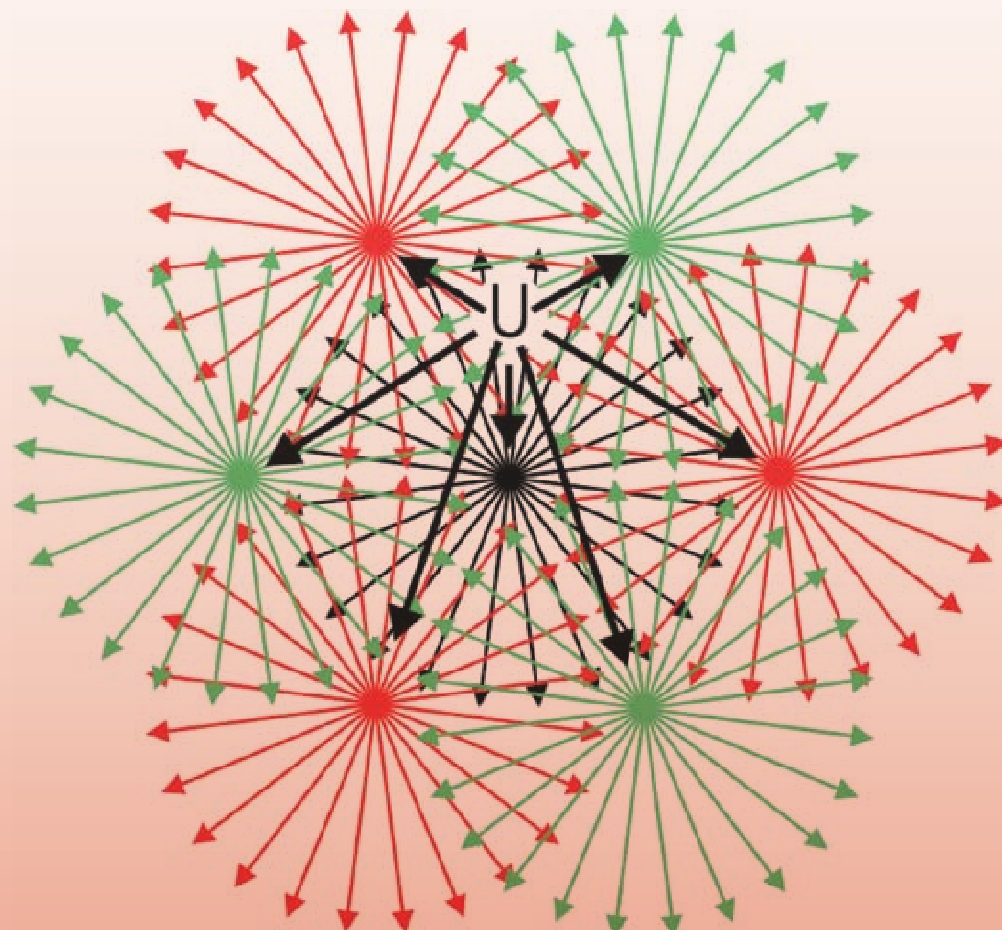
2006

Institute for Telecommunication Sciences

TECHNICAL PROGRESS REPORT

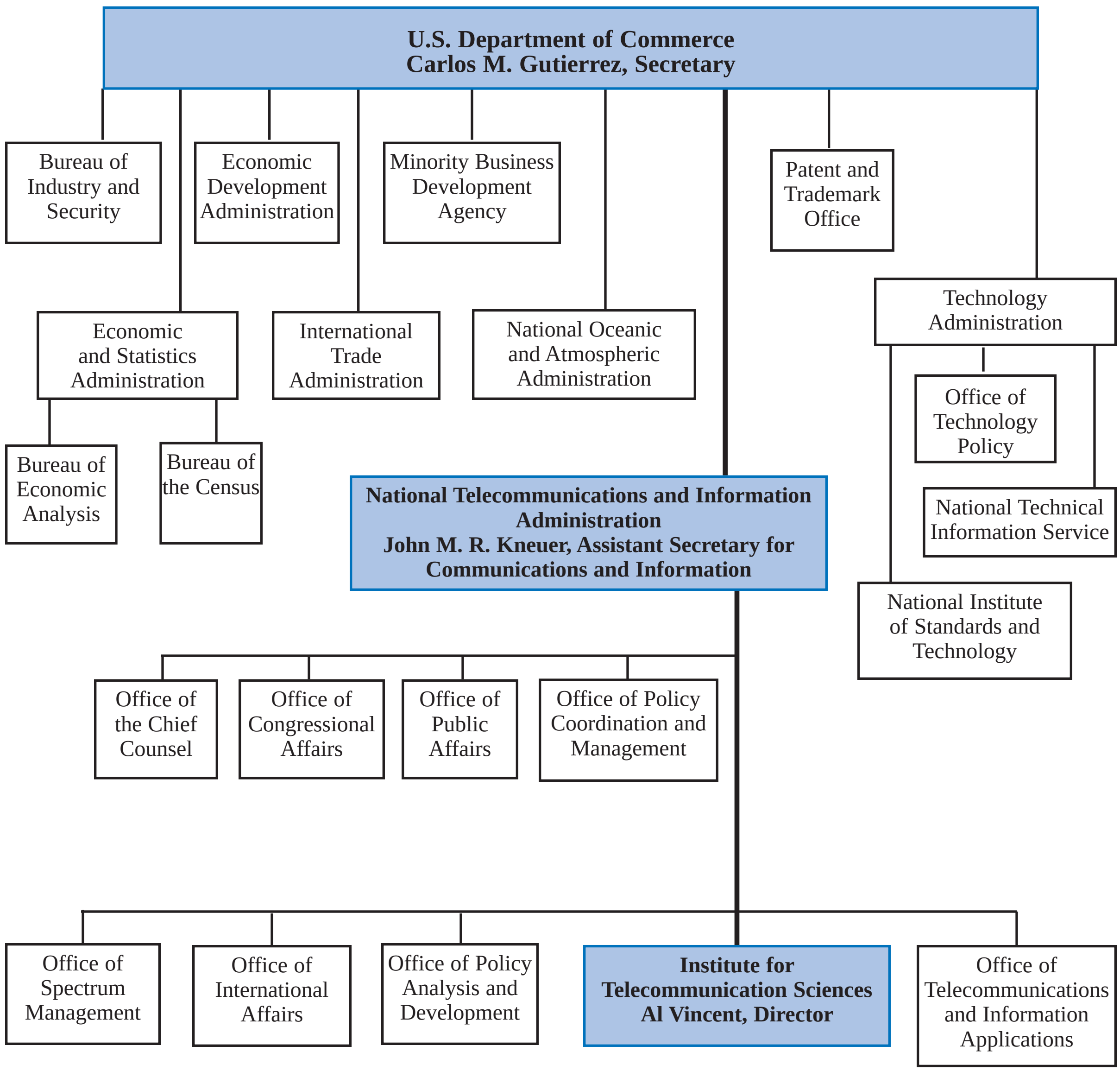


ITS

Institute for Telecommunication Sciences

Boulder, Colorado

DOC/NTIA Organization Chart



Institute for Telecommunication Sciences

FY 2006 Technical Progress Report

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

John M. R. Kneuer, Assistant Secretary
for Communications and Information

January 2007

Contents

A NEXRAD radar at Ft. Smith, Arkansas. ITS solved an interference problem involving this radar in FY 2006 (photograph by F.H. Sanders).

The ITS Mission

The Institute for Telecommunication Sciences (ITS) is the research and engineering laboratory of the National Telecommunications and Information Administration (NTIA). ITS provides technical support to NTIA in advancing telecommunications and information infrastructure development, enhancing domestic competition, improving U.S. telecommunications trade opportunities, and promoting more efficient and effective use of the radio spectrum.

ITS also serves as a principal Federal resource for solving the telecommunications challenges of other Federal agencies, State and local governments, private corporations and associations, and international organizations.

ITS supports private sector telecommunications activities through cooperative research and development agreements (CRADAs) based on the Federal Technology Transfer Act of 1986. The Act encourages sharing of Government facilities and expertise as an aid in the commercialization of new products and services. ITS is a member of the Federal Laboratory Consortium for Technology Transfer, formally chartered by the Act in 1986.

ITS provides leadership and technical contributions in national and international telecommunication standards committees under OMB Circular A-119, which provides ground rules and encouragement for Federal agency involvement in voluntary consensus standards development.

Engineers from ITS and OSM and an Army radar technician prepare to make measurements of interference effects on a precision approach radar (PAR) at the Tobyhanna Army Depot in Pennsylvania in FY 2006 (photograph by F.H. Sanders).

Overview

The Institute for Telecommunication Sciences (ITS), located in Boulder, Colorado, is the research and engineering arm of the National Telecommunications and Information Administration (NTIA), of the U.S. Department of Commerce (DOC). The Institute's staff of Federal employees provides strong engineering and scientific skills and experience to our technical programs. The majority of employees are electronics engineers, but the staff also includes mathematicians, physicists, computer scientists, and specialists in other fields. ITS' support during Fiscal Year 2006 consisted of $6 million of direct funding from the DOC and approximately $8 million for work sponsored by other Federal agencies and U.S. industry.

History

ITS began in the 1940s as the Interservice Radio Propagation Laboratory, which after the war became the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards, Department of Commerce. A new facility was built for CRPL in Boulder and dedicated by President Eisenhower in September 1954.

In 1965, CRPL joined the Environmental Science Services Administration and was renamed the Institute for Telecommunication Sciences and Aeronomy (ITSA). In 1967, ITSA split into two labs: the Aeronomy Laboratory and the Institute for Telecommunication Sciences (ITS). In 1970, Executive Order 11556 established the Office of Telecommunications (OT) within the DOC and the Office of Telecommunications Policy (OTP) in the Executive Office of the President; at the same time, ITS was transferred to OT. Under the President's Reorganization Act #1 of 1977, OT and OTP merged to form NTIA.

Since 1978, ITS has performed telecommunications research and provided technical engineering support to NTIA, and to other Federal agencies on a reimbursable basis. Over the last two decades, ITS has pursued cooperative research with U.S. industry and universities under the provisions of the Federal Technology Transfer Act of 1986.

Our Expertise

- **Radio Research Fundamentals and Spectrum Measurement:** ITS measures emission characteristics of Federal transmitter systems, and identifies and resolves radio frequency interference. We incorporate remote sensing data into our signal propagation models, and explore advanced antenna designs.

- **Communication Systems and Networks:** ITS plans, implements, and evaluates telecommunication systems.

- **Public Safety Interoperability:** ITS facilitates interconnectivity and interoperability between services and technologies.

- **Standards Development:** ITS has a long record of leadership and technical contributions to telecommunication standards committees.

- **Wireless Voice/Data Systems and Emerging Technologies:** ITS assesses telecommunications system components, evaluates network survivability, and assesses system effectiveness in national security/emergency preparedness, military, and commercial environments. We test emerging technologies, e.g., Voice over IP and ultrawideband.

- **Audio and Video Quality Research:** For over 15 years, ITS has conducted research on digital audio and video quality, grounded in signal processing theory and models of perception.

- **Electromagnetic Modeling & Analysis:** ITS maintains ongoing investigations in broadband wireless systems performance, propagation model development, advanced antenna designs, and noise as a limiting factor for advanced communication systems.

Our Facilities

The Institute's world-class facilities include:

- **Audio-Visual Laboratories**
- **Compliance Assessment Research Laboratory**
- **Radio Spectrum Measurement Science (RSMS)**
- **Secure Internet (SIPRNET)**
- **Table Mountain Field Site/Radio Quiet Zone**
- **Telecommunications Analysis Services**
- **Wireless Networks Research Center**

The Benefits Created by ITS

The Institute's research significantly benefits both the public and private sectors in several areas:

- **Spectrum Utilization:** Optimization of Federal spectrum allocation methods, identification of unused frequencies and potential interference through field measurements, and promotion of technology advances to aid in efficient use of the spectrum.

- **Telecommunications Negotiations:** Expert technical leadership at international conferences and development of negotiation support tools such as interference prediction programs.

- **Public Safety:** Systems engineering, planning, and testing of interoperable radio systems (e.g., voice, video, and data) for the use of "first responders" at the Federal, State, local, and tribal levels.

- **National Defense:** Improvement of network operation and management, enhancement of survivability, expansion of network interconnections and interoperation, and improvement of emergency communications that contribute to the strength and cost-effectiveness of the U.S. Armed Forces.

- **Domestic Competition:** Development of user-oriented, technology-independent methods of measuring telecommunications performance to give users a practical way of comparing competing equipment and services.

- **International Trade:** Promulgation of international telecommunications standards to remove technical barriers to U.S. export of telecommunications equipment and services.

- **Technology Transfer:** Direct transfer of research results and measurements to U.S. industry and Government to support national and international competitiveness, bring new technology to users, and expand the capabilities of national and global telecommunications infrastructures.

Our Organization

The Institute's technical activities are organized into four program areas:

- **Spectrum and Propagation Measurements**
- **Telecommunications and Information Technology Planning**
- **Telecommunications Engineering, Analysis, and Modeling**
- **Telecommunications Theory**

ITS's research and engineering work is supported by the Director's Office, which provides support to the program, budget, and administrative functions of the Institute. ITS also maintains an NTIA liaison function to provide assistance to NTIA on participation in national and international conferences and negotiations. The liaison also coordinates the laboratory's technical research with other Federal agencies.

Our Sponsors

Activities at the Institute are undertaken through a combination of programs sponsored by the Department of Commerce and other Federal agencies, and through cooperative research agreements with the private sector. The Institute's policy stipulates that research sponsored by other agencies must contribute to and reinforce NTIA's overall program and must be directed toward supporting the goals of the Department of Commerce. Major other agency sponsors include the National Institute of Standards and Technology's Office of Law Enforcement Standards, the Department of Homeland Security, the Department of Transportation, and the National Weather Service.

Cooperative research and development agreements (CRADAs) with telecommunication-operating companies and manufacturers support technology transfer and commercialization of telecommunications products and services, which are major goals of the Department of Commerce. ITS has CRADAs with large established companies as well as small start-up companies. Partnerships such as these enhance synergies between entrepreneurial ventures and broad national goals.

Because of its centralized Federal role, ITS can provide a cost-effective, expert resource that supports many Federal agencies and industry organizations. ITS provides research and engineering that is critical to continued U.S. leadership in providing telecommunications and information equipment and services. This Progress Report summarizes technical contributions made by ITS during Fiscal Year 2006 to both the public and private sectors.

The RSMS vehicle at the ITS Boulder Laboratories (photograph by J.R. Hoffman).

Spectrum and Propagation Measurements

The radio spectrum is an enigmatic natural resource that offers immense benefit to industry, government, and private citizens by supporting radio/wireless communications and a wide variety of other systems such as radar and remote sensing. It is non-depleting and exists everywhere, but it is finite and can be rendered less useful by noise and interference. Until recently, traditional methods of allocating spectrum and assigning channels have ensured effective and efficient use of the spectrum. Today, the rapidly expanding competition for spectrum use and the plethora of new signal types and applications have created an apparent shortage of radio spectrum. While new spectrum management methods will alleviate this problem, they cannot do so without increasingly more complex knowledge of the existing signals and noise environment and better understanding of how systems that share spectrum affect each other.

The Spectrum and Propagation Measurements Division provides the technical information needed to enable more effective and efficient use of the spectrum, thus enabling spectrum allocation and sharing regulations and policies that are effective, reliable, and enduring. To do so, the Division performs analyses and measurements of the effects of radio signals on the spectrum and on other systems. Measurements and assessments of spectrum occupancy can be accomplished at any location using the mobile Radio Spectrum Measurement Science system. New measurement methods are developed and complex testing is accomplished in well-equipped laboratories and at the Table Mountain Field Site.

The following areas of emphasis are indicative of the work done in the Division recently in support of NTIA, other Federal Agencies, academia, and private industry.

Areas of Emphasis

Radio Spectrum Measurement Science (RSMS) Operations
The Institute's RSMS is comprised of laboratory, transportable, and mobile facilities. This capability is used to assess spectrum occupancy and usage, and electromagnetic compatibility, and to resolve interference problems. This project is funded by NTIA.

RSMS 4th Generation System Development
The Institute continually refines and develops measurement methods, both established and new, supported by hardware and software. The RSMS fourth generation system software is capable of fully autonomous operation and remote monitoring, uniform data recording and storage, and powerful analysis and display routines. This project is funded by NTIA.

Table Mountain Research Program
The Institute's field site, protected by state law and Federal Regulation as a radio quiet zone, is used by many operations and experiments that require protection from strong, external radio signals, and minimum vibration. Research into new spectrum occupancy measurement methods, including radio noise measurement, new antennas, and complex radar measurements, are conducted by ITS at the site. These projects are funded by NTIA.

Spectrum Efficiency Research and Engineering
The Institute pursues investigations of the efficient and effective use of the radio spectrum, including allocation and assignment methods. Definitions for spectrum efficiency and effectiveness can be nontrivial and elusive. The Institute compares actual measurements of band and channel usage with known assignments to determine the merits of new and competing channel assignment schemes. This project is funded by NTIA.

Signal Characteristics, Spectral Emissions, and Interference Analyses
The Institute largely completed a complex assessment of the interference potential of ultrawideband (UWB) signals in FY 2006. This study required the utmost care and thoroughness to determine which characteristics of a variety of UWB signals were best correlated with interference effects observed in a digital television satellite receiver. This project is funded by Freescale, Inc.

Radio Spectrum Measurement Science (RSMS) Operations

Outputs

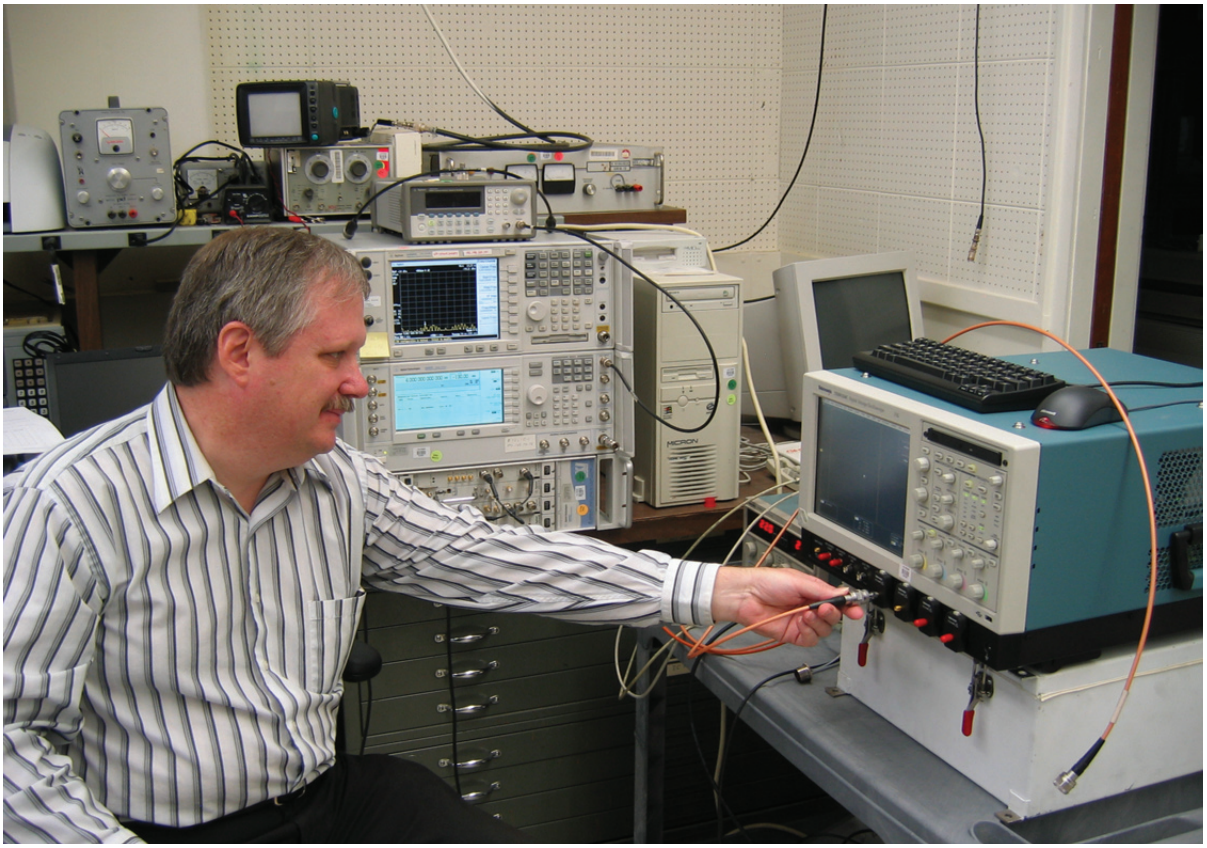
- Measurements to determine compatibility between prototype 5-GHz dynamic frequency selection (DFS) devices and a 5-GHz radar.
- Measurements and draft report on land mobile radio (LMR) channel occupancy in Federal bands 162-174 MHz and 406-420 MHz.
- Measurements to address compatibility between radiolocation and maritime and aeronautical services in the bands 9000-9200 MHz and 9300-9500 MHz.

The Radio Spectrum Measurement Science (RSMS) group is given the task of performing critically needed radio signal measurements necessary for making decisions regarding Federal Government spectrum allocations. As stated under Departmental Organization Order 25-7, issued 5 October 1992, and amended December 1993, the NTIA Office of Spectrum Management (OSM) is responsible for identifying and making arrangements for measurements necessary to provide NTIA and the various departments and agencies with information to ensure effective and efficient use of the spectrum. RSMS resides at ITS in Boulder, Colorado, and is tasked to perform measurements in support of OSM as required to fulfill their mission. ITS, through the RSMS Operations project, provides OSM and the executive branch with critically needed radio spectrum data, data analysis, reports, and summaries. The four basic areas of RSMS are 1) spectrum surveys and channel usage, 2) equipment characteristics and compliance, 3) interference resolution and compatibility, and 4) signal coverage and quality. In FY 2006, several different measurements were performed in support of the basic mission.

Dynamic frequency selection (DFS) is a method whereby a radio local area network (RLAN) device, using the 5-GHz band for unlicensed operations, will detect the operations of radar and promptly evacuate the channel if the radar is present. In FY 2004-2005, ITS performed testing to demonstrate DFS proof of concept with a table of radar signals developed in conjunction with the FCC, industry, the Department of Defense, and NTIA. In December 2005, field measurements were conducted to determine compatibility between prototype 5-GHz DFS devices and a 5-GHz radar at a missile facility in New Mexico. In preparation for these measurements, aggregate radiated emissions of multiple DFS devices were recorded at the Table Mountain facility located north of Boulder, Colorado, for the purpose of modeling these signals. ITS also provided assistance to Compliance Certifications Services, the Federal Communications Commission (FCC), and OSM with regard to simulated pulsed signals used for DFS compliance testing. The test results will help determine whether this technology is able to move forward toward deployment in commercially available RLAN-type communication devices.

In the early part of FY 2006, measurements were conducted in the Denver area to measure and provide a report on land mobile radio (LMR) channel occupancy in Federal bands 162-174 MHz and 406-420 MHz. These measurements supplement earlier LMR measurements in Washington, DC, for which a report is currently under review by OSM and the Interdepartment Radio Advisory Committee (IRAC). These measurements are part of NTIA's effort to improve the spectrum efficiency of Federal radio usage. Specifically, this effort was undertaken to help obtain data required to realistically design future possible shared trunked systems for Federal radio users and determine long-term usage trends by comparing results with previous measurements taken in the same location in 1986 and 1989. The measurements were made using new equipment and techniques developed at ITS that measure large areas of the spectrum and process it to obtain simultaneous signal levels of up to 480 individual LMR channels. These techniques provided faster measurements, but also allowed enhanced post-processing of the data to remove measurement defects.

In support of an International Telecommunication Union — Radiocommunication Sector (ITU-R) World Radiocommunication Conference (WRC-07) agenda item to upgrade the status of the radiolocation service in the bands 9000-9200 MHz and 9300-9500 MHz to primary status, three additional measurements were conducted in FY 2006: on a precision approach radar, an airborne weather radar, and an ASDE-X radar. The measurements were designed



An ITS engineer conducting pulsed waveform measurements in the ITS laboratory (photograph by J.R. Hoffman).

to address compatibility between radiolocation and maritime and aeronautical services in the above mentioned bands. Waveforms of the radiolocation systems were generated and injected into the receivers of the three radionavigation systems to determine levels of degradation.

To investigate waiver applications to the FCC's ultrawideband Part 15 Rules permitting devices to employ swept frequency techniques, additional measurements using different averaging times were conducted at the ITS Boulder Labs. The purpose was to provide an understanding of swept signals at the output of various filter bandwidths and to provide information to develop test procedures that could be used in compliance measurements.

Point-to-point microwave link measurements were conducted in the spring of FY 2006 to search for and record the signals from various links in the 7.125-8.8 GHz bands. These measurements were conducted as part of NTIA's effort to improve the spectrum efficiency of Federal radio usage. Specifically, this effort was undertaken to explore various techniques and capabilities for performing future, more extensive Fixed Services measurements in order to determine band usage.

Multiple measurements of various simulated chirped pulse waveforms and frequency modulated continuous waveforms were conducted in the ITS laboratory during the latter part of FY 2006. The purpose of these measurements is to provide measured waveforms to compare the 20- and 40-dB bandwidths for proposed equations used to calculate the bandwidths.

In support of an ongoing effort to characterize various radar emissions, measurements were conducted on three separate radars in the Baltimore, Maryland, area during the spring of FY 2006. This was in support of work with the ITU-R JRG 1A/1C/8B to develop ITU radar emission limits, which the committee has been tasked to review.

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RSMS 4th Generation System Development

Outputs

- Enhancements of existing preselectors.
- Real-time fully automated direction-finding system that can be used with pulsed signals such as radar.
- Several new ITS custom-designed software modules for instrument control and measurement.

The 4th generation system for Radio Spectrum Measurement Science (RSMS) consists of state-of-the-art tools (vehicle, software, and hardware) necessary for making measurements to characterize spectrum occupancy, ensure equipment compliance, determine electromagnetic compatibility, and analyze interference problems. The development of the 4th generation system originated out of the recognized need to upgrade to the latest technology for RSMS operations. RSMS operations, in turn, directly supports NTIA by providing critical measurement support for determining policies affecting both the public and private sectors. To this end, several new capabilities and improvements have been added to the system in FY 2006.

Integral to the RSMS measurement system has been the development of customized preselector units that filter out unwanted signals and amplify the input to increase system sensitivity. Over the last few years, two new fully functional 4th generation preselectors have been designed and constructed — one for frequencies between 0.5–18.0 GHz and the other for frequencies between 18.0–26.5 GHz. Both preselectors are protected against strong signals by highly shielded enclosures and are controlled via fiberoptic connections to prevent signals coupling into control lines. In addition to these 4th generations units, several improvements to the existing preselectors have been made. In FY 2006, testing, repair, and improvements to the 3rd generation preselectors, as well as development of control software, has made it possible to integrate these older, but still very functional, devices into the 4th generation system. In addition, several improvements have been made to existing tunable yttrium-iron-garnet (YIG) filter systems frequently used for radar measurement. A YIG tracking system is currently under development for the purpose of tracking frequency sweeps of spectrum analyzers, and a YIG calibration software routine has been developed that allows periodic characterization of the filter for offset control. Under the development of the 4th generation software, computer automated control of each of the units — new and old — has been integrated into the larger software package. Modularized instrument software units have made it possible to seamlessly swap out preselector units for different applications of the same measurement capabilities.

Currently in progress is the development of real-time “signal direction finding” capabilities. ITS engineering staff have been working together to develop these capabilities through implementation of digital control and processing using Field Programmable Gate Array (FPGA) technology. The system switches through the different antennas of a six-sided array to determine the angle of signal arrival. Using rapid digital processing and a switch control by the FPGA, information is relayed via the Internet to a computer, which can then be used for real-time high-gain antenna positioning toward stationary or moving targets. One of the advantages of this system over most off-the-shelf systems is that it can be used with pulsed signals such as radar. Because it is implemented in software as an instrument module, this system is easily integrated into the larger RSMS software package for use with a variety of measurement capabilities. Development of this system using FPGA technology will not only provide signal direction-finding capabilities but will open up a whole new way of acquiring and processing data, using what is essentially a hardware reprogrammable instrument that can be used for many different applications.

Two recent additions to the RSMS software have been the development of a rotator instrument control and an azimuth signal search routine. The rotator instrument control is a software module that can be integrated into the larger RSMS software, allowing remote control of an antenna position device. The signal search routine uses the rotator control software in combination with a spectrum analyzer to perform an azimuth sweep at a single frequency

RSMS 4th generation vehicle parked at the ITS Boulder Laboratories (photograph by J.R. Hoffman).

to determine the angle of greatest signal power. This routine is used to find signals on the horizon to determine the best azimuth angle setting for pointing narrow beam antennas. It can also be used to characterize antenna patterns.

Several additions have also been made to RSMS software measurement routines. These include an automated “swept measurement,” a “swept calibration” routine, a “stepped calibration” routine, and a “spectrum analyzer data dump.” The “swept measurement” is a routine that automates the acquisition of spectrum traces from multiple bands and stores data in a format that is easily usable. The “swept calibration” routine performs an automated system calibration where the measurement utilizes an externally tuned YIG or fixed filters. The “stepped calibration” routine performs an automated system calibration where YIG tuning is performed strictly through software control. The “spectrum analyzer data dump” routine provides quick setup of the RF path and downloads spectrum analyzer traces referenced to different locations along the RF path.

New features expected in FY 2007 include enhanced data file management, a vector signal analyzer instrument control module, a point-to-point microwave measurement system and software, a new noise measurement routine, a scheduler for automated control of multiple measurements, the completion of the YIG tracking system, and the development of an RSMS-4 low frequency preselector.

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Table Mountain Research Program

Outputs

- Tests of a prototype 3-axis antenna designed to study the total incident field and polarization of a radiated signal.
- New NOAA Weather Radio testing laboratory.
- Upgrades to the turntable facility at the Table Mountain field site to improve capability for testing the performance of antenna systems mounted on vehicles.
- Simulations of complex signals such as UWB, DTV, and man-made noise.

The Table Mountain Field Site and Radio Quiet Zone supports fundamental research into the nature, interaction, and evaluation of telecommunication devices, systems, and services. To achieve this goal, the Table Mountain Research Project actively solicits research proposals from inside the Institute as well as from external agencies.

The results of this work are disseminated to the public via reports, technical papers, journal articles, conference papers, web documents, and computer programs. Activities this year have included:

Digital Television Project:
NTIA has been tasked with the development of a program for the distribution of digital to analog converter boxes to facilitate the transition to digital television (DTV) broadcast scheduled to take place on February 17, 2009. To support this program, a system capable of generating DTV signals was assembled, allowing ITS to study the characteristics of the signals in a controlled environment. Additionally, a study to identify DTV performance metrics and to develop the procedures needed to evaluate the performance of DTV converter boxes was initiated.

Testing the pattern of antennas mounted on a mock-up of an unmanned aerial vehicle (UAV) at the Table Mountain field site, part of the cooperative research and development agreement (CRADA) between ITS and Johnson's Jobs (photograph courtesy of Russ Johnson, Johnson's Jobs).

Set-up for testing of 3-axis antenna at Table Mountain field site (photograph by R.N. Statz).

NOAA Weather Radio Testing:
To help ensure that radios displaying the NOAA Weather Radio emblem meet the NOAA performance criteria, ITS established a laboratory at the Table Mountain field site to measure the performance of these radios. This leverages earlier work undertaken in FY 2004 where ITS examined the overall performance of the NOAA Weather Radio system from signal generation to signal reception. This test facility provides NOAA with performance data based on tests outlined by the Consumer Electronics Association standard CEA-2009.

FY 2006 Cooperative Research and Development Partners

- Eton Corporation
- Johnson's Jobs
- RF Metrics Corporation
- Lockheed Martin/Coherent Technologies
- Deep Space Exploration Society
- University of Colorado, Ad Hoc UAV Ground Network (AUGNet)

Recent Publications

J. Diverdi, "Simple mapping project (SMP) Interim Report," Deep Space Exploration Society, Jun. 2006.

F. Sanders, J. Wepman, and S. Engelking, "Development of performance testing methods for dynamic frequency selection (DFS) 5-GHz wireless access systems (WAS)," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 7-9, 2006," P. Raush and K. Novik, Eds., NTIA Special Publication SP-06-438, Mar. 2006, pp. 39-48.

D. Henkel and T.X. Brown, "On controlled node mobility in delay-tolerant networks of unmanned aerial vehicles," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 7-9, 2006," P. Raush and K. Novik, Eds., NTIA Special Publication SP-06-438, Mar. 2006, pp. 29-38.

R. Howe, "Detection of gamma ray bursts and X-ray transient SGR 1806-20 with VLF radio telescopes," *Open European Journal on Variable Stars*, ISSN: 1801-5964, OEJV# 0022, Feb. 2006.

F. Sanders and B. Ramsey, "Phased array antenna pattern variation with frequency and implications for radar spectrum measurements," NTIA Technical Report TR-06-436, Dec. 2005.

F. Sanders and B. Ramsey, "Comparison of radar spectra on varying azimuths relative to the base of the antenna rotary joint," NTIA Technical Memorandum TM-05-430, Aug. 2005.

T. Brown, S. Doshi, S. Jdhav, D. Henkel, and R. Thekkekunnel, "A full scale wireless ad hoc network test bed," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 1-3, 2005," J.W. Allen and J. Ratzloff, Eds., NTIA Special Publication SP-05-418, Mar. 2005, pp. 51-60.

J.W. Allen, "Gain characterization of the RF measurement path," NTIA Report TR-04-410, Feb. 2004.

J.W. Allen and T. Mullen, "Digital television (DTV) field strength and video quality study," NTIA Technical Memorandum TM-03-405, Aug. 2003.

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Spectrum Efficiency Research and Engineering

Outputs

- Consultation with OSM and internal papers on spectrum efficiency planning.
- Consultation with OPAD and internal papers on flexible-use spectrum rights.

NTIA is pursuing an extensive multi-pronged program to improve the spectrum efficiency (SE) of Federal radio systems. This program was given additional importance by the May 2003 announcement of a Presidential Spectrum Policy Initiative to promote the development and implementation of a U.S. spectrum management policy for the 21st century. Although most of this work will be accomplished by NTIA in Washington, ITS is developing theoretical concepts and practical applications for improved SE.

NTIA's Office of Spectrum Management (OSM) asked ITS to examine possible metrics that describe the SE of several types of radio services. Previous work concentrated on land mobile radio (LMR) systems. The first phase of this work has been completed (see Hoffman et al. 2006 in "Recent Publications" below). A "signal capacity" model was developed to provide a combined geographical coverage "footprint" of the multiple independent existing radio systems now serving Federal Agencies, based on license data from the Government Master File. This model showed that 268 separate LMR radio channels were available in downtown Washington, DC, as well as summarizing the coverage of Federal LMR systems within a 100-mile radius.

The second phase of this work was the measurement of LMR traffic (Erlangs) in the Washington, DC, area, using the ITS RSMS-4 system, as described on pp. 6-7. The data from these first two phases can be used to design possible future alternative shared LMR systems, since they provide information on the number of channels available at each location, as well as the average traffic carried by each channel.

More recently, ITS work has shifted towards SE models of Fixed Services (FS) systems, including point-to-point microwave systems. Two distinct types of services are provided by FS radios: transport and access services. Transport services are provided where the base station relays all of the data it receives to the next station, without originating or terminating any data locally. Transport stations are often arranged in long chains where data is passed from station to station, sometimes transporting data for hundreds of miles. An "access" station uses or generates data locally or provides wireless connections to wired broadband networks. Some stations provide a mix of access and transport services.

Since one of the measures of SE calculation is to compare a given system with a theoretical maximum-performance system, it is useful to consider how to build such a system — even if many approximations need to be made. Figure 1 shows one possible maximum-traffic transport system.

Figure 1a shows a single link in a chain of FS transport stations, with data being transmitted from station X_1 to station X_2. The single link would be designed to carry a maximum amount of data between X_1 and X_2.

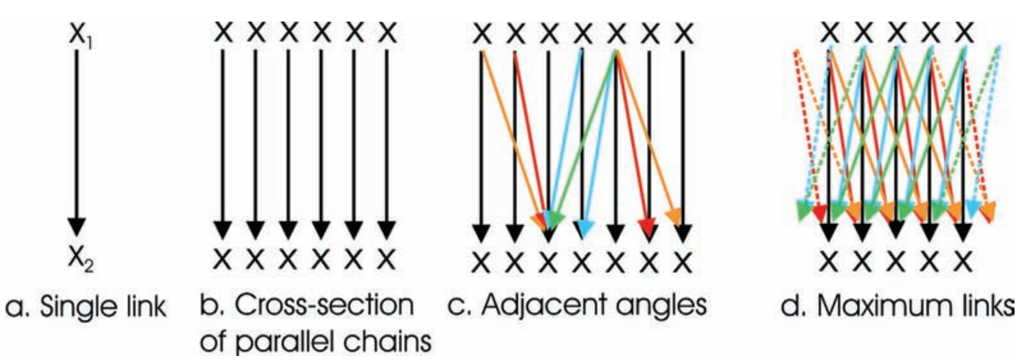

Figure 1. Maximum service transport system examples.

