Institute for Telecommunication Sciences

FY 2007 Technical Progress Report

U.S. Department of Commerce
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for Communications and Information

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Contents

Page

The ITS Mission 1

Overview 2

Spectrum and Propagation Measurements 5

Radio Spectrum Measurement Science (RSMS) Operations 6

RSMS 4th Generation System Development 8

Table Mountain Research Program 10

Telecommunications and Information Technology Planning 13

Public Safety Broadband Communications 14

Standards Development for Public Safety Interoperability 16

Project 25 Compliance Assessment Program 18

Department of Commerce ISSI Evaluation and Test System (DIETS) 20

Emergency Telecommunications Service (ETS) Standards Development 22

Multimedia Quality Research 24

Wireless Network Measurement Methods 26

Telecommunications Engineering, Analysis, and Modeling 29

Interference Issues Affecting Land-Mobile Systems 30

Public Safety Video Quality 32

Public Safety Architecture Framework 34

Analysis of the High-Accuracy Nationwide Differential Global Positioning System . . 36

Telecommunications Analysis Services 38

Geographic Information System (GIS) Applications 40

Broadband Wireless Standards 42

Short-Range Mobile-to-Mobile Propagation Model Development and Measurements . 44

Page

Telecommunications Theory 47
Audio Quality Research. 48
Effects of the Channel on Radio System Performance 50
1.7 GHz Advanced Wireless Systems Compatibility Testing 52
Signal Characteristics, Spectrum Emissions, and Interference Analyses 54
Video Quality Research 56

Support to Private Sector Telecommunications Activities 58
Technology Transfer to Industry and Academia 58
ITU-R Standards Activities 60
ITU-T & Related U.S. Standards Development 62

ITS Tools and Facilities 65

ITS Projects in FY 2007 74

ITS Publications and Presentations in FY 2007 78
NTIA Publications 78
Outside Publications 79
Unpublished Presentations. 80
Conferences Sponsored by ITS 81

ITS Standards Work in FY 2007 82
Standards Leadership Roles. 82
Representative Technical Contributions 83

ITS Awards in FY 2007 85

Abbreviations/Acronyms 87

The antenna of an air search radar during interference testing (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 addressing 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.

The Department of Commerce Boulder Laboratories in spring 2007 (photograph by J.R. Hoffman).

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 2007 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, U.S. 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 (ESSA) and was renamed the Institute for Telecommunication Sciences and Aeronomy (ITSA). In 1967, ITSA split into four laboratories: Aeronomy, Space Research, Wave Propagation, and the Institute for Telecommunication Sciences (ITS). In 1970, Executive Order 11556 established the Office of Telecommunications (OT) within the Department of Commerce 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**
- **Public Safety Audio and Video Laboratories**
- **Radio Spectrum Measurement Science (RSMS)**
- **Secure Internet (SIPRNET)**
- **Table Mountain Field Site/Radio Quiet Zone**
- **Telecommunications Analysis Services**

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 inter-operation, 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**

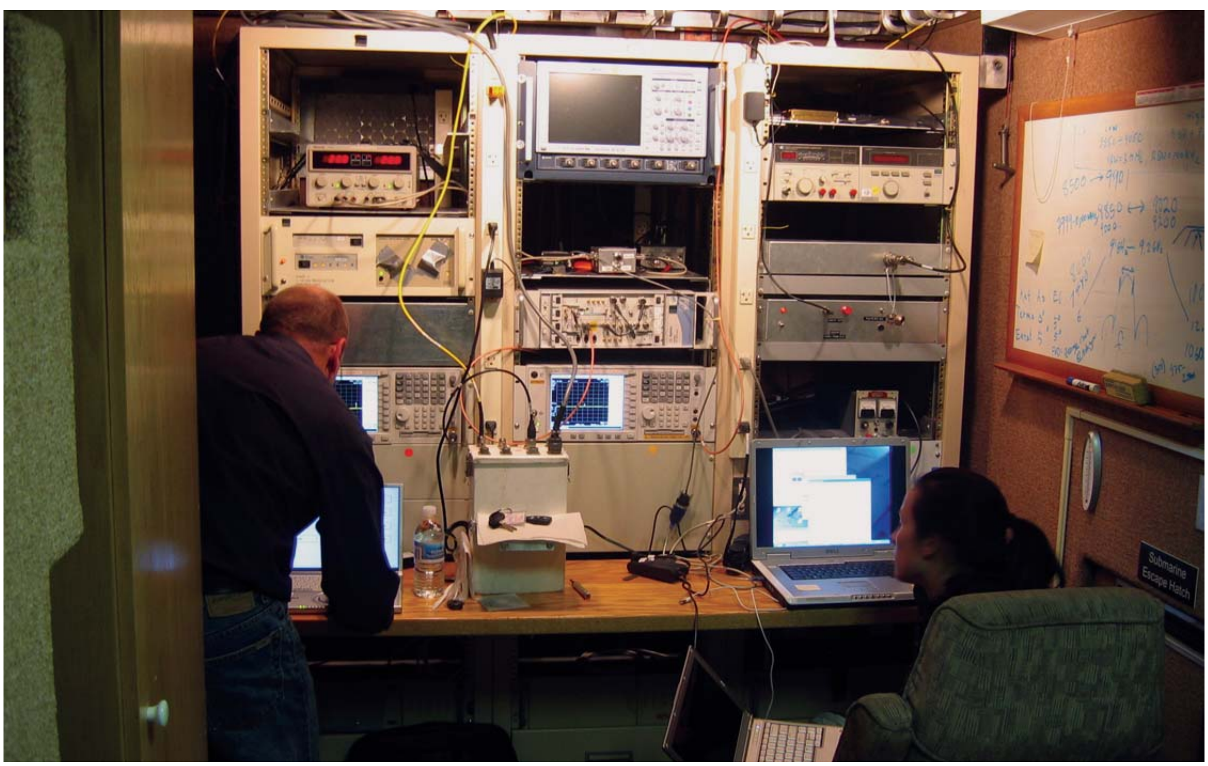
ITS's research and engineering work is supported by the Director's Office, which provides support to the program, budget, and administrative functions of the Institute. ITS also maintains an NTIA liaison function to provide assistance to NTIA on participation in national and international conferences 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. Other agency sponsors that provide significant support 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 had 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 2007 to both the public and private sectors.



Scenes from RSMS measurements in FY 2007, including land mobile radio measurements (top) and radar measurements (bottom) (photographs 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 can alleviate this problem, they cannot do so without increasingly more in-depth 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 measurements to characterize the existing radio environment, studies the effects of existing radio signals on electronic systems, and analyzes the potential effect and impact of new radio signals.

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 the well-equipped ITS laboratories and at the Table Mountain Field Site.

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

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Areas of Emphasis

Radio Spectrum Measurement Science (RSMS) Operations
The RSMS system is a complex toolbox of laboratory equipment, analysis tools, and mobile facilities. This capability is used to assess spectrum occupancy and usage, 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 Table Mountain Field Site is designated as an area where the magnitude of strong, external signals is restricted (by State Law and Federal Regulation). It is the principal experimental field site for the U.S. Department of Commerce Boulder Laboratories, and is used for experiments requiring protection from vibration and strong, external radio signals. Research at this site includes development and evaluation of: new spectrum occupancy measurement methods, radio noise measurements, new antennas, and complex radar testing. These projects are funded by NTIA.

Radio Spectrum Measurement Science (RSMS) Operations

Outputs

- Measurements to validate compatibility between off-the-shelf 5-GHz dynamic frequency selection (DFS) devices and a 5-GHz radar.
- Measurements to verify usage of fixed-service assignments located in the 7125-8500 MHz band.
- Measurements to determine the emissions of various radars with different output devices, including solid state and tube devices employing various modulation schemes.

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 various Federal agencies with information to ensure effective and efficient use of the spectrum. The RSMS team is based 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 analyses, 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 2007, several different measurements were performed in support of the basic mission.

In the summer of 2007, field measurements were conducted to determine compatibility between off-the-shelf 5-GHz dynamic frequency selection (DFS) devices and 5-GHz radars. DFS is a method where Unlicensed National Information Infrastructure (U-NII) devices, which use the 5-GHz band for unlicensed operations, will detect the operations of a radar and promptly vacate the channel if a radar is present. In FY 2006, OSM and ITS personnel bench- and field-tested devices from three U-NII vendors. The FCC adopted compliance rules and procedures for U-NII devices in FY 2006 and they will be sold to the public. In order to monitor the performance of the devices on the market, NTIA purchased two 5-GHz U-NII devices "off the shelf" and tested them to the published compliance standards. More of this type of testing is expected to occur in FY 2008.

Fixed-services measurements to verify assigned usage were conducted in the winter of FY 2007 (see photo). As part of the Presidential Initiative, this project provided technical direction and support in the study of ways to improve spectrum efficiency and effectiveness. In spring 2006 some cursory measurements of the fixed services in the 7125-8500 MHz band were conducted in the Washington, D.C., area. The measurements of the fixed services did not align with predicted results for signal presence, power levels, directions, and assignment activity. For those measurements, OSM prepared a report that predicted that information based on measurement location. To verify that the initial analyses and measurement procedures were correct and that the data for the fixed assignments in the GMF may be flawed, OSM prepared a similar report that ITS used in a measurement of fixed-service activity in the Denver area. Two methods were explored: one using an azimuthal scan in a fixed location and the other using a drive-up method where measurements are conducted in close proximity to several microwave towers. A summary of these methods will be published in an NTIA Technical Memorandum. Also in support of the Presidental Initiative, previously ITS surveyed the activity in Federal land mobile radio (LMR) services in the Washington, D.C., area. A report on the results was published in FY 2007.

In January of 2007, measurements were conducted to determine the emission characteristics of an HF FMCW radar located in New Jersey. In addition, spectrum measurements were conducted on various emulated pulsed waveforms to verify theoretical models. Both of these measurements are part of an ongoing effort to determine the emissions of various radars with different output devices, including solid state and tube devices employing various modulation schemes. These measurements will assist NTIA in revising the Radar Spectrum Engineering Criteria's

ITS engineers preparing for fixed-services measurements in Denver, Colorado (photograph by J.R. Hoffman).

(RSEC) 40-dB bandwidth equations and emission limits. They will also help NTIA develop implementation factors and guide similar efforts at the ITU-R, as Recommendation SM.1541 is revised. The United States has been actively involved in modifying ITU-R SM.1541 for out-of-band and spurious emissions.

Over the course of the year, measurements were conducted to characterize various off-the-shelf low noise amplifiers (LNAs). One of the primary components of an electromagnetic compatibility analysis is determining the interference effects on a receiver. The potential impact to the front-end of a receiver can be determined by characterizing the response of an LNA to single and multiple interfering signals. Compatibility problems can arise when front-end overload occurs, saturating the receiver front-end (e.g., the LNA). The objective of this task is to examine the response of LNAs to a variety of single-signal and multi-signal stimuli.

During FY 2007 ITS provided support for two separate measurements to determine interference potential to L-Band radars from new Radionavigation Satellite Services (RNSS) operating in the same frequency band. The Department of Defense, the Federal Aviation Administration, NTIA, and other Federal agencies have concerns about the operations of these RNSS devices in the 1215-1400 MHz band (L Band). Specifically, measurements and analyses show that RNSS signals coupling into radars operating in the L Band can cause interference which can lead to loss of targets and/or reduced detection range. Within the ITU-R, work has already begun on a study of the issues. The L-Band group in the United States was formed to perform a unified and comprehensive review of the issues and determine how to resolve them domestically and at the ITU-R.

Recent Publication

J.R. Hoffman, R.J. Matheson, and R.A. Dalke, "Measurements to characterize land mobile channel occupancy for federal bands 162-174 MHz and 406-420 MHz in the Washington, D.C., area," NTIA Report TR-07-448, Jul. 2007.

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RSMS 4th Generation System Development

Outputs

- Development of low-frequency preselectors and duplication of high-frequency 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.

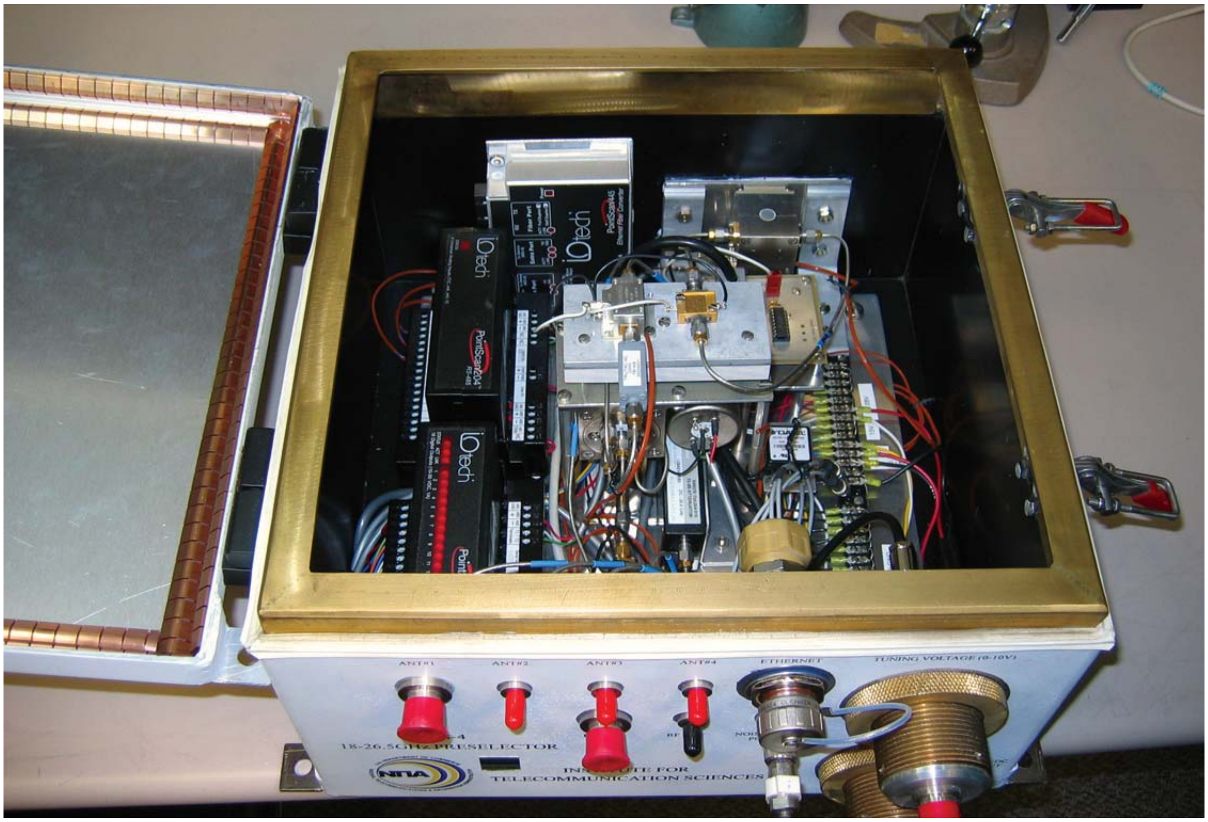
The 4th generation system for Radio Spectrum Measurement Science (RSMS) consists of state-of-the-art tools (vehicle, software, and hardware) necessary for making measurements to characterize spectrum occupancy, ensure equipment compliance, determine electromagnetic compatibility, and analyze interference 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 measurements for determining policies affecting both the public and private sectors. To this end, several new capabilities and improvements were added to the system in FY 2007.

