tpreparatory 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.

PCS Radio Systems — Ronald L. Ketchum (497-7600). Provide support for the development of personal communication services (PCS) radio technology through measurements, modeling, and simulation of the radio channel; analyze spectrum issues including spectrum sharing, interference, and access methods; and participate in national and international stadards development.

RSMS Engineering Enhancements — Frank H. Sanders (497-5727). Enhance the measurement capabilities of the RSMS and suitcase system as needed to provide improved measurement data.

RSMS Operations — Frank H. Sanders (497-5727). 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 — Robert J. Matheson (497-3293). 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 (TA-SERVICES) — Robert O. DeBolt (497-5324). 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 ITU-T, focusing on applications in video teleconferencing, high-definition television, and video communications over broadband ISDN.

Voice Quality Standards — Stephen D. Voran (497-3839). Develop objective voice quality assessment techniques and standards contributions in support of advanced voice coding and ISDN standards within T1 and ITU-T.

DEPARTMENT OF DEFENSE (DoD)

DoD Consulting — A. Donald Spaulding (497-5201). Provide consultation and advisory services on such things as optimum system design and performance determination, detection algorithms, and interference modeling.

ICEPAC Consulting — Greg R. Hand (497-3375). 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.

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.

Air Force (USAF)

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

Army Communications-
Electronics Command (CECOM)

HF Radio System Test Support — Patricia J. Longstaff (497-3568). Provide RSMS measurements to support field testing of an HF system development as an independent monitor and test evaluator.

Radio System Simulation — Edmund A. Quincy (497-5472). Software simulate HF radio systems to predict performance for a variety of channel conditions, sources, and modulations.

Voice Recognition Algorithm Analysis — Edmund A. Quincy (497-5472). Provide an independent analysis and evaluation of a proposed voice recognition algorithm for signals in an RF environment.

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.

Army Foreign Science & Technology Center

Jammer Effectiveness Model — Nicholas DeMinco (497-3660). 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.

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 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.

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.

Interoperability Standards for Land Mobile Radio— William J. Pomper (497-3730). Assist the NCS in the development of interoperability standards for the next generation of digital land mobile radios, particularly in the area of security.

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 FY93 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.

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 — Stephen D. Voran (497-3839). Provide expert technical support in the area of voice communications performance measurement and standardization.

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.

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.

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.

FEDERAL HIGHWAY ADMINISTRATION

IVHS EMC — J. Randy Hoffman (497-3582). Provide support to the intelligent vehicle highway system (IVHS) program as it applies advanced technology to the highway system for safety and throughput. Develop communication systems to provide information to travelers, their vehicles, and the infrastructure; support development of standards; and identify spectrum issues as they relate to electromagnetic compatibility in the IVHS program.

McLEAN RESEARCH

HF Support — Greg R. Hand (497-3375). Provide consultation and advisory services regarding radio propagation.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

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

NATIONAL SECURITY AGENCY

Impact of New Communications Technologies — Raymond D. Jennings (497-3323). Assess the impact that emerging and future telecommunications technologies will have on information systems security.

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)

HF Propagation Model Studies — Ronald L. Ketchum (497-7600). Provide VOA with a determination of the validity of broadcast service quality predictions using reception reports from VOA monitors. Provide modeling of advanced graphics displays to present VOA's propagation and monitoring results, and improve VOACAP software to calculate the combined power distribution of all feasible propagation nodes.

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

Building Penetration Measurements — Lynette H. Loew (497-3974). Conduct measurement and analysis of three basic environments: residential, urban, and suburban, to provide fundamental knowledge of building penetration at personal communication services (PCS) frequencies.

Broadband Broadcast Millimeter Wave Measurement Study — Peter B. Papazian (497-5369). Perform broadband channel impulse response measurements in a suburban broadcast microcell over a spectrum centered at 30.3 GHz, and covering a bandwidth of 1 GHz. Process the measured data.

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AVAILABILITY OF PUBLICATIONS