Figure 1b shows the configuration of a set of corresponding links in a set of parallel chains, where the transport capacity per unit of total path width is dependent on how closely the parallel chains can be spaced. All sites from the corresponding link of a chain use the same frequency sets, using the narrow antenna beamwidth to prevent interference from nodes on the adjacent microwave chains.

Figure 1c shows that a transport system could also support transport links to and from corresponding antennas on the adjacent parallel chains of microwave licenses, using the narrowness of the antenna's beamwidth to select the desired signal.

Figure 1d shows a possible arrangement of antenna beams that exploit "in-line" and "1st-adjacent-chain" paths. Figure 1d could be expanded to include "nth-adjacent-chain paths." This model probably represents something close to a real-world maximum-traffic transport system. In the real world, however, optical fiber would probably be installed long before such dense microwave networks would be built.

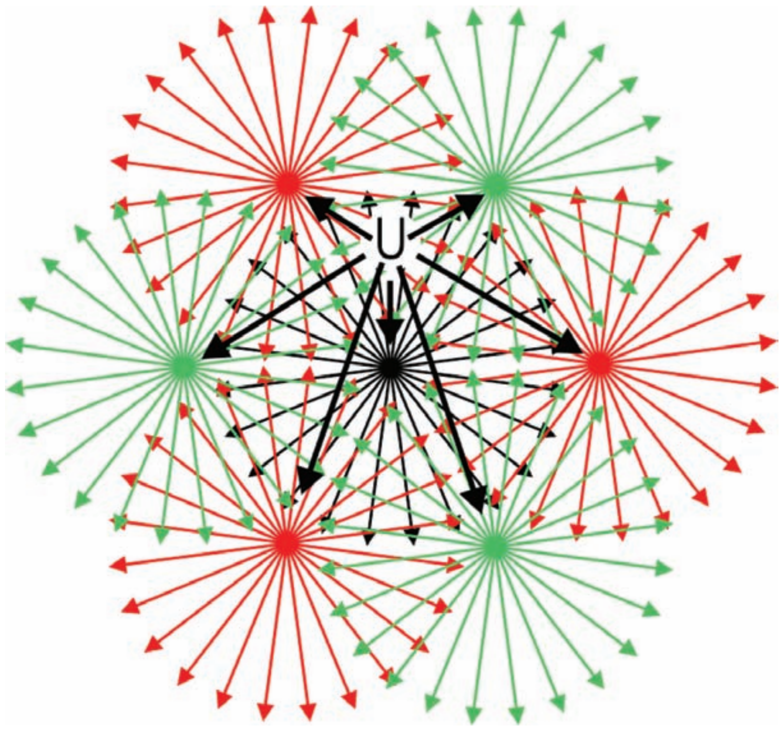

Figure 2. Maximum service access system example.

Similar models have been considered for the maximum access capacity of FS radios. Figure 2 shows a possible FS maximum access configuration, with a user "U" surrounded by various access sites with multiple directional antennas. The benefit from access services is merely the total number of bits transmitted across all paths. Total service can be maximized by decreasing the average path length (moving access nodes closer to users for better spatial frequency reuse) and decreasing antenna beamwidth (allowing better angular frequency reuse).

ITS has also been working with NTIA's Office of Policy Analysis and Development (OPAD) on various spectrum sharing strategies, including flexible-use spectrum rights. Flexible-use rules would be useful where spectrum is available for some services but not for others. Flexible-use rules allow changes in the way spectrum is used, including the use of secondary markets to rapidly acquire suitable spectrum. However, a switch to flexible-use rights requires individual users to have more system design expertise than is required when deploying "cookie-cutter" standardized systems licensed in most of the existing command-and-control frequency bands. Flexible-use issues involve: 1) an unambiguous description of the spectrum space (electrospace) that is licensed, 2) a minimal set of rules/property rights that allow the design of new radio systems while minimizing interference, and 3) a set of procedures for licensing systems and determining responsibility for any interference.

Recent Publications

R. J. Matheson, "Principles of flexible-use spectrum rights," *Journal of Communications and Networks*, vol. 8, no. 2, pp. 144-150, Jun. 2006.

C. Hoffman, R. Matheson, F. Najmy, and R. Wilson; "Federal land mobile operations in the 162-174 MHz band in the Washington, D.C., area, Phase 1: Study of agency operations," NTIA Report 06-440, Aug. 2006.

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Signal Characteristics, Spectral Emissions, and Interference Analyses

Outputs

- Technical publications and presentations demonstrating research results.
- Measurement and analysis of DTV susceptibility to ultrawideband signals.

Since the FCC permitted low power ultrawideband (UWB) emissions between 3.1 and 10.6 GHz in February 2003, a number of companies have developed new UWB technologies for application in wireless personal area networking (WPAN) to achieve high data rates at short distances (nominally less than 10 meters). Examples of these developments include Multi-band Orthogonal Frequency-Domain Multiplexing (MB-OFDM) and Direct-Sequence Ultrawideband (DS-UWB) technologies. MB-OFDM achieves its ultra-wide bandwidth with a 528-MHz wide OFDM signal that hops between 14 different bands. In contrast, DS-UWB combines conventional spread spectrum techniques and pulse shaping to achieve its ultra-wide bandwidth. Questions arose regarding how UWB signals interfere with legacy systems such as C-band satellite television, which demodulates signals that lie within the frequency band allocated for UWB operations. On March 22, 2004, ITS entered into a Cooperative Research and Development Agreement (CRADA) with Freescale Inc. to address these questions.

ITS researchers hypothesized that UWB interference potential could be quantified in terms of UWB signal characteristics. To test this hypothesis, a test system was designed and built to inject UWB signals with known characteristics into a C-band satellite digital television (DTV) receiver and quantitatively measure interference susceptibility via signal quality metrics, e.g., segment error rate, pre-Viterbi bit error rate, and modulation error ratio, taken from various

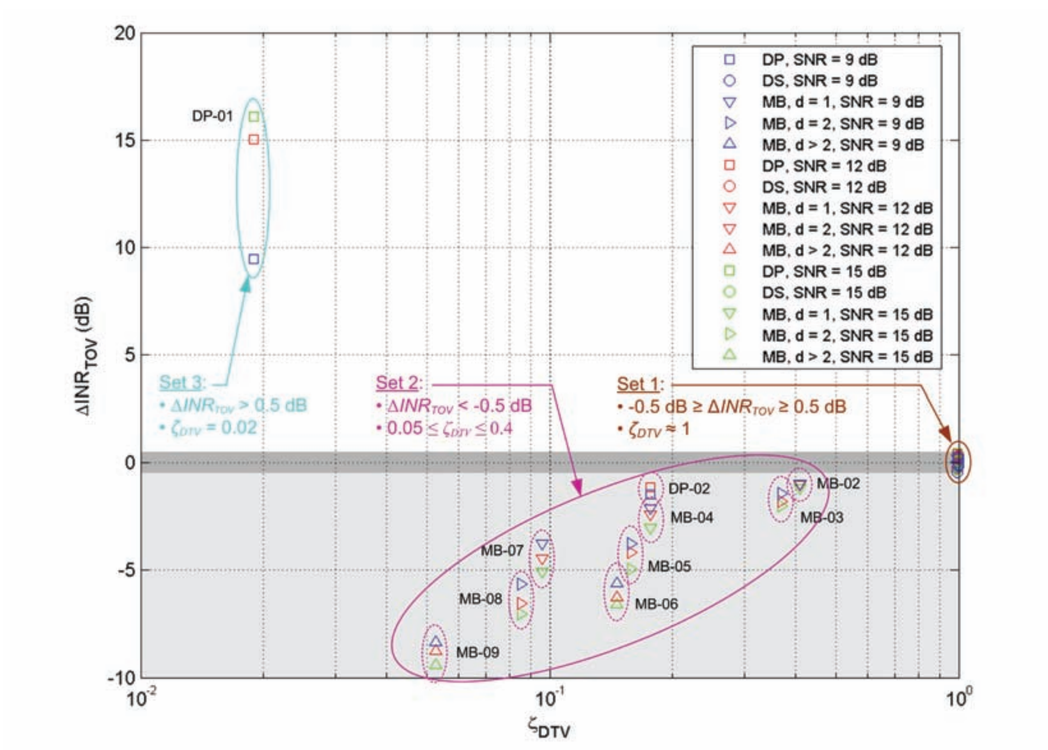

Figure 1. DTV susceptibility vs. fractional on-time of UWB interference signals in the bandwidth of the victim receiver. Contours are drawn around signals that caused similar interference effects to the DTV receiver.

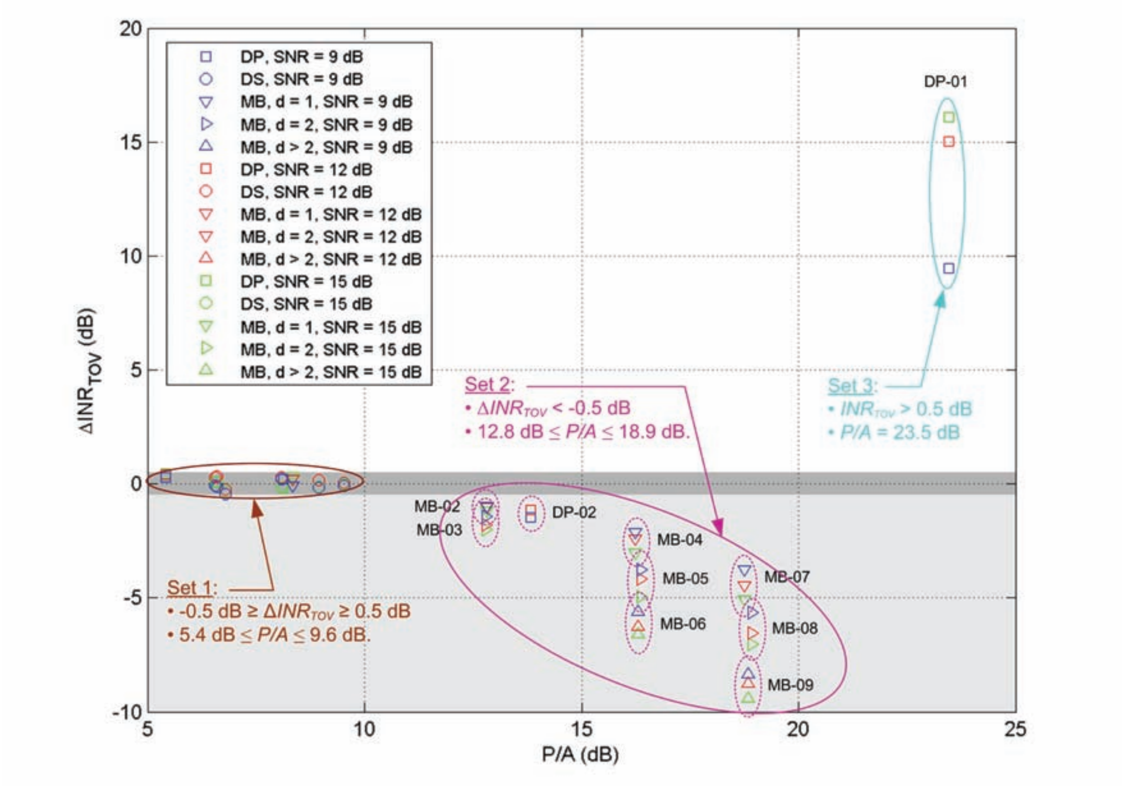

Figure 2. DTV susceptibility versus peak-to-average ratio of UWB interference signals in the bandwidth of the victim receiver. Contours are drawn around signals the caused similar interference effects to the DTV receiver.

points in the receiver signal processing chain. Results from the experiment were published in a three-part NTIA Report series entitled "Interference Potential of Ultrawideband Signals." Part 1 describes the test setup and procedures in detail. Part 2 provides signal characterization and DTV susceptibility results for gated-noise interference. Finally, Part 3 provides characterization and DTV susceptibility results for UWB interference. It was found that categorization of the UWB signals into three signal sets of common DTV susceptibility could be achieved with *a priori* knowledge of the interference signal characteristics and bandwidth of the victim receiver. These sets are illustrated in Figures 1 and 2, which plot DTV susceptibility versus fractional on-time (ζ_{DTV}) and peak-to-average ratio (P/A), respectively. DTV susceptibility was quantified by the metric ΔINR_{TOV}, which is the interference-to-noise ratio at the threshold of visibility normalized to the Gaussian noise interference case.

Recent Publications

M. Cotton, R. Achatz, J. Wepman, B. Bedford, "Ultrawideband interference potential: Part 1 – Procedures to characterize ultrawideband emissions and characterize interference susceptibility of C-band satellite digital television receivers," NTIA Report TR-05-419, Feb. 2005.

M. Cotton, R. Achatz, J. Wepman, P. Runkle, "Ultrawideband interference potential: Part 2 – Measurement of gated-noise interference to C-band satellite digital television receivers," NTIA Report TR-05-429, Aug. 2005.

M. Cotton, R. Achatz, J. Wepman, R. Dalke, "Ultrawideband interference potential: Part 3 – Measurement of ultrawideband interference to C-band satellite digital television receivers," NTIA Report TR-06-437, Feb. 2006.

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(Top) An engineer from the ITS Telecommunications and Information Technology Planning (P) Division working on the Radio Performance Measurements (RPM) software suite. (Bottom) Staff from ITS.P and NIST testing 4.9-GHz wireless devices and networks outside an apartment building (photographs by J.D. Ewan).

Telecommunications and Information Technology Planning

The telecommunications and information technology planning function represents the highest-level system or network perspective of the Institute. This work can be characterized generally as planning and analyzing existing, new, and proposed telecommunications and information technology systems, especially networks, for the purpose of improving efficiency and enhancing the technical performance and reliability of those systems. In many cases, ITS performs this work for both wireline and wireless applications. This portion of the ITS technical program encompasses work that is frequently referred to in industry as "systems engineering."

All phases of strategic and tactical planning are conducted under this work area, as well as problem solving and actual implementation engineering. ITS engineers identify users' functional requirements and translate them into technical specifications. Telecommunication system designs, network services, and access technologies are analyzed, as well as information technologies (including Internet and Internet-related schemes).

Following is a summary of significant activities that occurred in the area of telecommunications and information technology planning during FY 2006. Telecommunications interoperability remains the largest program area.

Areas of Emphasis

Interoperability Efforts for Justice/Public Safety/Homeland Security
The Institute conducts a broad-based technical program aimed at facilitating telecommunications interoperability and information-sharing among dissimilar wireless and information technology systems within the justice/public safety/homeland security community. ITS activities are sponsored by several Federal Agencies and programs, and are planned and performed after close coordination with local, State, tribal, and Federal practitioners. Technical thrusts within the program, described in separate sections on the following pages, include:

Statement of Requirements for Public Safety Communications

Public Safety Architecture Framework (described on pp. 38-39)

Standards Development for Public Safety Interoperability

Project 25 Compliance Assessment Program

Department of Commerce ISSI Emulation and Test System (DIETS)

Emergency Telecommunications Service (ETS) Standards Development
The Institute develops and verifies ETS Recommendations for ITU-T Study Group 9. The project is funded by the National Communications System.

Multimedia Quality Research
The Institute characterizes and analyzes the fundamental aspects of multimedia quality assessment and network interoperability. A primary goal of this research is to develop an algorithmic system to objectively assess multimedia quality by combining audio quality, video quality, and audiovisual synchronization information. The project is funded by NTIA.

Wireless Network Measurement Methods
The Institute studies the performance characteristics of wireless networks and attempts to standardize measurement methods in order to better understand the applicability of different types of wireless networks to specific user requirements. The project is funded by NTIA.

Statement of Requirements for Public Safety Communications

Outputs

- Statement of Requirements for public safety communications interoperability, Volume I, version 1.1.
- Statement of Requirements, Volume II.
- Voice and video quality testing.
- Technical management of practitioner working group to review and revise the Statement of Requirements.

The Department of Homeland Security's (DHS) Public Safety Wireless Communications (SAFECOM) Program released the first ever Statement of Requirements for public safety communications interoperability (PS SoR) in April 2004. This statement defined future requirements for crucial voice and data communications in day-to-day, task force, and mutual aid operations. The National Institute of Justice's CommTech Program (formerly AGILE) partnered with SAFECOM in formulating and releasing the requirements.

ITS manages the PS SoR program for the DHS Office of Interoperability and Compatibility (OIC). In this capacity, ITS leads the day to day development of the document, including the written revisions and the laboratory work used in developing the qualitative and quantitative requirements, and provides the long term strategy and vision for the document's maturation and use.

In April 2006, SAFECOM released an updated version of Volume I of the Statement of Requirements (PS SoR, Volume I, version 1.1) with refinements based on input from the emergency response community. In October 2006, SAFECOM released Volume II of the Statement of Requirements.

With the Statement of Requirements, the Nation's 60,000 emergency response agencies — for the first time — have a document that serves as a first step toward establishing base-level communications and interoperability standards for all emergency response agencies. The Statement of Requirements helps the emergency response community convey a shared vision that ultimately will help private industry better align research and development efforts with critical interoperable communication needs.

Version 1.1 (Volume I) of the PS SoR is intended to encourage and facilitate communications industry efforts to align research and development with emergency responder needs. It includes a description

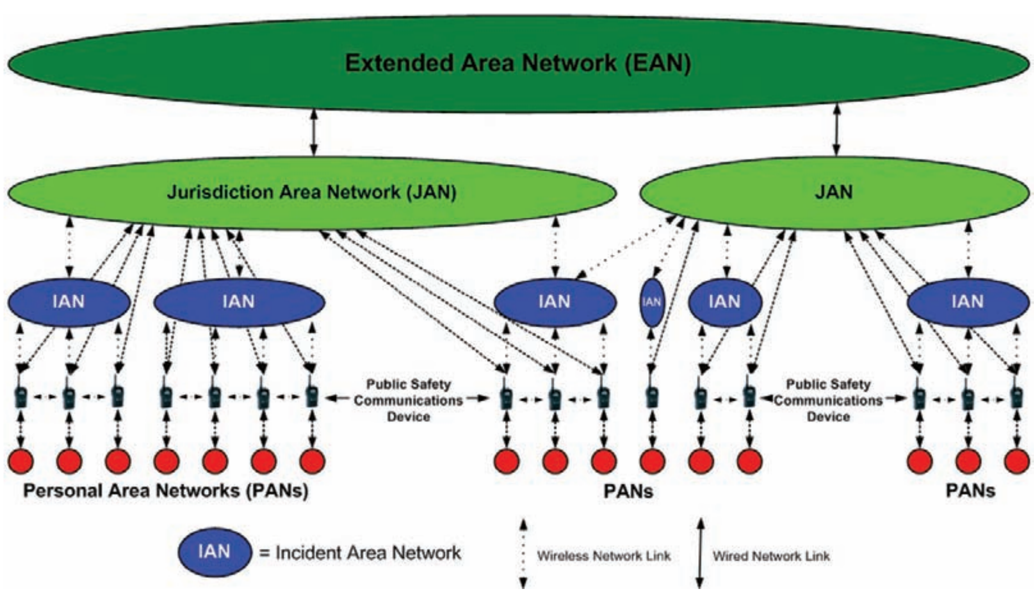

Figure 1. Logical system of systems diagram.

Figure 2. ITS staff members perform practice testing for the video quality testing described on pp. 36-37 (photograph by C. Ford).

of the "system of systems" (shown in Figure 1) concept that is central to OIC's efforts to advance emergency communications interoperability. This approach, which is based on interface standards, gives emergency response agencies the flexibility to select equipment that best meets their unique technical requirements and budget constraints, and allows systems owned and operated by different emergency response agencies to communicate without having to purchase equipment from the same manufacturer.

PS SoR Volume II, Version 1.0, covers three main areas: speech, video, and network performance. The initial application of this document is for mission-critical speech and video services, in addition to specifying network performance parameters to meet these applications' quality of service needs. ITS conducted the voice and video testing, and partnered with the National Institute of Standards and Technology (NIST)'s Advanced Networking Technology Division (ANTD) for network performance, involved in the creation of this document. See the Public Safety Video Quality section on pp. 36-37 for more information.

To help review and revise the PS SoR, the OIC established a working group comprised of members of the emergency response community from all disciplines with specialized expertise, knowledge, and understanding of communications technology. ITS, on behalf of the NIST Office of Law Enforcement Standards, acts as the technical manager for this practitioner working group. This working group will continue to provide on-going feedback and recommendations for future improvements to the document.

The Institute's involvement in the creation and ongoing development of the PS SoR has resulted in the team's reception of a Department of Commerce Gold Medal, which was awarded in November 2006.

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Standards Development for Public Safety Interoperability

Outputs

- Functional and performance specifications for Project 25/TIA digital radio & system standards.
- Standardized measurement methods for testing Project 25 radios and systems.
- Technical contributions to TIA-TR8 and APIC working groups.

Too often, public safety practitioners' communications systems do not meet their needs for operability (security, service area, performance, and survivability for intra-agency communications) and interoperability (inter-discipline and inter-jurisdiction communications where and when communications are needed). ITS, in cooperation with other agencies, is committed to addressing these operability and interoperability problems. A key step in achieving interoperability for public safety communications equipment is the standardization of the technical interfaces, protocols, measurement methods, and performance requirements for public safety communications equipment.

Standards development activities for the public safety community's new generation digital land mobile radio systems are being performed under a joint effort of public safety users and equipment manufacturers. The users are represented by local, State, and Federal government organizations and manufacturers are represented by industry members of the Telecommunications Industry Association (TIA). This standards development process is known as Project 25 (P25). P25 members establish user requirements and draft specifications based on the users' perspective, and TIA (and its TR-8 Committee) uses processes accredited by the American National Standards Institute (ANSI) to develop formal, nationally recognized standards that can be used to design and manufacture equipment and evaluate its performance and interoperability. ITS represents users on technical contributions and issues and provides guidance when technical decisions are to be made. ITS holds leadership positions within several P25 Working Groups: Vice Chair of the Inter-Radio Frequency Subsystem Interface (ISSI) Task Group, Vice Chair of the P25 Systems Architecture Working Group (PSAWG), Vice Chair of the Vocoder Task Group (VTG), and Chairman of the BroadBand Task Group (BBTG).

With Congress providing grants to state and local governments for telecom equipment and the funding for Federal public safety communications systems, Congressional bills have defined the importance of having P25 standards in place. As a result, the P25 Steering Committee and technical committees have set aggressive timeframes for completion of the documents that make up the standards associated with each P25 interface.

On behalf of the public safety community, ITS facilitated development of P25/TIA Standards for radio system interfaces critically needed by users. Through direct and extensive intervention with government and industry representatives and technical contributions across many fronts, ITS was responsible for advancing progress in the P25 Steering Committee and P25 and TIA TR-8 technical committees and associated APIC working groups more during the last two fiscal years than the previous 10 years combined. In FY 2006, critical specifications were standardized by TIA and ITS was instrumental in their completion. Most notably, the ISSI Messages and Procedures Standard (TIA-102.BACA-A) was finished and approved. The U.S. Congress deems ISSI to be the most critical interface for public safety interoperability. The Messages and Procedures Standard is the protocol for this interface and hence the most important standard of the ISSI suite. ITS is also a major contributor in these key P25 areas:

- ISSI Measurement Methods: TIA-102.CACA
- ISSI Performance Recommendations: TIA-102.CACB
- P25 Statement of Requirements
- ISSI Methods and Procedures Errata: TIA-102.BACA-1

Figure 1 identifies the principal functional entities involved in providing and using P25 voice services involving the ISSI. These functional entities are the Radio Frequency Subsystems (RFSSs), the ISSI, Subscriber Units (SUs), and Network Equipment

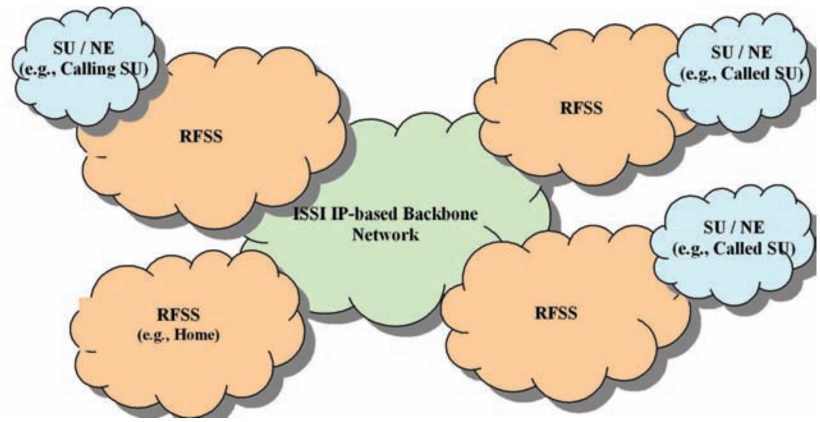

Figure 1. Principal functional entities supporting P25 wide area voice services involving the ISSI.

(NE). Multiple SUs and supporting NE are interconnected via RFSSs to enable P25-standardized wide area voice services. The ISSI IP-based backbone network, a "network of networks," establishes connectivity among RFSSs that implement ISSI functional services and protocols.

In addition to ISSI-related standardization, important work in public safety communications security is ongoing in P25 and TIA TR-8 as well. Currently the key areas in security where ITS is making significant contributions include the P25 Security Services Architecture Overview, the P25 Digital Land Mobile Radio Link Layer Encryption, the Key Management Facility (KMF) Interface Standard, security requirements and profiles for the ISSI, and an update of the Over The Air Rekeying (OTAR) specification.

Figure 2 is one view of how the rekeying of a land mobile radio might be accomplished as the radio roams from one KMF's domain to another (or from its home system to a visited system). The sequential steps in this proposed method are shown in the figure. In this method the visited KMF contacts the radio's home KMF to obtain key management information necessary to rekey the radio for operation in the visited system. Key management messages (KMMs) contain the new key information that are used in OTAR.

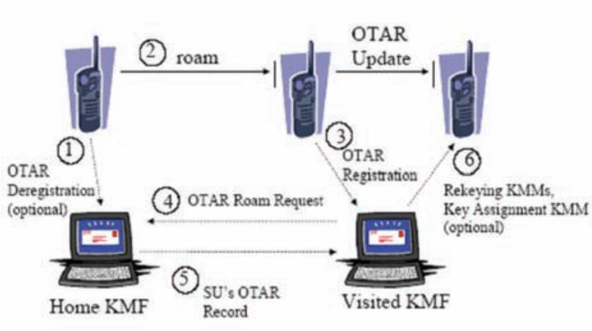

Figure 2. Inter-KMF roaming for end-to-end key management.

ITS is working on standardization in other standards development organizations (SDOs) as well. In Project MESA, a joint effort of the European Telecommunications Standards Institute (ETSI) and TIA, efforts have concentrated on defining the public safety requirements for broadband mobile applications worldwide. ITS has provided user operational requirements that represent the views of U.S. public safety users. An ITS engineer is Chair of the Technical Specification Group — Systems. In the Institute of Electrical and Electronics Engineers, (IEEE), ITS engineers are investigating 802.11x and 802.16x to determine their suitability for Public Safety telecommunications applications.

The ITS standards development for public safety program is sponsored by several Federal departments and programs with a keen interest in public safety interoperability, including: National Institute of Standards and Technology Office of Law Enforcement Standards, Department of Justice Office of Community Oriented Policing Services, Department of Homeland Security's Public Safety Wireless Communications (SAFECOM) Program, Federal Partnership for Interoperable Communications, and the Department of Homeland Security Chief Information Officer's Wireless Management Office. This work is being done in conjunction with projects underway in multiple public safety organizations and is closely tied to other ITS public safety projects.

In FY 2007, ITS will continue to work on the development of technical standards to extend and enhance operability and interoperability in public safety telecommunications.

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Project 25 Compliance Assessment Program

Outputs

- Support of the TIA Project 25 Compliance Assessment Working Group.
- Processes and procedures document describing approval and operation of Project 25 compliance assessment laboratories.
- Grant guidance language for Federal Project 25 equipment grant programs which defines Project 25 compliance requirements.

In FY 2006, ITS engineers continued to play key roles in support of the National Institute of Standards and Technology's (NIST) Office of Law Enforcement Standards (OLES) efforts to implement a compliance assessment program for Project 25 land mobile radio equipment. The program was initiated in response to Congressional legislation which mandated that "when Project 25 equipment is purchased with [grant] funds, the equipment meets the requirements of a conformity assessment program"[1] and that the grantors should at a minimum "require that all grant dollars for interoperable communication be used for Project 25 compliant equipment that meet the requirements of a conformity assessment program."[2] Work on the program began in earnest in April 2005 following a request from the Project 25 Steering Committee.

The Project 25 standard is being rolled out in phases and the compliance program is being structured to follow suit. Originally begun in 1989, Project 25 will ultimately define eight open interfaces:

1. Common Air Interface
2. Inter-RF Subsystem Interface
3. Fixed Station Subsystem Interface
4. Console Subsystem Interface
5. Network Management Interface
6. Data Network Interface
7. Subscriber Data Peripheral Interface
8. Telephone Interconnect Interface

To date, only the Common Air Interface (CAI) has been sufficiently developed to allow for development and deployment of interchangeable equipment. Accordingly, compliance assessment will begin with the CAI. As the program matures, testing will encompass the essential elements of compliance as defined by the Telecommunications Industry Association (TIA) Mobile and Personal Private Radio Standards (TR-8) subcommittee. They include the following types of tests:

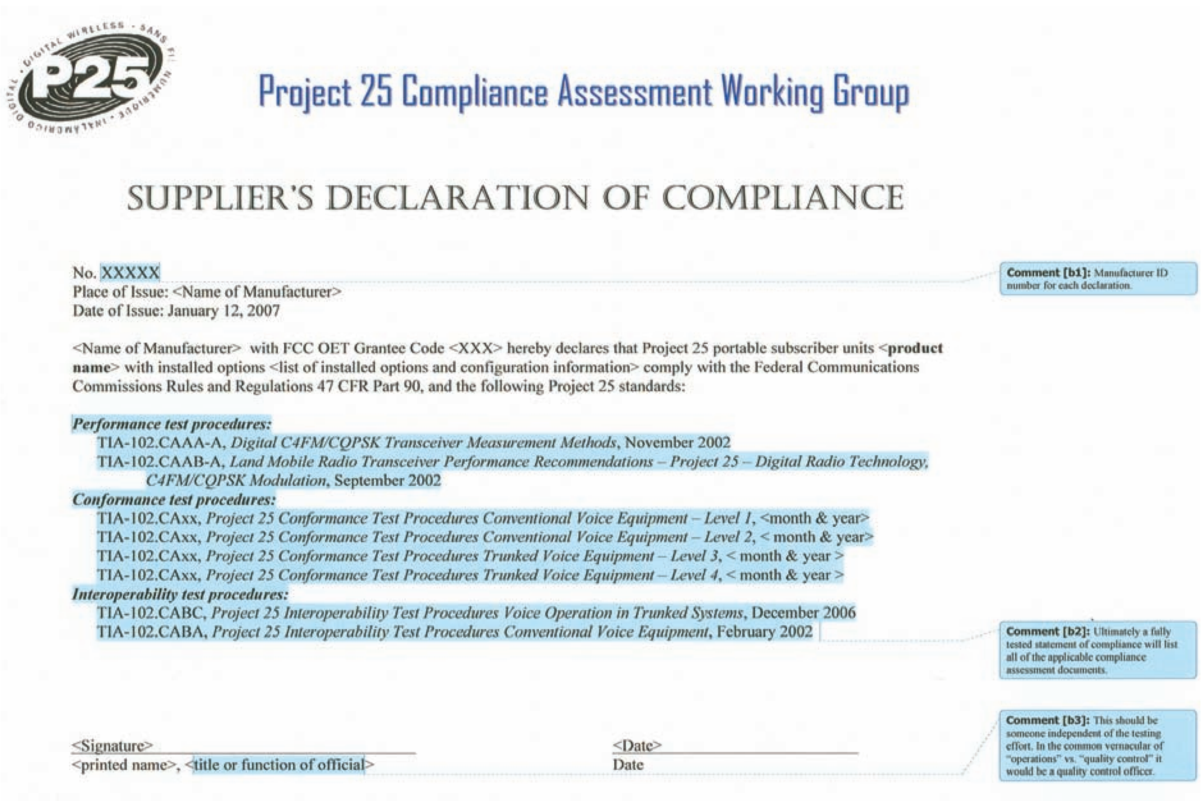
- Performance: measurements that verify the specifications for a component or sub-system.
- Conformance: bit-by-bit, message-by-message protocol verification.
- Interoperability: functional "can-you-hear-me-now" type testing to validate equipment interchangeability.

A framework for the program was developed by government and industry officials in 2006. Initially a third-party laboratory accreditation program was envisioned by representatives from ITS and NIST; however, industry members argued that third-party participation would hinder the program, as the unique nature of the Project 25 protocols and the subsequently steep learning curve would tax both third-party labs and Project 25 manufacturers alike. As an alternative, Project 25 manufacturers unanimously volunteered the use of their internal laboratories and facilities as test beds. They also agreed to submit to peer assessments of their laboratories' competence. Such an approach is formally known as a first-party, peer assessment model.

Peer assessment involves both initial laboratory assessments for competence and quality control processes as well as laboratory audits or reviews where processes and documentation are assessed. The policies and procedures for the program will be captured in a NIST publication to be entitled *Procedures and General Requirements for Compliance Assessment of Project 25 Land Mobile Radio Equipment*.

1 House Report 109-241 - "Making Appropriations for the Department of Homeland Security for the Fiscal Year Ending September 30, 2006, and for Other Purposes."

2 Senate Report 109-088 - "Department of Commerce and Justice, Science, and Related Agencies Appropriations Bill, 2006."



Project 25 Compliance Assessment Working Group

SUPPLIER'S DECLARATION OF COMPLIANCE

No. XXXXX
Place of Issue: <Name of Manufacturer>
Date of Issue: January 12, 2007

<Name of Manufacturer> with FCC OET Grantee Code <XXX> hereby declares that Project 25 portable subscriber units <**product name**> with installed options <list of installed options and configuration information> comply with the Federal Communications Commissions Rules and Regulations 47 CFR Part 90, and the following Project 25 standards:

Performance test procedures:
TIA-102.CAAA-A, *Digital C4FM/CQPSK Transceiver Measurement Methods*, November 2002
TIA-102.CAAB-A, *Land Mobile Radio Transceiver Performance Recommendations – Project 25 – Digital Radio Technology, C4FM/CQPSK Modulation*, September 2002
Conformance test procedures:
TIA-102.CAxx, *Project 25 Conformance Test Procedures Conventional Voice Equipment – Level 1*, <month & year>
TIA-102.CAxx, *Project 25 Conformance Test Procedures Conventional Voice Equipment – Level 2*, < month & year>
TIA-102.CAxx, *Project 25 Conformance Test Procedures Trunked Voice Equipment – Level 3*, < month & year >
TIA-102.CAxx, *Project 25 Conformance Test Procedures Trunked Voice Equipment – Level 4*, < month & year >
Interoperability test procedures:
TIA-102.CABC, *Project 25 Interoperability Test Procedures Voice Operation in Trunked Systems*, December 2006
TIA-102.CABA, *Project 25 Interoperability Test Procedures Conventional Voice Equipment*, February 2002

<Signature> <Date>
<printed name>, <title or function of official> Date

Comment [b1]: Manufacturer ID number for each declaration.

Comment [b2]: Ultimately a fully tested statement of compliance will list all of the applicable compliance assessment documents.

Comment [b3]: This should be someone independent of the testing effort. In the common vernacular of "operations" vs. "quality control" it would be a quality control officer.

Sample ISO 17050-1 compliant supplier's Declaration of Compliance.

Manufacturers will conduct tests in accordance with normative standards adopted by the Project 25 Steering Committee, which are typically published by TIA. In this area as well, ITS is making a significant contribution to facilitate the accelerated completion of the test standards. For example, ITS engineers are editing the Project 25 Standard, *Interoperability Testing for Voice Operation in Trunked Systems*, which will be published as TIA-102.CABC-A.

Program participants will produce and keep detailed test results for each device or system. For the Project 25 consumer they will produce at-a-glance type summary test reports using standard formats to simplify interpretation of the results and, where applicable, product comparisons. A product that has been tested against all of the available, published, normative test standards is deemed to be compliant — not by an independent third party, but by the manufacturer itself. Such a declaration or self-certification is made by a responsible company official following guidelines established in ISO/IEC 17050-1. Each Supplier's Declaration of Compliance (SDoC) details a product's configuration and the types of tests conducted on it. The documented test reports and the subsequent company declaration should go a long way toward increasing the public safety community's confidence in Project 25 equipment.

The Project 25 Compliance Assessment Program is voluntary in nature; participating Project 25 manufacturers need not test their products nor declare compliance. However, as the law mandates, public safety agencies seeking to use grant funds to purchase Project 25 equipment must select from compliant equipment with an accompanying SDoC.

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Department of Commerce ISSI Emulation and Test System (DIETS)

Outputs

- An ISSI reference implementation.
- Software capable of conformance testing the ISSI protocol.

The importance of the Project 25 (P25) suite of standards has been conveyed by Congress through several pieces of recent legislation. With Congress providing grants to all levels of government (local, State, and Federal) for the acquisition of public safety telecommunications equipment, the suite of P25 standards is necessary to ensure interoperability among the different levels of government. Congress considers the Inter-RF Sub-System Interface (ISSI), one of seven P25 interfaces, to have top priority for completion.