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 computer-controlled 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 (see figure). To provide redundancy in case of failure or dual system requirements, a second copy of each preselector is currently under construction. 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 higher frequency preselectors, a 4th generation low-frequency preselector (1.5–1000 MHz) was designed and parts were purchased in FY 2007; final construction will occur in the next fiscal year. In 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.

During FY 2007, several improvements were made to existing tunable 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 was developed that allows periodic characterization of the filter for offset control.

In preparation for fixed services measurements that occurred in the winter of 2007, a specialized azimuthal and spectrum scan measurement was developed. This measurement controls an antenna rotator so that a high-gain dish antenna is pointed in 1° increments through a full 360° azimuthal sweep. A spectrum trace is acquired and stored in association with each degree increment. The data is then plotted three-dimensionally in a contour plot: frequency, angle, and power in the x, y, and z planes respectively. This provides a visual display of the different signals and their angle of arrival, both of which can then be correlated with a transmitter database to verify spectrum usage.

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 controlled 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 intermittently 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



18.0–26.5 GHz 4th generation preselector (photograph by J.R. Hoffman).

a variety of measurement capabilities. Development of this system using FPGA technology will not only provide signal direction-finding capabilities but will also open up a whole new way of acquiring and processing data, using what is essentially a hardware re-programmable instrument that can be used for many different applications.

Several new additions and improvements have also been made to software measurement routines. These include an automated "noise-diode to noise-diode calibration" procedure, the "stepped" measurement, the "manual spectrum analyzer data dump" measurement, the "swept" and "swept calibration" measurements and new instrument control modules for the HP8566 and HP8563 spectrum analyzers. The "noise-diode to noise-diode calibration" procedure is an automated routine used to calibrate measurement noise diodes against a "gold standard" noise diode that is kept in pristine condition, with a calibration that is traceable to NIST. Noise diodes are used in laboratory and field measurements to calibrate measurement systems for gain and noise figure. The "stepped" measurement is an automated routine that is used frequently to characterize the emission characteristics of radars; improvements to this routine include a fully automated attenuation routine and re-measurement capabilities, as well as a "data viewer" used to examine data and output the data into various other file formats. "Data viewers" were also added to the "manual spectrum analyzer data dump" measurement, and the "swept" and "swept calibration" measurements. The instrument control modules for the HP8566 and HP8563 spectrum analyzers are still in progress but near completion.

Further developments expected in FY 2008 include enhanced data file management, a scheduler for automated control of multiple measurements, an RF noise measurement routine, further work on the FPGA re-programmable instrument module, the completion of the YIG tracking system, and the completion of the RSMS4G low-frequency preselector.

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Table Mountain Research Program

Outputs

- NOAA Weather Radio receiver performance testing.
- Antenna performance evaluation and testing.
- Geographic Information System (GIS) database to support radio propagation studies.

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 Program actively solicits research proposals both from inside the Institute and 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:

NOAA Weather Radio Testing:
To help ensure that radios displaying the National Oceanic and Atmospheric Administration (NOAA) Weather Radio (NWR) emblem meet the NOAA performance criteria, ITS operates a laboratory at the Table Mountain field site for the purpose of measuring the performance of these radios. This test facility provides NOAA with performance data based on tests outlined by the Consumer Electronics Association standard CEA-2009.

Antenna Performance and Evaluation Testing:
Knowledge of the performance characteristics of antennas (radiation pattern, gain, polarization, etc.) is necessary to ensure the correct operation of a radio system as well as to assess the compatibility of a system with other electronic devices and services. The controlled radio environment at the Table Mountain field site, and the 10.4 meter (34 foot) diameter turntable facility, make this an ideal place to gather these data.

Projects undertaken by the Table Mountain Research Program have included: measurement of open air antenna patterns, testing the effects of support vehicles on mobile antenna systems, evaluating the performance of new antenna designs, and studying the effect of antenna characteristics on radio system performance.

DSES group replacing the jack screw boots on the main dish drive mechanism of one of the 18.3-meter parabolic dish antennas at the Table Mountain field site (photograph by J.W. Allen).

FY 2007 Cooperative Research and Development Agreement (CRADA) Partners

- Lockheed Martin/Coherent Technologies
- First RF Corporation
- RF Metrics Corporation
- University of Colorado, AUGNet
- Deep Space Exploration Society (DSES)

Interior of one of the ITS buildings at the Table Mountain field site, set up for radar measurements (photograph by J.R. Hoffman).

Recent Publications

A. Jenkins, D. Henkel, and T. X Brown, "Sensor data collection through unmanned aircraft gateways," in *Proc. AIAA Infotech Aerospace Conference*, May 7–10, 2007.

E.W. Frew, C. Dixon, J. Elston, B. Argrow, and T. X Brown. "Networked communication, command, and control of an unmanned aircraft system." Submitted to *AIAA Journal of Aerospace Computing, Information, and Communication*, under review (revision submitted May 2007).

A. Jenkins, D. Henkel, and T. X Brown, "Sensor data collection through gateways in a highly mobile mesh network," in *Proc. IEEE Wireless Communications and Networking Conference (WCNC)*, Hong Kong, Mar. 2007.

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

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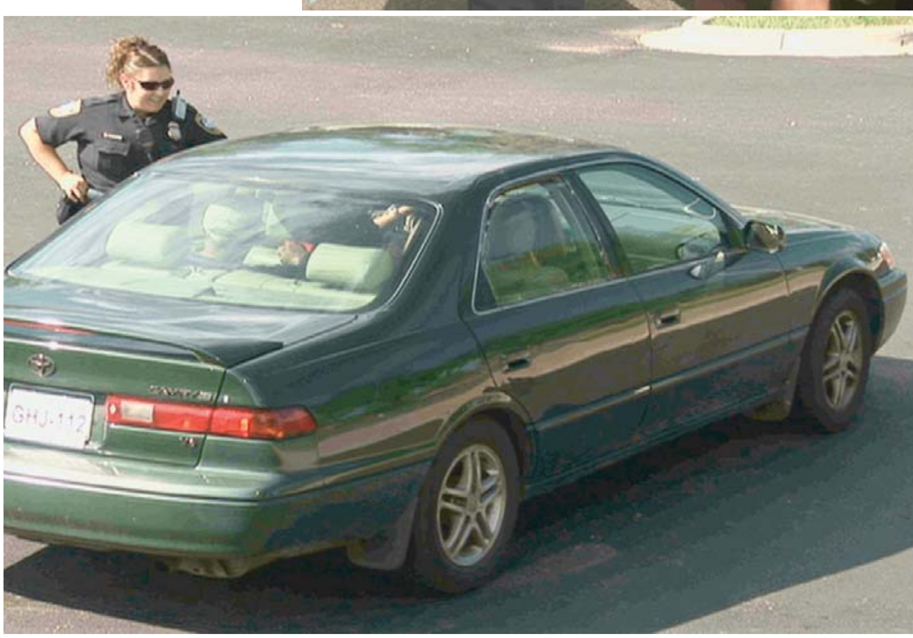
A frame from a video shot to support research into quality standards for the use of video in fighting fires. Firefighters look for such things as smoke color and trails.

A frame from a video shot to support research into quality standards for the use of video by patrol officers. In-car cameras can be used to document an incident for evidence or monitor a situation in real time.



A frame from a video shot to support research into quality standards for the use of video for surveillance. Data can be documented such as license plate, make/model/color of car, number of passengers, etc.

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 includes planning and analyzing existing, new, and proposed telecommunications and information technology systems, especially networks, to improve efficiency and enhance performance and reliability. ITS performs this work for both wireline and wireless applications. This encompasses work 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).

In November 2006, several members of the division were awarded the Department of Commerce Gold Medal, the highest honor given by the Department (see p. 86 for more information). The group was recognized for leading an effort to develop a national strategy to enhance public safety communications and assisting the development of technical standards to enable rapid deployment of a new generation of digital land mobile radio systems. This work supports the Commerce Department's goal of improving public safety communications to better serve Americans and protect American security.

Following is a summary of significant activities that occurred in the area of telecommunications and IT planning during FY 2007. Telecommunications interoperability relating to Public Safety communications remains the largest program area.

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Areas of Emphasis

Interoperability Efforts for Public Safety Communications The Institute conducts a broad-based technical program aimed at facilitating communications interoperability and information-sharing among wireless and IT systems within the public safety/homeland security community. These activities are sponsored by the NIST Office of Law Enforcement Standards Program and the Department of Homeland Security. These efforts are planned and performed with coordination among local, State, tribal, and Federal practitioners. Technical thrusts within the program, described in separate sections on the following pages, include:

Public Safety Broadband Communications

Standards Development for Public Safety Interoperability

Project 25 Compliance Assessment Program

Department of Commerce ISSI Evaluation 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 Department of Homeland Security's 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.

Public Safety Broadband Communications

Outputs

- DHS pilot project bridging land mobile radio and broadband.
- Public Safety 700-MHz Broadband Statement of Requirements.
- Protocol selection for the 4.9-GHz public safety band.

Broadband communications for the public safety community is currently in overdrive. The National Capital Region has deployed a broadband network at 700 MHz, the Department of IT in New York City has deployed a broadband network at 2.5 GHz, and a number of other public safety agencies have been deploying 4.9-GHz broadband systems. Couple this with all of the pilots, standards, and requirements work occurring at the national level, and it is easy to see there is a great deal of effort being put into this advancement in public safety communications.

On behalf of the NIST Office of Law Enforcement Standards (NIST/OLES) and the U.S. Department of Homeland Security's Office for Interoperability and Compatibility (DHS/OIC), ITS has launched and is managing a pilot project in the District of Columbia that will field-test the integration of new broadband technologies with existing emergency responder two-way radio systems. The project, known as Radio Over Wireless Broadband (ROW-B), will enable emergency responders to communicate across traditional radio and advanced wireless broadband communication systems. ROW-B will also integrate this communication with geographic information systems data, thereby providing real-time access to the locations of resources in an emergency responder's area. ROW-B is a partnership with OIC, the District of Columbia's Office of the Chief Technology Officer (OCTO), and Clarity Communication Systems Inc. The project will facilitate interoperability with OCTO's existing communication network and their citywide broadband network pilot program known as the Wireless Advanced Responder Network.

ROW-B will use a new standard called the Inter-RF Subsystem Interface (ISSI). ISSI is part of the Association of Public-Safety Communications Officials (APCO) Project 25, which is an effort to create standards that allow emergency responder radios to communicate and interoperate. In this project, the interface will provide a common connection point between the disparate two-way radio systems and wireless broadband networks (at 700 MHz).

In addition to the 700-MHz DHS pilot project, ITS is working on public safety's current 700-MHz broadband effort, where the 700-MHz broadband spectrum is shown in Figure 1. On August 10, 2007, the Federal Communications Commission (FCC) released the Second Report and Order as a revision to the 700 MHz Rules to Advance Interoperable Public Safety Communications and Promote Wireless Broadband Deployment. The Second Report and Order created, for the first time, a public/private partnership whereby public safety spectrum will be joined with commercial spectrum.

The combined spectrum will be managed by the Public Safety Broadband Licensee (made up of public safety organizations such as the International Association of Fire Chiefs and the International Association of Chiefs of Police) and a network built out by the winner of the spectrum auction currently scheduled for January 23, 2008.

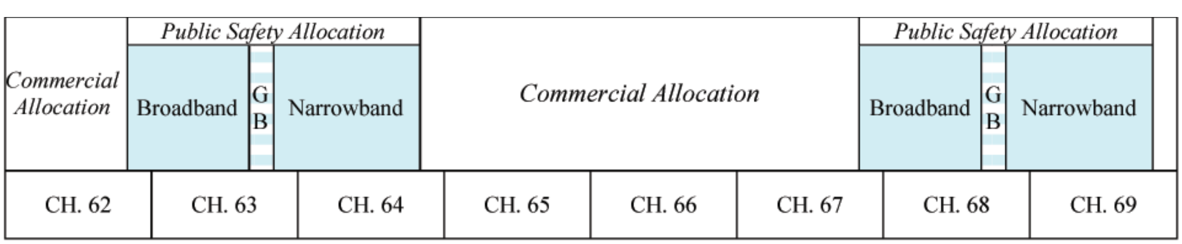

Figure 1. Depiction of public safety's revised spectrum allocation for the public/private partnership created by the FCC in 700 MHz.