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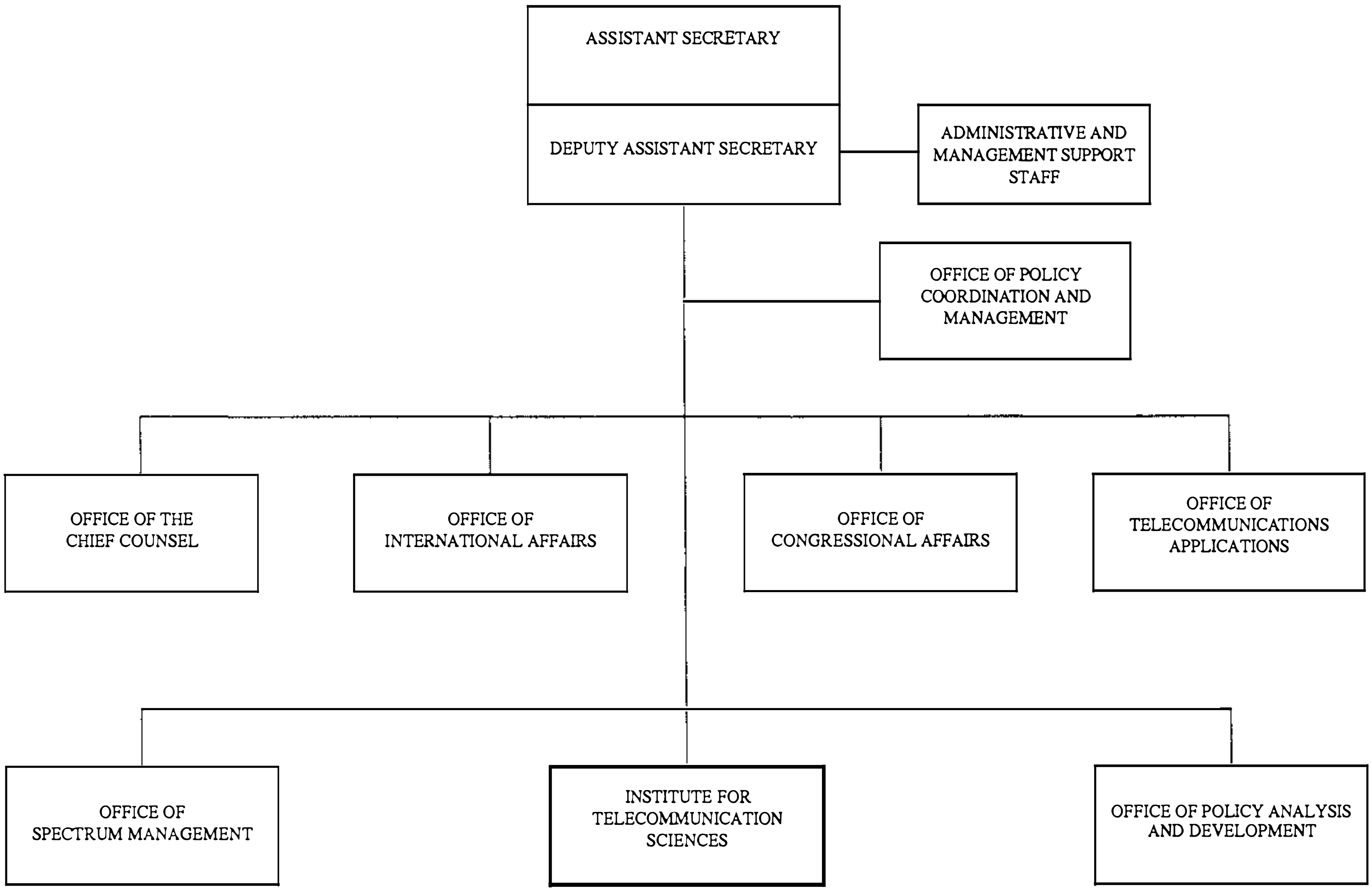
ACRONYMS AND ABBREVIATIONS

ACTS	Advanced Communications Technology Satellite
ALE	Automatic Link Establishment
AMOS	Analysis of Microwave Operational Scenarios
ANSI	American National Standards Institute
BER	Bit Error Rate
BIB	Bureau for International Broadcasting
BSS	Broadcast Satellite Service
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
ISDN	Integrated Services Digital Network
ITS	Institute for Telecommunication Sciences
ITU	International Telecommunications Union
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunications Standardization Sector
IVHS	Intelligent Vehicle Highway System
JTSSC	Joint Telecommunications Standards Steering Committee
LAN	Local Area Network
LFMS	Low-Frequency Measurement System
MMW	Millimeter Wave
MOSES	Microwave Operational Scenario Evaluation Software
NCAM	Network Connectivity Analysis Model
NCS	National Communications System
NTIA	National Telecommunications and Information Administration
OSI	Open Systems Interconnection (model)
PCS	Personal Communication Services
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 Level
RSMS	Radio Spectrum Measurement System
SHARES	Shared HF Resources
SSB	Single Sideband
TAS	Telecommunication Analysis Services
WAN	Wide Area Network
WAPM	Wide Area Prediction Model
WARC	World Administrative Radio Conference

NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION



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