ISSI can be thought of as a network protocol that is able to utilize a standard network interface card (NIC). The intent is for this interface to be present in future deployments of P25 Radio Frequency Sub-Systems (RFSS). A P25 RFSS is the infrastructure equipment that enables land mobile radios to communicate with each other and to dispatchers within a P25 system. An RFSS provides open P25 interfaces that enable narrowband voice and data services, including communication among radio users located in disparate coverage areas supported by different RFSSs. The ISSI of different RFSSs can be interconnected using various mediums, but the most common is Ethernet. When the ISSIs of various RFSSs are interconnected, IP packets that contain encoded voice can be transmitted and received. The ISSI is important to public safety agencies because it will foster competition among several vendors who manufacture RFSSs. Over time, this increased competition should drive down the cost of P25 infrastructure. In addition to lower cost, the most important reason for having an ISSI interface is to promote interoperability between the different vendors who manufacture RFSSs. This allows the end consumer to implement a P25 communications network that consists of RFSSs from multiple vendors.

Testing of the ISSI Interface

A balloted scope one version of the P25 ISSI Messages and Procedures for Voice Services (TIA-102.BACA) specification was formally released in August 2006. Conformance tests are currently being developed and scheduled for completion in early 2007. These conformance tests will verify that the vendor implementation under test conforms at a message level to what has been specified in TIA-102.BACA.

In order to verify objectively that a vendor conforms to TIA-102.BACA, a reference implementation of the ISSI protocol stack has been developed. This software reference implementation is referred to as the Department of Commerce ISSI Emulation and Test System (DIETS). ITS developed this software in conjunction with the National Institute of Standards and Technology's (NIST) Advanced Network Technologies Division. Since DIETS was implemented in Java, the software can be loaded on a regular desktop PC with a Linux or Windows operating system. DIETS is capable of emulating one of four different roles in a P25 ISSI-based network. The roles are (1) calling serving RFSS, (2) calling home RFSS, (3) called home RFSS, and (4) called serving RFSS. The idea is that DIETS will be placed in a test configuration, as defined in the conformance test document, which will fulfill one of the four roles depending on the test case under consideration. An example of this concept is shown in Figure 1. The number of vendor RFSSs and roles may vary depending on the test case requirements.

It is also possible to test in isolation the ISSI of a single vendor RFSS. This scenario implies that there is only one vendor RFSS with a real ISSI and the rest of the ISSI interfaces are emulated by DIETS. An example of this test architecture is illustrated in Figure 2. The number of emulated ISSIs and the role of the emulated interfaces will vary depending on the conformance test case under consideration.

Since DIETS does not currently have the capability to emulate the P25 common air interface, the behaviors of (or events generated by) subscriber units are emulated in the DIETS software. The conformance tests are implemented in XML scripts. The user has the capability to modify the specific test parameters in these scripts as necessary. As an example, the number of subscriber units involved in the conformance test is a parameter that the user can modify.

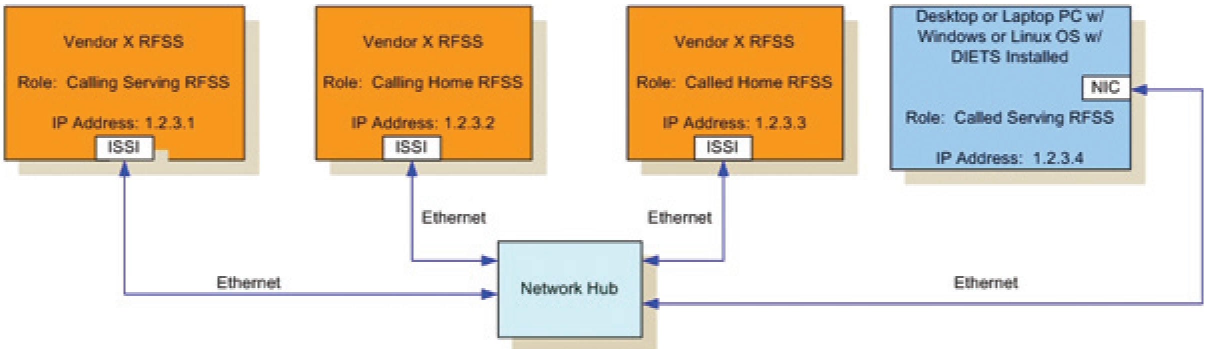

Figure 1. Test architecture with only one instance of DIETS. In this particular scenario, the network hub is critical to enabling packet collection from all Ethernet links. (IP addresses are for example purposes only, and these particular addresses are not meant to be used in a real network configuration.)

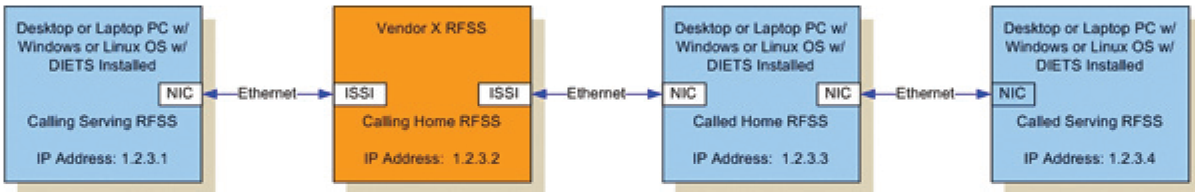

Figure 2. Test architecture with three instances of DIETS (IP addresses are for example purposes only).

From the DIETS graphical user interface (GUI), the user selects a conformance test case to execute. After the test case has completed execution, the user can then view the session initiation protocol (SIP) and real-time transport protocol (RTP) Push-to-Talk (PTT) messages that were exchanged between ISSIs in a graphical message sequence chart (MSC) to determine if the test case passed or failed. Raw IP packet data can be rendered by clicking on the message of interest in the MSC. DIETS has a packet capture ability that is based on the Ethereal packet capture (PCAP) engine. This gives DIETS the capability to capture the messaging that occurs between all ISSIs (emulated or real) that are involved in a given test.

Future Direction of DIETS

In addition to the ISSI, there are two other wireline interfaces that DIETS can be expanded to test. These interfaces are the Fixed Station Interface (FSI) and the P25 Trunked Console Interface (CI). The FSI standard, TIA-102.BAHA, was formally published in 2006. The CI is scheduled to be balloted in January 2007, and the intent is that this standard will be an addendum to TIA-102.BACA.

The primary purpose of the FSI is to enable connectivity of a fixed station (i.e., base station) to an RFSS. The FSI can be thought of as a protocol stack. The intent of this interface is to allow interoperability between different vendors' fixed stations and RFSSs. The physical medium that will interconnect FSIs is not limited to Ethernet.

The primary purpose of a trunked console interface is to enable the connectivity of a dispatcher's console to an RFSS's CI. The CI is very similar to the ISSI with minor variations.

The conformance document for the FSI is nearly complete and will be balloted in January 2007. As for the CI, the conformance test cases will be added to the ISSI conformance document. DIETS can be expanded to enable objective message level conformance testing of the FSI and CI. In addition to expanding DIETS's capability to test additional P25 interfaces, DIETS also can be expanded to test the performance of the ISSI according to the Project 25 ISSI Measurement Methods for Voice Services standard. At this time, the direction in which DIETS will be expanded is under consideration.

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Emergency Telecommunications Service (ETS) Standards Development

Outputs

- Technical contributions to ATIS Technical Committee PRQC.
- Technical contributions to ITU-T Study Group 9.

In the aftermath of the 2001 terrorist attacks, the Federal Government has become very interested in priority treatment for emergency communications. While the Government Emergency Telecommunications Service (GETS) has served emergency workers well for many years, it is limited to the Public Switched Telephone Network (PSTN) in the United States. The Emergency Telecommunications Service (ETS) is envisioned as a GETS-like service that will be available internationally and encompass virtually all wireless and wireline communications networks. Types of traffic to be carried include voice, video, database access, text messaging, e-mail, FTP, and web-based services.

The ETS Standards Development project conducts laboratory studies, computer simulations, and security analyses to further standards development supporting Critical Infrastructure Protection (CIP) initiatives. This project is funded by the National Communications System (NCS). The work supports NCS in its mission to protect the national security telecommunications infrastructure, and to ensure the responsiveness and availability of essential telecommunications during a crisis.

The ETS Standards Development project provides contributions to two standards development organizations: the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Study Group (SG) 9 and American National Standards Institute (ANSI)-accredited Performance, Reliability, and Quality of Service Committee, PRQC. ITU-T SG 9 is the Lead Study Group on integrated broadband cable and television networks, and PRQC works in the areas of Quality of Service (QoS), Reliability, and User-Plane Security.

In SG 9, ITS develops and verifies Recommendations to support preferential telecommunications services and user authentication. The major goal of this project is to ensure that future ETS mechanisms and the current GETS service will interoperate over broadband cable television networks in their delivery of voice, data, and multimedia communications.

In PRQC, ITS provides ETS expertise relating to priority support and network security. During FY 2006, an ITS engineer served as co-editor of several ANSI and Alliance for Telecommunications Industry Solutions (ATIS) Standards and Technical Reports. These provide guidelines, specifications, and requirements for aspects of ETS communications. An ITS engineer serves as the Chair of PRQC's Security Task Force where he leads security standardization for the Network User Plane. He also chairs the ATIS Joint Ad-Hoc Technical Committee for Issues PRQC A0029 and TMOC 95, which works across all relevant ATIS committees to provide a common security baseline suite of standards for telecommunications security in current and Next Generation Networks (NGN).

The standardization work in ITU-T SG 9 is focused on the IPCablecom and IPCablecom2 families of Recommendations. These Recommendations define the protocols and signaling to be used on broadband cable television networks to support telephony, multimedia, and Internet access. The IPCablecom Recommendations have been standardized in ITU-T SG 9, and equipment implementing them is currently in production worldwide. IPCablecom2 has recently been approved and equipment will be deployed in the coming years. One goal of this project is to identify where additions or changes might be needed to support the ETS. This effort also involves work with the Internet Engineering Task Force (IETF), since many of the underlying protocols used in IPCablecom (as well as some of the ETS mechanisms) are under development in the IETF. An ITS engineer served as editor and principal author of ITU-T Recommendation J.260, "Requirements for preferential telecommunications over IPCablecom networks," in SG 9. An ITS engineer also serves as the editor of Draft new ITU-T Recommendation J.pref, "Specifications for preferential telecommunications over IPCablecom networks," and J.preffr, "Framework for implementing preferential telecommunications in IPCablecom networks." J.pref will provide specifications to satisfy the requirements set forth in J.260, and J.preffr will provide a longer-term framework for standardizing preferential services and emergency user authentication in cable networks.

Another important study underway at ITS is a series of tests of GETS over IPCablecom networks. The evolution of GETS from a PSTN-only service to one that will interoperate over the wireless, IPCablecom, and Next Generation networks is an NCS goal. Another goal of this effort is determining the security needs of ETS in IPCablecom networks.

The diagram in Figure 1 shows the organization of IPCablecom specifications. IPCablecom2 is the next generation of IPCablecom and is based on the 3rd Generation Partnership Project's (3GPP) IP Multimedia Subsystem (IMS) architecture. The diagram shows the relationships between the various standards that make up IPCablecom2. The goal is to develop standards that support both GETS and ETS in IPCablecom2 as well as earlier versions of IPCablecom.

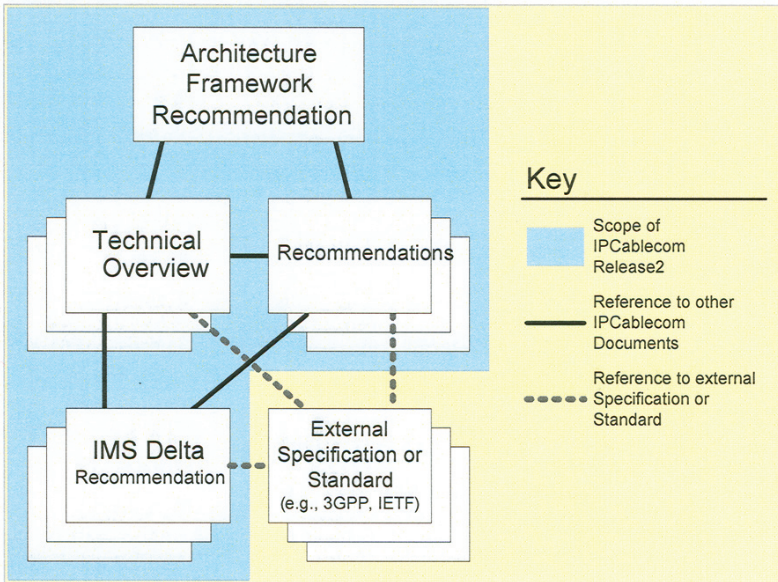

Figure 1. IPCablecom2 organization.

Figure 2 shows the major activity areas for security engineering of telecommunications networks. Threat Vulnerability Analysis (TVA) and Security Policy combine to form a Security Model which then drives Practices, Architecture, and Deployment. This diagram is from the draft Technical Report underway in the ATIS Joint Ad-Hoc Technical Committee for Issues PRQC A0029 and TMOC 95. Joint effort with the other ATIS groups doing security work is vital and will allow us to better define and coordinate this important network security work.

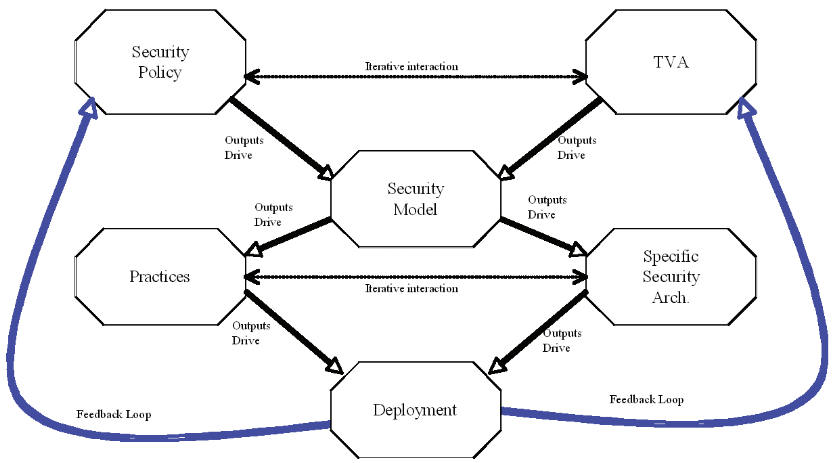

Figure 2. Security engineering major activity areas.

In FY 2007, ITS will continue to work on the development and standardization of ETS in ATIS PRQC, the IETF, and ITU-T SG 9. The projects will address technologies in the NGN and interactions with the IPCablecom networks. This work on ETS must of necessity be conducted with the help of representatives from network providers and cable television equipment manufacturers, as well as NCS. The work in FY 2007 will focus on priority and security in the NGN ETS as well as GETS and ETS compatibility in the IPCablecom and IPCablecom2 networks.

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Multimedia Quality Research

Outputs

- Technical contributions to VQEG.
- Technical contributions to ITU-T Study Group 9.

The transmission of audio/video (multimedia) signals over wireline and wireless channels has increased exponentially in the past decade. In particular, the distribution of multimedia signals over wireless links to devices such as laptops, personal digital assistants (PDAs), and cellphones is widespread and the need for quality measurements is great. The widespread use of digital technology for the transmission of audio and video signals has led to the need for new objective quality assessment methods based on human perception. ITS has a long history of successful research in the areas of voice and video quality assessment. Until recently, however, the development of an objective measure of overall multimedia quality has not been adequately addressed.

Multimedia is defined here as the combination of audio and video in the communication of information. The objective of the ITS Multimedia Quality Research project is to characterize and analyze the fundamental aspects of multimedia quality assessment. A primary goal of this research is to develop an algorithmic system to objectively assess multimedia quality by combining audio quality, video quality, and audiovisual synchronization information.

In 2003, International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) Recommendation J.148 was approved by Study Group 9, entitled "Requirements for an objective perceptual multimedia quality model." ITS staff contributed significantly to this Standard. Figure 1 is a diagram from J.148 showing the basic components of a multimedia quality assessment system. The boxes marked "Audio Quality" and "Video Quality" represent subsystems that assess the audio and video quality. The box marked "Differential Delay" outputs a measure of the error in synchronization between the audio and video channels in the audiovisual signal.

The box marked "Multimedia quality integration function" is the subsystem that will combine the previous subsystems' outputs to predict the overall multimedia quality. It will apply specific rules to the information provided by the other subsystems. The form of these rules will be based on data derived from subjective quality experiments. The aim is to produce a set of integration rules that enable the multimedia model to accurately predict human quality perception of systems and services under test. Therefore the validity of the model must be shown

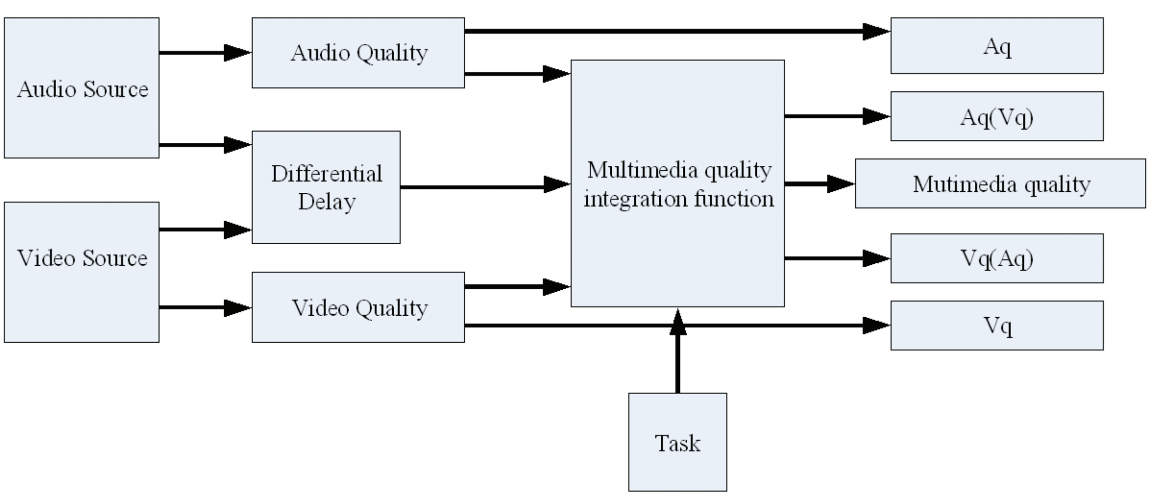

Figure 1. Basic components of a multimedia model.

by comparing the performance of the model against quality ratings obtained from subjective tests for a range of test materials.

The complete multimedia model provides five outputs. The primary output is a predicted measure of overall multimedia quality. Four subsidiary outputs provide predictions of perceived quality for the audio (denoted Aq), video (denoted Vq), audio accounting for any influence the video may have (denoted Aq(Vq)), and video accounting for any influence the audio may have (denoted Vq(Aq)).

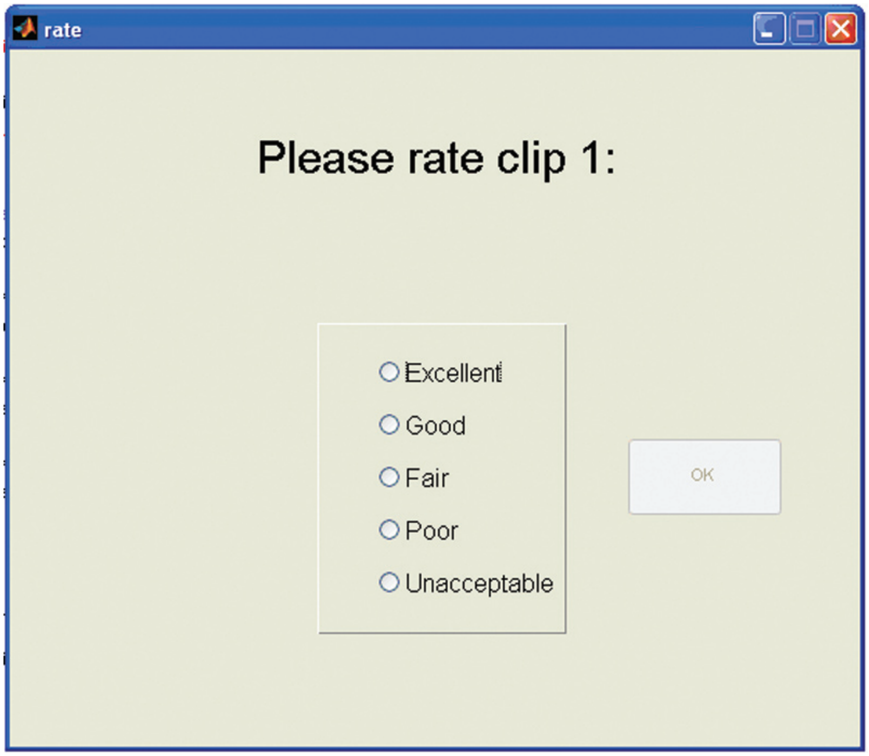

Figure 2. Subjective test scoring dialog box

Subjective testing has played an important part in ITS efforts to develop voice and video quality assessment methods. For multimedia research, subjective testing is no less important. Objective quality assessments are based on data derived from subjective quality experiments. A series of multimedia subjective tests will be executed to explore the relationships between the quality parameters for audio, video, and audiovisual synchronization. This will provide data for the development of the integration function.

Subjective testing employs human subjects to rate multimedia quality. The results are used to train and test the objective measurements calculated by the models. ITU Recommendations provide standardized methodologies for subjective testing of voice, audio, video, and multimedia. One of the methods used by ITS is the Absolute Category Rating (ACR) method. Figure 2 shows a multimedia clip rating box utilizing the ACR method. The testing system will play a multimedia clip on a computer screen and speakers and then display the rating box to elicit the subject's judgment of the quality. By averaging the scores of each clip from many subjects, a realistic assessment of the quality is obtained.

This work is being done in conjunction with projects underway in the Video Quality Experts Group (VQEG) and the ITU-T Joint Rapporteur Group on Multimedia Quality Assessment (JRG-MMQA). The JRG-MMQA is an official body of the ITU and is formed from members of ITU-T Study Groups 9 and 12.

In FY 2007, ITS will continue to work on the development of a multimedia quality assessment model by conducting subjective experiments and analyzing the results.

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Wireless Network Measurement Methods

Outputs

- Public safety 4.9-GHz indoor propagation and throughput measurements.
- Asynchronous radiated power measurement techniques for 802.11-based systems.

Federal operations have historically exhibited a heavy dependence on wireless networks, but these have typically been of the land mobile radio variety, with analog modulation methods and simple network topologies. In recent years, a more data-centric view of Federal operations has gained favor, probably fueled by the wide availability of high speed enterprise local area networks and the increased data processing ability of the ubiquitous desktop computer. This philosophy requires the ability to transmit significant volumes of digital data over the telecommunication medium being used, and its effects are being felt in the design of wireless networks.

Modern wireless networks are apt to be heavily weighted toward data transmission, with digital modulation and sophisticated protocol overlays. Since the Internet Protocol (IP) is so well known, it is often the kernel protocol of choice, but it may be encapsulated at the MAC and physical layers by other protocols like 802.11 or 802.16. New topologies, like mesh networking, are also being investigated. Finally, since these technologies often require greater spectral allocations than traditional voice services, spectrum reallocations to reassign spectrum for wireless data networking are becoming more commonplace.

As wireless technologies mature, manufacturers and standards bodies introduce test methods and instrumentation to investigate their behavior. However, at the introduction of a new wireless networking technology, or when a legacy technology is implemented within a new spectral regime, test methods and instrumentation must be developed. The ITS Wireless Network Measurement Methods project is charged with meeting these requirements.

Currently, the system under investigation is an 802.11j wireless data network operating in the licensed 50-MHz spectral band between 4.945 GHz and 4.995 GHz. This band has been assigned to Public Safety organizations and is also the spectral support for the 802.11j networking protocol. ITS engineers have studied this network operating within several different propagation environments, including outdoor to indoor, and indoor professional and residential environments.

The primary metric used in these measurements has been network throughput, as this is the parameter most visible to a public safety user. However, received radiated channel power has also been a parameter of interest, and this portion of the experiment has required the development of some new techniques.

The problem occurs, in 802.11-based systems, because each node is a transmitter as well as a receiver. The switch from one mode to another occurs within a time regime of microseconds, and is essentially asynchronous to the measurement device since no control signal is provided to warn that the node is changing states. A normal power measurement device (such as a swept filter spectrum analyzer) is designed for signals that are considerably less bursty than those provided by 802.11 protocols, so an FFT-based real time analyzer was used with some specialized techniques to prevent hopelessly conflating the transmitted and received signals.

An example of this type of measurement is given in Figure 1 on the next page, where signal strength is plotted on the horizontal axis and percentage of samples is plotted on the vertical axis. The top graph shows a trimodal distribution, where the rightmost peak is the acknowledgement signal transmitted by the network node under investigation, and the central peak shows the level of received channel power. The leftmost peak represents the quiescent noise floor of the test instrument.

These measurements were taken in a hallway where the node under test was continuously receiving 1536-byte packets over a distance of about 50 meters at a throughput rate of 11.5 megabits per second. The measurement represents approximately 250 40-microsecond windows sampled at a rate that gave 1024 points per sample window. The width of the central received peak shows that the radio channel transmission effects and the channel power of

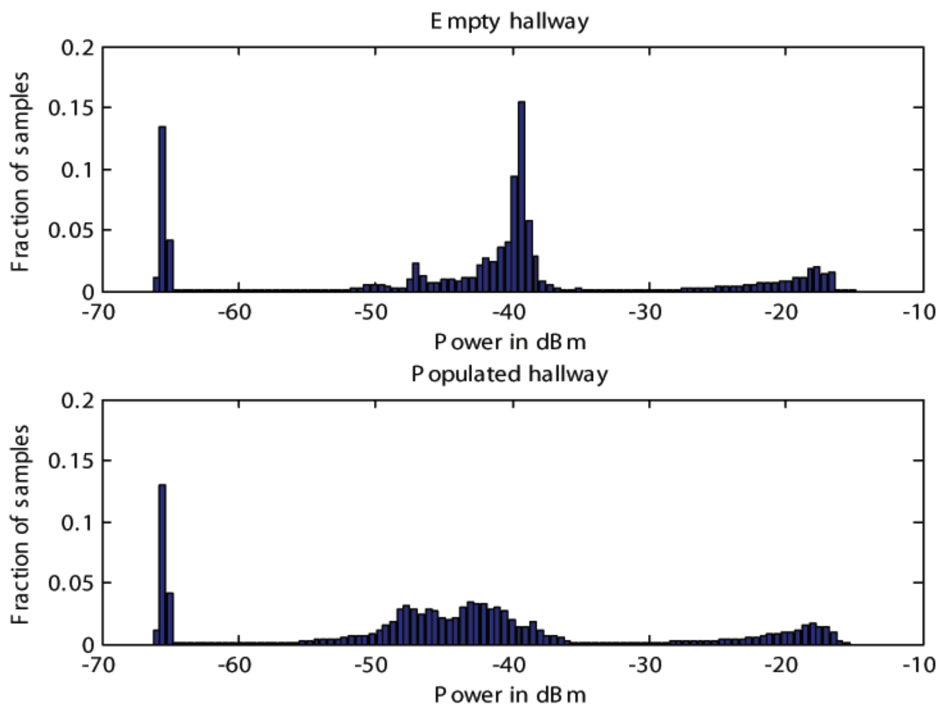

Figure 1. Sampled channel power measurements within an occluded hallway.

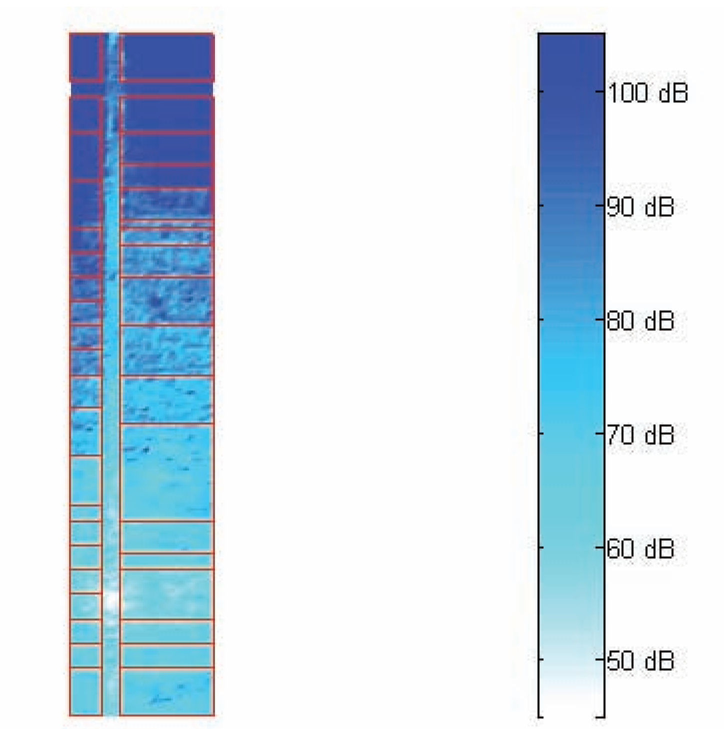

Figure 2. Propagation model path loss predictions for a concrete/ concrete block structure. The transmitter is in the light colored area at the lower left, and the red lines represent office walls.

the received signal vary over about a 10-dBm range during a 10-millisecond time regime. A later measurement is shown in the bottom part of the figure, with the hallway RF path occluded by a group of 20 people. Here the received signal has suffered some attenuation, as indicated by the left shift of the central distribution peak.

Measurements like these, coupled with the results of propagation prediction programs like those shown in Figure 2, allow the accurate prediction of coverage areas within complex indoor environments. In addition to providing insights into the benefits and limitations of targeted wireless networking technologies, these tools may be used to ensure coverage for public safety professionals in emergency situations.

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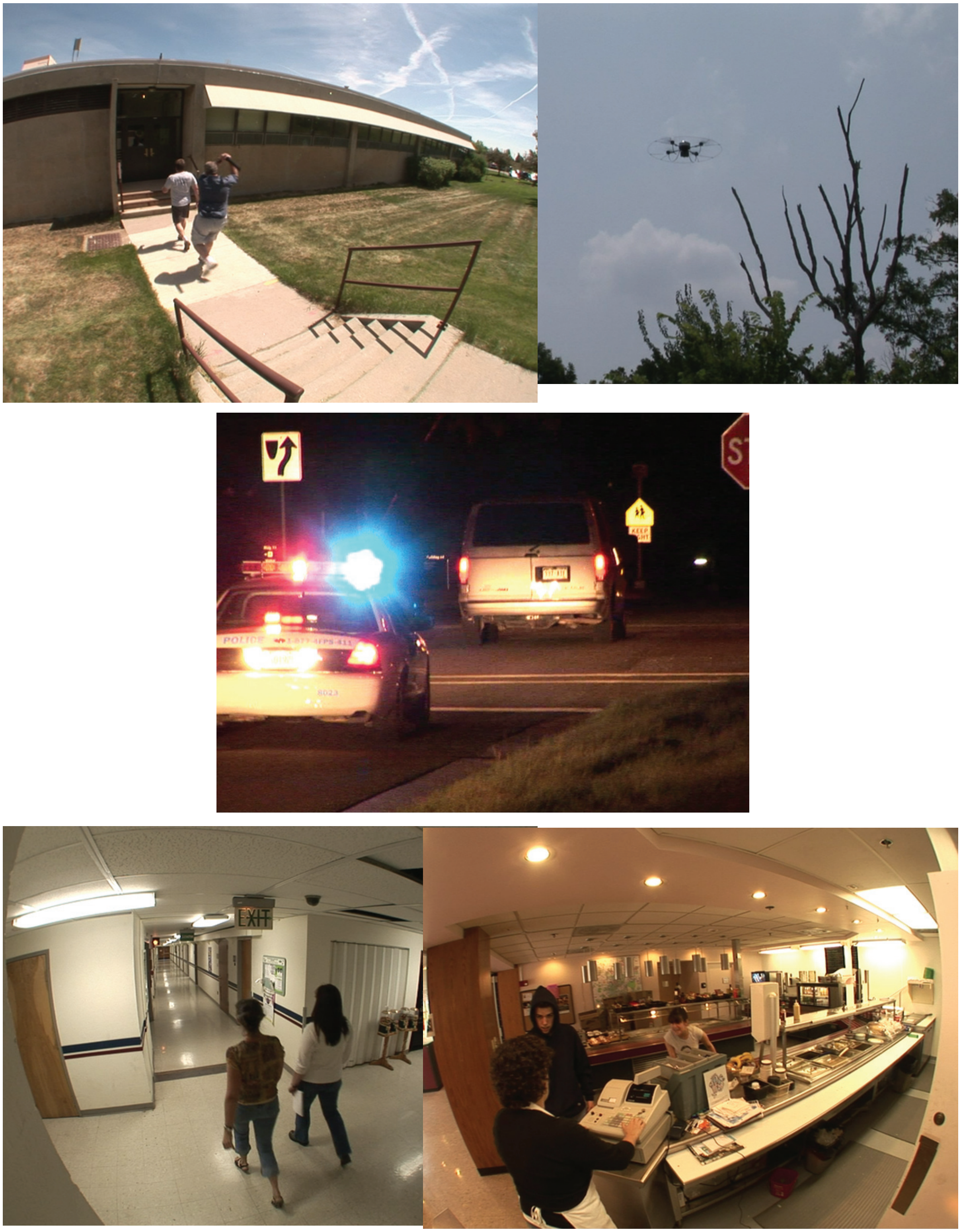


The scenes above are examples of video clips used by ITS to conduct subjective video tests for the Public Safety Video Quality (PSVQ) Project. Viewers watch a series of video clips and rate their quality. The results from these tests are then analyzed and used to help establish standards for video quality based on application.

Telecommunications Engineering, Analysis, and Modeling

The Telecommunications Engineering, Analysis, and Modeling Division conducts studies in the following three areas for wireless and wireless-wireline hybrid applications.

Engineering encompasses technical assessment of telecommunications systems, their components, and their performance, including impact of access, interoperability, timing and synchronization, and susceptibility to noise and interfering signals on system effectiveness in national security/emergency preparedness (NS/EP), military, and commercial operational environments.

Analysis is often performed in association with the TA Services project, which offers analytical tools via an on-line cooperative research and development agreement. ITS can customize these tools and analyses for specialized applications.

Modeling is one of ITS's core strengths. Propagation models are incorporated with terrain databases and other data. Adaptations of historic models, and those for specialized situations have been developed, enhanced, and compared. ITS engineers contribute to international and national standards bodies, such as ITU-R SG3, 8F, and ATIS WTSC/G3GRA.

Areas of Emphasis

ENGINEERING

Interference Issues Affecting Land-Mobile Systems The Institute participates in the ATIS subcommittee WTSC/G3GRA (Wireless Technologies and Systems Committee — Radio Aspects of GSM/3G and Beyond). ITS is now developing PCS interference models for CDMA and W-CDMA. This project is funded by NTIA.

Public Safety Video Quality (PSVQ) The PSVQ project is conducting a series of subjective tests that illustrate different types of video compression and artifacts. These examples of video are shown to viewers and then the data is analyzed and correlated. From this analysis NTIA/ITS hopes to make recommendations for video standards based on applications in the public safety arena. This project is funded by DHS/SAFECOM.

Public Safety Architecture Framework (PSAF) The PSAF project is establishing a common framework for information databases from various branches of the public safety community. NTIA/ITS is leading a large collaborative effort to ensure the ability to share information across many agencies — local, State, and Federal. This project is funded by DHS/SAFECOM.

Analysis of HA-NDGPS The Institute has developed a unique software model for performance and interference analysis and is conducting an analysis of the High Accuracy Nationwide Differential Global Positioning System (HA-NDGPS) for the Federal Highway Administration of the U.S. Department of Transportation.

ANALYSIS

Telecommunications Analysis Services The Institute provides network-based access to research results, models, and databases supporting applications in wireless system design and evaluation. These services are available to government and non-government customers and are funded by fee-for-use and fee-for-development charges through an on-line CRADA. ITS is examining migration of TA Services to a web-based system.

Geographic Information System (GIS) Applications The Institute continues to develop a suite of GIS-based applications for propagation modeling and performance prediction studies. This powerful GIS format complements ITS's propagation prediction capabilities nicely. The work is funded by the U.S. Department of Defense.

MODELING

Broadband Wireless Standards The Institute develops radio propagation algorithms and methods that improve spectrum usage of wireless systems. Technical standards are prepared that support U.S. interests in 3G broadband wireless systems and are then fed into the ITU-R SG 3, WPs 3J, 3K, 3L and 3M. ITS is active in path specific model development toward a draft new Recommendation. The project is funded by NTIA.

Short-Range Mobile-to-Mobile Propagation Model Development and Measurements The Institute is developing a model for short-range (less than 1 km) propagation between mobile radios. The propagation work consists of both modeling and measurements. A new propagation measurement system is under development, and preliminary measurements were performed in FY 2006. This project is funded by NTIA.