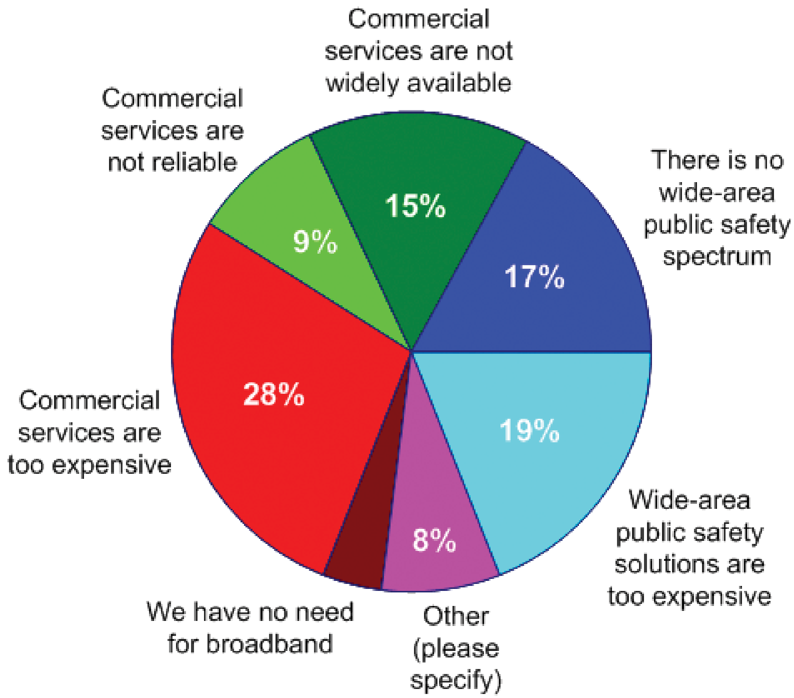

Figure 2. Barriers to public safety broadband communications.

To facilitate a comprehensive understanding between public safety and the winner of the auction, a Public Safety 700-MHz Broadband Statement of Requirements will be created. ITS is co-chairing the National Public Safety Telecommunications Council's Broadband Working Group, where the 700-MHz Statement of Requirements is being written. As part of this effort, information was gathered pertaining to current barriers faced by public safety in building out broadband systems on their own. The results of this information gathering are shown in Figure 2. Additionally, ITS is leading the authoring/editing of the document.

Once the auction is complete, ITS will continue to participate in the 700-MHz broadband effort on behalf of public safety through test and evaluation of the technology that will be deployed to meet the practitioner requirements. Where gaps are identified between the technology deployed and the requirements from the Public Safety 700-MHz Broadband Statement of Requirements, ITS, on behalf of NIST/OLES and DHS/OIC, will lead the effort in the technology's originating Standards Development Organization to reflect public safety needs.

In addition to the 700-MHz broadband effort, ITS is also heavily involved in public safety's 4.9-GHz broadband effort. For the last two years, ITS has chaired the APCO Project 25 Interface Committee's Broadband Task Group, where an effort is currently underway to select an air interface protocol for use as public safety's standard in the 4.9-GHz band.

In addition to chairing the group leading the standardization process, ITS also directly supports the Project 34 User Needs Committee on behalf of NIST/OLES through the creation of a public safety user selection process, where formal decision analysis will be used to lead the practitioners to a decision between the two proposed protocols (IEEE 802.11-2007 and 802.16e) based on their requirements and priorities.

Lastly, ITS is also leading the simulation effort related to the project. In this effort, the four scenarios from the main body of the SAFECOM Public Safety Statement of Requirements have been simulated to compare and contrast the two proposed protocols' performance, based on the Project 34 Incident Area Networking Statement of Requirements.

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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.

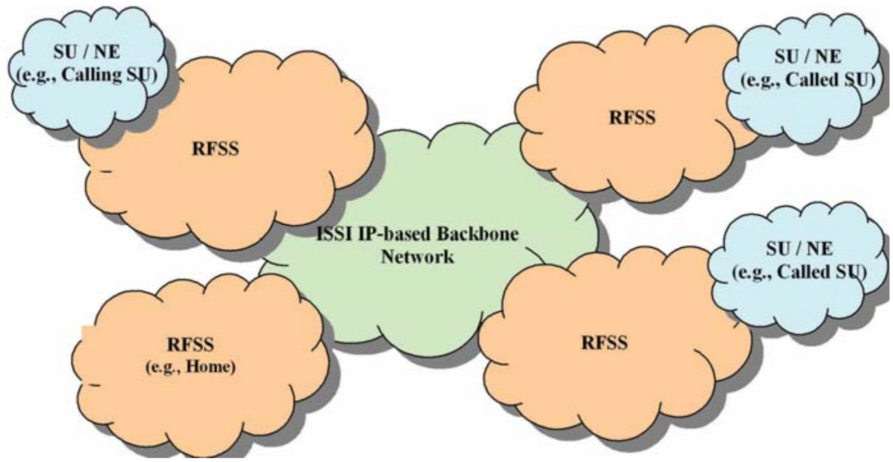
Too often, public safety practitioners' communications systems do not meet their needs for operability (security, service area, performance, and survivability for intra-agency communications) and interoperability (inter-discipline and inter-jurisdiction communications where and when communications are 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), Vice Chair of the Compliance Assessment Process and Procedures Task Group (CAPPTG), 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 involvement with government and industry representatives and technical contributions across many fronts, ITS was responsible for advancing progress in the TIA TR-8 technical committees and associated Project 25 APIC working groups. In FY 2007, critical specifications, including those recognized as essential by the U.S. Congress, were standardized by TIA and ITS was instrumental in their development, including the ISSI and other critical P25 wireline interfaces. Significantly, these new standards will enable essential advanced P25 services to be provided using the ISSI. For example, P25 supplementary data services have been standardized that will enable such key features as emergency alert signaling to be implemented on a multivendor, interoperable basis. In FY 2007, ITS continued to progress work on the ISSI suite of standards. ITS was and is a major contributor in these key P25 areas:

- ISSI Measurement Methods: TIA-102.CACA (approved in April 2007)
- ISSI Performance Recommendations: TIA-102.CACB (approved in April 2007)
- P25 Statement of Requirements (updated version approved in August 2007)
- ISSI Conformance Test Procedures for Voice Services (expected to be approved in February 2008)



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

As a result of technical research and standards contributions to the CAPPTG and ISSI Task Group, agreement was reached in October 2007 to undertake the development of a critical new standard that will define ISSI interoperability test procedures. ITS will, as a focus area in FY 2008, be providing support for the development of this unprecedented, and complex standard. Completion of such standards is required to enable successful conduct of the P25 Compliance Assessment Program (described on pp. 18-19).

The figure above 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 (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.

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. 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 Interoperability 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 (DHS) Office for Interoperability and Compatibility, Federal Partnership for Interoperable Communications, and the DHS 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 2008, 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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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, defining Project 25 compliance requirements.

Engineers from the Institute achieved significant milestones in FY 2007 in their continued efforts to implement a compliance assessment program for Project 25 land mobile radio (LMR) equipment. Consequently, formal competency assessment of test labs is poised to begin in 2008.

The Project 25 Compliance Assessment Program (P25 CAP) was initiated in response to Congressional mandates that Project 25 equipment purchased with grant funds should meet "the requirements of a conformity assessment program"[1] and that 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] The Program kicked off in April 2005.

Project 25 LMR technology is being rolled out in phases and the compliance program is being structured accordingly. The full suite of P25 standards will eventually define eight open interfaces: The Common Air Interface (CAI) was the first interface developed and is the most mature of the eight, so compliance assessment will begin with that interface. As the program matures, testing will encompass for each interface the essential elements of compliance as defined by the Telecommunications Industry Association (TIA) including:

- 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.

The Project 25 Steering Committee plans to adopt Telecommunications Systems Bulletins (TSBs) that define a key subset of tests for which manufacturers will demonstrate compliance. Test laboratories will produce and keep detailed test reports for each device or system evaluated. Manufacturers with products that meet the TSB requirements will issue a Supplier's Declaration of Compliance (SDoC) in accordance with the program guidelines. Each SDoC will contain a product's test configuration, enumerate the tests that were conducted, and indicate the test case verdicts. For the benefit of P25 equipment purchasers, manufacturers will produce at-a-glance type summary test reports using a common report template. This will simplify interpretation of the results and facilitate product comparisons. Summary test reports substantiate the SDoCs and will go a long way toward increasing the public safety community's confidence in Project 25 equipment functionality.

The framework for the laboratory assessment and recognition component of the program was jointly developed by engineers at ITS and NIST and reviewed by industry representatives. This process culminated in October 2007 with the publication of NIST Handbook 153, *Laboratory Recognition Process for Project 25 Compliance Assessment*. Handbook 153 was patterned after ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*, but with several key differences. First, the program offers qualified laboratories a means of being *recognized* by specialists in conformity assessment for competence executing P25 tests. This is in contrast to the more formal *accreditation* process followed by organizations such as NIST's National Voluntary Laboratory Accreditation Program. Also, the P25 CAP was specially tailored to facilitate testing at manufacturers' development or systems troubleshooting laboratories that generally do not have quality management

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 Program Lead Assessor Training at ITS in FY 2007. Those pictured include ITS staff as well as two contract assessors for the program (photograph by E.D. Nelson).

systems in place. Accordingly, the program places greater emphasis on technical competence of the laboratory personnel and the reproducibility of tests than on quality system management.

Besides developing the lab recognition handbook, ITS engineers have supported the program in a number of other ways. They developed rules for governance of the program and drafted preliminary program policies. They trained to serve as Subject Matter Experts for on-site assessments of prospective laboratories. Earlier in 2007 they released the Radio Performance Measurements automated testing software suite to streamline testing of radios. Finally, they drafted the latest revision of TIA-102. CABC, *Interoperability Testing for Voice Operation in Trunked Systems*, one of the two key standards required for program rollout. Next year the Department of Commerce ISSI Test and Evaluation System (DIETS), jointly developed by ITS and NIST engineers, promises to play a key role in conformance testing of the ISSI.

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 Evaluation 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 can 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). The ISSI of different RFSSs can be inter-connected using various mediums, the most common being 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 vendors who manufacture RFSSs. Over time, this increased competition should drive down the cost of P25 infrastructure. The other important reason for an ISSI interface is to promote interoperability between the vendors who manufacture RFSSs. This allows the consumer to implement a P25 network 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 being developed, and a formal published version of the ISSI conformance test document is expected in early 2008. These tests will verify that the vendor implementation under test conforms at a message level to what is specified in TIA-102.BACA.

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 Evaluation and Test System (DIETS). ITS developed this software in conjunction with the National Institute of Standards and Technology (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

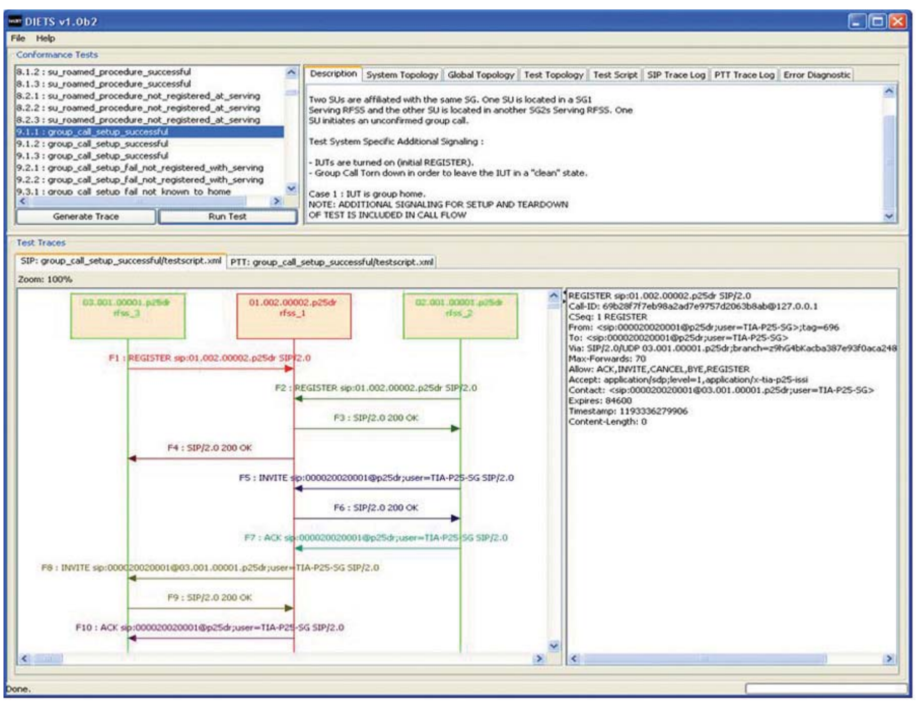

Figure 1. DIETS Conformance Test Tool Graphical User Interface (GUI).and SIP MSC for Test Case 9.1.1: Unconfirmed Group Call Successful.

system. DIETS can emulate one of four different roles in a P25 ISSI-based network: (1) calling serving RFSS, (2) calling home RFSS, (3) called home RFSS, and (4) called serving RFSS. 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. The number of vendor RFSSs and roles may vary depending on the test case requirements.

When attempting to determine a vendor's conformance, the preferred configuration is to test in isolation the ISSI of a single vendor's 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. 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 can 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. From the DIETS graphical user interface (GUI), the user selects a conformance test case to execute. Figure 1 shows the layout of the DIETS GUI. 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). Upon completion of test case execution, DIETS will declare either pass or fail. Figures 1 and 2 illustrate the MSCs generated as a result of executing test case 9.1.1 — Unconfirmed Group Call Successful. 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.

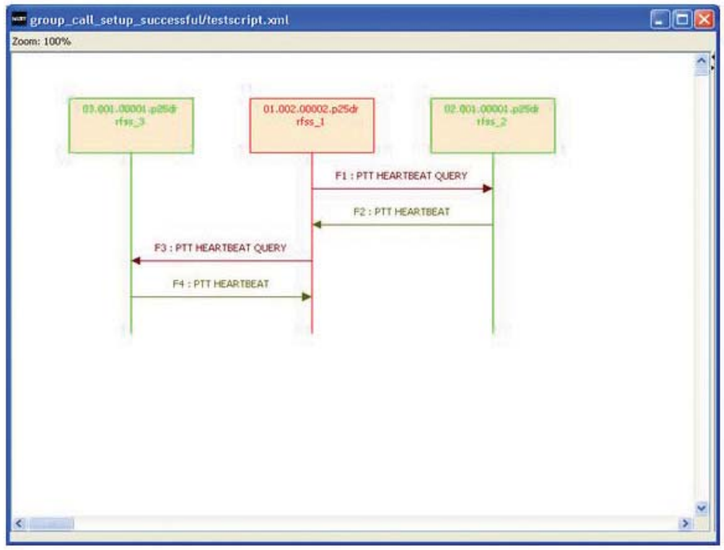

Figure 2. RTP PTT MSC for Test Case 9.1.1: Unconfirmed Group Call Successful.