Interference Issues Affecting Land-Mobile Systems

Outputs

- Self-interference models for dominant CMRS technologies.
- Technical contributions to industry-supported efforts for predicting, identifying, and mitigating interference related problems.
- Adapted model for use in evaluating adjacent channel systems.

Recent natural disasters demonstrate how important Commercial Mobile Radio Services (CMRS) have become in establishing emergency communications. Damage to the terrestrial telecommunication infrastructure forces users to resort to cellular resources. Emergency responders find themselves unable to establish inter-agency communication links, especially with responders from outside of the affected area and, as a last resort, must rely on cellular systems to fulfill their missions. The sudden influx of traffic by private, commercial, civil, and Federal users results in system overloads, a decrease in signal quality, and further disruption of service in the affected area. Beyond the physical damage caused by events, additional factors contribute to diminished channel capacity of the wireless network, such as co- and adjacent-channel interference and the operation of multiple, independent, non-interoperable systems servicing the same geographical area, often using the same frequency bands and infrastructure (base station sites and towers).

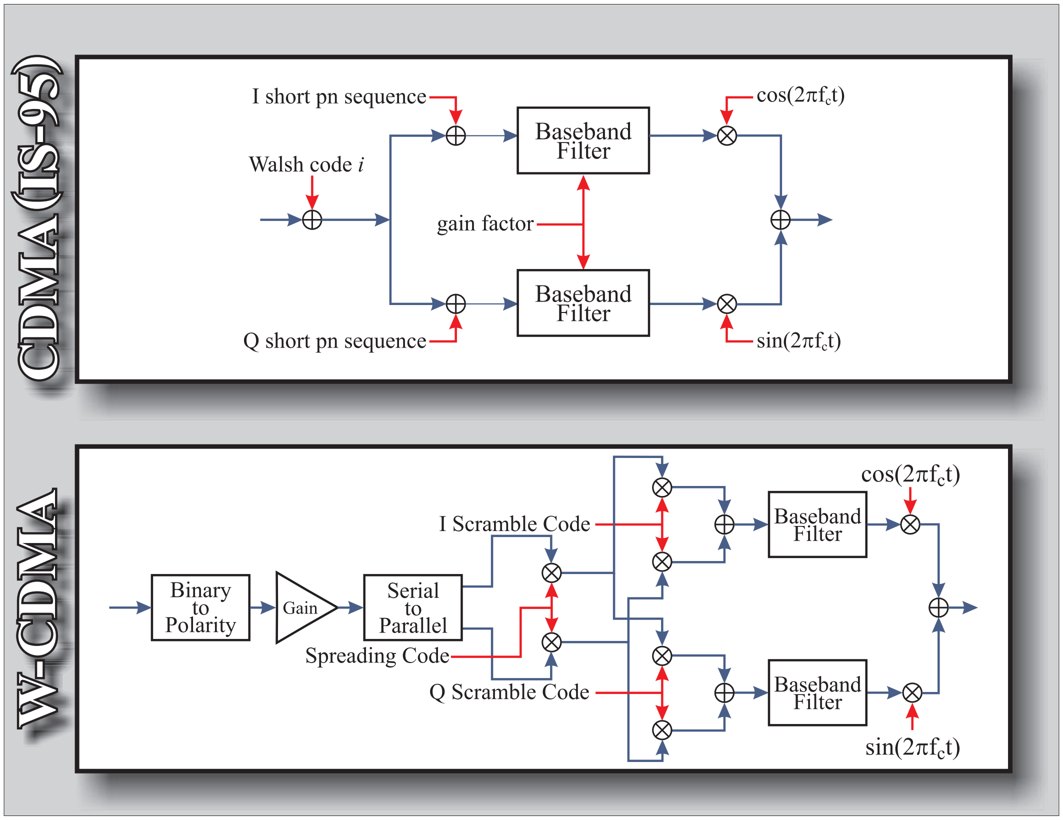
One way of coping with damaged or destroyed infrastructure is to deploy temporary equipment to supplement the surviving system. To make efficient use of limited resources, responders need to know what equipment needs to be deployed in which locations. Knowing the interference issues, dynamics and load patterns of the original system is key to effective, post-disaster support by national security/emergency preparedness (NS/EP) planners and network operators in an overloaded environment.

As plans for next- and future-generation communication systems develop, the lack of available spectrum becomes an issue. Also, spectrum dedicated to systems supporting emergency responders must be allocated from frequencies already in use. Spectrum sharing by multiple users will become absolutely necessary if all proposed systems are implemented.

ITS contributed to the understanding of inter-PCS interference by participating in the Telecommunication Industry Association (TIA) committee TR46.2 (Mobile & Personal Communications 1800-Network Interfaces). As a member of TR46.2, ITS contributed to the development of the Technical Service Bulletin "Licensed Band PCS Interference" (TSB-84A). This bulletin was a first step in characterizing the interfering environment caused by large numbers of active users and competing technologies. Since the completion of TR46.2's work, coverage of interference issues concerning all mobile communication systems has been adopted by the Alliance for Telecommunications Industry Solutions (ATIS) subcommittee WTSC/G3GRA (Wireless Technologies and Systems Committee — Radio Aspects of GSM/3G and Beyond). Work on the successor to TSB-84A is currently underway as Issue P0004, "Interference and Co-Existence Issues Affecting Land Mobile Systems." ITS continues to be involved in interference issues with this group as editor and contributor.

The increase in the demand for mobile communications capacity requires that the limited spectrum resources be used as efficiently as possible. Code division multiple access (CDMA) is a technology used in current cellular systems and will become even more prominent in next-generation systems. Code division schemes make efficient use of allotted spectrum and are relatively unaffected by noise. The capacity of technologies using CDMA is limited primarily by co-channel interference. Most automatic power control schemes in cellular systems increase power levels when the level of interference is unacceptable. This increases the interference level for all users of a common frequency band and can cause an exponential effect where all users of the spectrum are at maximum power levels and experiencing a diminished quality of service (QoS). With the increasing dependence on code division technology, a clear understanding of the effects of interference is essential to increase the efficiency of spectrum use.

Work in detecting, identifying, and mitigating co-channel interference requires tools to characterize the interference experienced by air-interface signals. An interference model is a tool that can be used to predict levels of interference and identify sources of interference. Several standard propagation models are accepted by industry members (i.e., Okumura and COST-231/Walfish/Ikegami) but no interference



Downlink diagram for IS-95 CDMA and W-CDMA as implemented in the co-channel interference model.

model has been developed or accepted. ITS is developing an interference model capable of implementing any cellular technology, including two CDMA-based systems: the TIA/EIA-95B standard and W-CDMA (wideband CDMA). The model involves system-specific interference modeling to determine the level of co-channel interference from both immediate and adjacent cells. The model produces a representation of an instantaneous air interface signal. The signal can contain outputs of multiple base stations with variable numbers of channels for each base station and can assign relative power levels for each individual channel. Both forward and reverse link processes are included in the model. The figure shows the block diagrams of the forward data paths for both technologies currently implemented.

The model calculates each channel's signal contribution separately from all other channel's signals and then adds the processed signal to the other signal contributions to form a composite output signal. The power level for a single channel is an arbitrary gain factor of the baseband filter which is set separately for each channel. The output of the model consists of a vector of numerical values representing a sampled QPSK or OQPSK signal. There is no error correction added to the input sequence; only spreading codes and modulation processes are used. This model does not check for recovery information contained in the input. Its only purpose is to determine how well the system can transmit the bits of an input binary sequence.

The output of the model is a sampled modulated signal which is the composite of the signals transmitted from all sources identified in a specified scenario. Software- and hardware-based simulations can use the sampled signal from the model to evaluate system designs. These simulations can characterize one-on-one, one-on-many, and many-on-one interference. As a result, potential solutions to congestion can be proposed to solve existing problems or to anticipate and avoid potential problems.

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Public Safety Video Quality

Outputs

- Test results from four phases of testing.
- Technical contributions to standards bodies to establish video quality standards for the public safety community.
- Statement of Requirements technical contributions on video quality standards to the sponsor.

Police and fire agencies often purchase radios, cameras and other communications equipment based on just their local needs. Unfortunately, this equipment may not always be of high enough quality for certain applications or be able to communicate with similar agencies with other specific needs. Until several years ago, there were no technical standards for emergency communications equipment. ITS is conducting audio and video quality research to determine standard parameters for levels of quality of communication systems based on the specific needs of public safety practitioners and their applications. ITS is working with the Department of Homeland Security (DHS) to ensure that first-responder video systems communicate clearly and accurately with each other.

The Public Safety Video Quality (PSVQ) project is a growing research effort. This project started with a single video quality test, the application of tactical video with a narrow field of view, conducted at ITS in December 2005. During the rest of FY 2006 and continuing through FY 2007, ITS has been expanding testing to include four additional test phases: wide tactical, narrow observed surveillance, wide observed surveillance, and narrow and wide recorded surveillance. "Wide" describes the field of view if the objects of interest are relatively small, for example, people in the stands at a football game. "Narrow" is used to describe the field of view in which the objects of interest are large, for example, a close up of a person's face. From these five tests, ITS researchers can develop specific technical requirements per each public safety video application.

A Video Quality Metric (VQM) is a tool that can be used to objectively predict levels of quality based on subjective tests. ITS engineers have developed several standard video quality metrics which are used to analyze the video quality of various public safety applications, such as in-car cameras and surveillance cameras. Shown in the figure on the next page is an example of an in-car camera application with relatively poor video quality.

ITS is developing a model to predict what a subjective viewer would think. How would a first responder evaluate the quality of the video necessary for him to do his job? Can the in-car camera read the license plate of a vehicle in front of the police car? A subjective viewer would rate the quality of such video on a scale ranging from good to bad. Public-safety practitioners — first responders — volunteer to participate in the subjective video quality tests at ITS in order to provide the necessary subjective data on acceptable video quality levels.

The resulting model produces correlation curves that provide the critical analysis to draw conclusions and make specific technical recommendations. The model calculates each viewer's contribution (video quality scores) separately and then combines them together with the other viewers' data to form a composite output result. Curves are fitted to the scatter plots created during the correlation analysis. The purpose of such analysis is to determine how high the video quality needs to be for public safety practitioners to do their job. The model is used to predict objectively a subjective viewer's perception of video quality.

With a model that allows for this translation from subjective methods to objective methods, subjective testing would become unnecessary. This resulting model could be used as an objective test method to determine the same video quality information without the need for subjective testing. Subjective testing is very time consuming and hence very expensive. This new method, an objective alternative, would provide savings of both time and money. This modeling tool could then be used by the public safety community to help evaluate and aid in the selection of video equipment.

The ITS VQM was developed by Margaret Pinson and Stephen Wolf of the ITS Telecommunications Theory Division. The Theory Division houses

The video from an in-car camera mounted on the dash of a police car illustrates how poor the quality can be from such a device especially given the harsh video environment such as night filming and high motion components with flashing lights.

long-term research programs in both video and audio quality. Pinson and Wolf's work is described in more detail on pp. 56-57 and has led to several international and national standards. In addition, ITS also houses a multimedia project in the Telecommunications and Information Technology Planning Division that brings many of these ITS technical products to national and international standards groups, such as the Video Quality Experts Group (VQEG). VQEG activities are supported by three of ITS's four Divisions. The multimedia project is described on pp. 28-29.

The goal of the PSVQ project is the identification of video quality standards. This identification of video quality parameters is part of a larger effort to develop a comprehensive Statement of Requirements (SoR) for public safety communications. ITS is developing the SoR for the public safety community, which reviews and approves the work and even participates in the research as incident experts and subjective test subjects. The public safety SoR is supported by representatives from various organizations: International Association of Chiefs of Police (IACP); International Association of Fire Chiefs (IAFC); Association of Public-Safety Communication Officials-International (APCO); National Association of State Emergency Medical Services (EMS) Directors; National Public Safety Telecommunications Council (NPSTC); and others. A number of Federal organizations are funding the work, most notably the U.S. Department of Homeland Security's SAFECOM Program and the National Institute of Standards and Technology (NIST) Office of Law Enforcement Standards (OLES).

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Public Safety Architecture Framework

Outputs

- Fully specified data model of a public safety radio communications system.
- PSAF data model populated with actual public safety land mobile radio (LMR) data.
- PSAF data model system view of an actual LMR network.

In FY 2006, the SAFECOM[1] sponsored Public Safety Architecture Framework (PSAF) Program began the first phase of actualizing the communications requirements outlined in the Public Safety Statement of Requirements (SoR).[2] The term "architecture framework" refers to the structured data used in comparing and integrating legacy communication systems to assess current resources and facilitate interoperability. In addition to characterizing current LMR system capabilities, the PSAF also allows "what if" scenarios to identify future system interoperability and functionality. The purpose of the PSAF is two-fold:

1) The PSAF program not only identifies key existing communication interface standards but also fleshes out newly emerging standards. Identifying these standards is essential to achieve SAFECOM's system-of-systems vision outlined in the SoR.

2) The PSAF serves as a guide for jurisdictional interoperability planning and functionality upgrades. It enables engineers and system planners to assess their current public safety communication capabilities and determine the level of interoperability between various jurisdictional systems.

To leverage current development, the ITS-led PSAF project has joined forces with the Communication Assets Survey and Mapping (CASM) project led by the Space and Naval Warfare Systems Center (SPAWAR), San Diego. CASM is sponsored by the Department of Homeland Security (DHS) under the ICTAP (Interoperability Communications Technical Assistance Program) umbrella. CASM is a web-based tool that agencies can use to store interoperable communications equipment inventory and current radio communications infrastructure information. The data resides in a secure SPAWAR database that is accessible only by the participating agencies.[3] The CASM tool was first released in July, 2005. It has 57 sites and 650 users. The PSAF project will extend the current CASM functionality into a new tool that will incorporate additional PSAF requirements. The joint ITS/SPAWAR development team has completed an initial PSAF data model, including the underlying database, relationships, and cardinality that provide the ability to evaluate public safety communications systems.

The PSAF data model, outlined in the PSAF definitions and guidelines documentation,[4] combines three different data perspectives (OV, SV, and TV) into one cohesive model. The OV (Operational View) identifies how public safety agencies perform their missions. The SV (Systems View) captures public safety systems of equipment and information flow. The TV (Technical Standards View) captures the technical interfaces that allow systems to interoperate. In order to create the PSAF data model, various scenarios, such as the radio subsystem, dispatch subsystem, etc., were diagrammed separately and then combined into a cohesive data hierarchy.

Figure 1 shows a high-level view of the SV portion of the PSAF data model. This diagram identifies the entities captured in the model and the relationships between entities. The data model also includes all of the critical public safety attributes that comprise each entity.

To validate the PSAF data model and to provide development feedback, a trial data collection effort was performed with Cobb County, Georgia, in

1 SAFECOM, a communications program of DHS's Office for Interoperability and Compatibility, with its Federal partners, provides research development, testing and evaluation, guidance, tools, and templates on communications-related issues to local, tribal, State, and Federal emergency response agencies (http://www.safecomprogram.gov/SAFECOM/).

2 The SOR defines future requirements for crucial voice and data communications in day-to-day, task force, and mutual aid operations (for more information visit http://www.safecomprogram.gov/SAFECOM/library/technology/1258_statementof.htm).

3 For more information visit the http://www.ojp.usdoj.gov/odp/docs/ICTAP_Fact_Sheet.pdf website.

4 See http://www.safecomprogram.gov/NR/rdonlyres/87C163DB-BF19-4E0D-B2DB-E9446E1151EC/0/ST06173PSAF1.pdf for additional PSAF documentation.

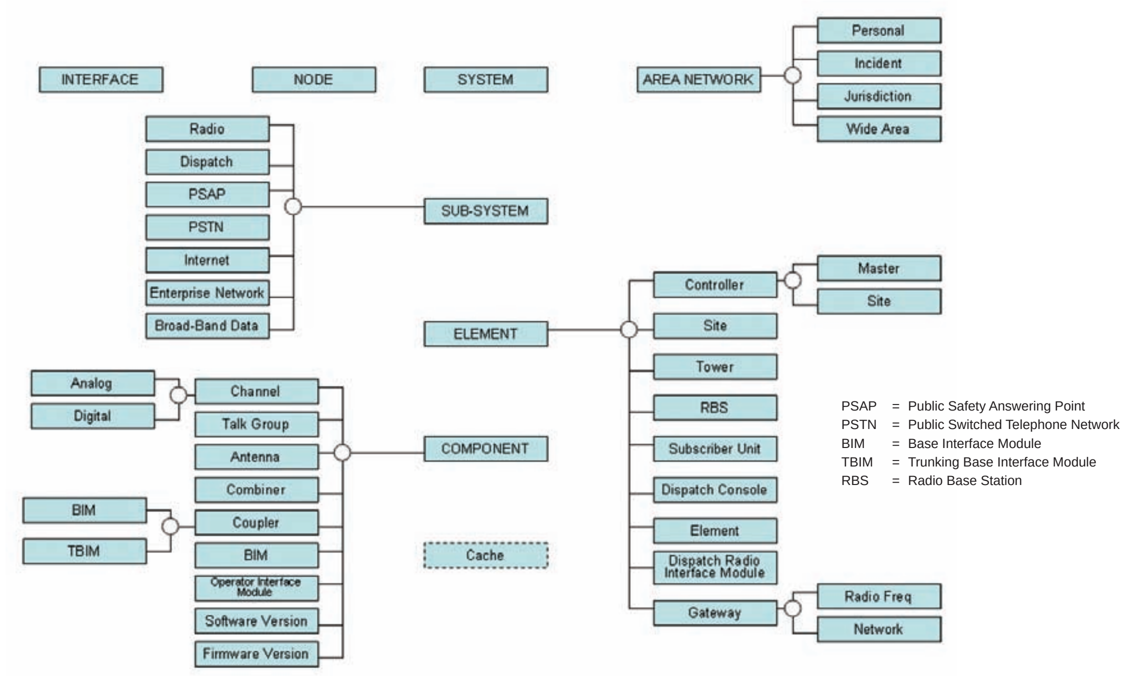

Figure 1. PSAF system view of a land mobile radio system.

November, 2006. The Cobb County site was selected to leverage the current data collection efforts already performed using the CASM tool. Figure 2 shows ITS personnel gathering LMR system information at an actual radio site.

Figure 2. ITS personnel gathering LMR system information at an actual radio site (photograph by C. Redding).

Prior to the trial, the PSAF data model was pre-populated with existing CASM data. An analysis was performed to determine the "delta" between PSAF and CASM and then a PSAF questionnaire was created to allow for entry of the additional PSAF data. The SV produced from the trial will show, as modeled in Figure 1, the system, subsystems, elements, and components of the Cobb County LMR network. The next phase of the project, slated for May 2007, will be a pilot data collection process that will expand the trail data collection effort into a more fully developed model and incorporate the results into a database storage mechanism.

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Analysis of the High-Accuracy Nationwide Differential Global Positioning System

Outputs

- Unique ITS-developed software model for performance and interference analysis.
- ITS interference analysis used to allocate frequencies for the HA-NDGPS station sites.

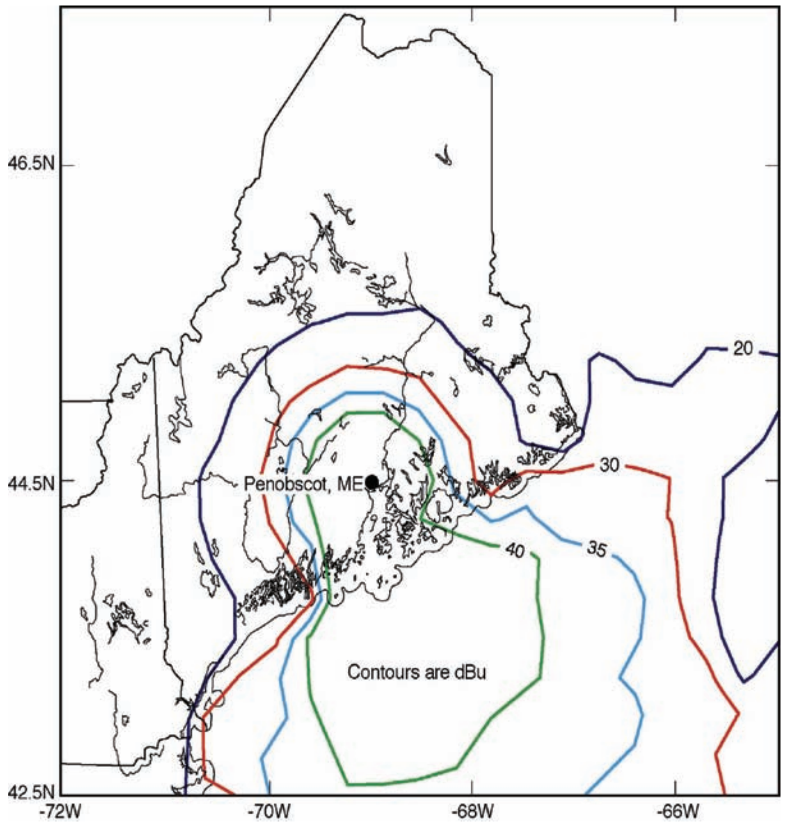
The Institute is performing an interference analysis of the High Accuracy Nationwide Differential Global Positioning System (HA-NDGPS) for the Federal Highway Administration (FHWA) of the U.S. Department of Transportation. The HA-NDGPS system can provide correction signals to the location provided by the Global Positioning System (GPS) satellites that will result in a position location more accurate than that provided by the GPS satellites alone. The HA-NDGPS differential-correction signal is computed by comparing the GPS satellite determined position of the HA-NDGPS reference station site with the surveyed geodetic position of the HA-NDGPS reference station site. The HA-NDGPS differential-correction signal is then broadcast over a wide area at medium frequencies from reference station sites geographically distributed over the United States to provide contiguous coverage. A HA-NDGPS receiver collects navigational information from all GPS satellites in view, and also receives differential correction signals from a local HA-NDPGS reference station site to determine a precise geographic location.

There are two versions of the Nationwide Differential Global Positioning System (NDGPS): the Legacy NDGPS operating in the 285–325 kHz band, and the HA-NDGPS operating in the 435–495 kHz band. Both of these systems provide correction signals to the locations given by GPS satellites. The Legacy NDGPS system can provide one meter position accuracy and the HA-NDPGS system can provide one-tenth meter position accuracy. The planned HA-NDGPS station sites will be collocated geographically with all of the Legacy NDGPS sites at a total of 130 sites when complete. ITS is performing the interference analysis for all of the planned 130 HA-NDGPS sites.

The NDGPS system was originally designed for use by the U.S. Coast Guard in harbor approach and navigation, vessel tracking, and buoy tracking, but the increased accuracy of the recently developed HA-NDGPS has expanded its use to land applications such as: mapping, precision surveying, positive train control, precision farming, smart vehicles, lane keeping, collision avoidance, snow plow management, accurate waterway dredging, and improved public safety emergency response. The FHWA in cooperation with other Federal, State, and local organizations is deploying both NDGPS and HA-NDGPS sites across the country to provide this service to cover the inland waterways and all land regions of the continental United States, Alaska, Hawaii, and Puerto Rico. Coverage of the coastal regions of these locations will also be included.

Prediction of coverage and interference for HA-NDGPS requires special analysis considerations. For the frequency bands 285–325 kHz and 435–495 kHz, the propagation of radio waves at night includes both a ground wave and a sky wave. The expected sky-wave signal combined with the ground-wave signal may be compared with the expected radio noise environment (consisting of atmospheric, galactic, and man-made noise components) to predict the likelihood that the communications link will operate satisfactorily. The presence of the sky wave at night could create potential interference problems between distant stations on the same frequency or frequencies that are near each other. The sky-wave models provide some means of estimating the expected field strengths of signals to assist in frequency allocation and avoid potential interference problems. At night the undesirable interference from the sky wave can manifest itself as adjacent and co-channel interference to stations that it would not normally reach in the daytime.

The HA-NDGPS interference analysis involves selecting frequencies for these systems so that they will not interfere with each other or other users of the bands. The planned HA-NDGPS sites are being analyzed for coverage and interference using the Low and Medium Frequency Ground-Wave and Sky-Wave model developed at ITS. The model can evaluate the broadcast circuit from a proposed transmitter to a particular receiver site as a point-to-point problem. The user selects the transmitter



Coverage of one HA-NDGPS site in Penobscot, Maine.

characteristics, receiver characteristics, site characteristics, and a propagation model. The model can also perform an interference analysis including all adjacent and co-channel transmitters (referred to as the interfering transmitters) within a user-defined search radius to compute signal-to-interference ratios at the receiver location. For each adjacent and co-channel transmitter, the model lists the computed signal-to-interference ratio as well as the amount that the ratio exceeds or fails to exceed the required signal-to-interference ratio for the adjacent or co-channel case. One of the outputs of the model is a map of the user-selected area, showing contours of signal coverage or signal-to-interference ratios. An example is shown in the figure above.

Antenna modeling in this band is also quite unlike that in other bands, since the performance of an antenna on or near the surface of the Earth is dependent on the interaction with the lossy Earth. Therefore, specific antenna algorithms have been included in the model that correctly launch the ground wave at the horizon angle and the sky wave at the appropriate elevation angle. The model contains a special database that determines the interfering transmitters and susceptible receivers in the environment.

In FY 2006, most of the work effort was directed towards gathering information to build this extensive database. The interference analysis was performed for approximately one-fourth of the sites. The interference analysis for the remainder of the sites is planned for completion in FY 2007.

This ITS interference analysis will demonstrate that the HA-NDGPS system can conduct operations on an unprotected, non-interference basis in the 435–495 kHz band and provide a first look at frequency assignments for each of the 130 facilities located nationwide. Low and medium frequencies have been used for many years in maritime and aviation applications for coarse position location and navigation. A broadcast technique in the low and medium frequency bands is used to ensure coverage over a large geographic area and in the presence of obstructions such as terrain, forests, and buildings between the broadcast site and the user's location.

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Telecommunications Analysis Services

Outputs

- Internet access on a cost reimbursable basis for U.S. industry and Government agencies to the latest ITS engineering models and databases.
- Contributions to the design and evaluation of broadcast, mobile, radar systems, personal communications services (PCS) and local multipoint distribution systems (LMDS).
- Standardized models and methods of system analysis for comparing competing designs for proposed telecommunication services.

Telecommunications Analysis Services (TA Services) gives industry and Government agencies access to the latest ITS research and engineering outputs on a cost reimbursable basis. It uses a series of computer programs designed for users with minimal computer expertise or in-depth knowledge of radio propagation. The services are updated as new data and methodologies are developed by the Institute's engineering and research programs.

Currently available are: on-line terrain data with 1-arc-second (30m) resolution for CONUS and 3-arc-second (90m) resolution for much of the world, and GLOBE (Global Land One-km Base Elevation) data for the entire world; the U.S. Census data for 2000, 1997 update, and 1990; Federal Communications Commission (FCC) databases; and geographic information systems (GIS) databases (ArcInfo). For more information on available programs, see the Tools and Facilities section (pp. 73-74) or call the contact listed below.

Over the past 20 years, TA Services has developed both generic propagation models for a wide variety of applications in many frequency bands and application specific models used for a particular type of analysis such as High Definition Television (HDTV). These models are placed on the TA Services web access system for use by customers with active accounts on the TA Services system. These customers can activate models, enter information about their broadcast equipment and produce a generic transmitter coverage map such as that shown in Figure 1 below for a typical broadcast television station using the Communications System Performance Model (CSPM) application program. These coverages follow FCC guidelines and requirements in order to show both the signal coverage and the population that resides within the various analysis contours. Users can also combine many individual transmitter coverages into a composite coverage such as that shown in Figure 2. This allows the user to determine both single transmitter performance and integrated system performance.

TA Services has assisted the U.S. broadcast television providers with their transition to digital television (DTV) by providing an application-specific model for use in advanced television analysis (high-definition television, advanced television, and digital television). This model allows the user to create scenarios of desired and undesired station mixes. The model maintains a catalog of television stations and

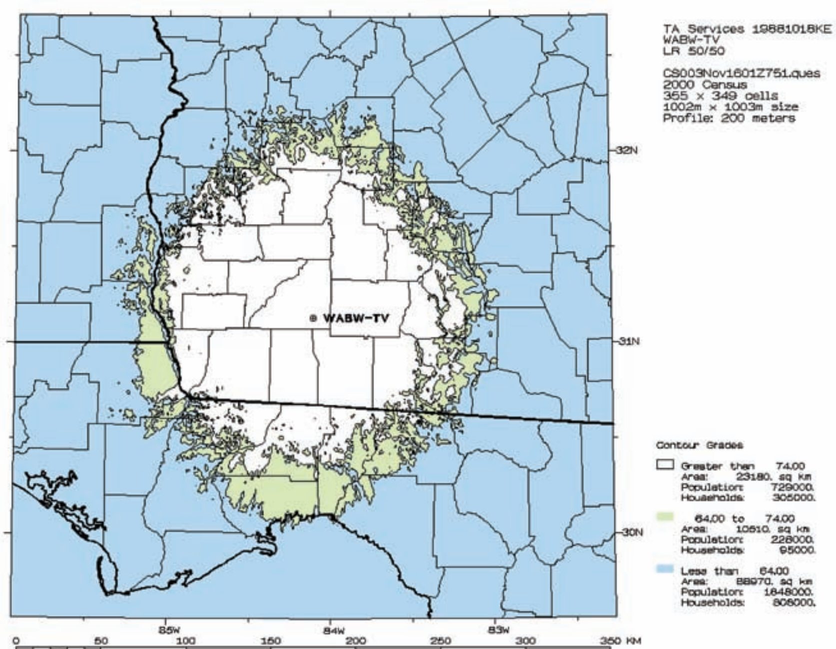

Figure 1. Sample output of the CSPM model of a TV transmitter located in Georgia.

advanced television stations from the FCC from which these analyses are made. The results of these studies show those areas of new interference and the population and number of households within those areas so that designers can mitigate possible interference situations before they become a problem. The model can also determine the amount of interference a selected station gives to other stations. This allows the engineer to make modifications to the station and then determine the effect those modifications have on the interference that station gives other surrounding stations. In addition to creating graphical plots of signal levels, the program creates tabular output which shows the distance and bearing from the selected station to each potential interfering station, as well as a breakdown of the amount of interference each station in the study contributes to the total interference.

TA Services has also assisted the Public Broadcasting System (PBS) and the National Weather Service in the determination of their system coverage and public outreach. These two major public providers ensure that more than 95% of all Americans have access to potentially life-saving information in the event of a national crisis of any kind. With the use of the TA Services system and databases, these two national systems were able to improve and verify the coverage of their large diverse systems and even determine where there is overlapped coverage of multiple transmitters, as shown in Figure 3. This provided invaluable services to the people of the southeastern portions of the United States in the severe hurricane season of 2005.

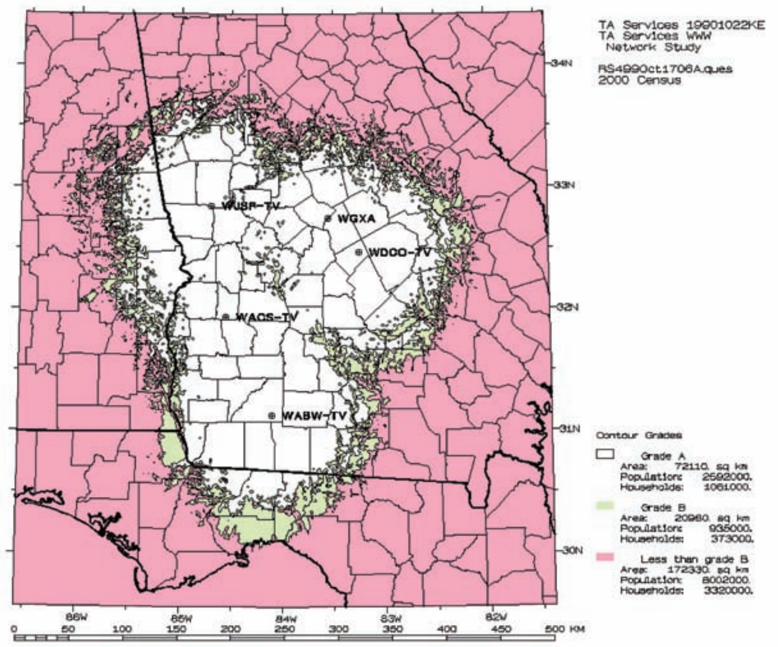

Figure 2. Composite coverage of several TV stations located in Georgia.

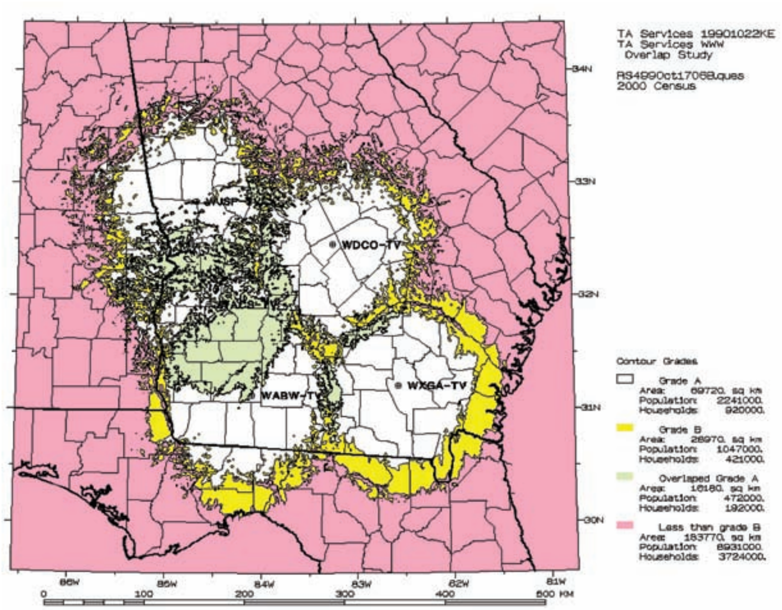

Figure 3. Overlap study of several TV stations located in Georgia.

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Geographic Information System (GIS) Applications

Outputs

- Propagation coverages (LFMF, HF, and VHF) for one or more transmitters draped over surfaces.
- Composite, interference, overlap, point-to-point, and coupled outdoor/indoor coverages (VHF).
- 2D and 3D visualization environments.
- Fly-through visualization capabilities.

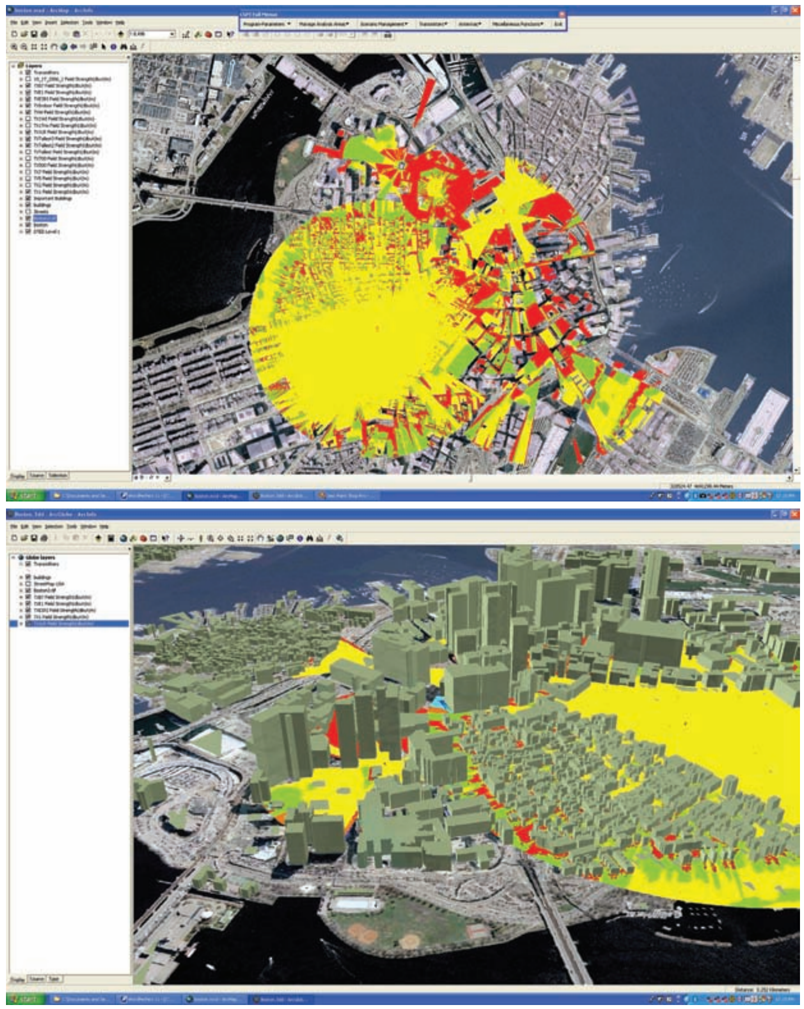

Figure 1. A CSPT-VHF study for Boston showing both 2D (top) and 3D (bottom) results.

ITS has developed and continues to improve a suite of Geographic Information System (GIS) based applications incorporating propagation models for outdoor and indoor analyses. Databases for GIS use, including terrain, satellite and aircraft imagery, roads and other transportation infrastructure layers, building data, and population, are becoming more available and affordable. These databases can be easily connected to GIS systems and can be shared among users in web-based or standalone GIS applications. ITS has developed generic and application-specific GIS programs that aid Government Agencies, private cellular companies, public and private television stations, transportation companies, and consultants in the performance of their missions to efficiently manage the U.S. telecommunications infrastructure.

The primary GIS-based tool developed by ITS is the Communication Systems Planning Tool (CSPT-VHF). CSPT is a menu and icon driven propagation model developed for frequencies from 20 MHz to 20 GHz that allows the user to connect to a variety of image catalogs and terrain libraries that cover most of the world. The user can create specific analysis areas using these catalogs and libraries and can then perform propagation scenarios for his/her application. These applications can range from outdoor coverage studies of large-scale areas of hundreds of square miles to indoor propagation studies of one building in an urban environment. Figure 1 shows a sample case of a transmitter coverage of the city of Boston. This coverage is shown in both 2D and 3D. CSPT allows the user to transition into 3D and fly through the environment.

A second tool is the CSPT-HF model, which provides the user with a GIS front end and back end to the ITS HF ICEPAC model, suitable for analyses from 2 MHz to 20 MHz. The GIS tool allows the

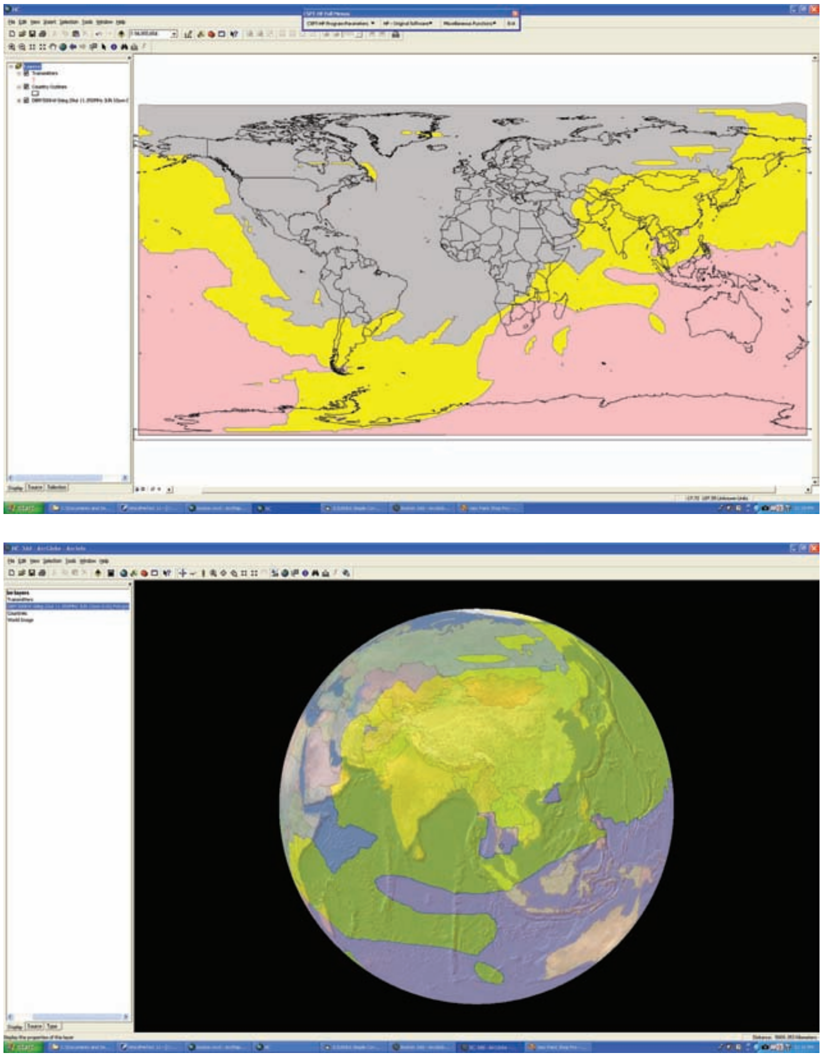

Figure 2. A CSPT-HF study for the entire earth showing both 2D (top) and 3D (bottom) results.

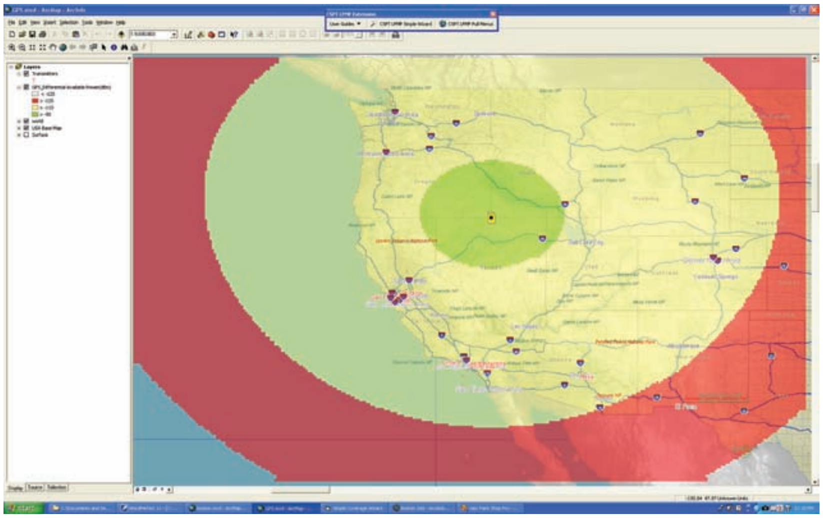

Figure 3. A CSPT-LFMF study for the western United States.

user greater flexibility in creating scenarios for HF area coverage studies and in viewing their results. Input parameters to the model can be incremented and run in a batch mode. The output results of ICEPAC are imported into the GIS and can be displayed in 2D or 3D as shown in Figure 2.

A third tool is the CSPT_LFMF model, which provides the user with an easy-to-use GIS input capability so that low frequency and medium frequency analyses (150 kHz to 2 MHz) can be run and displayed, as shown in Figure 3.

The general flow of the CSPT GIS Tool is as follows. The user defines an area within which a study will be performed. This area can be defined graphically by zooming into a map of the world or the U.S., or by defining the latitude and longitude of the boundaries of the desired area. The user then imports desired GIS information such as political boundaries, roads, rivers, special imagery, or application-specific GIS data. After creating the analysis area, the user creates or imports transmitter, receiver, and antenna data. Lastly, the user selects the type of coverage and the propagation model to be used in the analysis.

Coverages, composites and interference analyses can be imported into GIS visualization tools, allowing the user to see and often fly through their studies so that a better understanding of the analysis results can be obtained.

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Broadband Wireless Standards

Outputs

- Studies of candidate standards for site general and site specific radio propagation models.
- Comparison of radio propagation models' predictions to measurements.

During FY 2006, the Broadband Wireless Standards Project focused on development and evaluation of site specific radio propagation models under consideration for standardization by ITU-R Working Party (WP) 3K. Testing of proposed modifications to Rec. ITU-R P.1546-2, a site general radio propagation model, was also undertaken. The culmination of these activities was a presentation to a special workshop on site specific and site general propagation models at ITU Headquarters in Geneva, Switzerland, on September 26-27, 2006, immediately preceding the Block Meetings of the Working Parties of ITU-R Study Group 3. The workshop was very successful in stimulating the work of subgroups 3K-1 and 3K-2 of WP 3K during these meetings.

Within the ITU-R, the requirement for a standardized site specific radio propagation model is pressing. The Regional Radio Conference, RRC-06, published the Final Acts of RRC-06 which contain the Regional Agreement GE06, adopted by RRC-06. The GE06 Agreement governs the use of frequencies by the broadcasting service and other primary terrestrial services in bands 174–230 MHz and 470–862 MHz in parts of ITU-R Regions 1 and 3. The Final Acts also contain frequency assignment and frequency allotment plans for the digital broadcasting service, the analog television plan applicable in the transition period, the coordinated list of assignments to other terrestrial primary services in these bands, and the Resolutions adopted by RRC-06. The GE06 Agreement is provisionally applicable from June 17, 2006.[1] One of the RRC-06 Resolutions highlights the urgent need for a site specific model for use in bilateral and multilateral planning and coordination activities to take place under the GE06 Agreement.

Six different site specific propagation models are being considered as candidates for a Draft New Recommendation (DNR) that will be developed by WP 3K at its next meetings (April 2007). If consensus is achieved within WP 3K, it is almost certain that Study Group 3 will approve the DNR for adoption. Three models are variants of Rec. ITU-R P.452, separately proposed by the European Broadcasting Union (EBU), China, and the UK. Of the remaining three models, one was proposed by Switzerland, and the last two were proposed by the United States: the ITS Irregular Terrain Model (ITM) in its point-to-point prediction mode and the Site Specific Model (SSMD). Since the latter two models were relatively unknown internationally, there was a need to increase their visibilities in this forum.

The ITM is a mature, general purpose radio propagation model, intended for use on tropospheric circuits with path lengths of 1–2,000 km, antenna heights above ground of 0.5–3,000 m and frequencies of operation of 20–20,000 MHz. When the link's radio climate is specified, it can be used to make predictions for the quantiles of attenuation relative to free space for long-term time variability, location variability and situation variability.

The SSMD, a less mature model, is a hybrid model: its median predictions are a weighted combination of the 50% time sea curves of Rec. ITU-R P.1546-2 and the Deygout three-edge diffraction method of Rec. ITU-R P.526-9, with the smooth earth component removed. When applicable, these predictions are limited to the troposcatter losses of Rec. ITU-R P.452-12. To obtain predictions for time percentages less than 50% and greater than or equal to 1%, the variability of the corresponding land curves of Rec. ITU-R P.1546-2 is applied to the median prediction described above. Because this model is heavily based on Rec. ITU-R P.1546-2, the distance, antenna height, and frequency limits of that Recommendation apply: path lengths of 1–1,000 km, effective antenna heights less than 3,000 m and frequencies of operation of 30–3,000 MHz.

One method that may be employed to evaluate site specific radio propagation models is to compare their predictions to measured propagation data. When this is done, the comparison results are stated in terms of the prediction error, i.e., the difference between the predicted and measured attenuations (dB), and the central moment statistics of the prediction errors. Five U.S. propagation measurement campaigns have data at least partially applicable to both of the models: the ITS Phase 1, Phase 2, and Low Antenna campaigns, and the Ft. Huachuca and

1 http://www.itu.int/pub/R-ACT-RRC.14-2006/en.

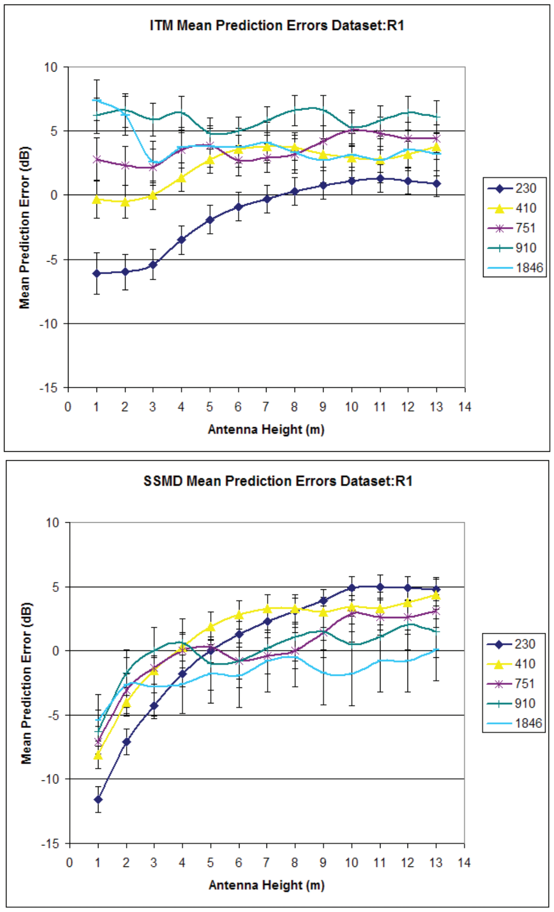

Figure 1. (Top) ITM and (bottom) SSMD mean prediction errors plotted as functions of antenna height and frequency for the Phase 2 R1 measurement dataset. The values of the measurement frequencies (MHz) are given in the legend.

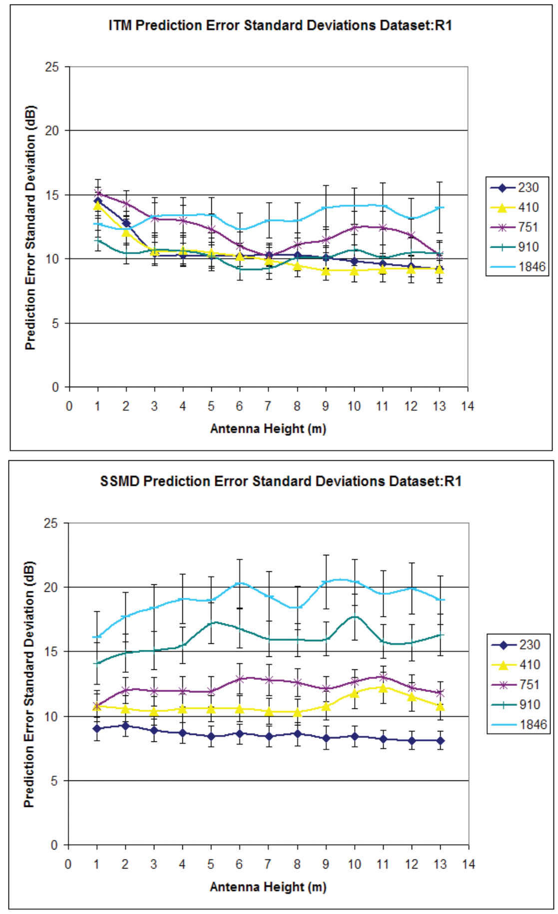

Figure 2. (Top) ITM and (bottom) SSMD prediction error standard deviations plotted as functions of antenna height and frequency for the Phase 2 R1 measurement dataset. The values of the measurement frequencies (MHz) are given in the legend.

FCC/TASO measurement campaigns. Both models' prediction errors and central moment statistics were computed for all the above measurements.

Figures 1 and 2 show examples of the prediction error means and standard deviations for the two models, respectively, for the Phase 2 R1 dataset, for frequencies below 3,000 MHz. In this dataset, measurements were attempted at multiple frequencies and antenna heights for each path. As a result, measurements made on the same path are correlated, as are the models' prediction errors. Therefore, the models' prediction error means and standard deviations are presented individually (i.e., for a given frequency and antenna height) with the error bars corresponding to the univariate standard error estimates for these quantities. Figure 1 shows that the variation of the models' mean prediction errors with height and frequency is markedly different. The fact that both models have roughly comparable mean prediction errors for heights above 10 m suggests that SSMD height extrapolations below the 10 m sea curves might benefit from additional refinements. Somewhat in contrast, Figure 2 shows that the models' prediction error standard deviations are roughly constant with antenna height, but that the frequency dependence of this quantity is more pronounced for SSMD's prediction errors.

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Short-Range Mobile-to-Mobile Propagation Model Development and Measurements

Outputs

- Analysis effort to develop propagation models for short-range mobile-to-mobile applications.
- Measurement program to support analysis effort and refine propagation models.

With the tremendous growth in demand for mobile wireless devices, it is necessary to address the problems of interference between existing and new radio spectrum users. The evolution of our communications infrastructure depends heavily on these mobile communication devices, and the successful operation of these devices in a crowded electromagnetic spectrum has a profound impact on our economy. An accurate and flexible radio-wave propagation model is essential for meeting the needs of both the spectrum management process and the electromagnetic compatibility analysis process.

In an Executive Memorandum from the President dated November 30, 2004, the Department of Commerce was asked to submit a plan to implement recommendations to ensure that our spectrum management policies are capable of harnessing the potential of rapidly changing technologies. These recommendations included (1) providing a modernized and improved spectrum management system; (2) developing engineering analysis tools to facilitate the deployment of new and expanded services and technologies; (3) preserving national security and public safety; and (4) encouraging scientific research and development of new technologies. To implement these recommendations, it is necessary to determine the best practices in engineering for spectrum management, and also address the electromagnetic compatibility (EMC) analysis process.

ITS was tasked by NTIA/OSM to review and evaluate the current propagation models and ITU-R Recommendations to determine which could be used to perform propagation analyses to facilitate EMC analyses of mobile wireless devices. After performing an exhaustive review of current models, ITS determined that none were suitable for use in analyzing mobile-to-mobile (MTOM) interference interactions. Although the models had their own regions of validity with respect to frequency, separation distance, and antenna heights, they were all inadequate for the short-range MTOM model requirements of: 1 m to 2 km separation distances, 1–3 m antenna heights, and a frequency range of 150–3000 MHz. Existing radio-wave propagation models are valid only for much higher antenna heights (4 m or greater) and larger separation distances (greater than 1 km). It was therefore necessary to initiate an analysis effort to develop models valid in this parameter range.

In FY 2006, ITS performed an initial analysis and determined that the development of a model that will satisfy the above requirements requires the use of mutual coupling predictions and should also include the effects of the surface wave, and the near-field effects of the antennas for these frequencies. The antenna patterns or gains of the antennas may not be valid at close separation distances, since they may not be in the far field of the antennas. In addition, for low antenna heights, the effects of the close proximity of the Earth to the antenna produces a strong interaction of the antenna with the ground, changing its impedance and thus affecting the efficiency and gain of the antennas.

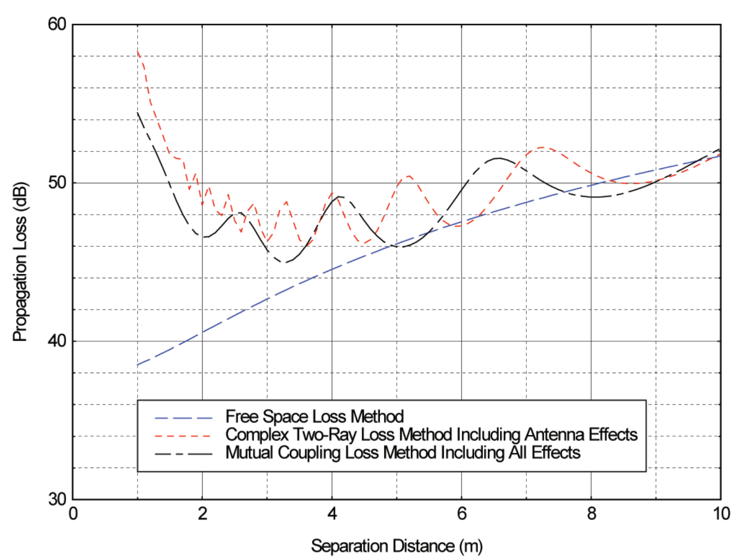

Figure 1. Three propagation loss prediction methods at 900 MHz for a transmitter height of 3 meters and receiver height of 1 meter.

Figure 2. Exterior view of the ITS propagation measurement receiver vehicle (foreground). The rear of the propagation transmitter vehicle is visible at the far right, with an NTIA logo (photograph by F.H. Sanders).

Investigations of propagation modeling techniques and the special considerations of a short-range propagation model with low antenna heights have resulted in the development of new approaches to accurately model propagation loss in an MTOM environment. This initial analysis addressed the line-of-sight (LOS) propagation environment in an open scenario for vertical polarization. Horizontal polarization will be addressed in future efforts. A hierarchy of approaches was utilized to develop the short-range MTOM model that would account for different levels of complexity. Figure 1 shows a comparison of propagation loss versus distance predicted by three analysis methods of increasing complexity and accuracy. Free-space loss is the least complex and least accurate method, and a mutual coupling method including all effects is the most complex and most accurate method. A method of intermediate complexity is the complex two-ray theory with complex reflection coefficient and antenna effects included.

In FY 2006, an initial radio-wave propagation measurement program was performed in conjunction with the ITS Telecommunications Theory Division to validate and refine the MTOM propagation models. Simultaneous wideband (~10 MHz bandwidth) measurements were made over the 150–5800 MHz band in various scenarios of antenna-height combinations and separation distances for comparison to propagation loss predicted by the analysis models. The program used a newly outfitted van as the receiver vehicle with data collection instrumentation, and the third-generation RSMS van as the pseudo-mobile transmitter vehicle (see Figure 2 above). The initial testing for a concept demonstration was performed in an environment where it was possible to make measurements at distances ranging from a few meters up to one kilometer. The measurements were performed in two very large parking lots for different filling conditions ranging from empty or sparse vehicle population (approximating a two-ray LOS condition) to completely full of vehicles (approximating a heavy traffic LOS and diffraction condition). The measured data is currently being processed.

In FY 2007, mathematical algorithms will be developed from the results of the FY 2006 analysis and measurement effort. Other analysis and measurement efforts to be performed will address LOS and non-LOS scenarios for: the urban/suburban canyon environment, the suburban/residential environment, the parking lot canyon, and the rural environment.

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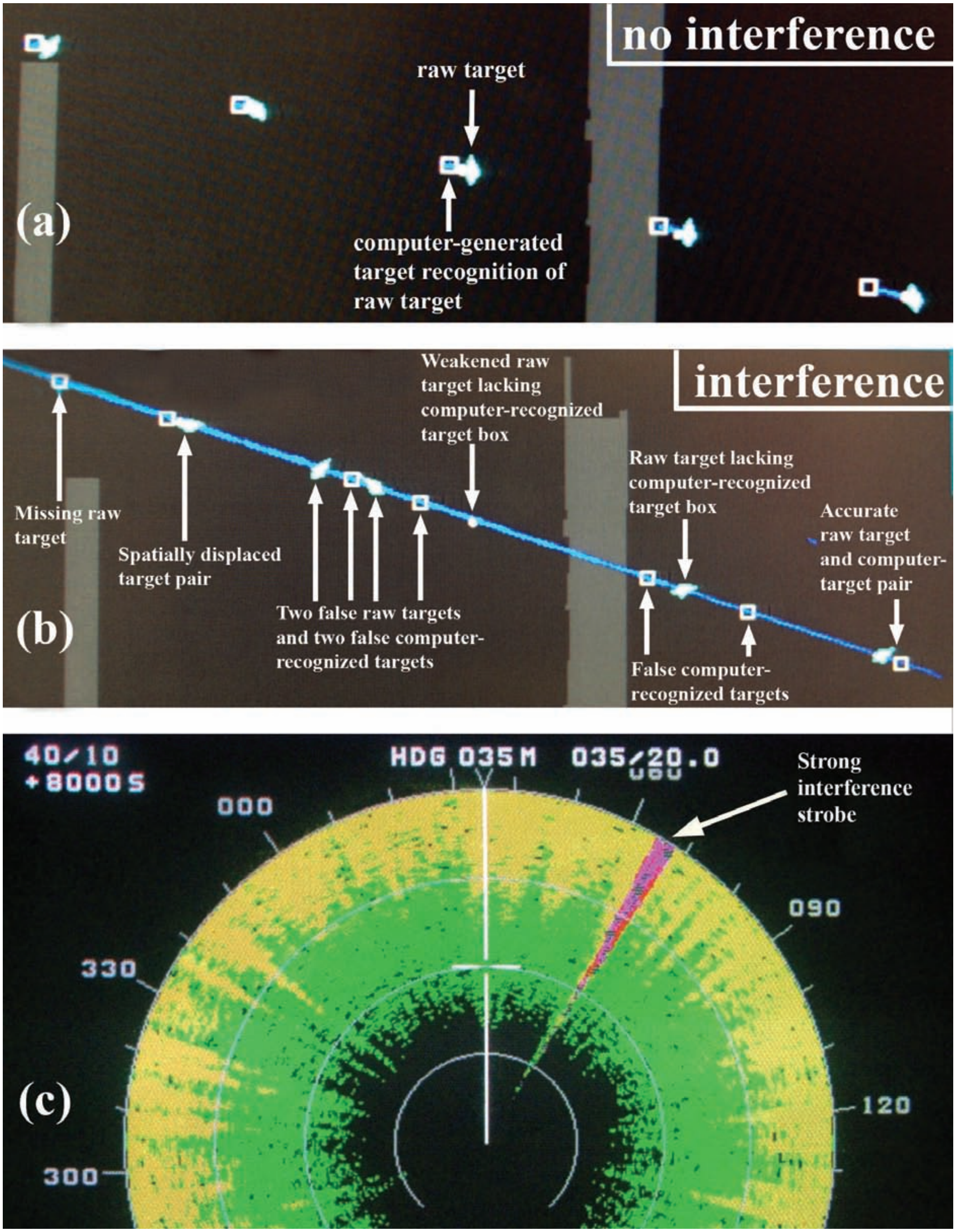

Examples of interference effects in radar receivers as observed during NTIA tests. (a) and (b): A ground-control radar screen with and without interference. (c): Interference from a communication signal in an airborne weather radar (photographs by F.H. Sanders).

Telecommunications Theory

The explosive growth of telecommunications traffic continues to generate ever-increasing demands for radio spectrum while greatly increasing the loading of telecommunications networks, both wireless and wireline. Yet the radio spectrum is a limited resource. In response to these realities, new radio technologies are being developed and implemented to use spectrum more efficiently and effectively. Also, the basic paradigm of radio spectrum management is beginning to move away from traditional, top-down frequency-assignment methods and is migrating toward autonomous, interference-limited technologies that allow dynamic reassignment of radio frequencies by systems that utilize intelligent algorithms for recognizing and avoiding interference. But to fulfill the promise of more autonomous, locally self-controlled spectrum use schemes, the effects of noise and interference on radio receiver performance must be thoroughly understood, and such knowledge must be focused on improvements in the performance of both existing and new networks. Tools to monitor the quality of audio and video information on communication channels also must be developed and used so that audio and video quality levels can be accurately adjusted in real-time to achieve maximal quality with minimal use of available bandwidth.

To achieve these goals for the U.S. government as well as the private sector, the Institute's Telecommunications Theory Division performs research in both wireless and wireline telecommunications, seeking to understand and improve telecommunications at the most fundamental levels of physics and engineering. Strong ongoing investigations are being maintained in the major areas of broadband wireless systems performance; short-range propagation modeling and measurements; noise and interference as critical limiting factors for advanced communication systems; audio and video quality assessment; advanced spectrum sharing concepts; and radio propagation.

Through technical publications, cooperative research and development agreements (CRADAs), and interagency agreements, ITS transfers the results of its work in all these technology areas to both the public and private sector, where the knowledge is transformed into better telecommunications for the United States, new and better products for consumers and the Government, and new opportunities for economic development and growth for the economy.

Areas of Emphasis

Audio Quality Research
The Institute conducts research and development leading to standardization and industry implementation of perception-based, technology-independent, quality measures for voice and other audio communication systems. Projects are funded by NTIA.

Effects of Radio Channel on Receiver Performance
The Institute, a recognized leader in radio channel measurement and modeling, is researching the effects of interference and noise on the performance of radio receivers and networks. Current work is focused on the effects of noise and interference as limiting factors in system performance. The project is funded by NTIA.

Video Quality Research
The Institute develops perception-based, technology-independent, video quality measures and promotes their adoption in national/international standards. Projects are funded by NTIA.

Audio Quality Research

Outputs

- Technical publications and presentations on new research results.
- Measurements and estimates of speech and audio quality and algorithm performance.
- Algorithms and data supporting speech and audio coding and quality assessment.

Digital coding and transmission of speech and audio signals are enabling technologies for many telecommunications and broadcasting services including voice over Internet protocol (VoIP) services, cellular telephone services, and digital audio broadcasting systems. Speech and audio signals can be coded and transmitted at low bit-rates with good fidelity. In addition, coded speech and audio signals can be packetized for transmission, thus sharing network bandwidth or radio spectrum with other data streams.

It is important to note that digital coding and transmission of speech and audio involves compromises and trade-offs among at least five basic factors: signal quality, transmission bit-rate, robustness to transmission errors and losses, coding and transmission delay, and coding and transmission algorithm complexity. For a simple example of one trade-off, consider receive-side buffering of data packets delivered by a best-effort network. Increasing the size of a buffer can reduce the number of packets lost (desirable), but this will also increase the algorithm delay (undesirable). For a complete system of coding and transmission, all five factors will generally come into play. For any given application, joint optimization with respect to these five factors can be an attractive but elusive goal.

The ITS Audio Quality Research Program works to identify, develop, and characterize new techniques that will increase relative quality or robustness or will reduce relative bit-rate, delay, or complexity of speech and audio coding and transmission algorithms. In addition, the Program seeks to develop techniques that aid in attaining a desired optimum balance between the five factors. Integral to this effort is the development of more effective and efficient ways to characterize speech and audio quality, since this can be the most intangible of the five factors. The ultimate result of these efforts is better sounding, more reliable, more efficient telecommunications and broadcasting services.

The robustness of digital coding and transmission algorithms is critical in applications that use lossy channels such as those associated with wireless systems and those provided by the Internet. In FY 2006, Program staff evaluated the robustness of a specific family of speech coding algorithms. Example results are shown in Figure 1. This figure shows how one measure of speech quality drops as the percentage of lost data packets increases. The results shown in blue correspond to a more robust algorithm and the results shown in red correspond to a less robust algorithm (quality drops more quickly as packet loss increases).

In FY 2006, Program staff performed an extensive evaluation of three objective estimators of speech quality. These algorithms process digital speech signals and generate estimates of perceived speech quality. These estimates can then be compared with actual perceived speech quality values that have been obtained through formal subjective listening tests using the same speech signals. If an objective estimator provides speech quality estimates that largely agree with the actual perceived speech quality values, then that estimator can be readily used. But if the agreement is poor, then the estimator can be used only with great caution.

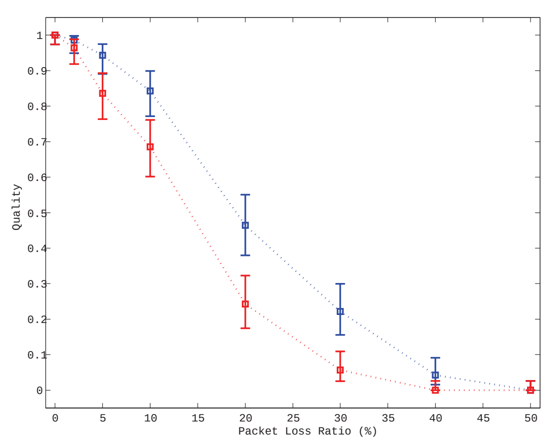

Figure 1. Examples showing how speech quality drops as packet loss ratio increases for two speech coding algorithms.

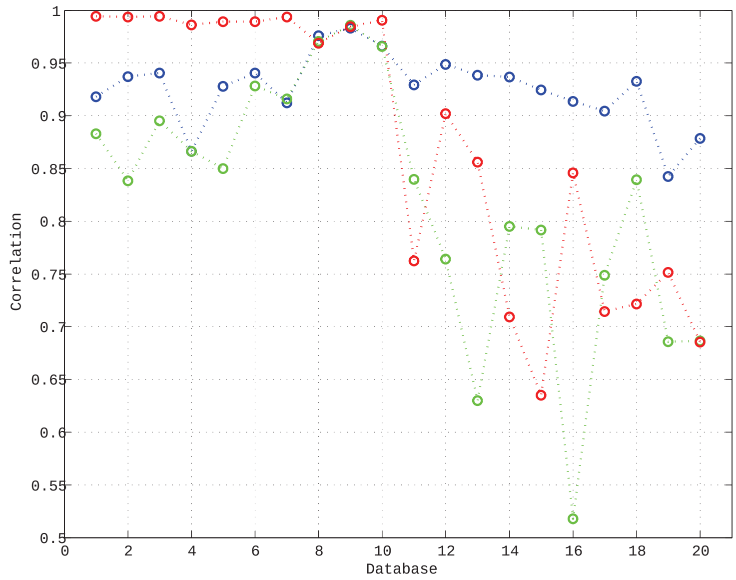

Figure 2. Example performance of three different objective estimators of speech quality on 20 different speech databases.

In our evaluation we measured agreement through the use of a correlation value. A value of 1.0 indicates perfect agreement, and smaller values indicated lesser agreement. Our evaluation used 20 different databases of digitally recorded speech signals. Together these databases include a wide variety of speech signals and systems under test. Example results are given in Figure 2. This figure shows correlation values for the three objective estimators of speech quality. The results in blue describe an estimator that has consistent, moderately good agreement (correlation above 0.9 in most cases). The results in green describe an estimator that has a widely varying agreement. The results in red describe an estimator that has very good agreement on the first ten databases (correlations mostly near 1.0), but a much lower and less consistent agreement on the second ten databases. These results suggest that this third estimator has potential if it can be successfully generalized for operation on databases 11-20 with agreement similar to that found on databases 1-10.

Quantization is a pervasive component in speech and audio coding. It enables concise digital representations, but it always induces some quantization error or quantization noise. In FY 2006, Program staff developed and characterized a new generalized technique that can reduce the noise associated with certain quantization processes when particular classes of signals are used. This technique is centered on the use of a pseudoinverse that requires a small amount of prior knowledge of the signal at design time. Given this information, the pseudoinverse may be constructed from an appropriate adaptive filter. In operation, the filter portion of the pseudoinverse adapts so that the statistics of its input-output difference signal are matched to the statistics of the associated quantizer noise. In certain cases, this results in partial cancellation of the original quantization noise.

Throughout FY 2006, Program staff continued with significant speech quality testing using both objective and subjective techniques. These tests support both this program and other ITS programs. Staff continued to transfer program results to industry, Government, and academia by means of technical publications, lectures, laboratory demonstrations, and poster presentations. Staff also completed a significant number of peer reviews for technical journals and conference proceedings. Program staff supported telecommunications standards development through research efforts, technical exchanges, and a formal written technical contribution. Program publications, technical information, and other program results are available at http://www.its.bldrdoc.gov/audio.

Recent Publications

S.D. Voran, "Listening-time relationships in a subjective speech quality experiment," in *Proc. 5th International MESAQIN (Measurement of Speech and Audio Quality in Networks) Conference*, Prague, Czech Republic, Jun. 2006.

S.D. Voran, "Reducing quantization error by matching pseudoerror statistics," in *Proc. of the 12th IEEE Digital Signal Processing Workshop*, Grand Teton National Park, Wyoming, Sep. 2006.

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Effects of Radio Channel on Receiver Performance

Outputs

- Analytic and discrete receiver models.
- Correlations between radio channel characteristics and receiver performance.
- Uncertainty analysis of communications system measurements.

Telecommunications play a vital role in providing services deemed essential for modern life. Many systems providing these services use radio links composed of a transmitter, a receiver, and a channel separating the two. The radio channel is often the primary impediment to fast and reliable operation of these systems. Understanding how the channel affects those systems is crucial to the advancement and regulation of telecommunications. Hence, ITS has historically directed considerable research towards radio channel characterization. This project expands this focus to include quantifying the effects of the radio channel on receiver performance.

Receiver performance is degraded by a number of radio channel phenomena, such as attenuation, multipath, man-made noise, and signals from other radio links. Various combinations of these factors affect each system uniquely. For example, personal communications services (PCS) systems operating outdoors in the 1900-MHz band are primarily compromised by time-varying multipath introduced by buildings and terrain. Wireless local area network (WLAN) systems operating indoors in the 900-, 2400-, and 5800-MHz industrial, scientific, and medical (ISM) bands contend with man-made noise from microwave ovens, signals from cordless phones, and multipath introduced by reflections from walls, ceilings, floors, and objects within the room.

Practical limitations prevent us from testing the effects of the radio channel phenomena on all legacy or proposed radio systems. Hence, the goal of this effort is to identify, model, and characterize a small number of radio systems and use these to predict the effects of the radio channel on others. The results of this work are of vital importance in the development of telecommunications policy. For example, the results can be used to predict how interference introduced by new spectrum engineering methods such as spectral overlay will impact legacy systems.

The effects of the radio channel on receiver performance are quantified by correlating radio link performance metrics to radio channel characteristics, as shown in Figure 1 below. As an example, bit error rate (a performance metric) can be correlated to interfering signal power (a channel characteristic) as is shown in NTIA Reports TR-05-419,[1] TR-05-429,[2] and TR-06-437[3] on the interference potential of ultrawideband signals. These correlations are verified in three ways, i.e., mathematical analysis, software simulation, and laboratory measurements, when possible, to ensure reliability. The laboratory

1 M. Cotton, R. Achatz, J. Wepman, and B. Bedford, "Interference potential of ultrawideband signals — Part 1: Procedures to characterize ultrawideband emissions and measure interference susceptibility of C-band satellite digital television receivers," NTIA Report TR-05-419, Feb. 2005.

2 M. Cotton, R. Achatz, J. Wepman, and P. Runkle, "Interference potential of ultrawideband signals — Part 2: Measurement of gated-noise interference to C-band satellite digital television receivers," NTIA Report TR-05-429, Aug. 2005.

3 M. Cotton, R. Achatz, J. Wepman, and R. Dalke, "Interference potential of ultrawideband signals — Part 3: Measurement of ultrawideband interference to C-band satellite digital television receivers," NTIA Report TR-06-437, Feb. 2006.