Future Direction of DIETS

In addition to the ISSI, there are two other wireline interfaces that DIETS is being expanded to test: the Fixed Station Interface (FSI) and the P25 Trunked Console Sub-System Interface (CSSI). The FSI standard, TIA-102.BAHA, was formally published in 2006. The CSSI was published in April 2007, and this standard is an addendum to TIA-102.BACA.

The 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 vendors' fixed stations and RFSSs. The medium that will interconnect FSIs is not limited to Ethernet. The purpose of a CSSI is to enable the connectivity of a dispatcher's console to an RFSS. The CSSI is very similar to the ISSI.

The conformance test document TIA-102.CADA for the FSI has been published. As for the CSSI, the conformance test case development may begin at the end of 2008. By mid-2008, DIETS will have been expanded to enable objective message level conformance testing of the FSI. In addition to expanding its capability to test additional P25 interfaces, DIETS is being expanded to test the performance of the ISSI according to the Project 25 ISSI Measurement Methods for Voice Services standard. This is scheduled for completion by early 2008.

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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 has been 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, requirements and specification development, and security analyses to further the approval of standards supporting National Security/Emergency Preparedness (NS/EP) and Critical Infrastructure Protection (CIP) initiatives. This project is funded by the National Communications System (NCS) — a part of the Department of Homeland Security (DHS). 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 three standards development organizations. These are the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Study Group (SG) 9 and two American National Standards Institute (ANSI)-accredited groups: the Alliance for Telecommunications Industry Solutions (ATIS)'s Performance, Reliability, and Quality of Service Committee, PRQC, and the Society of Cable Telecommunications Engineers (SCTE). ITU-T SG 9 is the Lead Study Group, internationally, on integrated broadband cable and television networks and the SCTE produces North American Standards for the cable industry. PRQC works in the areas of Quality of Service (QoS), Reliability, and User-Plane Security, and produces North American Standards. In SG 9, ITS develops and verifies Recommendations to support preferential telecommunications services and user authentication. One 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 2007, an ITS engineer served as co-editor of several ANSI and ATIS Standards and Technical Reports. These provide guidelines, specifications, and requirements for aspects of ETS communications and network and computer security. 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 GETS-like capabilities. 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 Recommendations J.pref, "Specifications for preferential telecommunications over IPCablecom networks," J.prefp2, "Specifications for preferential telecommunications over IPCablecom2 networks," and J.preffr, "Framework for implementing preferential telecommunications in IPCablecom networks." J.pref and J.prefp2 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.

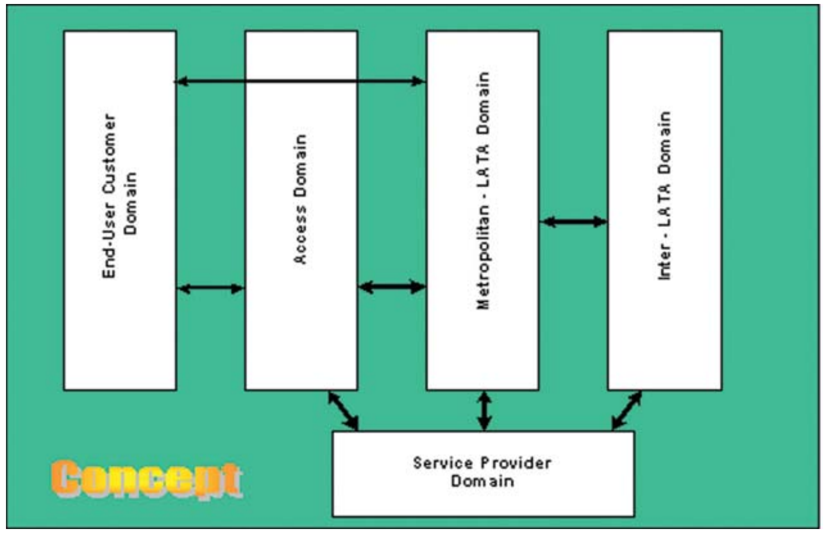

Figure 2. Typical Trust-Security domains to consider.

Another important study under way 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 — most notably authentications — in IPCablecom networks.

Figure 1 shows the IPCablecom releases. The IPCablecom architecture continues to evolve as new capabilities are added, and as such is comprised of several releases. Release 1.0 provides support for a telephony application using media terminal adaptors. It is specified in the initial release of ITU-T Recommendations J.160-178. Release 1.5 provides incremental new capabilities and adds SIP for session management within and among IPCablecom networks. It is specified in the revisions to ITU-T Recommendations J.160-178. The Multimedia release separates out the QoS capabilities and defines a generic QoS architecture. It is specified in ITU-T Recommendation J.179. Release 2 adds support for SIP-based endpoints, and a SIP-based service platform that may be used to support a variety of services. IPCablecom2 is based upon Release 6 of the IP Multimedia Subsystem (IMS). The IMS is the product of the 3rd Generation Partnership Project (3GPP). The diagram is taken from J.360, "IPCablecom2 Architecture Framework." Note that IPCablecom2 includes provisions for backwards compatibility with previous IPCablecom releases.

Figure 1. IPCablecom releases.

Figure 2 shows the typical Trust/Security domains that must be considered when developing a security plan for telecommunications networks. Note that the service provider is responsible for all but the customer premises domain.

In FY 2008, ITS will continue to work on the development and standardization of ETS in ATIS PRQC, SCTE, 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 2008 will focus on priority and security in the NGN ETS as well as GETS and ETS specifications 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

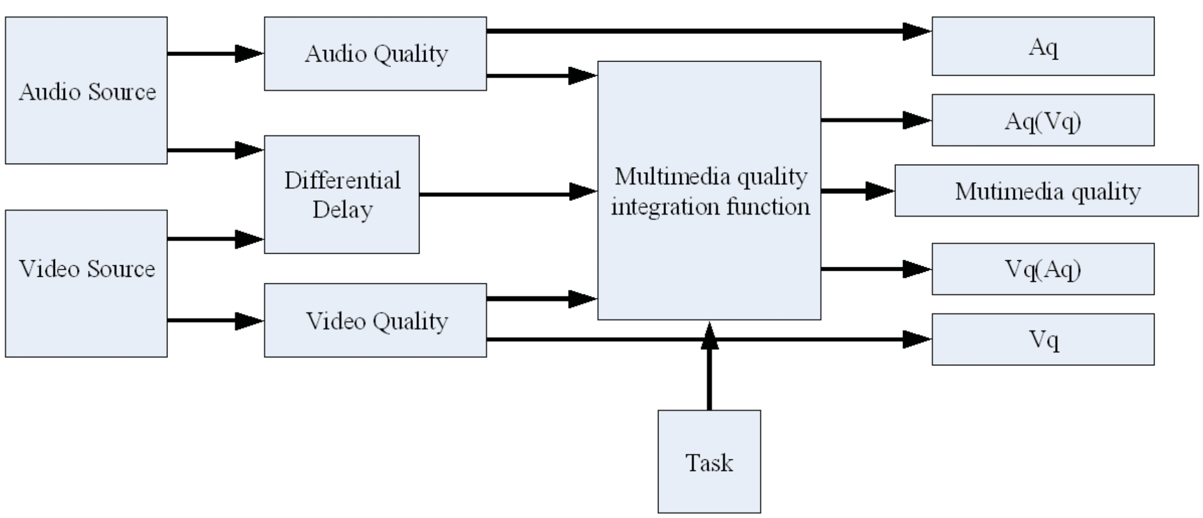

Figure 1. Basic components of a multimedia model.

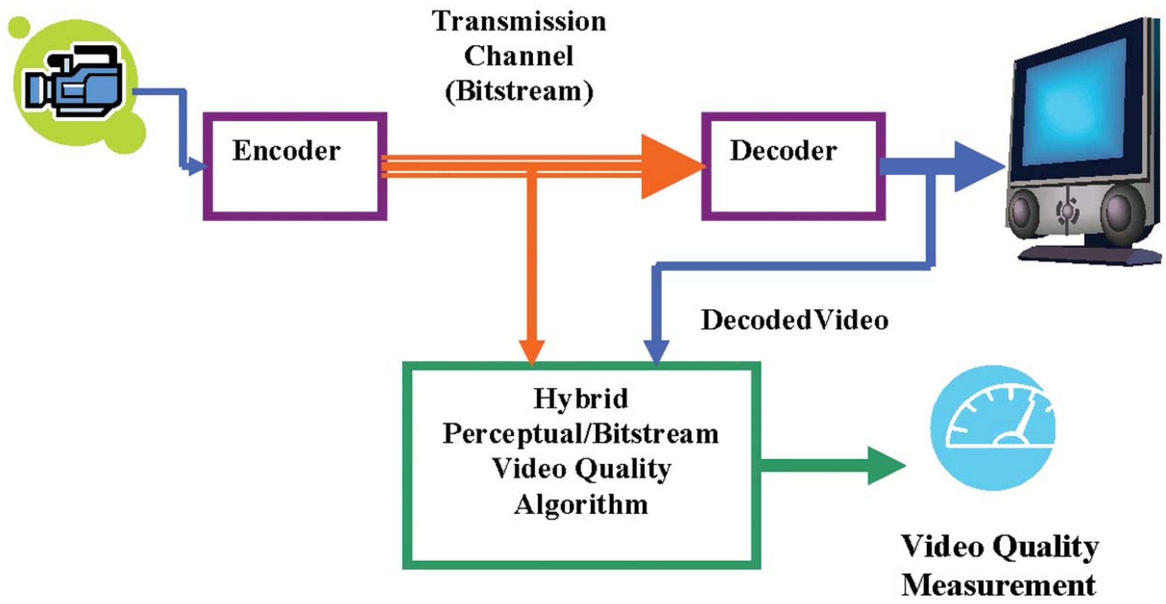

Figure 2. Diagram of the Hybrid Perceptual/Bitstream video quality approach.

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 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)).

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.

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 2008 this project will also conduct research into the Hybrid Perceptual/Bitstream models in conjunction with projects in progress in VQEG and the JRG-MMQA. Tools will be developed to aid in the processing of transport and bitstreams containing audiovisual signals (see Figure 2).

Also in FY 2008, 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.
- Wireless channel measurement techniques for high speed data networks.

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, such as 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. This parameter typically correlates well with received radiated channel power, so that conditions of high received power represent high throughput environments. However, the discrete time characteristic of digital modulation, coupled with the behaviors of network protocols, can give rise to paradoxical situations where good reception does not automatically translate into high throughput.

A situation of this type has occurred in the measurements illustrated in Figure 1. These measurements depict the behavior of an 802.11j network inside the corridors of an oil treatment plant. The middle row of numbers represents throughput in megabits per second and the lower row represents signal strength in dBm. An example of the anomalous condition described is seen in the values given for test points 4, 5, and 6. Between test point 4 and test point 5 the received signal strength decreases by 8 dB, but the measured throughput increases. Conversely, between test point 5 and test point 6 the received signal strength returns to its former level, but throughput drops by 22%! Another indication that the radio

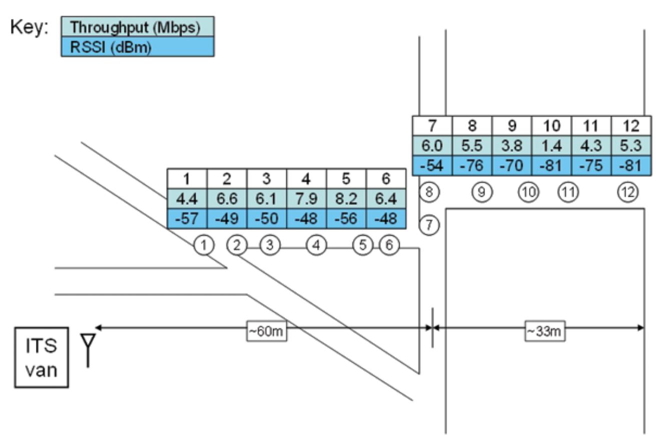

Figure 1. Throughput and signal strength measurements at an oil treatment plant.

Figure 2. Photograph of the propagating environment (photograph by G. Koepke, NIST).

channel is behaving oddly is the *a priori* knowledge that the system under test normally supports throughput values of 11 megabits per second when the received signal strength exceeds -80 dBm, as it does at almost all of these test points. Indeed, at test point 3 the received signal strength has exceeded the -80 dBm threshold by 30 dB, but the throughput is only 55% of its expected value.

A clue to the probable cause of this behavior is given in Figure 2. In this picture it is clear that the radio transmission environment consists of a dense network of pipes and metallic objects that offer a rich multipath environment for the radio signal. As radio symbols are transmitted, they can bounce off objects and become delayed enough to interfere with succeeding symbols, leading to intersymbol interference and errors in reception. In this case, the 802.11j protocol specifies that the packet must be retransmitted. If the proportion of retransmitted packets rises high enough, throughput degradation will be evident.

Specialized swept frequency measurements can be post processed to simulate an extremely short RF pulse, from which the multipath delay of the channel can be measured. This is an example of the type of new measurements that must be devised to evaluate radio channels used for high speed data networks. An understanding of the radio metrology, as well as knowledge of the protocols under use, is necessary to properly evaluate the propagation environment necessary for such networks.

The project is also investigating the use of inexpensive software defined radio (SDR) platforms as dynamically reconfigurable test instruments for new spectral domains, or tests that require flexibility not present in commercial test instruments. SDR-based instruments can also be used to bridge the gap between the fundamentally analog radio domain and the digital world of standard wired network tracing tools. This allows the creation of wireless network protocol analyzers to allow visibility of the intermediate wireless space between digital transmitters and receivers.