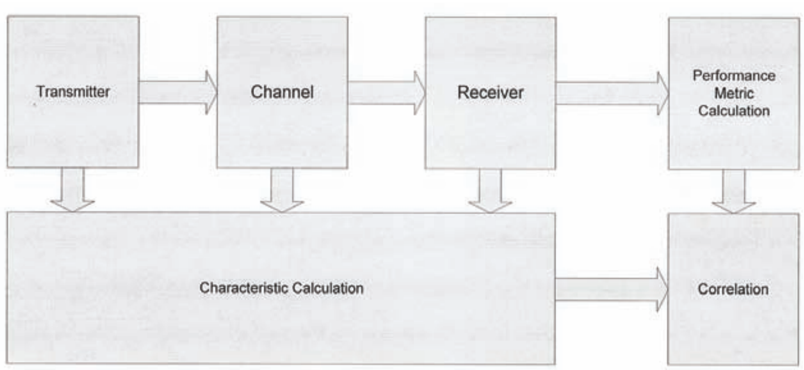

Figure 1. Conceptual diagram of approach which correlates radio link characteristics to radio receiver performance.

measurements can be executed with commercial off-the-shelf equipment or vector signal generators and analyzers downloaded by transmitter and receiver emulation codes. Considerable effort is vested in evaluating the uncertainties associated with working from the finite sample sets of measurements and simulations.

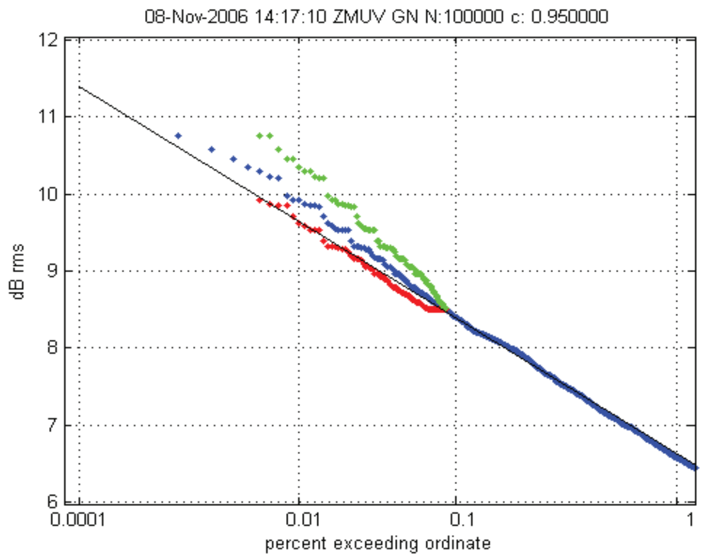

Figure 2. Confidence interval applied to low probabilities of an APD built from 100,000 samples of simulated zero-mean, unit-variance Gaussian noise. The solid line is the theoretical APD. The three dotted lines represent the measured APD flanked by the upper and lower 95% confidence interval values.

Success depends on project engineers' familiarity with communications signal processing methods, mathematical theory of probability, and statistical analysis. Engineers must also understand radio-frequency measurement methods along with radio channel measurement and analysis techniques.

Currently, efforts are focused on the mathematical analysis and software simulation of a linearly modulated radio system operating within a Gaussian noise channel. Linear modulation was chosen because it includes a wide range of commonly used modulations such as pulse amplitude modulation, phase shift keying, and quadrature amplitude modulations. Linear modulations are also used by low power radio links most vulnerable to interference, such as satellite links.

Considerable progress has been made in FY 2006. Major sections of the forthcoming report, "Effects of the radio channel on receiver performance. Part 1: Analytic model" by R.J. Achatz and R.A. Dalke, have been written. These sections include a mathematical description of the linearly modulated transmitter/receiver pair, including signal, noise, and receiver components, derivations of signal and noise amplitude probability distributions (APD), power spectral density (PSD), and average power characteristics, and extensive appendices which help the reader understand the communications analysis techniques involved. This report is expected to be completed in FY 2007. Work on "Part 2: Discrete model," which will include software simulation code, will begin upon publication of Part 1.

In addition, a comprehensive review of the statistical considerations for communications systems measurement or simulation is nearing completion. This work will culminate in the NTIA Report, "Statistical considerations for communication systems measurement" by R.A. Dalke, expected to be published in FY 2007. This work addresses the calculation of the uncertainties associated with computing performance metrics and statistical signal characteristics from the finite data sets provided by measurement. Uncertainties associated with measurement of APDs, PSDs, and average power have been completed. Uncertainties associated with bit error statistics are now being developed. An example of this work is shown in Figure 2.

In FY 2006, ITS formed an important alliance with NTIA's Office of Spectrum Management (OSM) regarding the application of this work. OSM is interested in including pertinent results in its "Best Practices Handbook," which will be used by all spectrum regulatory bodies in the United States Federal Government. In particular, they are interested in using these results as guidance for the assessment of the effect the radio channel has on modern signal processing methods such as error correction coding.

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Outputs

- Digital video quality measurement technology.
- Journal papers and national/international video quality measurement standards.
- Technical input to development of U.S. policies on advanced video technologies.
- A national objective and subjective digital video quality measurement laboratory.

Objective metrics for quantifying the performance of digital video systems (e.g., direct broadcast satellite, digital television, high definition television, video teleconferencing, telemedicine, internet, and cell phone video) are required by end-users and service providers for specification of system performance, comparison of competing service offerings, network maintenance, and use optimization of limited network resources. The goal of the ITS Video Quality Research project is to develop the required technology for assessing the performance of these new digital video systems and to actively transfer this technology to other Government Agencies, end-users, standards bodies, and the telecommunications industry, thereby producing increases in quality of service that benefit all end-users and service providers.

To be accurate, digital video quality measurements must be based on perceived "picture quality" and must be made in-service. This is because the performance of digital video systems is variable and depends upon the dynamic characteristics of both the input video and the digital transmission system. To solve this problem, ITS has continued to develop new measurement paradigms based upon extraction and comparison of low bandwidth perception-based features that can be easily communicated across the telecommunications network. These new measurement paradigms (now commonly known throughout the world as "reduced reference" measurements) have received four U.S. patents (with one additional patent pending), been adopted as the North American Standard for measuring digital video quality (ANSI T1.801.03-2003), been included in two International Recommendations (ITU-T Recommendation J.144, and ITU-R Recommendation BT.1683), and are currently being used by hundreds of individuals and organizations worldwide.

To facilitate the transfer of ITS-developed video quality metrics (VQMs) into the private sector, ITS has developed three software tools that run under both the Windows and Linux operating systems. Using these new software tools, users and service providers can quantify the digital video quality of their networks using methods standardized by

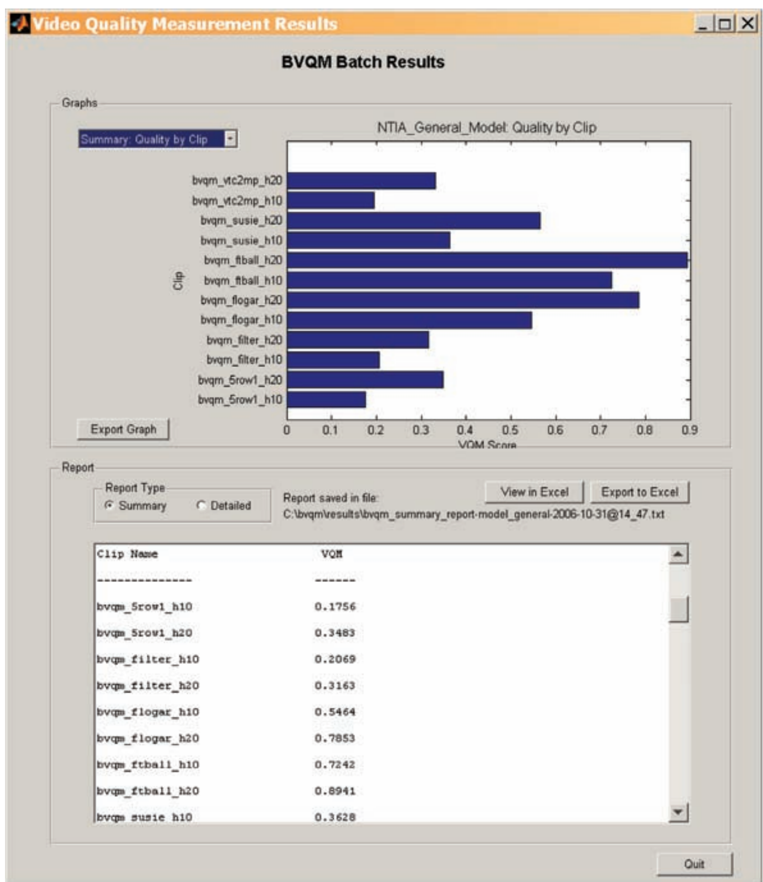

Figure 1. Example snapshot of the BVQM results screen showing summary results for the processed video clips.

the American National Standards Institute (ANSI) and the International Telecommunication Union (ITU).

The first tool, called the “Laboratory VQM Tool,” is useful for bench testing of video systems. For this tool, video from the source and destination ends of a video system must be present at a single PC for analysis.

The second tool, called the “In-Service VQM (IVQM) Tool,” requires two PCs, one located at the source end and the other located at the destination end of a digital video transmission system. The two PCs communicate their reduced reference features via the Internet, producing in-service end-to-end video quality monitoring results.

The third tool, developed in FY 2006, is called the “Batch VQM (BVQM) Tool.” The BVQM tool allows the user to perform Graphical User Interface (GUI) based batch mode processing of many captured video streams, or files.

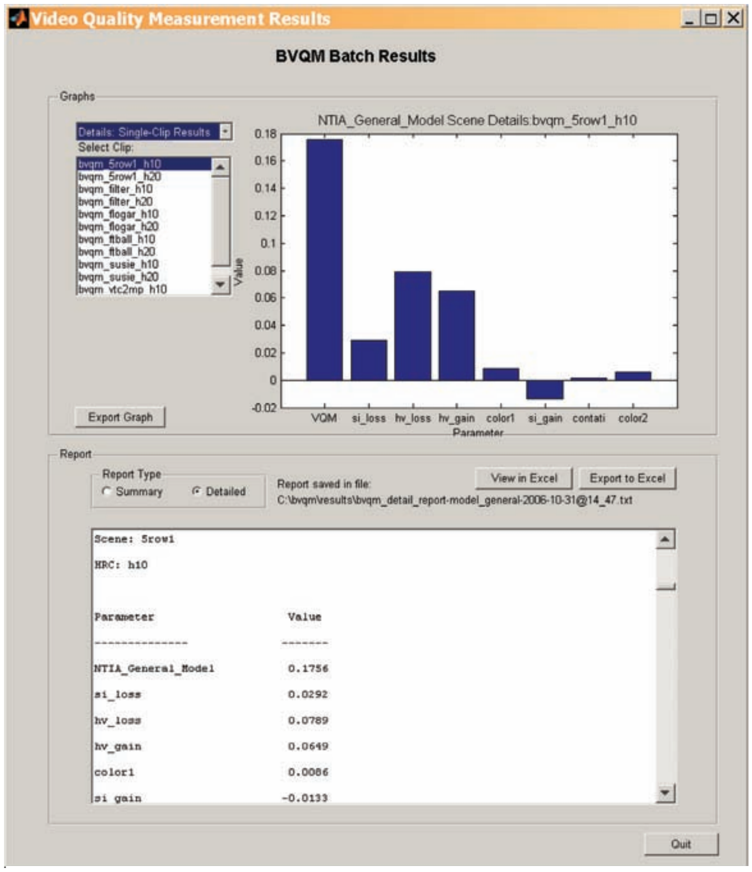

Figure 2. Example snapshot of the BVQM results screen showing detailed results for a user-selected video clip.

Figures 1 and 2 give example screen snapshots of the BVQM results screen after processing multiple video files. The user can display summary results for the processed video clips (Figure 1) or detailed results for a user-selected video clip (Figure 2). Other options (not shown) include displaying results by video system (i.e., averaged over all video scenes) or by video scene (i.e., averaged over all video systems). Summary and detailed reports of the video calibration (e.g., gain and level offset, spatial scaling/registration, temporal registration) and VQM scores/parameters can be saved in either text or Microsoft Excel® formats.

During FY 2006, 126 new Cooperative Research and Development Agreements (CRADAs) were implemented with U.S. companies/individuals and 75 new Evaluation License Agreements (EVAs) were implemented with foreign companies/individuals. These CRADAs and EVAs provide companies with an easy mechanism for evaluating ITS video quality measurement technology and software before signing commercial licensing agreements. As a result of this arrangement, five companies signed commercial licensing agreements with ITS in FY 2006.

Recent Publications

M. McFarland, M.H. Pinson, and S. Wolf, “Batch video quality metric (BVQM) user’s manual,” NTIA Handbook HB-06-441, Sep. 2006.

M.H. Pinson and S. Wolf, “Reduced reference video calibration algorithms,” NTIA Report TR-06-433a, Jul. 2006.

M.H. Pinson and S. Wolf, “In-service video quality metric (IVQM) user’s manual,” NTIA Handbook HB-06-434a, Jul. 2005.

Further information can be found on the Video Quality Research home page at http://www.its.bldrdoc.gov/n3/video.

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Cooperative Research with Industry

Outputs

- Interoperability measurements of Project 25 public safety radios.
- Measurements of ad hoc wireless network performance.
- Measurements of time-based transmitter and receiver performance.
- Measurements of X-band emissions from a newly developed radar.

The Federal Technology Transfer Act of 1986 (FTTA), as amended, allows Federal laboratories to enter into cooperative research agreements with private industry, universities, and other interested parties. The law was passed in order to provide Federal laboratories with clear legal authority to enter into these arrangements and thus encourage technology transfer to the private sector. Under this Act, a cooperative research and development agreement (CRADA) can be implemented that protects proprietary information, grants patent rights, and provides for user licenses to corporations, while allowing Government expertise and facilities to be applied to interests in the private sector.

ITS is a member of the Federal Laboratory Consortium for Technology Transfer (FLC), a network of over 700 Federal laboratories and the only government-wide forum for technology transfer. Organized in 1974 and formally chartered by the FTTA, the FLC provides the framework for developing technology transfer strategies and opportunities by promoting and facilitating technical cooperation among Federal laboratories, industry, academia, and State and local governments.

ITS participates in technology transfer and commercialization efforts by fostering cooperative telecommunications research with industry where benefits can directly facilitate U.S. competitiveness and market opportunities. ITS has participated for a number of years in CRADAs with private sector organizations to design, develop, test, and evaluate advanced telecommunication concepts. Research has been conducted under agreements with the following organizations:

- American Automobile Manufacturers Association
- ARINC
- AudioLogic, Inc.
- Bell Atlantic Mobile Systems
- Bell South Enterprises
- Coherent Technologies
- East Carolina University's Brody School of Medicine
- Eton Corporation
- FirstRF Corporation
- General Electric Company
- GTE Laboratories Inc.
- Hewlett-Packard Company (HP)
- Integrator Corporation
- Intel Corporation
- Johnson's Jobs
- Lehman Chambers
- Lucent Digital Radio
- Lucent Technologies
- Motorola/Freescale Inc.
- Netrix Corporation
- RF Metrics
- Savi Technologies
- Spectrum Mapping LLC
- Telesis Technology Laboratories
- University of Colorado
- University of Pennsylvania
- US WEST Advanced Technologies
- US WEST New Vector Group

Not only does the private sector partner benefit, but the Institute is able to undertake research in commercially important areas that it would not otherwise be able to do. Some of the active CRADAs in FY 2006 are described below.

The University of Colorado conducted measurements of the performance of ad hoc wireless networks with both ground-based and airborne terminals at ITS' Table Mountain Field Site. The Table Mountain Field Site is a National Radio Quiet Zone protected by Federal Regulation. Using IEEE 802.11 type equipment, routing protocols were tested and the performance of the ad hoc networks monitored. These measurements are contributing to the development of new wireless ad hoc network technologies.

Through a CRADA with **Eton Corporation** (and a Memorandum of Understanding (MOU) with the National Oceanic and Atmospheric Administration (NOAA), ITS has been testing radios manufactured by Eton Corporation and others for their ability to respond to the signals sent out by the NOAA All-Hazards Warning System.

Johnson's Jobs, a small Colorado technical contracting firm doing research for the Department of

ITS and Johnson's Jobs staff at the Table Mountain Field Site, preparing to perform antenna measurements using the large turntable (photograph by J.W. Allen).

Defense, entered into a CRADA with ITS in order to use the large turntable facility at Table Mountain for antenna testing. The turntable, a 10.4-meter diameter rotatable steel table mounted flush with the ground, is an unusual and valuable resource at the Table Mountain Field Site. As part of the CRADA, Johnson's Jobs upgraded the software in the test instrumentation housed in the laboratory space beneath the turntable.

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

ITS is interested in assisting private industry in all areas of telecommunications. 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 useful to them. Because of the great commercial importance of many new and emerging telecommunication technologies, including third generation wireless (3G), wireless local area networks, digital broadcasting, and intelligent transportation systems, ITS will continue to vigorously pursue technology transfer to the private sector through CRADAs and thereby contribute to the rapid commercialization of these new technologies. ITS also plans to commit substantial laboratory resources to the development and standardization of new telecommunication technologies.

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ITU-R Standards Activities

Outputs

- Technical support to the U.S. Administration in Working Party 8B, the Radar Correspondence Group, and Joint Rapporteurs Group 1A-1C-8B, as well as Study Group 3 (see pp. 46-47).
- Measurements to determine the performance of prototype 5-GHz DFS devices in the presence of a 5-GHz air defense radar.
- Tests and measurements performed on effects of interference from communication system signals into an airborne weather radar and an airport ground-surveillance radar.
- Radar spectrum emission measurements performed on U.S. radars to support the U.S. Administration's position on tightening radar emission criteria for better spectrum efficiency.
- Presentation for the Tri-Service Radar Symposium in Boston on the effects of interference in radar receivers.

Success in worldwide telecommunication markets, as well as effective and compatible use of telecommunications technologies both domestically and abroad, is critical to the long-term economic health of the United States. To achieve these goals, the U.S. Administration actively participates in the most important worldwide telecommunications standards and regulatory body, the International Telecommunication Union — Radiocommunication Sector (ITU-R), to further its objectives with regard to all forms of wireless communications. ITS in turn provides important, ongoing technical support to the U.S. Administration in ITU-R Study Groups 3 and 8; Working Party 8B; the Radar Correspondence Group (RCG), and Joint Rapporteurs Group (JRG) 1A-1C-8B. Current areas of interest include (but are not limited to): potential reallocation of radar spectrum; effects on radars of interference from communication systems; dynamic frequency selection technology proposed for 5-GHz spectrum sharing between communication systems and radars; development of radar emission spectrum measurement techniques; and development of more efficient radar spectrum emission criteria.

Proposals have been made by non-U.S. Administrations in ITU-R to introduce communication systems into bands that have heretofore been allocated for radars on a primary basis. One of these is dynamic frequency selection (DFS), in which communication systems automatically sense the presence of radar signals and avoid operations on locally occupied radar frequencies. Since the U.S. Administration has made an enormous investment in the development and deployment of both military and civilian radars, it is essential that new systems proposed for spectrum sharing with radars be shown to be electromagnetically compatible with existing and future radars. To this end, ITS engineers in FY 2006 tested the new technology, DFS, for the U.S. Administration.

The tests were conducted jointly between ITS, the NTIA Office of Spectrum Management (OSM), other Federal Agencies, and industry. Several 5-GHz DFS RLAN prototypes were tested at the White Sands Missile Range to determine the extent to

Figure 1. A 2006 meeting of ITU-R Working Party 8B (the maritime and radar group) in Geneva (photograph by F.H. Sanders).

Figure 2. A radar during emission measurements performed in support of the U.S. Administration position in the ITU-R (photograph by F.H. Sanders).

which they could successfully sense the presence of signals from an air defense radar; those results were used by the U.S. Administration at ITU-R meetings in FY 2006.

ITS and OSM have worked closely together for the last several years to learn more about the effects of interference in radar receivers. In FY 2006 they published a landmark NTIA Report on the results of the last five years of work in this area. Additional interference tests and measurements were performed by ITS and OSM engineers on an airborne weather radar and an airport ground-control radar. Interference signals were injected into the radar receivers while targets were observed. At a variety of interference levels, the effects on target detection were observed. The effects of swept-frequency pulses generated by some other radars, called chirped pulses, were also studied. The radar receivers were found to be highly sensitive and susceptible to interference from communication signals at low levels, well below the noise floor of the radar. However, no interference effects were noted in the presence of chirped pulses and other types of radar pulses; these results indicated that all of the radar types that have been studied to date have been highly compatible with other radar systems but not so compatible with communication signals. The test results have been used for U.S. Contributions in WP-8B, the Tri-Service Radar Symposium, and NTIA Reports and Technical Memoranda.

Additional work in the ITU-R has been devoted to chairmanship of the Radar Correspondence Group by an ITS engineer, as well as ongoing support and written Contributions for JRG 1A-1C-8B on the topic of future development of radar spectrum emission criteria.

Finally, in FY 2006 ITS organized and hosted an important meeting of the Joint Rapporteurs Group 1A-1C-8B in Boulder, Colorado, on topics related to improvement of radar emission spectrum mask limits.

Recent Publications

F.H. Sanders and B.J. Ramsey, “Phased array antenna pattern variation with frequency and implications for radar spectrum measurements,” NTIA Report TR-06-436, Dec. 2005.

F. Sanders, J. Wepman, and S. Engelking, “Development of performance testing methods for dynamic frequency selection (DFS) 5-GHz wireless access systems (WAS),” in “Proceedings of the International Symposium on Advanced Radio Technologies, March 7-9, 2006,” P. Raush and K. Novik, NTIA Special Publication SP-06-438, Mar. 2006.

F.H. Sanders, J.R. Hoffman, and Y. Lo, “Resolving interference from an airport surveillance radar to a weather radar,” NTIA Technical Memorandum TM-06-439, Apr. 2006.

F.H. Sanders, R.L. Sole, B.L. Bedford, D. Franc, and T. Pawlowitz “Effects of interference on radar receivers, NTIA Report TR-06-444, Sep. 2006.

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ITU-T & Related U.S. Standards Development

Outputs

- Leadership of ITU-T and related U.S. telecommunications standards committees.
- Technical contributions presenting U.S. standards proposals and ITS research results.
- Proposed ITU-T Recommendations and associated U.S. industry standards.

The Institute has a long history of leadership, technical contributions, and advocacy of U.S. Government and industry proposals in the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) and related U.S. standards organizations. ITU-T is a specialized agency of the United Nations, responsible for developing the international standards (Recommendations) providers use to plan, interconnect, and operate public telecommunication networks and services worldwide. ITU-T Recommendations strongly impact both the evolution of U.S. telecommunication infrastructures and the competitiveness of U.S. telecommunication products in international trade.

The Institute's long-term goal in ITU-T (and related national standards work) is to motivate the standardization of user-oriented, technology-independent measures of telecommunication service quality, and to relate those measures with the technology-specific performance metrics and mechanisms providers use to provision and operate networks. This work promotes fair competition and technology innovation in the telecommunications industry, facilitates interworking among independently-operated networks and dissimilar technologies, and helps users define their telecommunication needs and select products and services that meet them.

In FY 2006, the Institute provided leadership in two key ITU-T groups: Study Group (SG) 13 and SG 9's Working Group on Quality Assessment. Institute staff also provided leadership in the ANSI-accredited Performance, Reliability, and Quality of Service Committee (PRQC). SG 13 is developing international standards for Internet Protocol (IP) based Next Generation Networks (NGNs) that will offer integrated voice, video, data, and multimedia services — and innovative new services like IP television — with assured quality levels. An ITS staff member serves as Vice Chair of ITU-T SG 13 and chairs SG 13's Working Party (WP) 4, which develops NGN standards on Quality of Service (QoS) and Operations, Administration, and Maintenance (OAM). An ITS staff member chairs SG 9's Working Group on Quality Assessment, which defines quality objectives for integrated broadband cable networks and television and sound transmission. In that group, ITS chairs Question 14/9, "Objective and Subjective Methods for Evaluating Audiovisual Quality in Multimedia Services." ITS also leads and contributes to the ITU-affiliated Video Quality Experts Group (VQEG), which works with SG 9, SG 12, and ITU-R WP 6Q (Broadcasting Services — Performance Assessment and Quality Control) to develop objective, computer implementable, perception-based video quality metrics (VQMs) that emulate the human visual system. ITS also leads the Joint Rapporteur Group on Multimedia Quality Assessment (JRG-MMQA), a cross-cutting ITU-T standards body that unites the video quality expertise of SG 9 with the audio quality expertise of SG 12 in an effort to develop objective, perception-based metrics for combined audio and video signals in mobile and PC environments. ATIS PRQC develops national standards and contributes strongly to ITU-T standardization in all of these technology areas. ITS leads PRQC's QoS and Security Task Forces.

In FY 2006, SG 13 processed over 1000 technical contributions and completed 14 new ITU-T Recommendations, collectively defining the key requirements and architectures for NGN. WP 4/13 developed four of these new Recommendations: Y.2111, which defines the architecture for the NGN Resource and Admission Control Function (RACF); Y.1731, which defines OAM fault management and performance monitoring functions for carrier class Ethernet networks; Y.2171, which defines admission control priority levels for Emergency Telecommunications Service (ETS) in NGNs; and Y.1714, which defines a management and OAM framework for multi-protocol label switching (MPLS) networks. Y.2111 is central to ITU's NGN concept and is considered by many to be the most important NGN standard published to date. Y.1731 will enable carriers to deploy Ethernet technologies in metropolitan and wide-area networks.

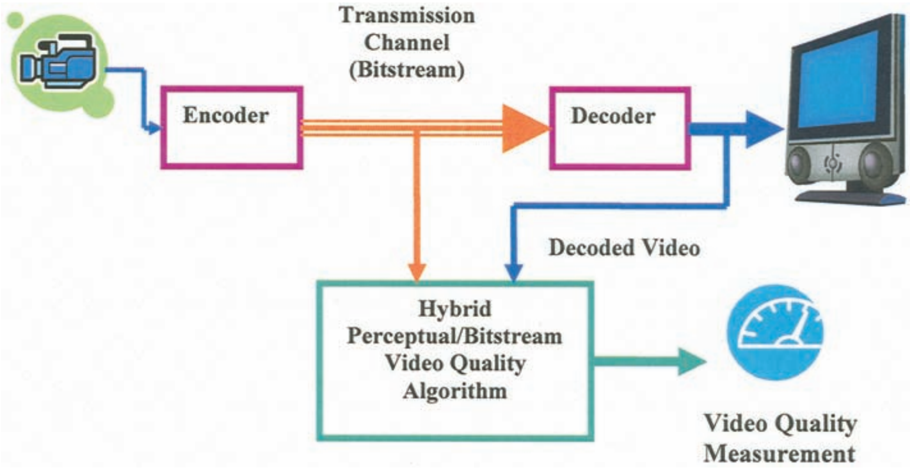

Diagram of the hybrid perceptual/bitstream video quality approach.

PRQC's FY 2006 work produced a new American National Standard that specifies an algorithm that can assess transmitted voice quality using only observations of the output voice signal. This "single-ended" assessment technique will be valuable to providers in situations where non-intrusive, in-service quality measurements are required. ITS performed an independent technical evaluation of the proposed algorithm using its Audio Quality Measurement System. In other standards leadership, ITS developed a major section of the ATIS Board of Directors' NGN Focus Group (NGN-FG) report, "ATIS Next Generation Network (NGN) Framework, Part III: Standards Gap Analysis." This work motivated four new standards project proposals in PRQC.

ITS has co-chaired the ITU Video Quality Experts Group since its formation in 1997. VQEG enables video experts from many countries to collaborate in developing and evaluating video quality metrics (VQMs), and its results strongly impact the standardization of VQMs in both ITU-T and ITU-R. The group works primarily via an e-mail reflector, publicly accessible at http://www.VQEG.org. During FY 2006 the number of participants subscribed to this reflector grew to 519. ITS chaired two physical VQEG meetings in FY 2006. ITS also contributed to VQEG's Reduced Reference-No Reference (RR-NR) TV, HDTV, and Multimedia video test plans and provided key video source material during FY 2006. ITS is spearheading new ITU-T work on multimedia quality assessment through its leadership in VQEG and the JRG-MMQA. The latter group met three times during FY 2006.

In both VQEG and ITU-T Study Group 9, work has begun on a new approach to objective video quality assessment (illustrated in the figure above). This approach, called the hybrid perceptual/bitstream method, combines information obtained from analysis of the transmission channel bitstream (e.g., codec type and parameters, bit rate, error rates, etc.) with perceptual information obtained from analysis of the decoded video frames (e.g., edge detail, frame rate, amount of jerky motion, tiling, errored blocks). This approach promises to provide monitoring capabilities that will be both more accurate and more easily implemented than currently available methods. Several organizations are developing such composite objective video quality assessment methods. This methodology is well suited to the monitoring needs of cable television and IPTV providers, and can be used to monitor the quality of video to cell phones, PDAs, and PCs. VQEG is developing a test plan to validate these methods, and Study Group 9 plans to standardize the specific systems that prove to be most useful.

During FY 2006, ITS staff members also organized and chaired technical sessions at two ITU-T sponsored workshops: a SG 13/SG 15 Joint Workshop on NGN and its Transport Networks and a SG 12 Workshop on QoS. The two workshops together attracted over 500 participants. Results are summarized at http://www.itu.int/ITU-T/worksem/ngn/200604/program.html and http://www.itu.int/ITU-T/worksem/qos/200606/programme.html.

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The large turntable at the Table Mountain Field Site, showing recent renovations and upgrades: both outside (top), and inside (bottom) (photographs by J.W. Allen).

ITS Tools and Facilities

Advanced Antenna Testbed

The advanced antenna testbed (ATB) is a multi-channel test facility using ITS digital sampling channel probe technology. It can be configured for multiple channel recordings at one or multiple frequencies. When configured at one frequency, orthogonal pseudo noise codes can be transmitted from multiple antenna elements. The table summarizes the range of permissible values for the ITS channel sounding system, and gives an example of a measurement system configured for 2.3 GHz and 10 Mb/s operation.

Configurable Testbed Parameters

Parameter	3G Example	ITS System
Receiver Channels	8	1-8 (expandable to 16)
Carrier Frequency	2.3 GHz	.45 – 6 GHz
Bit Rate	10 Mb/s	.1 – 50 Mb/s
Resolution	100 ns	20 ns – 10 µs
Code Type	Maximal Length	Programmable
Code Length	511 bits	Programmable
Acquisition Mode	Burst	Continuous or Burst
Positioning	GPS/Dead Reckoning	GPS/Dead Reckoning
Transmitters	16	Multiple
Data Processing	Post	Post

The ATB provides reference sites for evaluating next-generation antenna systems. Data from multiple channels can be used to test the diversity gain resulting from various signal combining algorithms. Digital beam forming and MIMO techniques may also be examined by simultaneous digitization of signals from multiple antenna elements.

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Audio-Visual Laboratories

The ITS Audio-Visual Laboratories offer a wide range of audio and video recording, storage, processing, reproduction, objective quality assessment, and subjective testing capabilities. These capabilities in turn support the development and verification of new quality estimation techniques for compressed digital audio and video, the development of novel subjective testing techniques for audio and video signals, and the development of new coding algorithms.

Laboratory equipment supports standard-definition (SD) and high-definition (HD) video signals, as well as monophonic, stereophonic, and 5.1-channel audio streams. Signals are acquired with high-quality microphones and cameras. Recording and playback devices include studio-quality analog and digital video tape recorders with two to eight audio channels, digital audio tape machines, and CD players.

These systems are augmented with several digital audio and video workstations and a set of high quality Analog-to-Digital and Digital-to-Analog converters. Analog audio mixing, filtering, and equalizing equipment is available. An array of digital audio and video encoders and decoders are available as well as an HDTV modulator and demodulators. Analog and digital audio and video routing switchers and patch panels allow for nearly arbitrary interconnections between the various pieces of equipment. Reproduced signals are presented through studio quality video monitors, monitor loudspeakers, headphones, or handsets.

Three separate rooms with controlled visual and/or acoustic environments are available for the subjective testing of audio and video signals. The controlled environments are specified in ITU-T Recommendation P.800 and ITU-R Recommendation BT.500, respectively. These specifications address background noise levels, wall colors, light levels, room dimensions, and other properties.

Finally, the labs feature an array of audio and video signal generators and analyzers to support laboratory measurement and calibration activities. Computers play a key role in laboratory operations. Two systems offer the ability to record and play back uncompressed digital audio bit-streams together with synchronized SD video bit-streams that conform to ITU-R Recommendation BT.601 (i.e., SMPTE 259M/272M specification) and synchronized digital audio streams to and from high-speed workstations. Two of these computer-based systems can also record and play back uncompressed HD audio and video bit-streams in accordance with the SMPTE 292M format. Much audio and video processing is performed on a cluster of high-performance workstations, supported by high capacity RAID arrays for storage of the uncompressed audio and video streams.

Lab activities include objective estimation of audio and video quality, and subjective testing of audio and video quality. Random access digital audio video playback systems coupled with discrete-time and continuous-time wired and wireless electronic data entry systems greatly facilitate many of the subjective testing activities. Because multiple subjective testing rooms are available, the laboratory can support conversation, teleconferencing, and video teleconferencing tests as well as viewing and listening tests. Objective video quality estimation software, written in C++ and MATLAB, processes video signals in accordance with ANSI T1.801.03-2003, ITU-T Recommendation J.144 Revised, and ITU-R Recommendation BT.1683, resulting in estimates of video quality that show good correlation with subjective test results. Several different objective speech and audio quality estimation algorithms are available, including those defined in ANSI T1.518, ITU-T Recommendation P.862, and ITU-R Recommendation BS.1387. The labs support both batch-mode and real-time objective quality estimation.

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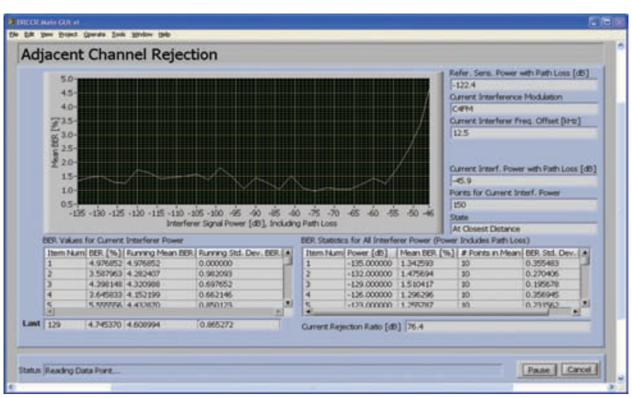
Compliance Assessment Research Laboratory

The Compliance Assessment Research Laboratory provides ITS with the capability to assess the compliance of Land Mobile Radio (LMR) systems to the Telecommunications Industry Association's TIA-102 and TIA-603 series of standards. Engineers and resources in the laboratory are being employed to support the development of all three types of compliance assessment documents defined by the TIA subcommittee TR-8 Mobile and Personal Private Radio Standards: performance, interoperability and conformance test standards.



User interface for radio performance measurements tool.

In FY 2007, ITS engineers will complete development of the Radio Performance Measurements automated testing software suite. The performance measurement capabilities in the tool include receiver and transmitter procedures such as receive sensitivity, co-channel and adjacent-channel rejection, spurious response rejection, and transmitter emissions mask. The software suite supports highly accurate measurements made possible by laboratory grade equipment such as signal generators, real-time digital spectrum and vector signal analysis tools, and wideband digital oscilloscopes. Sensitive measurements are facilitated by the use of a room-sized RF shielded enclosure. Interoperability tests are made possible through interactive testing using the laboratory's extensive cache of Project 25 (P25) radios and repeaters, while conformance assessments are accommodated by communications analyzers. The lab possesses both types of commercially available P25 compatible communications system analyzers as well as a one of a kind P25 Trunked Protocol Off-Air-Monitor. These instruments can decode various aspects of the link control information, such as network access code, talk group identification, and status bit. Common air interface protocol logging and data capture are supported as well.

The primary use for this capability is compliance assessment of P25 LMRs, but the equipment and facilities can support a much broader range of tests and radio equipment. This capability is available on a first-come, first-served basis to both NTIA and other agencies.

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Digital Sampling Channel Probe

The digital sampling channel probe (DSCP), designed and patented at ITS, is used to characterize the wideband propagation characteristics of the radio channel. Consisting of a transmitter, receiver, and data acquisition system, the DSCP is used to make complex impulse response measurements. The DSCP digitizes a pseudo-noise signal at an intermediate frequency (IF) and then post processes the data. The system can collect data on multiple channels every 600-800 µs, allowing characterization of the Doppler spectrum and time variability of the mobile channel for HF systems (up to 5.8 GHz). Historically, the DSCP was employed extensively for channel characterization of cellular and personal communications services. ITS expanded the probe to eight channels capable of mobile phased array or MIMO measurements. Also available is a wide-bandwidth, high-frequency probe, particularly suited for high resolution requirements such as wireless local area network (LAN) applications up to 30 GHz. Most recently, the probe's measurement range has been expanded down to the UHF TV bands, and has been used for short-range mobile to mobile propagation channel characterization. For more information, see http://flattop.its.bldrdoc.gov/rcirms/

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Green Mountain Mesa Field Site

The main Department of Commerce Boulder Laboratories campus contains a field site used for outdoor wireless network research. The site is connected to the ITS laboratories via both fiber optic and 802.11 links. The fiber optic link provides access to the ITS local area network (LAN) while the 802.11 link connects this field site to ITS' Wireless Networks Research Center (see p. 74). The site can provide six independent duplex fiber channels to the ITS lab. This allows research to be conducted over an isolated one-mile outdoor Wi-Fi link. The fiber connectivity provides a LAN connection to the outdoor wireless router and for capability to operate remote data collection equipment. The outdoor router, located on an 80-foot tower, provides long range 802.11 links to other sites. Currently these links provide 802.11b services and are also used for network performance testing. The site's unique location, several hundred feet above the main Department of Commerce campus, allows for the provisioning of wireless test links over a large portion of eastern Boulder county. The site is operated year round.