Measurements like these 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 help predict wireless coverage for public safety professionals in emergency situations.

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Staff from the Telecommunications Engineering, Analysis, and Modeling Division at work on various projects.

Telecommunications Engineering, Analysis, and Modeling

The Telecommunications Engineering, Analysis, and Modeling Division conducts studies in these 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, jamming, 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.

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Areas of Emphasis

ENGINEERING

Interference Issues Affecting Land-Mobile Systems The Institute participates in ATIS subcommittee WTSC/G3GRA (Wireless Technologies and Systems Committee — Radio Aspects of GSM/3G and Beyond) and ITU-R 8F. ITS is developing PCS interference models for CDMA and W-CDMA. The 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) ITS is establishing a common framework for information databases from the public safety community. NTIA/ITS leads a large collaborative effort to ensure the ability to share information across local, State, and Federal agencies. The project is funded by DHS/SAFECOM.

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.

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.

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 field measurements. With a new customized propagation measurement system, field measurements were performed in FY 2007. This project is funded by NTIA/OSM.

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.
- Model adapted for use in evaluating adjacent channel systems.

Recent natural disasters demonstrate how important Commercial Mobile Radio Services (CMRS) have become in establishing emergency communications. In times of emergency, communication services experience usage rates significantly greater than average. When emergency responders are unable to establish inter-agency communication links, especially with responders from outside the affected area, they must rely on commercial systems as a last (or only) resort. This sudden influx of traffic 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).

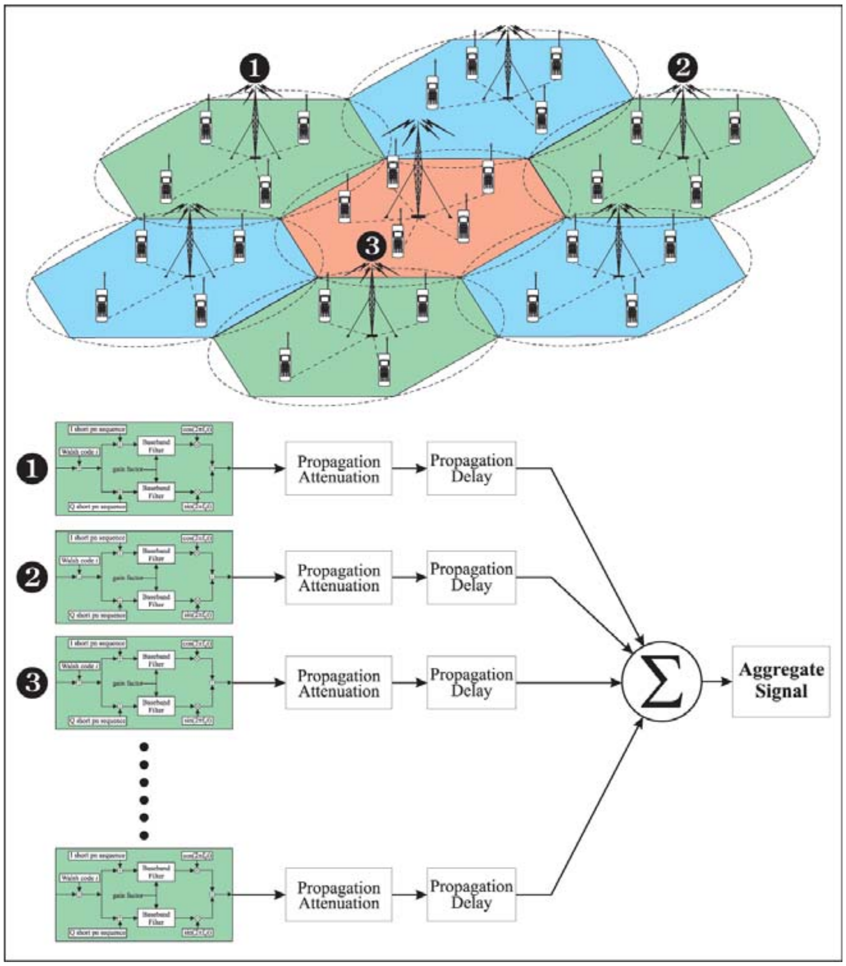
One way of coping with damaged or destroyed infrastructure is to deploy temporary equipment to supplement the surviving system. To make efficient use of limited resources, responders need to know what equipment needs to be deployed in which locations. Knowing the interference issues, dynamics, and load 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.

Aside from emergency situations, as plans for next- and future-generation commercial 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 necessary if all proposed systems are implemented.

ITS contributed to the understanding of inter-PCS interference by participating in the Telecommunications 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 as editor and contributor in interference issues with this group.

Even more work is being done on the international scene with coordinating worldwide development of future systems. The International Telecommunication Union (ITU) is the lead organization in this effort. ITU Working Party 8F (WP8F) is developing standards and recommending frequency allocations for the group of future technologies referred to as IMT-2000 and IMT-Advanced. Coordinating worldwide frequency allocations is a near-impossible task, given the disparity in the historical evolution of frequency use and requirements in each country. As more systems try to use the same limited quantity of spectrum, interference issues will become the primary concern. ITS participates in the activities of WP8F involving interference and propagation issues.

The increase in the demand for mobile communications capacity requires that 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 by the number of other CDMA users occupying the same frequency band. These legitimate users appear to each other as an increase in the noise floor and are referred to as *co-channel interferers*.



Aggregate downlink signal generation with the ITS interference model.

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 frequency band and can cause a cumulative effect where all users are operating 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 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. It 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 model calculates each channel’s sampled QPSK or OQPSK signal contribution separately, then sums all signals identified in a scenario to form a composite output signal. The power level for a single channel is a gain factor of the baseband filter and is set separately for each channel. No error correction is added to the input sequence; only spreading codes and modulation processes are used. The figure shows an example of how the model calculates the aggregate downlink signal from the base stations of the nearest cells which transmit on the same frequency.

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 measurements and 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 their local needs. Unfortunately, this equipment may not be of high enough quality for certain applications or be able to communicate with other agencies with 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.

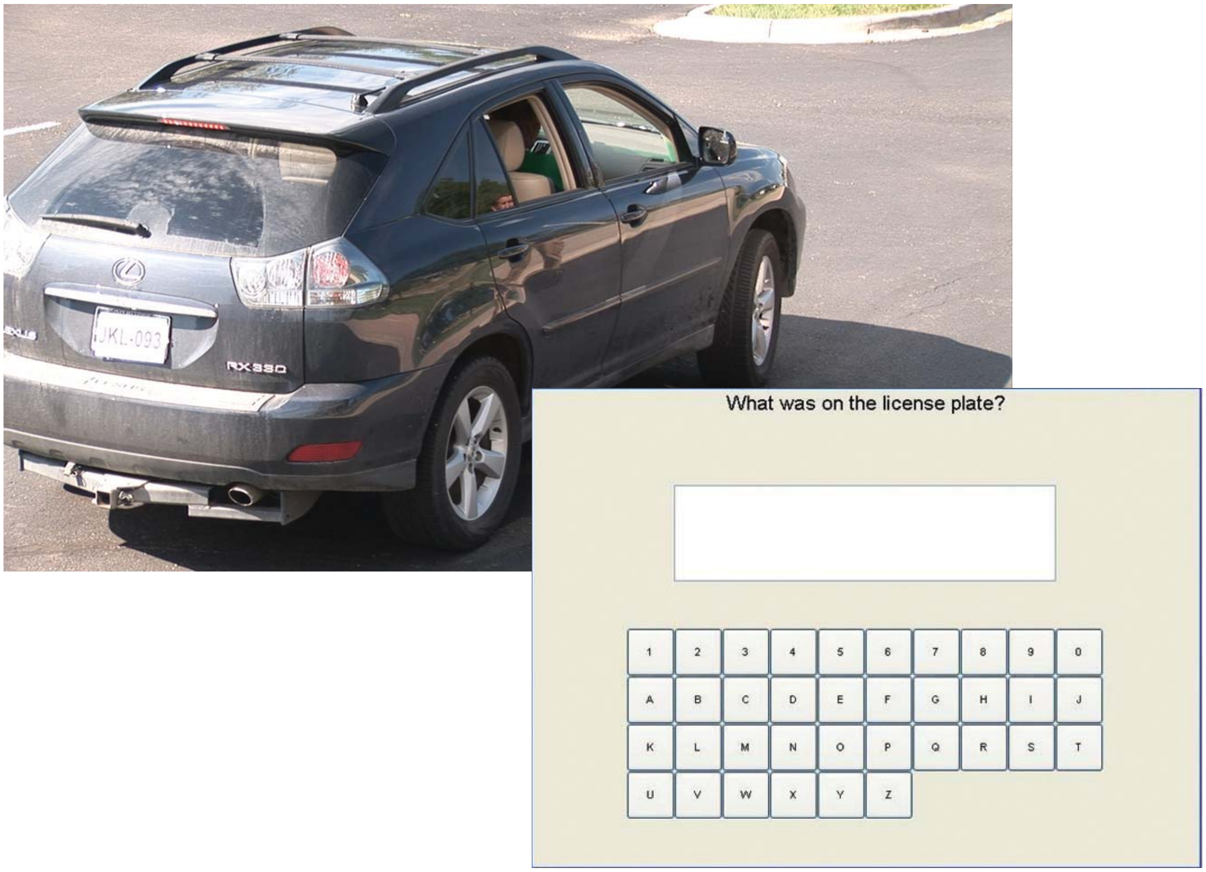
The Public Safety Video Quality (PSVQ) project is a growing research effort. This project started with a single video quality test, narrow tactical (the application of tactical video with a narrow field of view), conducted in December 2005. Over the past two years, ITS has expanded testing to include five 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" describes the field of view if the objects of interest are large, for example, a close-up of a face. From these six tests, ITS researchers can develop specific technical requirements for each public safety video application.

To assess video quality, subjective experiments are performed. Viewers watch video that has been impaired, and report their perceived quality of it using a rating system. The International Telecommunication Union (ITU) has several recommendations regarding rating systems and test methods, but most were developed for testing commercial entertainment. The purpose of the PSVQ project is to set standards for the quality of video used by first responders to recognize crucial details and make decisions. Methods that rely on a viewer's rating of quality may not capture the answer to the underlying question: at what level of impairment does video data become unable to carry the information necessary to make decisions regarding the task at hand?

The first series of tests in FY 2007 highlighted the need to develop new quality assessment methods for video used to perform tasks for specific applications. Research was conducted in the areas of military target, computer object, and human facial recognition. The results were adapted for development of video quality tests for public safety applications. A new standard was developed for video quality assessment for recognition tasks, and has been submitted to ITU-T Study Group 9 for consideration.

The subsequent test designed for the PSVQ project was based on this work. Instead of reporting an opinion of quality (e.g., on a scale from excellent to bad), subjects are asked to perform specific recognition tasks, such as identify an object or read an alpha-numeric sequence. For example, practitioners who use video in live applications (e.g., real-time surveillance and tactical operations) are asked to watch a video clip and identify the object being held or used by a person, or recognize if an object appeared in the video. Additional examples are the tasks of reading a license plate or a hazmat sign. The results of this testing will determine what percentage of experts (first responders) are able to perform the desired task at a certain video impairment level. This will also be correlated to the size of the target (object or alpha-numeric character) of interest. Facial recognition is also a very important use of public safety video, and experiments are being developed to measure the effect of video quality on the ability to perform this task.

Tests are also being designed for users of recorded video. These practitioners testify using recorded, or forensic, video in trials. Tasks will be defined that mirror their uses of video. Object, alpha-numeric character, and facial recognition will be the focus of the recorded video tasks, as they are for live video tasks, but the subjects will be allowed to examine the video in non-real time, as they would for their normal job activities.



An example of a task-based video quality assessment method.

A Video Quality Metric (VQM) is a tool that can be used to analyze video and objectively predict a human subject's assessment of its quality. ITS has developed several standard VQMs. One goal of the PSVQ project is to determine if the existing models can be applied to video used in recognition tasks. That is, can a model predict a video user's ability to recognize a face, an object, a character, or an action? With a model that allows for this translation from subjective methods to objective methods, subjective testing — which is very time-consuming and hence very expensive — would become unnecessary. This new objective modeling tool could then be used by the public safety community to help evaluate and aid in the selection of video equipment. While the development of such a model is not currently in the scope of the PSVQ project, the data collected during the quality testing could be used for model development.

The goal of the PSVQ project is the identification of video quality standards. This 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 Department of Homeland Security's SAFECOM Program and the National Institute of Standards and Technology's Office of Law Enforcement Standards (NIST/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 business rules for analyzing and assessing LMR inter-system compatibility.

The Public Safety Architecture Framework (PSAF) provides an industry-validated enterprise architecture methodology for public safety LMR communication systems. The term *architecture framework* refers to the structured process of comparing and integrating legacy communication systems to assess current resources and facilitate interoperability. It is used to plan and develop the migration from current public safety architectures to interoperable systems. The PSAF methodology for capturing information has driven the development of the PSAF data model. This model will be the foundation for the development of a PSAF tool for use by public safety personnel. The PSAF tool will adhere to PSAF Volume I[1] and II[2] methodology to plan and develop the migration to the interoperable communications systems outlined in the Public Safety Statement of Requirements (PS SoR):[3]

The PSAF data model, outlined in the PSAF definitions and guidelines documentation, combines three different data perspectives into one cohesive model. The Operational View (OV) identifies how public safety agencies perform their missions. The Systems View (SV) captures public safety systems of equipment and information flow. The Technical Standards View (TV) captures the technical interfaces that allow systems to interoperate. To validate the data model and to provide feedback into the development process, trial and pilot efforts were conducted with public safety agencies. The trial was performed in Cobb County, Georgia in November 2006 and the pilot was conducted with multiple agencies in Atlanta, Georgia in June 2007.

The PSAF trial concentrated on the development of a complete, technically accurate definition of a single radio system and provided an incremental step in the development of the data model. The PSAF pilot built upon the success of the PSAF trial, and characterized the compatibility between two agencies operating on two different radio systems. It also enabled the identification of information needs for communication restoration in the event of system destruction. The goal for the PSAF pilot was to validate the completeness of the PSAF data model, with respect to its support of inter-system compatibility assessment and system restoration requirements. Furthermore, the pilot provided an opportunity to support development of data requirements and business rules relating to the assessment of interoperability between agencies.

Prior to the trial, the PSAF data model was pre-populated with existing Communication Assets Survey and Mapping (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 shows the system, sub-systems, elements, and components of the Cobb County LMR network. The next phase of the project, the pilot data collection process conducted in June 2007, expanded the trial data collection effort into a more fully developed model and incorporated the results into a database storage mechanism.

The PSAF business rules, or decision logic, for assessing inter-system compatibility were developed and documented in PSAF Volume III.[4] Their development drew upon the experience of numerous subject matter experts in public safety radio systems, as well as the findings from the PSAF trial[5] and PSAF pilot.[6] The PSAF team consolidated its trial and pilot research findings to identify business rules

1 Volume I of the SAFECOM PSAF document is available at: http://www.safecomprogram.gov/SAFECOM/library/technology/1251_publicsafety.htm

2 Volume II of the SAFECOM PSAF document is available at: http:www.safecomprogram.gov/SAFECOM/library/technology/1252_publicsafety.htm

3 The SAFECOM PS SoR document is available at: http://www.safecomprogram.gov/SAFECOM/library/technology/1258_statementof.htm

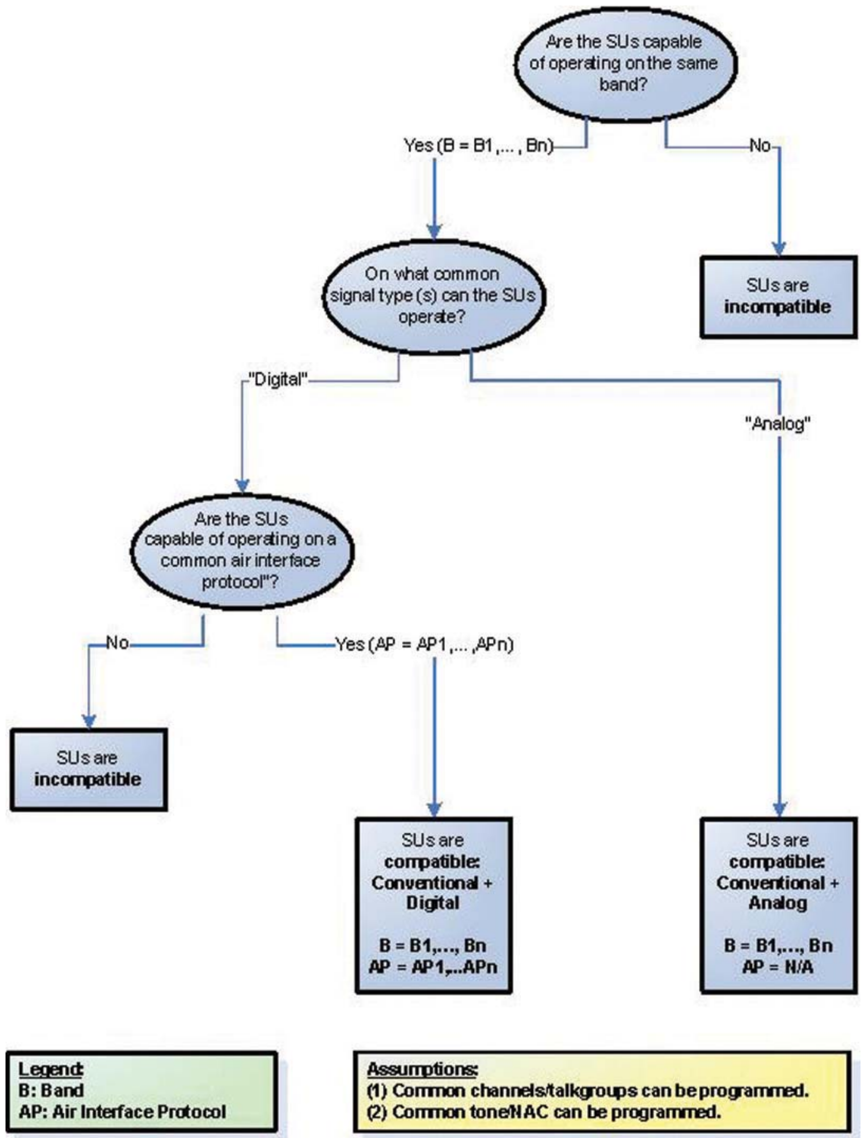
4 Public Safety Architecture Framework Volume III, October 2007 (in review at this writing).

5 Public Safety Architecture Framework Trial Report, January 2007. http://www.safecomprogram.gov/SAFECOM/library/technology/1305_publicsafety.htm

6 Public Safety Architecture Framework Pilot Report, August 2007 (in review at this writing).

for determining the compatibility between two LMR systems.

Understanding inter-system compatibility is useful in a variety of situations. Radio system architects, managers, and engineers can use the analysis output of the PSAF business rules to understand compatibility impediments among specific pieces of equipment, and develop appropriate, cost-effective solutions. PSAF business rules enable an agency to understand the degree to which each LMR system alternative it considers will interoperate with other systems in the agency's jurisdiction and in neighboring ones. Additionally, these business rules can be used to compare system upgrade alternatives. Finally, during large-scale incidents, first responder units traveling across jurisdictions can apply the business rules presented here to understand the degree to which their equipment will be compatible with that of the agencies in the hosting jurisdiction.



Subscriber unit to subscriber unit business rules.

Inter-system compatibility assessments focus solely on the Technology element of the SAFECOM Interoperability Continuum. This document assesses technical compatibility using three perspectives:

- Subscriber Unit to Subscriber Unit
- Subscriber Unit-to-system
- System-to-system

Using these three perspectives to identify system compatibility, various aspects of system compatibility can be researched. The subscriber unit to subscriber unit perspective identifies compatibility when the subscriber units are in "talk-around" mode, meaning they are not connected to a LMR system. The figure above shows the business rules for the subscriber unit to subscriber unit view. The subscriber unit to system perspective identifies subscriber units that are connected to a particular system, or are capable of operating on a LMR system. The system-to-system view identifies LMR systems that are compatible with each other and do not require a bridging device to achieve compatible communications.

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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.

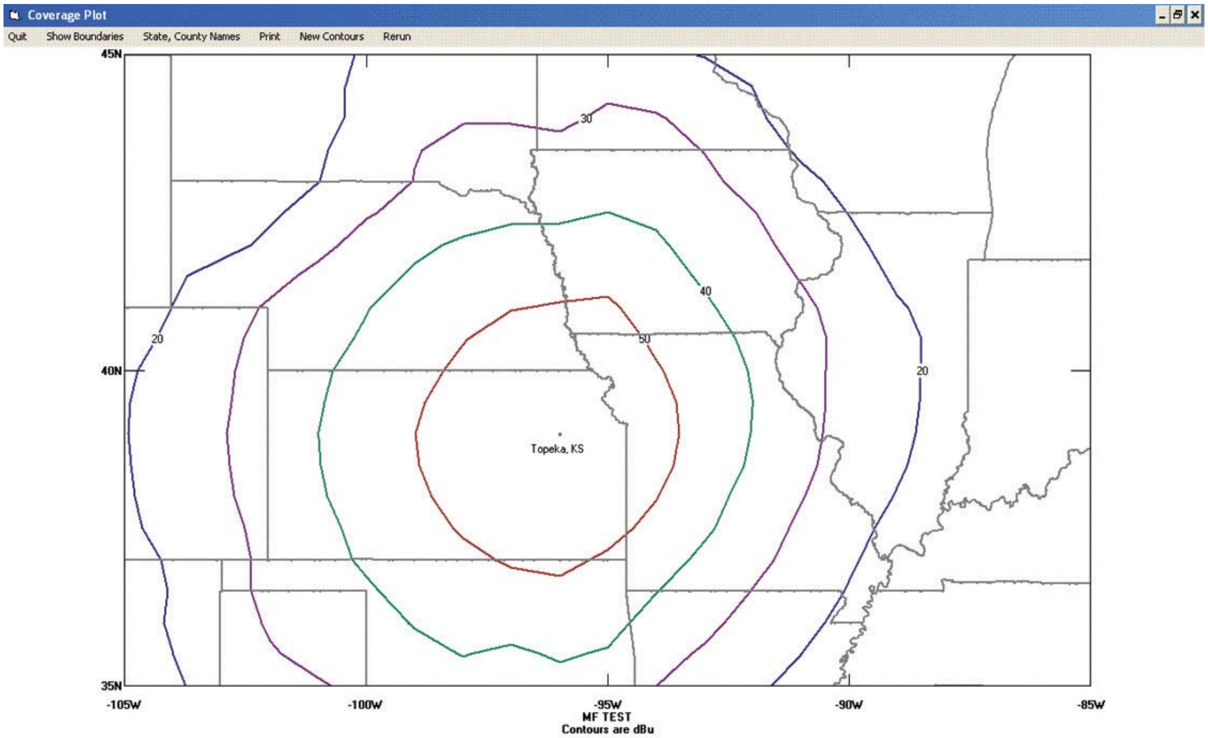
The Institute is performing an interference analysis of the High Accuracy Nationwide Differential Global Positioning System (HA-NDGPS) for the Federal Highway Administration (FHWA) of the U.S. Department of Transportation. The HA-NDGPS system can provide correction signals to the location provided by 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-NDGPS 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 Topeka, Kansas.

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.

Antenna modeling in this band is also unlike that in other bands, since the performance of an antenna on or near the Earth's surface is dependent on the interaction with the lossy Earth. Therefore, specific antenna algorithms have been included in the model that correctly launch the modeled ground wave at the horizon angle and the modeled 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 2007, most of the work effort was directed towards performing an interference analysis for the sites in the continental United States. The interference analysis has now been completed for approximately one-half of the sites. The interference analysis for the remainder of the sites is planned for completion in FY 2008.

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.

The figure above shows the coverage of one HA-NDGPS site, in Topeka, Kansas, at 488 kHz. The contours are electric field strength in dB microvolts per meter.

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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. 72-73) 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. An example of such a map is shown in Figure 1 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

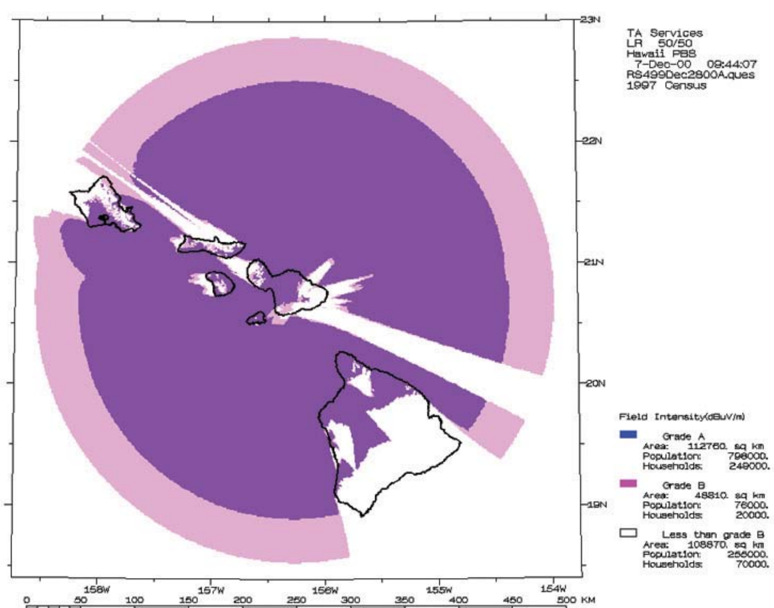

Figure 1. Sample output of the CSPM model of a TV transmitter located on Oahu in Hawaii.

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.

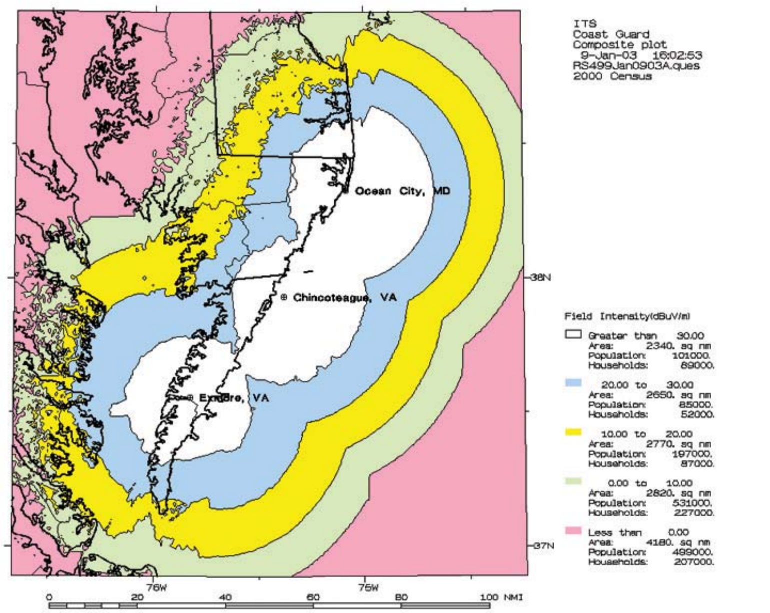

Figure 2. Composite coverage of several Coast Guard stations located in Virginia and Maryland.