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ITS Internet Services

ITS provides public Internet access to NTIA/ITS publications, program information, meeting information, and on-line resources such as Telecommunications Analysis Services, which are used by other Federal Agencies, research partners, and private industry. Restricted-access services including electronic mail lists are used to facilitate communications with project sponsors and partners, and to support various standards committees. Highlights of ITS Internet Services include:

- Information about ITS programs and projects. Available at http://www.its.bldrdoc.gov/programs/
- An ITS organization chart and a listing of ITS staff with contact information. Available at http://www.its.bldrdoc.gov/organization.php
- Recent ITS publications including NTIA Reports, special publications, and journal articles. Available at http://www.its.bldrdoc.gov/pub/pubs.php
- Radio propagation data. Available at http://www.its.bldrdoc.gov/data/radio_propagation_data/

- Radio propagation software. Available at http://www.its.bldrdoc.gov/software/
- Information about the Table Mountain Field Site. Available at http://www.its.bldrdoc.gov/table_mountain/
- Telecommunications Analysis Services. Available at http://tas.its.bldrdoc.gov/
- Video Quality Metric software. Available at http://www.its.bldrdoc.gov/n3/video/vqmsoftware.htm
- Information about ITS-sponsored events such as ISART. Available at http://www.its.bldrdoc.gov/meetings/
- The ITS brochure. Available at http://www.its.bldrdoc.gov/ITS_brochure/ITS_brochure.pdf

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ITS Local Area Network

ITS maintains a highly flexible local area network to support local networking services and laboratory interconnections. A structured cabling system interconnects all offices and laboratories with optical fiber, category 5, and category 6 twisted-pair cabling to support high-bandwidth communications on demand. Over 200 devices are supported on 10Base-T, 100Base-T, and gigabit segments. This provides ITS with great flexibility and rapid reconfiguration capability for new programmatic needs. A firewall-based VPN capability securely extends the network to authorized personnel anywhere in the world.

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Mobile Radio Propagation Measurement Facilities

ITS maintains a measurement vehicle capable of radio channel characterization over a wide frequency range. The vehicle is equipped with on-board power, a telescoping mast, azimuth elevation controllers, and global positioning system (GPS) devices with dead-reckoning backup. A suite of measurement equipment is also available for use in this vehicle, including wideband systems for measuring radio channel impulse response from 180 MHz to 30 GHz. Impulse response measurement capability at 30 GHz with 2ns resolution has been enhanced with the addition of a digital wideband recording system. ITS has increased its mobile channel measurement capability with the addition of an 8-channel receiver and an 8-channel 14-bit data acquisition system. Multichannel synchronous acquisition can be used for antenna array measurements or multi-frequency broadband measurements. Mobile measurement capability allows space division multiple access (SDMA) algorithms to be studied using data collected in typical mobile environments. This data can then be used to simulate and model radio systems. A suite of measurement software is maintained for calculating mobile propagation metrics from the impulse response data. Typical metrics are power delay profiles, delay spread, received power versus bandwidth, Doppler spectrum, and coherence bandwidth.

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Public Safety Audio Laboratory

One of the most challenging aspects of public safety communication is the harsh noise environment in which public safety practitioners must effectively establish and conduct voice communications. The Public Safety Audio Laboratory (PSAL) is a facility for investigating the voice quality of public safety communication systems in those harsh environments. It consists of digital systems for mixing, storage, and distribution of audio; sound attenuated chambers for effective isolation; and International Telecommunication Union (ITU)-compliant head and torso simulators (HATS) for acoustic coupling to radio interfaces.

The PSAL is built on a foundation of digital audio mixing and distribution. All audio mixing, distribution, storage, and filtering are conducted in the digital realm with 48 kHz-sampled audio. This provides a high-quality, distortion-free distribution system that is not impacted by other equipment in the laboratory. The digital capabilities include: digital mixing, 24-track digital recording, 8-channel digital input and output to Windows-based computers, digital audio tape (DAT), and 1/3 octave digital filters. Usage of analog audio signals is kept to a minimum by 1) digitizing analog inputs at the input and keeping them digital throughout any processing, and 2) only performing digital-to-analog conversion on signals that are to be converted to acoustic signals.

The sound attenuated chambers serve two functions: (1) they isolate the audio equipment under test from any ambient noise that might be present, and (2) they isolate the laboratory from environmental noise that might be injected into the chambers to evaluate how well the equipment operates in harsh noise environments. For example, high-quality digital recordings of the interior of a fire-truck can be played into the chambers in 5.1 surround sound at the same level encountered in the field. Two chambers are used to enable emulation of the acoustic environment at both ends of a communication link.

The HATS systems are defined by the ITU in recommendations P.58 (Head and torso simulator for telephonometry), P.57 (Artificial ears), and P.51 (Artificial mouth). These recommendations specify the physical characteristics and acoustical/electrical interface characteristics that enable a consistent simulation of the speaking and hearing frequency responses of the “average” human. The HATS enable consistent acoustic input to communications equipment under test and provide a “willing subject” that will not be subject to hearing loss when exposed to harsh noise environments for extended periods.

Head and torso simulator configured as a “listener” with a hand-held public safety radio (photograph by D.J. Atkinson).

Combined together, the various parts of the PSAL provide a reproducible acoustic path that enables emulation of the harsh noise environments encountered by public safety practitioners. The recorded output from the system can be used in a number of ways. For example, the recordings might be analyzed by an objective measurement technique such as that defined in ITU Recommendation P.862 (Perceptual evaluation of speech quality (PESQ): an objective method for end-to-end speech quality assessment for narrow-band telephone networks and speech codecs). Alternatively, the recordings might be incorporated into a subjective test experiment where listeners will rate the quality of the audio. Both methods can provide valuable insight into the requirements of public safety communications.

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Pulsed Radar Target Generator

The Pulsed Radar Target Generator is an electronic tool used to produce targets on a radar screen. The generator produces signals that simulate the returns that would normally be seen by a radar from targets in the environment. The signals are injected into the radar’s receiver at the normal frequency of operation. Some radar models transmit modulated pulses. The generator can produce modulated pulses such as chirped and phase coded modulations (including the popular Barker code set). Several parameters of the signals can be adjusted over a wide range to be compatible with several different radar models. For the same model radar, the number of targets and the range to the targets can be adjusted. Other adjustments include the displayed bearing of the targets and whether the targets are stationary or moving along concentric circular paths. Compensation adjustments can be made for radars that have large tolerances in their operating specifications. The targets can be set to occur at a fixed time interval after a timing pulse (for example, beginning of scan) supplied by the radar. The generator can be used to verify operation or troubleshoot the radar under test. ITS has used the generator to provide simulated desired signals in interference studies where interference is injected into the radar and the effect on the targets is recorded.

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Radio Noise Measurement System

The ITS radio noise measurement system hardware consists of an omnidirectional antenna mounted on a ground plane, preselector filter, low noise preamplifier, off-the-shelf spectrum analyzer, digitizer, and computer. Noise samples are digitized prior to spectrum analyzer detection, just after spectrum analyzer log amplification. Spectrum analyzer demodulation circuits are used for aural noise identification during measurements. The measurement system noise figure is nominally 2 dB above the theoretical noise floor. Noise is measurable approximately 15 dB below and 60 dB above system noise.

The noise measurement system uses custom data acquisition software written and maintained at ITS. The software graphical user interface allows the user to customize and notate each measurement. It also displays noise samples and their corresponding first-order statistics. The statistics are revealed through an amplitude probability distribution (APD). The APD is plotted on a Rayleigh graph where the Gaussian noise appears as a straight line with a negative slope. Non-Gaussian noise is easily identified during measurements as a deviation from the straight line or a change in slope. Non-Gaussian noise exists throughout the radio spectrum. ITS has used the noise measurement system to measure noise at 137.5 MHz, 402.5 MHz, and 761.0 MHz. The system can also be used to measure noise at higher frequencies, e.g., at 2.4 GHz in spectrum occupied by unlicensed Part 15 low power communication devices such as wireless local area networks and Part 18 industrial, scientific, and medical (ISM) devices such as microwave ovens.

The noise measurement system can be run from a building or a measurement van. A direct current converter with noise suppressor is used to power the van-mounted equipment if 120 V alternating current is not available. Calibration measurements in radio quiet zones have shown that noise contributed by the noise measurement system and power conversion equipment is negligible.

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Radio Spectrum Measurement Science (RSMS) System Tools

The Radio Spectrum Measurement Science (RSMS) system is a state-of-the-art measurement system designed for gathering information regarding spectrum occupancy, equipment compliance, electromagnetic compatibility, and interference resolution. Its purpose is to provide NTIA's Office of Spectrum Management (OSM) with critical measurement support from ITS for determining policies regarding government radio systems and spectrum utilization.

The RSMS system is a dynamic and flexible system that incorporates automated, semi-automated, and manual techniques for the measurement and analysis of radio emissions. While not defined by any single hardware configuration, the system includes such devices as the latest in spectrum analyzers, digital oscilloscopes, vector signal analyzers, and signal intercept and collection systems. Measurements can take place in a laboratory or

Radio Spectrum Measurement Science (RSMS) vehicle performing measurements in the field (photograph by J.R. Hoffman).

in the field, and they can be mobile or stationary; therefore the system has been made flexible enough to accommodate each of these situations.

An integral part of the system is the measurement vehicle, now in its 4th generation. The vehicle has a highly shielded enclosure (60 dB) with three equipment racks, three 10-meter masts, and a 20-kW diesel generator, as well as internet connections, fiberoptic control lines, multiple power outlets, and overhead cable racks.

The control and acquisition software is fully developed by ITS so that new and innovative measurement techniques can be easily altered to meet immediate needs. Major objectives in the development of the 4G software have been to provide a tool that can easily accommodate new equipment and different hardware configurations, and to expand on existing measurement capabilities.

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SIPRNET Capability

ITS maintains a connection to the Secret Internet Protocol Routable Network (SIPRNET). This connection allows ITS sponsors and Department of Defense users direct access to ITS tools and facilities in a secure environment, improving the quality of support that the Institute can give organizations with classified needs. Since many of the planning and associated support activities of the military require a classified channel for discussions and data transfer, the need exists for a secure environment within which project planning and support can be carried on without interruption. ITS maintains several computer systems with a variety of software capabilities to support propagation planning and modeling, as well as emerging technologies research. The secure facilities allow users to import data from many military facilities and support organizations into propagation models and other management software. A complete end-to-end propagation planning capability in a secure environment is available for classified needs. Various research studies that ITS conducts (that are determined as classified information) can also reside on the SIPRNET, allowing access by agencies on a need to know basis.

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Spectrum Compatibility Test and Measurement Sets

The introduction of new radio technologies in close physical and frequency proximity to older ones often results in electromagnetic compatibility (EMC) problems. Although theoretical models and simulations provide useful information in guiding design decisions, the complexity of modern systems and the existing spectral environment often require real-world measurements of a proposed system's effects within its proposed operating environment to determine its impact on other users of the radio spectrum. Another problem is to adequately produce controlled interfering signals with known characteristics in environments where suspected interferers may be unavailable for tests and measurements, e.g., laboratory investigations of possible interference from ship or aircraft mounted radars or communications systems. In both situations a system is needed that simulates the spectral emissions of other devices with a wide range of latitude. An example is the requirement to determine the thresholds at which various types of interference from communication transmitters are manifested as observable interference effects in a variety of radar receivers. Another example is to determine the ability of dynamic frequency selection (DFS) wireless communication devices to detect various types of radar energy without actually obtaining a wide variety of real radars for tests.

To meet these needs, ITS engineers have developed two different approaches to generating interference signals. One approach is to build custom hardware and software combinations of discrete-component equipment, including programmable arbitrary waveform generators, mixers, RF signal generators and amplifiers. ITS uses a number of these configurations to simulate the spectral output of a wide variety of communication systems. These signals can be coupled directly into a system under test or they can be transmitted through space into a target system's receiver to more accurately gauge its response to a real interference situation. The second approach is to utilize high-speed digitizers, called vector signal analyzers (VSAs) to record interference waveforms in bandwidths up to 36 MHz, and to then radiate (or hardline-couple) those waveforms into victim receivers using vector signal generators (VSGs) that operate somewhat as inverses to VSAs. Alternatively, VSGs may be preprogrammed with mathematical information to create particular types of modulation, such as quadrature phase shift keyed (QPSK) signals. The ITS VSGs can be used in conjunction with high-power amplifiers to generate interference signals at high power at frequencies as high as 26 GHz. The advantages of VSGs include simplicity of operation and use, plus the ability to replicate very complex interference waveforms with complete confidence in the fidelity of the simulated signal to the characteristics of the original signal from which it was derived.

In FY 2006 the Institute began to develop a new, mobile system for propagation measurements. Two vehicles have been dedicated to this system: one for transmitters and one for receivers. The transmitter vehicle is an adaptation of the earlier RSMS-3 (since replaced by the RSMS-4 for general-purpose spectrum measurements). The receiver vehicle is completely new. It is a modified utility van that contains multiple, parallel receivers for simultaneous propagation measurements on several frequencies. The receiver van incorporates an on-board generator, air conditioner, pneumatic mast, GPS tracking system, and roof platform. The ITS propagation measurement system will be further developed in FY 2007 as it is used to develop a short-range (less than 1 km), mobile-to-mobile propagation model for NTIA.

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Table Mountain Field Site and Radio Quiet Zone

Established in 1954, the Table Mountain Field Site and Radio Quiet Zone is a unique radio research facility. Located north of Boulder, the site extends approximately 2.5 miles north-south by 1.5 miles east-west, and has an area of approximately 1,800 acres. The site is designated as a Radio Quiet Zone where the magnitude of strong, external signals is restricted by State law and Federal Regulation to minimize radio-frequency interference to sensitive research projects. Facilities at the site include:

- **Spectrum Research Laboratory** — A state-of-the-art facility for research into radio spectrum usage and occupancy. Radio Quiet restrictions ensure that no signal incident on the mesa overpowers any other.

- **Open Field Radio Test Site** — A flat-topped butte with uniform 2% slope, Table Mountain is uniquely suited for radio experiments. It has no perimeter obstructions and the ground is relatively homogeneous. This facilitates studying outdoor radiation patterns from bare antennas or antennas mounted on structures.

- **Mobile Test Vehicles** — There are several mobile test equipment platforms available at the mesa, ranging from 4-wheel drive trucks to full-featured mobile laboratories.

- **Large Turntable** — A 10.4-meter (34-foot) diameter rotatable steel table mounted flush with the ground. Laboratory space underneath houses test instrumentation as well as the control equipment and motors to rotate the turntable. This facility can be operated remotely by computer.

- **18.3 Meter (60 Foot) Parabolic Dish Antennas** — These two antennas are steerable in both azimuth and elevation and have been used at frequencies from 400 MHz to 6 GHz.

- **Radar Test Range** — A large space just south of the Spectrum Research Laboratory is available for testing radar systems.

The Table Mountain Research program supports a number of research activities, e.g., studying the effects of radio propagation on digital signal transmission, environmental and man-made noise, verification of antenna propagation models, and the development of measurement methods needed to assess efficient spectrum occupancy and usage (see pp. 10-11). Partnerships and cooperative research activities are encouraged at the site. Other organizations currently using the facilities include the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the Deep Space Exploration Society.

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Telecommunications Analysis Services

The Telecommunications Analysis (TA) Services program provides the latest ITS-developed engineering models and research data to industry and other Government Agencies via a web-based interface (http://tas.its.bldrdoc.gov/). User-friendly and efficient, it offers a broad range of programs that allow the user to design or analyze the performance of telecommunications systems. Currently available are: on-line terrain data with 1-arc-second (30 m) resolution for CONUS and 3-arc-second (90 m) resolution for much of the world, and GLOBE (Global Land One-km Base Elevation) data for the entire world; the U.S. Census data for 2000, 1997 update, and 1990; FCC databases; and GIS databases (ArcInfo). TA Services has developed models that predict communication system coverage and interference for many broadcast applications. New models in the GIS environment have been developed (see pp. 44-45). The following is a brief description of programs available through TA Services.

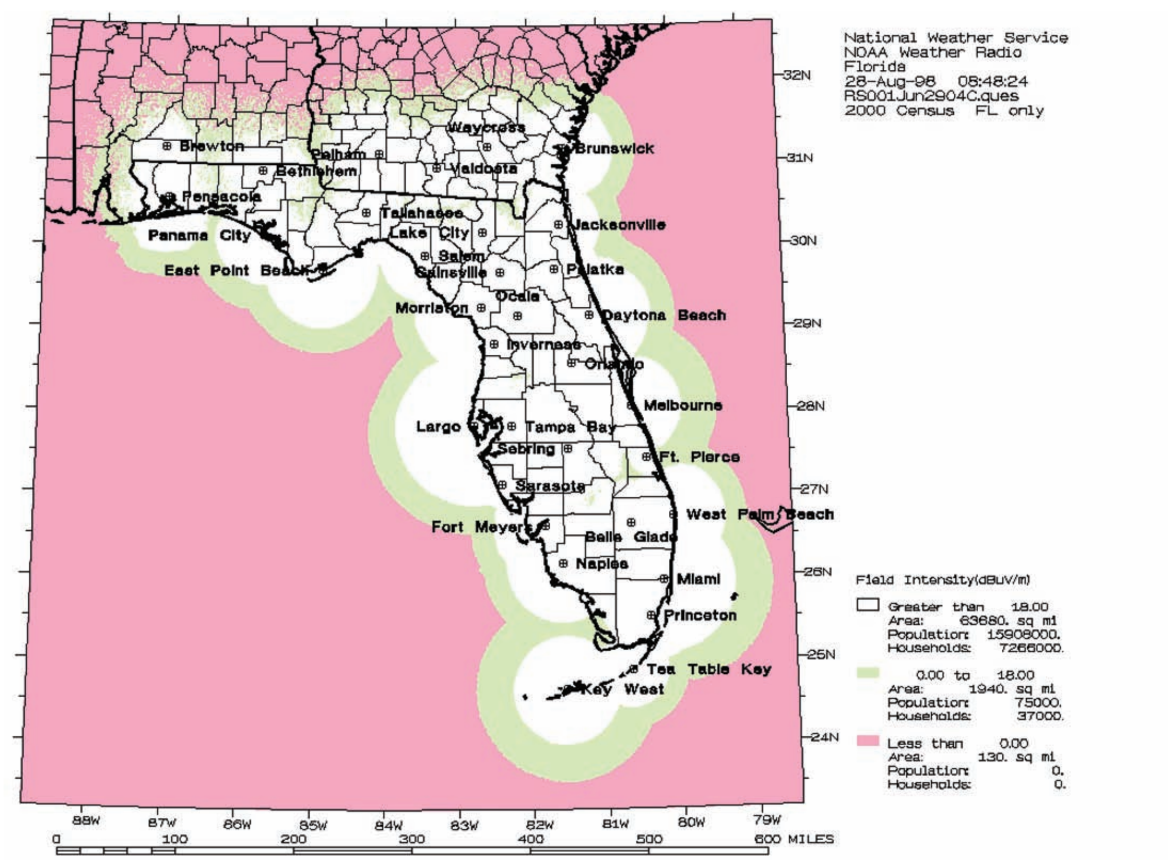
HAAT – Calculates Height Above Average Terrain for an antenna at a specified location.

PCS/LMDS – Allows the user to create or import surfaces which may include terrain, buildings, vegetation, and other obstructions in order to perform line of sight (LOS) and diffraction studies.

FCCFIND, FMFIND, TVFIND, AMFIND, and TOWERFIND – Allows the user to search the FCC database for particular stations or by search radius around a point of interest.

PROFILE – Extracts path profiles according to user-specified input parameters. After the data is extracted, either the individual elevations or an average elevation along the profile can be obtained. A user can also receive plots of the profiles adjusted for various K factors. For microwave links, Fresnel zone clearance can be determined so that poor paths can be eliminated from a planned circuit or network.

SHADOW – Plots the radio LOS regions around a specified location in the United States using digitized topographic data. The program shows areas that are LOS to the base of the antenna, areas that are LOS to the top of the antenna, and areas that are beyond LOS to the antenna.



National Weather Service coverage for Florida.

TERRAIN – Plots terrain elevation contours from any of the terrain databases available (1-arc-second SDTS for CONUS, 3-arc-second USGS, and GLOBE for the whole world).

COVERAGE – Calculates the received 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. Either the FCC broadcast rules or the ITS Irregular Terrain Model (ITM) can be chosen for calculations.

CSPM – Determines the system performance of mobile and broadcast systems in detailed output plots of signal intensity. Plotted outputs can be faxed to the user, plotted on clear plastic for overlaying on geopolitical maps, or downloaded to the user site (in HPGL, GIF, or TARGA format). This program uses the ITS ITM in a point-to-point mode, or other user-chosen algorithms for path loss calculation.

HDTV – Allows the user to analyze interference scenarios for proposed digital television (DTV) stations. The model contains current FCC and MSTV allotment tables and maintains the catalogs created by all program users. The user can create new stations by hand, or by importing station information directly from the FCC database. Analyses may be performed using existing FCC database and allotment assignments, or the user can replace a station with one created and maintained in his/her catalog.

NWS – A specialized application to assist the National Weather Service in maintaining its catalog of weather radio stations (currently about 920).

PBS – An analysis model similar to the HDTV model, but specialized for Public Broadcasting Stations (PBS). Typical outputs may consist of composite plots showing Grade A and B coverage of several stations or "overlap" plots which show areas covered by more than one station.

ICEPAC/VOACAP/REC533 – High Frequency prediction models which can be downloaded (free) and executed on Windows based platforms.

ITM – Source code available for the ITS Irregular Terrain Model (Longley/Rice).

IF-77 – Source code available for the IF-77 Air/Ground, Air/Air, Ground/Satellite prediction software (.1 to 20 GHz).

Contact: Robert O. DeBolt (303) 497-5324
e-mail: rdebolt@its.bldrdoc.gov

Wireless Networks Research Center (WNRC)

The Wireless Networks Research Center (WNRC) provides a common laboratory area for research in wireless networks and wireless network access technologies. The WNRC allows the Institute to consolidate efforts in several areas, such as the RF/network interface. This work uses RF link characterization correlated with low-level network management protocols to develop PCS-to-PCS interference models, wireless network propagation models, non-cooperative wireless measurement, and wireless network discovery. RF/network interface measurement devices are used to make detailed measurements of PCS and cellular networks. One device uses a series of PCS/cellular phones to extract low-level protocol messages, network management information, and RF signal quality parameters. Another device has the ability to perform provider-independent PN offset scans and cdma2000 level 3 message logging.

The WNRC contains an experimental IEEE 802.11b wireless local area network (WLAN). ITS has conducted a series of wireless Voice over IP (VoIP) tests utilizing this infrastructure. The WLAN resources include IP packet logging equipment that can be used in network measurements. A code domain analyzer (CDA) measurement capability, used to collect both short and long term Walsh channel data for any target IS-95 base station, has been added to the WNRC. The CDA operates in both the cellular and PCS frequency bands and can be used in fixed or mobile environments. The WNRC is used to conduct ITS work in the area of inter-PCS interference, in support of the Alliance for Telecommunications Industry Solutions (ATIS) subcommittee WTSC/G3GRA. ITS also has the capability to simulate PCS interference using a series of ITS implemented interference models.

Contact: Christopher J. Behm (303) 497-3640
e-mail: cbehm@its.bldrdoc.gov

ITS Projects in FY 2006

NTIA S&E Projects

Audio Quality Research
Develop and evaluate new techniques for estimating perceived speech quality. Combine, generalize, and extend recent advances. Further develop robust, scalable, speech and audio coding algorithms.
Project Leader: Stephen D. Voran (303) 497-3839
e-mail svoran@its.bldrdoc.gov

Broadband Wireless Research
Continue development of state-of-the-art measurement systems for collecting broadband radio-wave propagation data. Provide measurement tools and propagation data used for simulation of the spectral efficiency of proposed communication systems.
Project Leader: Peter B. Papazian (303) 497-5369
e-mail ppapazian@its.bldrdoc.gov

Broadband Wireless Standards
Develop technical means to improve predictions of signal coverage and interference for 3G wireless services through support to ITU-R and TIA TR-8 (Project 25). Develop enhancements and/or refinements to propagation-related models. Evaluate and make recommendations for spectrum optimization techniques for NTIA, FCC, and ITU-R.
Project Leader: Paul M. McKenna (303) 497-3474
e-mail pmckenna@its.bldrdoc.gov

Effects of Radio Channel on Receivers
Study the effects of the radio channel on receiver performance. Describe the process of estimating signal characterization and calculate corresponding uncertainties. Simulate ultrawideband signals.
Project Leader: Robert J. Achatz (303) 497-3498
e-mail rachatz@its.bldrdoc.gov

Network Interoperability
Develop and document interoperable architectures. Participate in Project 25/TIA TR-8 and other organizations (e.g., VQEG). Enhance the laboratory to include end-to-end interoperability measurement capabilities across various application scenarios. Investigate multimedia applications and research establishing baseline interoperability for multimedia applications.
Project Leader: Jeffrey R. Bratcher (303) 497-4610
e-mail jbratcher@its.bldrdoc.gov

Network Performance
Provide objective, expert leadership and key technical contributions in ITU-T and related U.S. industry committees responsible for developing broadband network performance, Quality of Service (QoS), and resource management standards.
Project Leader: Neal B. Seitz (303) 497-3106
e-mail nseitz@its.bldrdoc.gov

Networking Technology
Develop networking technology methodologies and tools to address network management and network security/protection issues. Research, develop, and demonstrate state-of-the-art methods and tools related to the measurement of wireless data networks, such as wireless local area networks (WLANs).
Project Leader: David J. Atkinson (303) 497-5281
e-mail dj@its.bldrdoc.gov

Policy Support
Provide engineering and technical support to NTIA in telecommunications policy development.
Project Leader: Alan W. Vincent (303) 497-3500
e-mail avincent@its.bldrdoc.gov

RSMS Enhancements
Develop and maintain software, hardware, systems, and equipment for FY 2006 operations tasks.
Project Leader: J. Randy Hoffman (303) 497-3582
e-mail rhoffman@its.bldrdoc.gov

RSMS 4th Generation Development
Provide new and innovative measurement tools for RSMS capabilities. Continue to develop and document the architectural design of the core software. Add additional instrument modules to the collection of Dynamic Link Libraries (DLLs).
Project Leader: J. Randy Hoffman (303) 497-3582
e-mail rhoffman@its.bldrdoc.gov

RSMS Operations
Provide NTIA with critical measurement support to determine radio spectrum usage across the U.S.; resolve interference problems involving Government radio systems; and determine the emission characteristics of radio transmitter systems that may affect Government operations.
Project Leader: J. Randy Hoffman (303) 497-3582
e-mail rhoffman@its.bldrdoc.gov

Table Mountain Modernization
Ensure a safe working environment at the Table Mountain Field Site, maintain and upgrade the site infrastructure, and provide support for research activities ongoing at ITS.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

Table Mountain Research
Utilize the Table Mountain Field Site and Radio Quiet Zone to support fundamental research into the nature, interaction, and evaluation of telecommunication devices, systems, and services that will expand the ITS knowledge base, help identify emerging technologies, and develop new measurement methods.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

Third Generation Wireless Interference Modeling and Characterization
Present technical contributions on PCS interference effects to ATIS Technical Subcommittee WTSC/G3GRA. Contribute to related fora (e.g., ITU-R TG 8/1, SG 3M) as appropriate. Develop a technology-independent, multi-channel PCS interference model for use in the evaluation of PCS and other potentially affected (e.g., public safety) systems.
Project Leader: Timothy J. Riley (303) 497-5735
e-mail triley@its.bldrdoc.gov

Video Quality Research
Develop technology for assessing the performance of digital video transmission systems. Create improvements to the existing video quality metric (VQM) software tools. Develop multimedia definition (MD) and high definition (HD) video quality measurement algorithms and software. Transfer this technology to other Government agencies, end-users, standards bodies, and the U.S. telecommunications industry.
Project Leader: Stephen Wolf (303) 497-3771
e-mail swolf@its.bldrdoc.gov

NTIA/OSM Projects

Antenna Polarization Measurements
Provide guidance on the antenna polarization mismatch loss to be used in analyses to determine EMC between antennas using the same radiocommunication service or different services. Perform measurements to determine the loss as a function of various misalignment angles between various antennas.
Project Leader: Brent L. Bedford (303) 497-5288
e-mail bbedford@its.bldrdoc.gov

Effects of Receiver Signal Processing
Determine the feasibility of using a commercially available computer capability to simulate the signal processing for a range of different error correction schemes. Supplement this effort by a literature search to identify theoretical and/or measured results of receiver performance involving signal processing in the presence of interference.
Project Leader: Robert J. Achatz (303) 497-3498
e-mail rachatz@its.bldrdoc.gov

Extent of Frequency Range to Consider in EMC Analysis
Develop and document guidelines for determining the extent of the frequency range that should be considered in assessing potential interference to victim receivers, in order to simplify the electromagnetic compatibility (EMC) analysis between different radio services, and make them more consistent.
Project Leader: John J. Lemmon (303) 497-3414
e-mail jlemmon@its.bldrdoc.gov

LMR Channel Occupancy Measurements
Conduct land mobile radio (LMR) channel occupancy measurements in the Denver area, in order to investigate the current general state of crowding in the Federal and non-Federal LMR bands, and to test the current system. These measurements will provide occupancy data for federal and non-federal LMR bands 30-50 MHz, 138-174 MHz, 406-420 MHz, 450-470 MHz, 764-806 MHz, 806-896 MHz, 896-901 MHz and 935-940 MHz.
Project Leader: J. Randy Hoffman (303) 497-3582
e-mail rhoffman@its.bldrdoc.gov

Characterization of Low Noise Amplifiers
Characterize the response of low noise amplifiers (LNAs) to single and multiple interfering signals. Measure LNAs from several manufacturers to gain insight into the effects of manufacturer design choices on LNA performance.
Project Leader: Yeh Lo (303) 497-3393
e-mail ylo@its.bldrdoc.gov

Radar Spectrum Efficiency, Interference Results, and ITU-R Support
Complete NTIA Report on the effects of interference in radar receivers; complete NTIA Report on radar spectrum efficiency; and provide support to the U.S. Administration in ITU-R through attendance, hosting, and leadership at meetings of the ITU-R JRG 1A-1C-8B, the RCG, and WP-8B.
Project Leader: Frank H. Sanders (303) 497-7600
e-mail fsanders@its.bldrdoc.gov

Short-Range Mobile-to-Mobile Propagation
Develop new approaches to accurately model propagation loss in a mobile-to-mobile (MTOM) environment. Perform an initial radio-wave propagation measurement program to validate and refine the MTOM propagation models.
Project Leader: Paul M. McKenna (303) 497-3474
e-mail pmckenna@its.bldrdoc.gov

Spectrum Efficiency Concepts for Fixed and Satellite Services
Perform initial studies to determine the spectrum efficiency of both the Federal fixed and satellite (mobile and fixed) services. Analyze and discuss various parameters and tradeoffs that must be considered in such studies. Develop spectrum efficiency metrics for the fixed and satellite services.
Project Leader: Robert J. Matheson (303) 497-3293
e-mail rmatheson@its.bldrdoc.gov

Other Agency Projects

Department of Commerce / National Institute of Standards and Technology EEEL / Office of Law Enforcement Standards

Standardization to Facilitate Wireless Telecommunications Interoperability for the SAFECOM Program
Provide engineering support, scientific analysis, technical liaison, and test design and implementation to allow the identification/development and validation of interoperability standards for the justice/public safety/homeland security community. Provide technical assessments and evaluations of commercial products and services that may provide interim solutions for various interoperability scenarios.
Project Leader: Jeffrey R. Bratcher (303) 497-4610
e-mail jbratcher@its.bldrdoc.gov

PSAF Data Model Development and Validation
Develop and coordinate the Public Safety Architecture Framework (PSAF) product, data model, and tool for SAFECOM. Finish the preliminary data model and the PSAF tool; plan and conduct a trial of the data model; develop a Users' Manual; determine hosting requirements of the PSAF tool; and specify the parameters of a secure national repository of architecture descriptions and its required operation.
Project Leader: Christopher Redding (303) 497-3104
e-mail credding@its.bldrdoc.gov

Public Safety Video Quality Testing
Develop and conduct a series of video quality tests to assist public safety agencies with telecommunications systems and equipment selections. Gather information on these video technologies and applications relevant to, and useful in, the SAFECOM applications in NS/EP environments.
Project Leader: Carolyn Ford (303) 497-3728
e-mail cford@its.bldrdoc.gov

Department of Commerce / National Oceanic and Atmospheric Administration / NWS Radar Operations Center

NWS Radar Compatibility Study
Characterize the emissions of an FAA ASR-11 air surveillance radar and trace its signal into and through the front-end of an NWS NEXRAD WSR-88D weather radar receiver. Determine the cause of interference. Offer technical solutions.
Project Leader: Frank H. Sanders (303) 497-7600
e-mail fsanders@its.bldrdoc.gov

Department of Defense

Enhancements to Communication System Planning Tool (CSPT) for DOD
Enhance the ITS CSPT model through improvements in the setup, operation, processing, and review of analysis results.
Project Leader: Robert O. DeBolt (303) 497-5324
e-mail rdebolt@its.bldrdoc.gov

International Symposium on Advanced Radio Technologies (ISART)
Develop and conduct a symposium that addresses emerging and advanced wireless technologies (http://www.its.bldrdoc.gov/isart/). Gather information on these technologies for the sponsor.
Project Leader: Patricia J. Raush (303) 497-3568
e-mail praush@its.bldrdoc.gov

Department of Homeland Security / Federal Partnership for Interoperable Communications

DHS/FPIC Technical Engineering Support
Provide the technical and operational resources to continue to operate a Project 25 (P25) radio test facility for Federal Government agencies to validate the interoperability of P25 radios. Provide the technical and engineering resources to assist in the development of P25 standards in accordance with

the APCO P25 Interface Committee (APIC) and TIA procedures. Identify conditions advanced by P25 vendors or interested parties that require further engineering analysis by an independent entity.
Project Leader: DJ Atkinson (303) 497-5281
e-mail datkinson@its.bldrdoc.gov

Department of Homeland Security / National Communications System

Emergency Telecommunications Service (ETS) Standards Development
Facilitate the standardization of NS/EP specifications, protocols, and/or mechanisms. Develop and/or verify ETS mechanisms to advance their recommendation/standardization. Use laboratory studies, security analyses, and protocol testing to assist NCS in support of PDD-63 and associated CIP initiatives as they relate to Broadband Cable Television Networks.
Project Leader: Arthur A. Webster (303) 497-3567
e-mail awebster@its.bldrdoc.gov

Federal Highway Administration

ITS EMC for HA-NDGPS
Perform an interference analysis for the High Accuracy Nationwide Differential GPS (HA-NDGPS) System to ensure compatibility with existing systems and sufficient spectrum for the new system. Determine locations and characteristics of other users in the 435–495 kHz band.
Project Leader: Nicholas DeMinco (303) 497-3660
e-mail ndeminco@its.bldrdoc.gov

Federal Railroad Administration

Railroad Telecommunications Study
Continue technical support to the Federal Railroad Administration as it pertains to railroad telecommunications and the activities of the Wireless Communications Task Force (WCTF).
Project Leader: John M. Vanderau (303) 497-3506
e-mail jvanderau@its.bldrdoc.gov

Miscellaneous Federal and Non Federal Agencies

Telecommunications Analysis Services
Develop, maintain, and make available to other Government Agencies and to the public, through user friendly computer programs, a large menu of engineering models, scientific and informative databases, and other useful communication tools.
Project Leader: Robert O. DeBolt (303) 497-5324
e-mail rdebolt@its.bldrdoc.gov

Cooperative Research and Development Agreements (CRADAs)

RF Metrics

A Study of the Use of a New Antenna Pattern Collection Technique for Radar Emissions
Improve the usefulness, efficiency, and effectiveness of an experimental antenna pattern collection technique used in making radio spectrum measurements under the ITU-R M-1177 standard.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

University of Colorado

Ad hoc UAV Ground Network Test Bed
Experiment with communication networks between low-cost small unmanned aerial vehicles similar to model RC airplanes, and ground-based radios.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

Lockheed Martin Coherent Technologies

Laser Testing
Use the Table Mountain Field Site for distributed target and hard target laser radar testing, as well as measuring the effects of atmospheric scintillation of the measurement of coherent eye safe laser beams.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

Johnson's Jobs

Antenna Testing at the Table Mountain Turntable
Evaluate the performance of an array of HF/VHF monopole antennas mounted on a full-scale model of a UAV. Use the Table Mountain turntable facility to facilitate the measurement of the azimuthal antenna pattern of the combined UAV/antenna system.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

Spirent Communication

IP-Based Video Quality Measurements
Develop Internet Protocol Audio Video Quality (IP-AVQ) test and measurement products for measuring the quality of new IP-based TV and video telephony services being deployed by service providers.
Project Leader: Stephen Wolf (303) 497-3771
e-mail swolf@its.bldrdoc.gov

ITS Publications and Presentations in FY 2006

NTIA Publications

M. Cotton, R. Achatz, J. Wepman, and R. Dalke, "Interference potential of ultrawideband signals – Part 3: Measurement of ultrawideband interference to C-band satellite digital television receivers," NTIA Report TR-06-437, Feb. 2006.

This report provides results from tests that measured digital television (DTV) susceptibility to ultrawideband (UWB) interference. A test system was developed to inject interference with known characteristics into a victim receiver and quantitatively measure susceptibility. In this experiment, a C-band satellite DTV victim receiver was injected with Dithered-Pulse (DP), Direct-Sequence (DS), and Multi-Band OFDM (MB) UWB interference. Results showed that the UWB signals could be categorized into three signal sets of common DTV susceptibility behavior. Interestingly, the categorized signals, band-limited by the DTV receiver filter, also had common characteristics. Set 1 consists of signals whose DTV susceptibility and band-limited signal characteristics resemble Gaussian noise. Set 2 consists of signals more deleterious than Gaussian noise interference. Notably, these signals had a wide range of band-limited signal characteristics and susceptibilities. Set 3 consists of a signal that is relatively benign. Results also showed that measurable band-limited characteristics, e.g., burst duration (BD), burst interval (BI), fractional on-time (ζDTV), and peak-to-average ratio (P/A), of the interfering signal are useful for predicting susceptibility. Finally, it was determined that continuous and gated noise signals can be used to emulate the interference effects of DS and MB signals for the DTV victim receiver and operational scenarios tested in this study. This might not be true, however, for testing the susceptibility of other victim receivers operating in narrower bandwidths as indicated by amplitude probability distributions as a function of frequency for MB signals band-limited to relatively narrow bandwidths.

M. McFarland, M.H. Pinson, and S. Wolf, "Batch video quality metric (BVQM) user's manual," NTIA Handbook HB-06-441, Sep. 2006.

This handbook provides a user's manual for the batch video quality metric (BVQM) tool. BVQM runs under the Windows XP® operating system. BVQM performs objective automated quality assessments of processed video clip batches (i.e., as output by a video system under test). BVQM reports video calibration and quality metric results such as: temporal registration, spatial registration, spatial scaling, valid region, gain/level offset, and objective video quality estimates. BVQM operates on original and processed video files only, and has no video capture capability.

BVQM compares the original video clip to the processed video clip and reports quality estimates on a scale from zero to one. On this scale, zero means that no impairment is visible and one means that the video clip has reached the maximum impairment level (excursions beyond one are possible for extremely impaired video sequences).

M. McFarland, M.H. Pinson, and S. Wolf, "BVQM software," NTIA Software & Data Product SD-06-443, Aug. 2006.

M.H. Pinson and S. Wolf, "CVQM software," NTIA Software & Data Product SD-06-442a, Jul. 2006 (revision of SD-06-442, Nov. 2005).

M.H. Pinson and S. Wolf, "In-service video quality metric (IVQM) user's manual," NTIA Handbook HB-06-434a, Jul. 2006 (revision of HB-06-434, Dec. 2005, and HB-05-424, Apr. 2005).

The purpose of this handbook is to provide a user's manual for the in-service video quality metric (IVQM) tool. IVQM performs automated processing of live video signals. This program runs under the Windows XP® operating system on two PCs communicating through an IP connection. IVQM performs image acquisition, temporal registration, other video calibration (spatial registration, spatial scaling, valid region, and gain/level offset), and video quality estimation.

IVQM compares the source video sequence to the destination video sequence (i.e., as output by the video system under test). Each program alternates between video capture and video analysis. Every source/destination video sequence pair is processed through three main steps. First, the sequences are buffered onto a hard drive. Second, the sequences are temporally registered. Third, the video quality of the destination video sequence is estimated. Quality estimates are reported on a scale of zero to one, where zero means that no impairment is visible and one means that the video clip has reached the maximum impairment level. Some video sequences may also be used to estimate other calibration values (spatial registration, spatial scaling, valid region estimation, and gain/level offset). The user has control over how often these other calibration values are calculated.

M.H. Pinson and S. Wolf, "IVQM software," NTIA Software & Data Product SD-06-435a, Jul. 2006 (revision of SD-06-435, Nov. 2005, and SD-05-425, Apr. 2005).

M.H. Pinson and S. Wolf, "Reduced reference video calibration algorithms," NTIA Report TR-06-433a, Jul. 2006 (revision of TR-06-433, Oct. 2005).

This report describes four Reduced Reference (RR) video calibration algorithms of low computational complexity. RR methods are useful for performing end-to-end in-service video quality measurements since these methods utilize a low bandwidth network connection between the original (source) and processed (destination) ends. The first RR video calibration algorithm computes temporal registration of the processed video stream with respect to the original video stream (i.e., video delay estimation). The second algorithm jointly calculates spatial scaling and spatial shift. The third algorithm calculates luminance gain level offset of the processed video stream with respect to the original video stream. The fourth algorithm estimates the valid video region of the original or processed video stream (i.e., the portion of the video image that contains actual picture content). All the algorithms utilize only the luminance (Y) image plane of the video signal.

P.J. Raush and K.E. Novik (Eds.), "Proceedings of the International Symposium on Advanced Radio Technologies, March 7-9, 2006," NTIA Special Publication SP-06-438, Mar. 2006.

No abstract available.

F.H. Sanders and B.J. Ramsey, "Phased array antenna pattern variation with frequency and implications for radar spectrum measurements," NTIA Report TR-06-436, Dec. 2005.

Measured antenna patterns of an end-fed slotted waveguide antenna and a phased-array patch antenna used in maritime radionavigation radars across the frequency range 8500-10800 MHz are presented along with a measurement technique that characterizes the antenna patterns as a function of frequency. The frequency-dependent variation in the measured pattern of the slotted waveguide is compared to the frequency dependence of an ideal pattern based on the slot geometry. The implications for radar emissions measurement techniques are discussed.

F.H. Sanders, J.R. Hoffman, and Y. Lo, "Resolving interference from an airport surveillance radar to a weather radar," NTIA Technical Memorandum TM-06-439, Apr. 2006.

In response to interference from an S-band (2700-2900 MHz) airport surveillance radar (ASR) to a meteorological (weather) radar in the same band, measurements were performed at the field location of the two radars to determine the interference mechanism and any possible mitigation options. Measurements included emission spectra of the ASR and observations of the interference energy in the RF front-end and IF stages of the weather radar. Measurement results showed that interference energy originated in the unwanted emissions of the ASR (i.e., front-end overload was not occurring in the weather radar). But the problem was exacerbated by the placement of a passive diode limiter ahead of a bandpass filter in the weather radar receiver's RF front-end. The interference could not be mitigated unless the front-end configuration of the weather radar was modified. With the necessary modification completed, the interference was successfully mitigated by installing a conventional notch filter on the ASR's output stage, the notch being tuned to the weather radar frequency. It is recommended that the front-end configuration of all weather radars of the type in question should be immediately changed in the same way as the weather radar in this study, and that appropriate output filters should be installed in ASRs that are located in close proximity to these weather radars to mitigate interference effects at all sites in the U.S.

F.H. Sanders, R.L. Sole, B.L. Bedford, D. Franc, and T. Pawlowitz, "Effects of RF interference on radar receivers," NTIA Report TR-06-444, Sep. 2006.

This report describes the results of interference tests and measurements that have been performed on radar receivers that have various missions in several spectrum bands. Radar target losses have been measured under controlled conditions in the presence of radio frequency (RF) interference. Radar types that have been examined include short range and long range air traffic control; weather surveillance; and maritime navigation and surface search. Radar receivers experience loss of desired targets when interference from high duty cycle (more than about 1-3%) communication-type signals is as low as -10 dB to -6 dB relative to radar receiver inherent noise levels. Conversely, radars perform robustly in the presence of low duty cycle (less than 1-3%) signals such as those emitted by other radars. Target losses at low levels are insidious because they do not cause overt indications such as strobes on displays. Therefore operators are usually unaware that they are losing targets due to low-level interference. Interference can cause the loss of targets at any range. Low interference thresholds for communication-type signals, insidious behavior of target losses, and potential loss of targets at any range all combine to make low-level interference to radar receivers a very serious problem.

Outside Publications

Articles in Conference Proceedings

D.J. Atkinson, "Public safety environmental noise challenges for land mobile radio vocoders," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 7-9, 2006," P.J. Raush and K.E. Novik, Eds., NTIA Special Publication SP-06-438, Mar. 2006, pp. 71-78.

This paper investigates the effect on vocoders of background noise that exists in environments where public safety officials and first responders need to communicate. Four different environments were examined: police cruiser, fire engine, rescue boat, and rescue helicopter. During the examination, noise levels were measured, as well as speech levels of actual practitioners working in that environment. Based on those results a controlled laboratory experiment was conducted to determine the effectiveness of vocoders used in communications equipment subjected to those environments. The experimental conclusion is that while digital vocoders do not perform as well as analog transmission in the presence of high levels of background noise, moderate amounts of noise cancellation prior to the signal injection into the vocoder can somewhat mitigate those detrimental effects.

C. Ford and A. Webster, "Introduction to objective multimedia quality assessment models," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 7-9, 2006," P.J. Raush and K.E. Novik, Eds., NTIA Special Publication SP-06-438, Mar. 2006, pp. 8-14.

The transmission of multimedia signals over wireless channels has increased exponentially in the past decade. The widespread use of digital technology for the transmission of audio and video signals has led to the need for objective quality assessment methods based on human perception. In particular, the distribution of multimedia signals over wireless links to devices such as laptops, PDAs, and cell phones is widespread. Manufacturers can use objective models to improve products and analyze deployment. Service providers can use objective models to monitor the quality of service they provide. This paper is an introduction to the concepts of multimedia quality assessment models and the design of subjective tests for objective model validation.

J. Kub and E. Nelson, "Extensible software for automated testing of public safety P25 land mobile radios," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 7-9, 2006," P.J. Raush and K.E. Novik, Eds., NTIA Special Publication SP-06-438, Mar. 2006, pp. 92-97.

One of the most prominent digital Land Mobile Radio (LMR) technologies used by public safety agencies, Project 25, is built upon an expansive suit of standards defining numerous open interfaces. As the P25 standard has matured and greater numbers of subscriber units and fixed station equipment have reached the market, increasing complaints of non-interoperability and substandard performance have arisen. In response, P25 users and manufacturers are forming a P25 Compliance Assessment Program. One element of this program requires electrical performance measurements on P25 portable and mobile radios. These tests will be conducted using an automated test software application developed at the Institute for Telecommunication Sciences. This paper describes background information on the compliance program, discusses the technical approaches taken in application development, and provides a detailed overview of the test application's functionality and capabilities.

F. Sanders, J. Wepman, and S. Engelking, "Development of performance testing methods for dynamic frequency selection (DFS) 5-GHz wireless access systems (WAS)," in "Proceedings of the International Symposium on Advanced Radio Technologies: March 7-9, 2006," P.J. Raush and K.E. Novik, Eds., NTIA Special Publication SP-06-438, Mar. 2006, pp. 39-48.

Dynamic frequency selection (DFS) is an agile radio technology designed to allow wireless access systems (WAS) to operate in 5-GHz spectrum bands that are allocated on a primary basis to radiolocation systems (radars) without causing interference to radar operations. DFS is designed to accomplish this feat by detecting co-channel radar emissions and then avoiding or vacating any locally occupied radar frequencies. DFS technology thus promises to provide more radio spectrum for applications including multimedia transmission without denying use of that spectrum to existing users. Because the successful deployment of 5-GHz DFS technology in commercially available WAS devices depends critically on the ability of testing labs to verify that such products can detect co-channel radar emissions and vacate those channels, the development of adequate performance verification methods has been critical to the development of DFS technology as a whole. This paper summarizes the history of DFS spectrum allocation by the International Telecommunication Union (ITU), the specification of DFS performance parameters in a seminal ITU Recommendation, and the development in the United States of DFS performance verification test methods that can be applied to commercially produced DFS WAS products. That development has been carried out primarily by the U.S. Department of Commerce National Telecommunications and Information Administration Office of Spectrum Management and the NTIA Institute for Telecommunication Sciences, working in close coordination with other Federal agencies (including the Federal Communications Commission) and U.S. industry.

S.D. Voran, "Listening-time relationships in a subjective speech quality experiment," in *Proc. of the 5th International Conference on Measurement of Speech and Audio Quality in Networks (MESAQIN)*, Prague, Czech Republic, Jun. 2006.

We have designed, conducted, and analyzed a subjective speech quality experiment with unrestricted timing where subjects can vote whenever their opinions are fully formed, rather than at fixed time intervals. Analysis of the resulting listening times reveals that subjects tend to listen for a longer time before approving a recording and for a shorter time before rejecting a recording. This listening-time difference tends to increase for poorer quality systems and for more critical subjects. We present a mathematical model that reproduces these results. In addition, subjects operate more quickly as they move through the experiment.

S.D. Voran, "Reducing quantization errors by matching pseudoerror statistics," in *Proc. of IEEE Digital Signal Processing Workshop*, Grand Teton National Park, Wyoming, Sep. 2006.

We investigate the use of an adaptive processor (a quantizer pseudoinverse) and the statistics of the associated pseudoerror signal to reduce quantization error in scalar quantizers when a small amount of prior knowledge about the signal x is available. This approach uses both the quantizer representation points and the thresholds at the receiver. No increase in the transmitted data rate is required. We discuss examples that use low-pass, high-pass, and band-pass signals along with an adaptive processor that consists of a set of filters and clippers. Matching a single pseudoerror statistic to a target value is sufficient to attain modest reductions in quantization error in situations with one degree of freedom. Adaptive processing based on a pair of pseudoerror statistics allows for quantization noise reduction in problems with two degrees of freedom.

Journal Articles

R.J. Matheson, “Principles of flexible-use spectrum rights,” *Journal of Communications and Networks*, vol. 8, no. 2, Jun. 2006, pp. 144-150.

A serious problem with traditional “command & control” spectrum management techniques is that they do not easily accommodate new technologies and new services. This paper describes the necessary principles of flexible-use spectrum rights which may allow a wide variety of spectrum uses in a single general-purpose band. Based on the electrospace description of the radio spectrum, these principles allow general aggregation or division of licensed electrospace regions via secondary markets, providing rules for how regulatory limits change under aggregation or division. These flexible-use principles limit transmitter behaviors that tend to create a more difficult operating environment for receivers, while making receivers responsible for handling any remaining interference. The author shows how flexible-use principles could provide a basis for real-world flexible-use frequency bands.

K. Tilley, “Major telecommunications institute seeks volunteers to help with testing the performance of first-responder video,” *Evidence Technology Magazine*, Jul.-Aug. 2006, p. 10.

No abstract available.

Unpublished Presentations

K. Allen, “Software radio and spectral efficiency,” talk given at the Institute for Defense and Government Advancement’s 2006 Software Radio Summit, Feb. 2006.

R. DeBolt, “Developing a Geographic Information System (GIS) based propagation tool,” talk and demonstration given at ESRI International User Conference, San Diego, California, Aug. 6, 2006.

N. DeMinco, “Analysis of mutual coupling of antennas on a 47-foot Coast Guard boat,” International Union of Radio Science (URSI) Meeting, Boulder, Colorado, Jan. 7, 2006.

R. Matheson, class on spectrum measurements and monitoring, presented for the United States Telecommunications Training Institute (USTTI) Mar. 2006.

R. Matheson, “Modern spectrum management alternatives,” guest lecture given to class on Spectrum Management, University of Colorado Interdisciplinary Telecommunications Program, Jun. 29, 2006.

P. McKenna, “Propagation prediction models and techniques,” guest lecture given to class on Spectrum Management, University of Colorado Interdisciplinary Telecommunications Program, Jun. 20, 2006.

E. Nelson, “Managing intersystem interference between analog and digital two-way radio systems,” International Wireless Communications Expo (IWCE), Las Vegas, Nevada, May 2005.

S. Wolf, M.H. Pinson, and S.D. Voran, “Objective measurement of user-perceived audio and video quality,” Tutorial given at ISART 2006, Mar. 7, 2006.

Conferences Sponsored by ITS

International Symposium on Advanced Radio Technologies (ISART 2006)

The International Symposium on Advanced Radio Technologies (ISART 2006) was held March 7-9, 2006, in Boulder. This symposium explores the current state of the radio art with an eye towards forecasting the use of wireless technology in the future. The theme for ISART 2006 was “The Future of Multimedia Communications.” The keynote, “The Role of the Regulator in Fostering Innovation,” was given by Christopher Haslett of Ofcom, UK. The proceedings were printed as NTIA Special Publication SP-06-438. ISART brings together a diverse collection of people from academia, business, and government agencies to discuss the interplay between technological “how-to,” the possibilities and restrictions created by regulation and policy, and the economic motivation of the business world. For more information about ISART, see: http://www.its.bldrdoc.gov/isart/.

ITS Standards Work in FY 2006

Standards Leadership Roles

David J. Atkinson, Vice-Chair of the APIC Vocoder Task Group affiliated with TIA TR-8.

Randall S. Bloomfield, Federal Representative on Project 25/34 Steering Committee; Vice-Chair of the ISSI Task Group (ISSI TG) and Vice-Chair of the P25 Systems Architecture Working Group (PSAWG) (both within the APCO Project 25 Interface Committee); Editor of Project 25 Statement of Requirements (P25 SoR).

Paul M. McKenna, U.S. Chair of ITU-R Study Group 3 (Radiowave Propagation); U.S. Chair of Working Party 3K; Chair of (international) Subgroup 3K-2 to Working Party 3K; Chair of Drafting Group 3M-3C.

Patricia J. Raush, Chair of Drafting Group 3J-2A, Working Party 3J, ITU-R U.S. Study Group 3.

Timothy J. Riley, Member of Alliance for Telecommunications Industry Solutions (ATIS) committee WTSC-G3GRA (Wireless Technologies and Systems Committee — Radio Aspects of GSM/3G and Beyond) and issue champion and editor for development of a document addressing interference issues affecting wireless communication systems.

Teresa Rusyn, Chair of Drafting Group 3M-3B, Working Party 3K, ITU-R U.S. Study Group 3.

Frank Sanders, Chair of ITU-R Radar Correspondence Group (radar technical spectrum issues); Delegate to ITU-R Working Party 8B (radar spectrum allocation and sharing) and Joint Rapporteur Group 1A-1C-8B (radar spectrum efficiency issues).

Neal B. Seitz, Vice Chair of ITU-T Study Group 13 (Next Generation Networks); Chair of ITU-T Study Group 13 Working Party 4 (OAM and QoS); Vice Chair of ATIS Network Performance, Reliability, and Quality of Service Committee (PRQC).

Bruce R. Ward, Editor for TIA102-BACx, "ISSI measurement methods for voice services," and TIA102-BACx, "ISSI performance recommendations for voice services."

Arthur Webster, Co-chair of Video Quality Experts Group (VQEG); Rapporteur for Question 14/9 (Objective and subjective methods for evaluating perceptual audiovisual quality in multimedia services within the terms of Study Group 9) in ITU-T Study Group 9 (Integrated broadband cable networks and television and sound transmission); Chair of Joint Rapporteur Group on Multimedia Quality Assessment (JRG-MMQA); Chair of ATIS PRQC's Security Task Force. Study Group 9's Liaison Officer for the ITU's Telecommunications for Disaster Relief and Mitigation - Partnership Co-ordination Panel (PCP-TDR); Chair of the ATIS Joint Ad-Hoc Technical Committee for Issues PRQC A0029 and TMOC 95.

Representative Technical Contributions

Contributions listed below are a sample of the extensive standards work that ITS does each year. More details of this work can be found in the individual write-ups throughout this report.

Audio Quality

- "Additional results on the performance of the ANIQUE+ non-intrusive speech quality estimation algorithm," ATIS PRQC-2005-155, Oct. 2005 (S.D. Voran).

Emergency Telecommunications Service Projects

- Draft New Recommendation J.pref "Specifications for Preferential Telecommunications over IPCablecom networks" (Arthur Webster and Greg Bain (NCS), Editors and Authors). (ITU-T Study Group 9)
- Draft New Recommendation J.preffr "Framework for implementing preferential telecommunications in IPCablecom networks" (Arthur Webster and Greg Bain (NCS), Editors and Authors). (ITU-T Study Group 9)
- Draft ATIS Technical Report on Security For Next Generation Networks — An End User Perspective (Mike Lee (Nortel), An Nguyen (NCS), and Arthur Webster, Editors). (ATIS Committee PRQC)
- Draft Revision of T1.TR.79-2003 "Overview of Standards in Support of Emergency Telecommunications Service (ETS)" (Arthur Webster and An Nguyen (NCS), Editors and Authors). (ATIS Committee PRQC)
- Draft Revision of ANSI Standard T1.523-2001 TELECOM GLOSSARY (Arthur Webster and John Colombo (Verizon), Editors). (ATIS Committee PRQC)

High-power Radars and Spectrum Sharing

- Proposed Modification to Radar Emission Spectrum Measurement Bandwidth Limit in Recommendation M.1177-3, ITU-R WP-8B (F. Sanders).
- Proposed Modification to Radar Emission Spectrum Antenna Rotation Procedure in Recommendation M.1177-3, ITU-R WP-8B (F. Sanders).

APCO Project 25

- "Experiment 3 MOS test plan for vocoder technology for Project 25 Phase 2," APCO Project 25 Interface Committee Vocoder Task Group, Denver, CO, Aug. 2005 (D. Atkinson).
- ITS Comments as of October 7, 2005 on EADS Sip Messages and Parameter Definitions (05-10-145), TR8.19, Oct. 2005 (B. Ward).
- ITS Comments as of December 9, 2005 on V3 of Project 25 ISSI Messages and Procedures for Voice Services (05-12-259), TR8.19, Dec. 2005 (B. Ward).
- NIST/OLES Letter Ballot Comments on Draft Project 25 ISSI Messages and Procedures for Voice Services (TIA-102.BACA), TR8.19, Feb. 2006 (R. Bloomfield, B. Ward).
- ITS Contribution Errata Comments as of June 2, 2006 on TIA-102.BACA (06-05-041_ISSIMsgProcDraft_v9_060524.doc), TR8.19, Jun. 2006 (N. Walowitz (Protiro for ITS), M. Ranganathan (NIST/ANTD), K. Behnam, B. Ward).

- Project 25 (P25) Inter-RF Subsystem Interface (ISSI) Measurement Methods for Voice Services Status Update 06-21-06, ISSI TG, Jun. 2006 (B. Ward).

- Project 25 (P25) Inter-RF Subsystem Interface (ISSI) Performance Recommendations for Voice Services Status Update 06-21-06, ISSI TG, Jun. 2006 (B. Ward).

- ITS Comments 09-26-06 for Issue O of ISSI Measurement Methods for Voice Services (06-045), ISSI TG, Sep. 2006 (B. Ward and N. Walowitz (Protiro for ITS)).

- ITS Comments 09-26-06 for Issue L of ISSI Performance Recommendations for Voice Services (06-047), ISSI TG, Sep. 2006 (B. Ward and N. Walowitz (Protiro for ITS)).

- DIETS: ISSI Conformance Test Tool, ISSI TG, Mar. 2006 (K. Behnam and M. Ranganathan (NIST/ANTD)).

- ITS & ANTD Technical Comments on ISSI Conformance Test Procedures Draft Standard (06-008), ISSI TG, Sep. 2006 (K. Behnam and M. Ranganathan (NIST/ANTD)).

- Draft Project 25 Fixed Station Interface Messages and Procedures, FSI TG and TR8.19, Nov. 2005 (R. Bloomfield and K. Tilley, Editors).

- NIST/OLES Letter Ballot Comments on Draft Project 25 Fixed Station Interface Messages and Procedures (TIA-102.BAHA), TR8.19, Dec. 2005 (R. Bloomfield).

- Project 25 (P25) Statement of Requirements (March 9, 2006), P25 User Needs Subcommittee and P25/34 Steering Committee, Mar. 2006 (R. Bloomfield and W. Pomper (Protiro for ITS), Editors).

Quality of Service

- “Towards an NGN QoS solution: New information and related discussion issues,” PRQC-2005-180, Oct. 2005 (N. Seitz).

- “Draft text for ATIS NGN-FG NGN framework part III (gap analysis), section 6 (QoS),” PRQC-2006-045, Feb. 2006 (N. Seitz).

- “Comparison of Draft ITU-T Recommendation Y.RACF QoS information handling specifications with Q-series supplement 51 requirements,” PRQC-2006-066, Mar. 2006 (N. Seitz).

- “ATIS NGN-FG standards gap analysis: Implications for future standards work of PRQC,” PRQC-2006-100, Jun. 2006 (N. Seitz).

Video Quality

- “Reduced reference video calibration algorithms,” ITU-T Study Group 9 D036, October 2005 (M. Pinson and S. Wolf).

Abbreviations/Acronyms

3G	third generation
3GPP	3rd Generation Partnership Project
4G	fourth generation

A

ACR	Absolute Category Rating
AGILE	Advanced Generation of Interoperability for Law Enforcement
ANSI	American National Standards Institute
ANTD	Advanced Networking Technologies Division (of NIST)
APCO	Association of Public-Safety Communications Officials
APD	Amplitude Probability Distribution
APIC	APCO Project 25 Interface Committee
ASR	airport surveillance radar
ATB	antenna testbed
ATIS	Alliance for Telecommunications Industry Solutions

B

BBTG	BroadBand Task Group
BIM	Base Interface Module
BVQM	Batch VQM

C

CAI	Common Air Interface
CASM	Communication Assets Survey and Mapping
CD	compact disk
CDA	Code Domain Analyzer
CDMA	Code Division Multiple Access
CEA	Consumer Electronics Association
CI	Console Interface
CIP	Critical Infrastructure Protection
CMRS	Commercial Mobile Radio Services
CONUS	Continental U.S.
COPS	Office of Community Oriented Policing Service
CRADA	Cooperative Research and Development Agreement
CRPL	Central Radio Propagation Laboratory
CSPM	Communication System Performance Model
CSPT	Communication System Planning Tool
CVQM	Command Line VQM

D

DAT	digital audio tape
dB	decibel
DFS	Dynamic Frequency Selection
DHS	Department of Homeland Security
DIETS	Department of Commerce ISSI Emulation and Test System
DLL	Dynamic Link Library
DNR	Draft New Recommendation
DOC	Department of Commerce
DOD	Department of Defense
DSCP	Digital Sampling Channel Probe
DSES	Deep Space Exploration Society
DS-UWB	Direct-Sequence Ultrawideband
DTV	digital television

E

EBU	European Broadcasting Union
EIA	Electronic Industries Alliance
EMC	electromagnetic compatibility
EMS	Emergency Medical Services
ETS	Emergency Telecommunications Service
ETSI	European Telecommunications Standards Institute
EVA	Evaluation License Agreement

F

FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FFT	fast Fourier transform
FG	Focus Group
FHWA	Federal Highway Administration
FLC	Federal Laboratory Consortium for Technology Transfer
FPGA	Field Programmable Gate Array
FPIC	Federal Partnership for Interoperability Communications
FS	Fixed Services
FSI	Fixed/Base Station Interface
FTP	File Transfer Protocol
FTTA	Federal Technology Transfer Act 1986
FY	Fiscal Year

G

GETS	Government Emergency Telecommunications Service
GHz	gigahertz
GIF	Graphics Interchange Format
GIS	Geographic Information System
GLOBE	Global Land One-km Base Elevation
GPS	Global Positioning System
GSM	Global System for Mobile
GUI	Graphical User Interface

H

HA-NDGPS	High Accuracy NDGPS
HATS	head and torso simulator
HD	high definition
HDTV	High Definition Television
HF	high frequency
HTML	Hypertext Markup Language

I

IACP	International Association of Chiefs of Police
IAFC	International Association of Fire Chiefs
ICEPAC	Ionospheric Communications Enhanced Profile Analysis and Circuit Prediction Program
ICTAP	Interoperability Communications Technical Assistance Program
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IF	intermediate frequency
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IP-AVQ	Internet Protocol Audio Video Quality
IPTV	Internet Protocol Television
IRAC	Interdepartment Radio Advisory Committee
ISART	International Symposium on Advanced Radio Technologies
ISM	Industrial, Scientific, and Medical
ISO/IEC	International Organization for Standardization/International Electrotechnical Commission
ISSI	Inter-rf Subsystem Interface
ITM	Irregular Terrain Model
ITS	Institute for Telecommunication Sciences
ITSA	Institute for Telecommunication Sciences and Aeronomy
ITU	International Telecommunication Union
ITU-R	ITU — Radiocommunication Sector
ITU-T	ITU — Telecommunication Standardization Sector
IVQM	In-Service VQM
IWCE	International Wireless Communications Expo

J

JRG	Joint Rapporteur(s) Group

K

kHz	kilohertz
KMF	Key Management Facility
KMM	Key Management Message

L

LAN	Local Area Network
LFMF	low frequency/medium frequency
LMDS	Local Multipoint Distribution Service
LMR	Land Mobile Radio
LNA	low noise amplifier
LOS	line of sight

M

MAC	media access control (layer)
MB-OFDM	Multi-Band Orthogonal Frequency-Division Multiplexing
Mb/s, Mbps	megabits per second
MD	Multimedia Definition
MHz	megahertz
MIMO	Multiple Input Multiple Output
MMQA	Multimedia Quality Assessment
MOU	Memorandum of Understanding
MPLS	Multiprotocol Label Switching
MSC	message sequence chart
MSTV	Association for Maximum Service Television
MTOM	mobile-to-mobile

N

NCS	National Communications System
NDGPS	Nationwide Differential Global Positioning System
NE	Network Equipment
NGN	Next Generation Network
NIC	network interface card
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPSTC	National Public Safety Telecommunications Council

NS/EP	National Security and Emergency Preparedness
NTIA	National Telecommunications and Information Administration
NWS	National Weather Service

O

OAM	Operation, Administration and Maintenance
Ofcom	Office of Communications
OIC	Office of Interoperability and Compatibility (of DHS)
OLES	Office of Law Enforcement Standards
OMB	Office of Management and Budget
OPAD	Office of Policy Analysis and Development
OQPSK	Offset Quadrature Phase-Shift Keying
OSM	Office of Spectrum Management
OT	Office of Telecommunications
OTAR	Over the Air Rekeying
OTP	Office of Telecommunications Policy
OV	operational view

P

P25	Project 25
P/A	peak-to-average ratio
PAR	precision approach radar
PBS	Public Broadcasting System
PC	personal computer
PCAP	packet capture
PCS	Personal Communications Services
PDA	personal digital assistant
PESQ	Perceptual Evaluation of Speech Quality
PRQC	Network Performance, Reliability and Quality of Service Committee
PS	public safety
PSAF	Public Safety Architecture Framework
PSAL	Public Safety Audio Laboratory
PSAP	Public Safety Answering Point
PSAWG	P25 Systems Architecture Working Group
PSD	power spectral density
PSTN	Public Switched Telephone Network
PSVQ	Public Safety Video Quality
PTT	Push-to-Talk

Q

QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying

R

RACF	Resource and Admission Control Function
RAID	redundant array of independent disks
RBS	Radio Base Station
RCG	Radar Correspondence Group
RF	radio frequency
RFSS	Radio Frequency Subsystem
RLAN	Radio Local Area Network
RPM	Radio Performance Measurements
RR	Reduced Reference
RRC	Regional Radio Conference
RR-NR	Reduced Reference – No Reference
RSMS	Radio Spectrum Measurement Science
RSMS-4	4th Generation RSMS
RTP	Real-time Transport Protocol

S

SAFECOM	Public Safety Wireless Communications
SD	Standard Definition
SDMA	Space Division Multiple Access
SDO	Standards Development Organization
SDoC	Supplier’s Declaration of Compliance
SDTS	Spatial Data Transfer Standard
SE	spectrum efficiency
SG	Study Group
SIP	Session Initiation Protocol
SIPRNET	Secret Internet Protocol Routable Network
SMP	simple mapping project
SMPTE	Society of Motion Picture and Television Engineers
SOR	Statement of Requirements
SPAWAR	Space and Naval Warfare Systems Command
SSMD	Site Specific Model
SU	Subscriber Unit
SV	Systems View

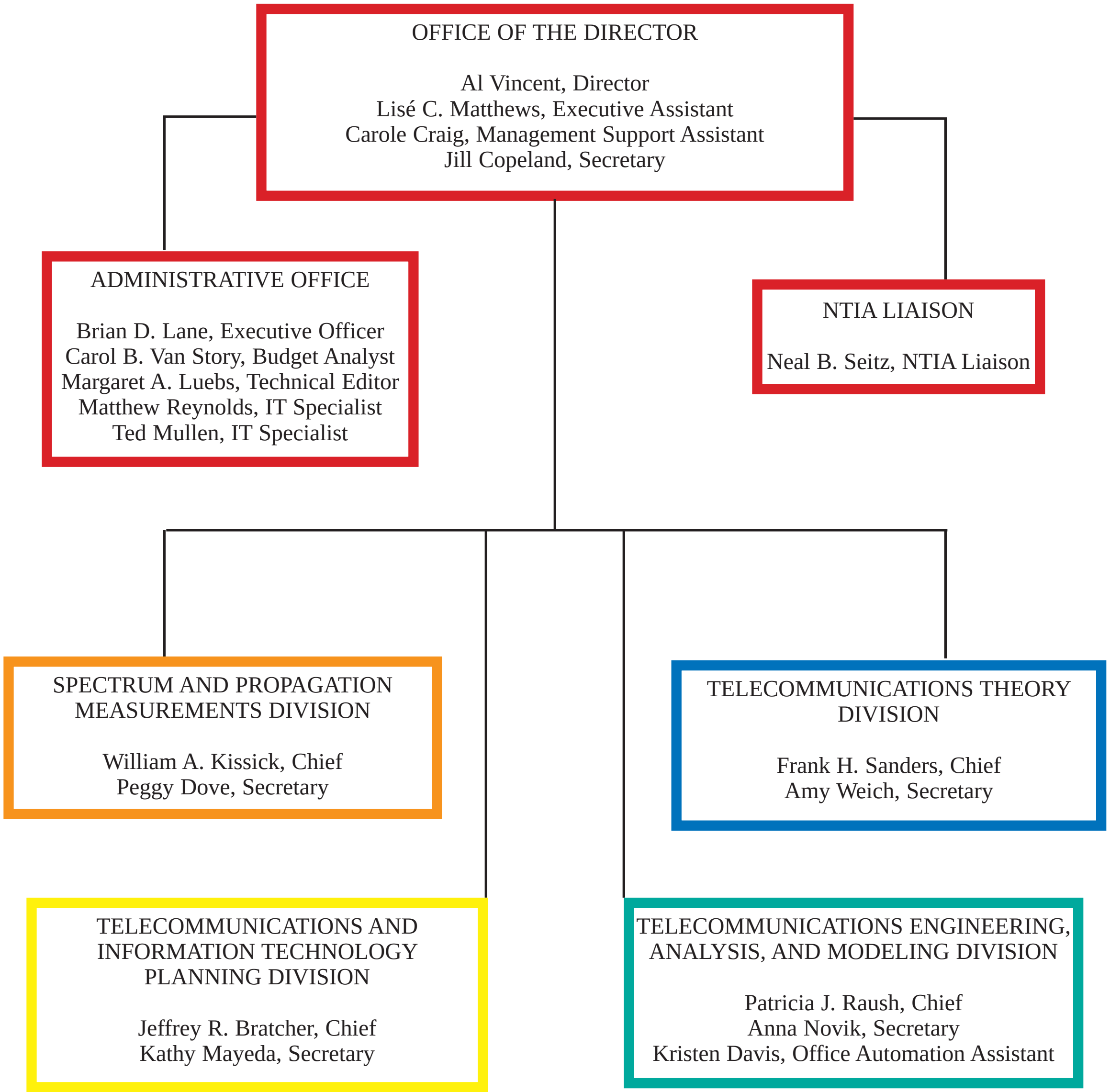
T

TA Services	Telecommunications Analysis Services
TASO	Television Allocations Study Organization
TBIM	Trunking Base Interface Module
TG	Task Group
TIA	Telecommunications Industry Association
TMOC	Telecom Management and Operations Committee
TR	Technical Report
TSB	Telecommunications Systems Bulletin

TV	television
TVA	Threat Vulnerability Analysis
U	
UAV	unmanned aerial vehicle
UHF	ultra high frequency
URSI	International Union of Radio Science
U.S.	United States
USGS	U.S. Geological Survey
USTTI	U.S. Telecommunications Training Institute
UWB	ultrawideband
V	
VHF	very high frequency
VLF	very low frequency
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
VQEG	Video Quality Experts Group
VQM	Video Quality Metric
VSA	vector signal analyzer
VSG	vector signal generator
VTG	Vocoder Task Group
W	
WAS	Wireless Access System
W-CDMA	Wideband CDMA
WCTF	Wireless Communications Task Force
Wi-Fi	Wireless Fidelity
WLAN	Wireless LAN
WMO	Wireless Management Office
WNRC	Wireless Networks Research Center
WP	Working Party
WPAN	Wireless Personal Area Network
WRC	World Radiocommunication Conference
WTSC	Wireless Technologies and Systems Committee
X	
XML	Extensible Markup Language
Y	
YIG	yttrium-iron-garnet

An ITS engineer at work (photograph by F.H. Sanders).

ITS Organization Chart



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