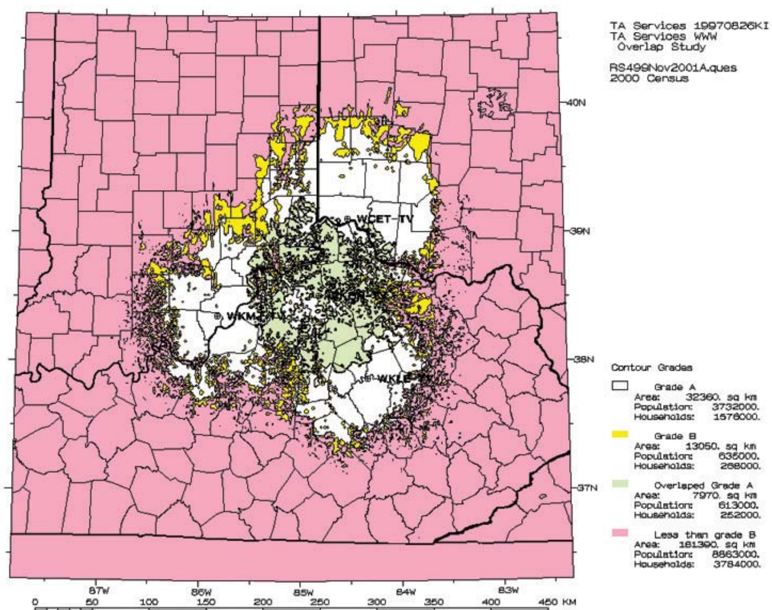

Figure 3. Overlap study of several TV stations located in Kentucky, Ohio, and Indiana.

ITS has begun the effort to upgrade the TA Services System to a new Geographic Information System (GIS) web-based interface that will place the power of state of the art GIS functions and features in the hands of TA Services customers.

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Geographic Information System (GIS) Applications

Outputs

- Propagation coverages (LF and MF, HF, and VHF frequencies) 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.

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 telecommunications infrastructure of the United States.

The primary GIS-based tool developed by ITS is the Communication Systems Planning Tool (CSPT-VHF). CSPT is a menu-driven propagation tool suite 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 New York. This coverage is shown in both 2D and 3D. CSPT allows the user to transition into 3D and fly through the environment. The CSPT-VHF tool also allows the user to create a simple 3D rendition of a building, including windows, doors, and interior walls, so that the tool can create coupled indoor/outdoor and outdoor/indoor coverages. Figure 2 shows an outdoor to indoor and an indoor to outdoor coverage of two buildings in New York.

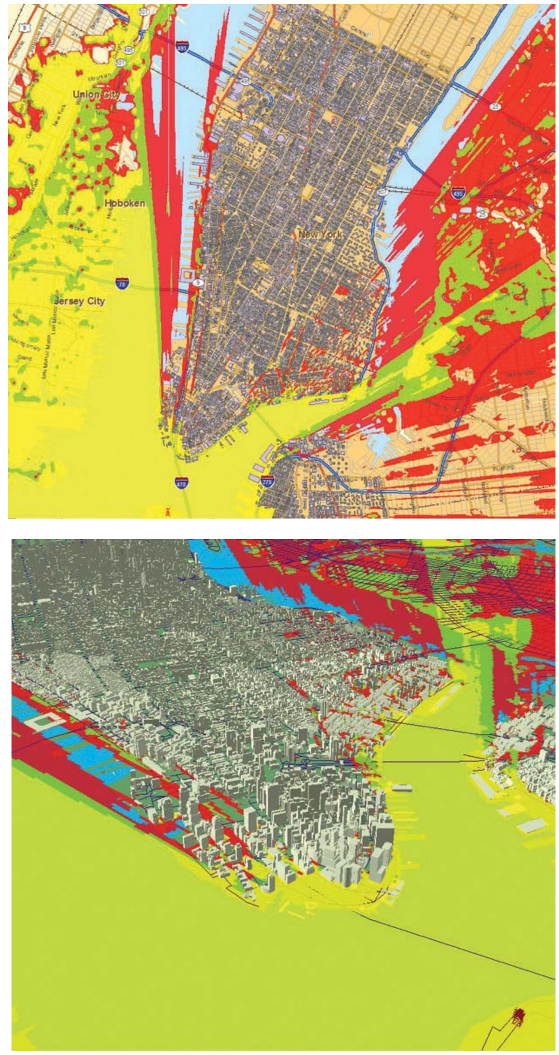

Figure 1. A CSPT-VHF study for New York showing both 2D (top) and 3D (bottom) results.

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 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 3.

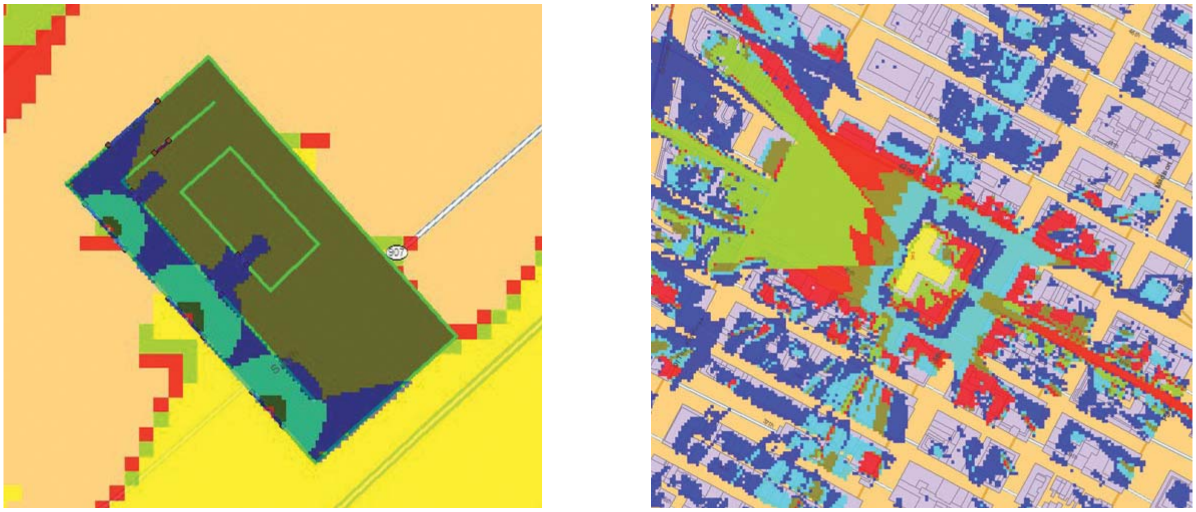

Figure 2. A CSPT-VHF Outdoor/Indoor (above left) and Indoor/Outdoor (above right) study in New York.

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 (see Figure 4).

The general flow of the CSPT GIS Tool is as follows. The user defines an area within which a study will be performed. This analysis area can be defined graphically by zooming into a map of the world or of 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.

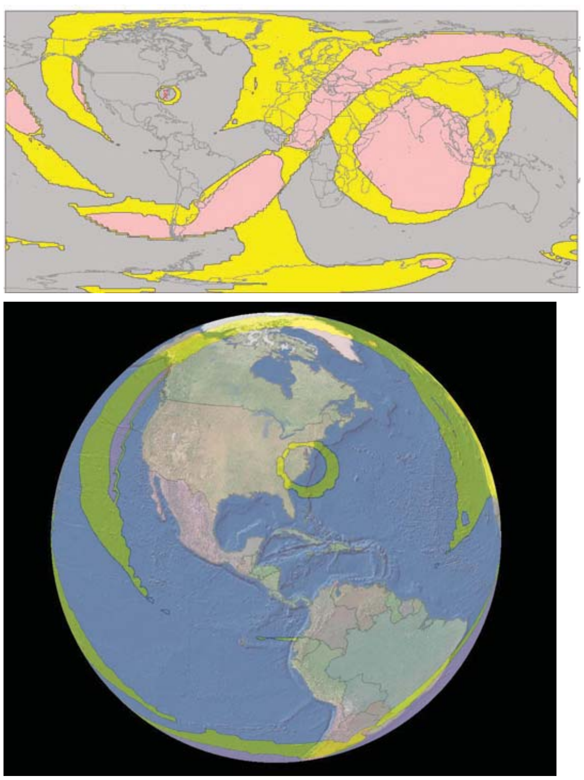

Figure 3. A CSPT-HF study for the entire earth showing both 2D (top) and 3D (bottom) results.

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.

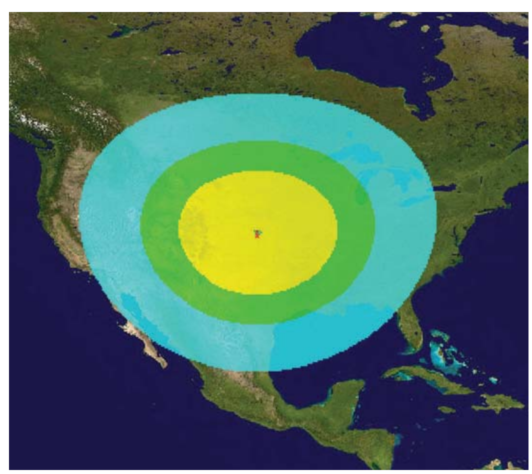

Figure 4. A CSPT-LFMF study for the central U.S.

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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 2007, the Broadband Wireless Standards project was focused on activities supporting the development of the new international standard for the detailed prediction method for terrestrial point-to-area propagation in the VHF and UHF bands, Recommendation ITU-R P.1812. This method was selected by members of the Subgroup 3K-1 Correspondence Group during meetings of a Special Workshop, held in early March, at ITS in Boulder, Colorado, in conjunction with ISART 2007. The method was approved for adoption by consensus at the April meetings of the ITU-R Working Party 3K and the meetings of the ITU-R Study Group 3, both of which were held in Geneva, Switzerland and, lastly, adopted by the Member States of the ITU through its adoption procedures, in November 2007.

The propagation prediction method given in the Recommendation is path-specific and globally applicable. Its intended uses are predictions of desired signal coverage and undesired signal interference for terrestrial point-to-area services in the VHF and UHF bands. Point-to-area predictions are accomplished by computing the basic transmission loss not exceeded (or the electric field strength exceeded) for a specified time percentage, p ($1\% \leq p \leq 50\%$), for many different point-to-point (i.e., point-to-multipoint) paths distributed over the area(s) of interest.

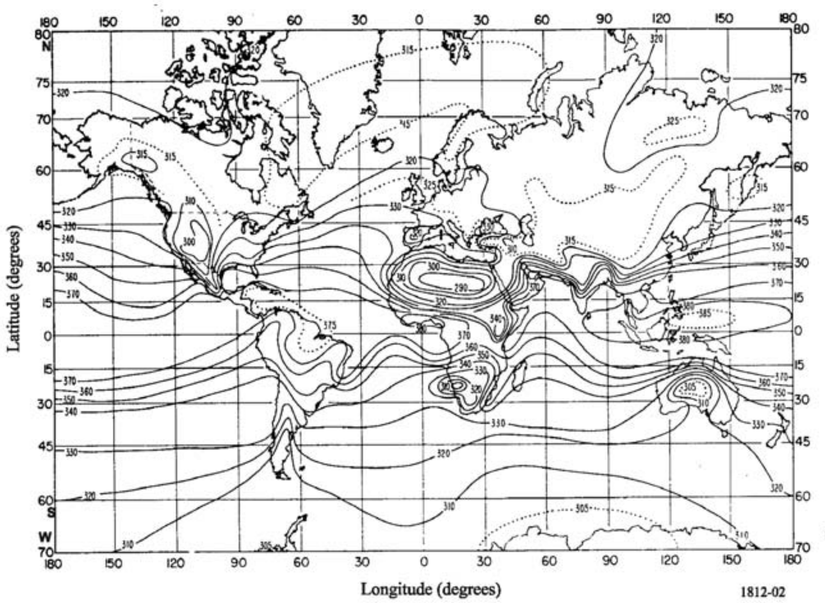
Although the need for this standardized prediction method was widely recognized and much of the groundwork had been accomplished by correspondence, the Boulder Special Workshop and an earlier Special Workshop (held prior to the ITU-R Working Party 3K meetings in Geneva in 2006) were essential to bringing the Recommendation forward for adoption in 2007. The close proximity in time of the ITU-R Working Party 3K and Study Group 3 meetings was to be followed by a long hiatus until their next meetings, due to the 2007 World Radio Conference. The timing of these meetings imposed the requirement that all decisions about the propagation model and the drafting of the recommendation be completed in a period of approximately 6 months.

Provided that consensus on the elements of the propagation model could be reached, the time interval between the March 2007 3K-1 Correspondence Group Special Workshop and the April 2007 ITU-R Working Party 3K meetings just made it possible for the Subgroup 3K-1 Correspondence Group Rapporteur to submit a Preliminary Draft New Recommendation (PDNR) as a contribution that could subsequently be approved by Working Party 3K as a completed Draft New Recommendation (DNR) which, in turn, could be contributed as an input to the meetings of Study Group 3, later in April, thereby beginning the international approval and adoption process. The Boulder Special Workshop was particularly important in meeting this aggressive timeline because a key outcome there was the hard-fought consensus agreement concerning the elements of the propagation model.

At the beginning of the Boulder Special Workshop, six different path-specific propagation models were still under consideration as candidates for the propagation prediction method. Three of the models could be loosely categorized as different variants of Recommendation ITU-R P.452, "Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth above about 0.7 GHz," separately proposed by the UK, the European Broadcasting Union (EBU) and China. Of the three remaining models, one was proposed by Switzerland, and 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). The results of a number of studies by participants of the 3K-1 Correspondence Group were presented at the Workshop. These studies, taken together, indicated that a combination of the UK and EBU models provided the most promising approach for further development of this Recommendation. However, it was also noted that further refinements of the height-gain in clutter and diffraction model elements, based on the Swiss, Chinese, and UK studies, was warranted. These will be addressed at the next Special Workshop, tentatively scheduled for March 2008. This understanding was the basis for the consensus agreement and made it possible to begin the drafting (i.e., writing by committee) of the PDNR. An ITS engineer served as the principal editor and distributor of the versions of the PDNR during the drafting process.

The Recommendation's propagation prediction method accounts for the following model elements (i.e., dominant propagation mechanisms):

- line-of-sight
- diffraction (embracing smooth-Earth, irregular terrain and sub-path cases)
- tropospheric scatter
- anomalous propagation (ducting and layer reflection/refraction)
- height-gain variation in clutter
- location variability
- building entry losses (where applicable).



Average annual values of sea-level surface refractivity, N_0, in N-units. This radio-meteorological data is required for the prediction procedure.

Given the frequency of operation, the terminals' electrical center heights above ground, the path center latitude and longitude, and the desired percentages of time and locations, these model elements' basic transmission losses are computed, based on examination of the great-circle path profile between terminals, certain path-specific radio-meteorological parameters and, if available, the land-use/land-clutter classifications along the path. (At a minimum, in addition to the input parameters given above, the sea-level surface refractivity (see figure above), the average refractive index lapse-rate through the lowest 1 km of the atmosphere and the path profile elevations, it is also necessary to identify the radio-climatic zones (i.e., coastal land, inland land, or sea as defined in the Recommendation) along the path profile. If any part of the path is over the sea, it is necessary to specify the terminals' distances to the coast in the direction of the opposite terminal.) Finally, the model elements' basic transmission losses are combined (or blended) together in order to yield an overall prediction of the path-specific basic transmission loss at the desired percentages of time and locations.

Activity in the Subgroup 3K-1 Correspondence Group continued through the remainder of FY 2007, to further refine and improve the Recommendation. In the short term, various authors' software implementations of the propagation prediction method are being tested and compared. In due course, it is anticipated that one of these implementations will be made available for distribution on the ITU-R's Study Group 3 website. Longer term activities are focusing on refinements/improvements to the diffraction and the height-gain in clutter model elements. These issues and others will be discussed at the Subgroup 3K-1 Correspondence Group Special Workshop tentatively scheduled for early March 2008 in London, England.

Other project activities include support for the ITU-R Coordination Committee for Vocabulary (CCV) and the ongoing activities of the ITU-R Working Parties 3J, 3K, 3L, and 3M. Four ITS engineers are working to support ongoing activities of the Working Parties. As part of the support for the CCV, an ITS engineer undertook a review of all of the recommendations maintained by Study Group 3 (P Series), to identify vocabulary and abbreviations used in the recommendations that required definitions. Approximately 1200 such items were identified. As part of the support for Working Party 3L, another ITS engineer is implementing revisions of the Recommendations ITU-R P.533 (Method for the Prediction of Performance on HF Circuits) and P.372 (Radio Noise).

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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 on these 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 propagation model is essential to meet the needs of the spectrum management and electromagnetic compatibility (EMC) analysis processes.

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. The 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 address the 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 was entirely 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 and measurement effort to develop and validate models in this parameter range.

In FY 2006, ITS conducted concept demonstrations of the measurement system using 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 Figures 1-3). In FY 2007, hardware and software was developed and integrated into the above system to investigate three additional frequencies (183 MHz, 915 MHz, and 1602 MHz) along with the four original frequencies (430 MHz, 1350 MHz, 2260 MHz, and 5750 MHz) used for the FY 2006 concept demonstrations. Because two of the new frequencies (183 MHz and 1602 MHz) are close to occupied bands, it became necessary to reduce the bandwidths of the transmitted and received signals to 4 MHz and 10 MHz, respectively, to reduce the possibility of causing or receiving interference. The bandwidths of the signals at the remaining frequencies, however, were kept at 20 MHz, in order to maintain the time resolution of the existing system.

Figure 1. Interior view of the ITS propagation measurement transmitter van (photograph by F.H. Sanders).

Figure 2. Interior view of the ITS propagation measurement receiver van (photograph by F.H. Sanders).

Because of space limitations within the vehicles (and on the roof of the receiver vehicle), it is currently infeasible to measure (i.e., transmit and receive) all seven frequencies simultaneously. Instead, a compromise measurement protocol is used, wherein the original four frequencies are measured (Tx/Rx Block 1) and then the "new" frequencies are measured, including repetition of the 5750 MHz signals (Tx/Rx Block 2). Repetition of the 5750 MHz measurements makes it possible to perform quantitative comparisons between results obtained with the two Tx/Rx blocks at different times. Experience has also shown that it is useful to measure the ambient signal environment with the system, particularly at 915 MHz. To achieve the full distance range with this system, receiver dynamic range limitations necessitate conducting drive tests with the transmitters operating at both high power (Pt < 10 W) and low power (Pt < 10 mW). However, for the low transmitter powers only a limited distance range is available and a full drive-test grid with the receiver van is not required.

ITS personnel performed measurements with this system in different environments, ranging from dense urban to rural, at various locations in the Denver-Boulder, Colorado, metroplex. In order to characterize radio propagation in each of the environments, typically several different transmit van locations or sites were chosen within the environment. These transmitted signals are then measured along the receive van's drive-test grid through this environment, effectively repeating the reception locations for each of the different transmit van sites. Reduction and analysis of the measurements is in progress, as are additional measurement sites/environments.

In parallel with the measurement effort, analytic model development efforts focused on refinement of radio wave diffraction models useful for understanding propagation in these environments. These models and additional models applicable to preliminary measurements seen in the dense urban environments will be further developed and applied in FY 2008.

Figure 3. 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).

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Major activities of the Telecommunications Theory Division (top to bottom): Calculation of interference effects; video quality lab; audio quality lab; electromagnetics calculations; propagation measurement equipment being prepared for field work (photographs by F.H. Sanders).

Telecommunications Theory

The world's telecommunications network of terrestrial and undersea cables, and terrestrial and satellite radio systems is undergoing explosive growth, in terms of both the build-out of hardware infrastructure and ever-increasing loading demands. Wireline and radio networks complement each other, but whereas wireline capacity can be expanded almost indefinitely, radio spectrum is a limited resource. In response to increasing demand for radio spectrum capacity, new technologies are being developed and implemented to use spectrum more efficiently and effectively. Also, the basic paradigm of radio spectrum management is moving away from traditional, top-down frequency-assignment methods and toward autonomous, interference-limited technologies. Historically rigid spectrum band allocations on a service-by-service basis are being supplanted by more sharing of radio bands by multiple services. The new sharing schemes emphasize new capabilities in radio systems to recognize and avoid interference. But to fulfill the promise of these interference-limited 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 in the presence of interference; the development of new propagation models for short-range mobile radio systems; the effects of noise and interference as critical limiting factors for advanced communication systems; automated tools for assessing audio and video quality; and the further development of advanced spectrum sharing concepts such as dynamic frequency selection.

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.

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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 the Channel on Radio System 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.

1.7-GHz Advanced Wireless Systems Compatibility Testing The Institute performed electromagnetic compatibility testing between newly developed advanced wireless systems (AWS) and Government communication systems. The goal of the testing was to determine the extent to which these two types of systems might be able to share spectrum at 1.7 GHz temporarily. This project was funded by NTIA.

Signal Characteristics, Spectrum Emissions, and Interference Analysis The Institute characterizes the effects of interference from radio transmitters to victim radio receivers. This work has become critically important as more emphasis is placed on radio band-sharing schemes in which services considered mutually incompatible are supposed to share spectrum on an interference-limited basis. 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. Audio and speech signals can be coded and transmitted at low bit-rates with good fidelity. Encoded signals can be packetized for transmission, thus allowing them to share network bandwidth or radio spectrum with other data streams.

Digital coding 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. More complex encoding schemes can generally encode a given signal into fewer bits. But when a signal is described by fewer bits, each bit is inherently more critical to the overall description of the signal. That is, the data stream is less robust to errors and losses. The trade-off between delay and robustness can be seen in the issues of 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 identifies, develops, and characterizes 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. Perhaps the most difficult of the five factors to characterize is quality. Thus a key component of our efforts is the development of more effective and efficient ways to characterize speech and audio quality. The ultimate result of these efforts would be better sounding, more reliable, more efficient telecommunications and broadcasting services.

In FY 2007 Program staff investigated the relationship between two speech quality estimation algorithms as part of a project aimed at the development of a unified speech quality scale. Staff applied software simulations of 62 different speech coding and transmission scenarios to 128 digital speech recordings resulting in a set of 7936 data points. Figure 1 shows the relationship between two speech quality scales for these data points graphically, and a mathematical relationship, described by the solid line, can be extracted. Some clustering of data points can be seen in Figure 1, which motivated further investigation. Staff then separated the data points into two classes according to the type of filtering applied

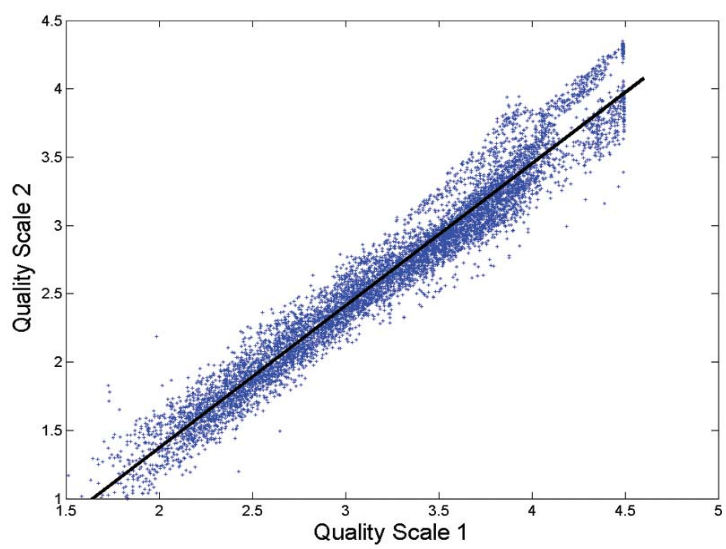

Figure 1. Graphical relationship between two speech quality scales for 7936 data points. Mathematical relationship is represented by the solid line.

to the speech signal. These two classes are displayed in two different colors in Figure 2. Here it is apparent that indeed, two separate mathematical relationships exist for the two classes. These relationships are described by the two broken lines in Figure 2. These results allow for a more refined and accurate approach to the unification of the two scales.

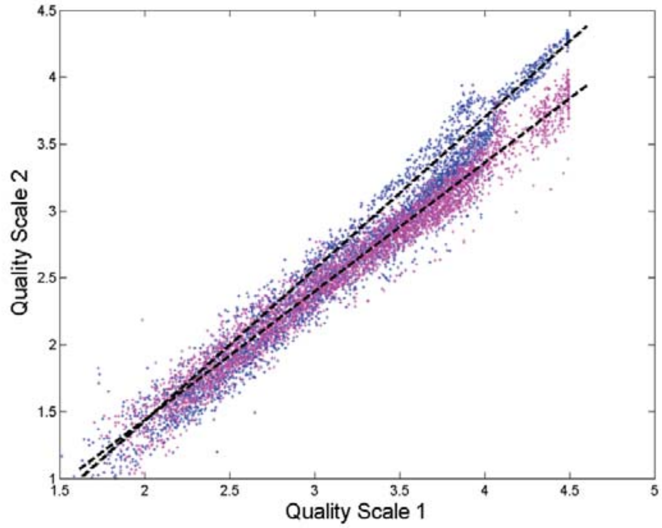

Figure 2. Data points of Figure 1 divided into two classes according to speech filtering. Now two separate mathematical relationships, represented by the broken lines, are evident.

Program staff carried out significant investigations aimed at high quality audio coding at reduced bit rates. The extreme in high quality coding is lossless coding, where a bit-exact copy of the original signal is reproduced at the decoder output. Staff considered numerous alternatives to the standard transformation-based and prediction-based algorithms. Staff also developed a scheme where multiple lossless layers can be transmitted, thus allowing an efficient decomposition and reconstruction of an audio signal into the lossless representations associated with multiple related sample rates. Staff also continued with prior work related to quantization — one of the key elements in many digital speech and audio processes. This work addresses increased efficiency in quantization as well as the reduction of quantization noise.

In response to a set of important open questions, project staff developed, implemented, and verified a new subjective testing protocol. Those questions concern the extent to which various speech communication links can convey or obscure the emotion in a talker's voice, and how one would one test a speech communication link for its ability to preserve emotion. Project staff created a set of speech recordings that contained both real and dramatized emotions and set out a protocol in which listeners heard these recordings through various speech communication links in a controlled and balanced way. Listeners had the task of detecting one of two emotional states in each recording. Listeners also participated in an additional protocol that tested word intelligibility in a sentence context. The detection results and the intelligibility results were then jointly analyzed in order to identify relationships that shed light on the questions above.

Throughout FY 2007, Program staff continued with significant speech quality testing using both objective and subjective techniques. These tests support both this program and other ITS programs. Numerous laboratory upgrades, including high resolution recording systems, were accomplished throughout the year. 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 and associate editor functions for technical journals and conference proceedings. Program staff supported telecommunications standards development through research efforts and technical exchanges. Program publications, technical information, and other program results are available at http://www.its.bldrdoc.gov/audio.

Recent Publication

S.D. Voran, "Lossless audio coding with bandwidth extension layers," in *Proc. 2007 Workshop on Applications of Signal Processing to Audio and Acoustics*, New Paltz, New York, Oct. 2007.

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Effects of the Channel on Radio System Performance

Outputs

- Interference susceptibility analysis.
- Translation of channel measurements directly to receiver performance metrics.
- Correlations between channel characteristics and receiver performance.

Telecommunications play a vital role in providing services deemed essential for modern life. Many of these services use radio links composed of a transmitter and receiver or *radio system* and the *channel* separating the two. The channel is often the primary impediment to fast and reliable radio system performance. Understanding the channel and the effects of the channel on radio system performance are crucial to the advancement and regulation of telecommunications. ITS has historically directed considerable research towards channel characterization. Currently, ITS is developing a radio link model with computer simulation to study the effects of the channel on radio system performance.

The channel degrades radio system performance by introducing multipath and undesired signals. Multipath filters the radio signal. The filtering is due to reflection, diffraction, and scattering propagation phenomena supported by the channel media which can be as diverse as the earth's ionosphere or an urban landscape. In sufficiently narrow bandwidths this filtering is simply attenuation. The addition of undesired signals obscures the radio signal. Undesired signals include information bearing signals from other radio systems (e.g., interfering signals), natural noise created by phenomena such as atmospheric lightning, and man-made noise created by electrical devices such as automobile ignition systems and power lines.

In the past several years, spectrum managers have been evaluating new spectrum management approaches such as ultrawideband modulation and dynamic frequency selection which allow new radio systems to share spectrum occupied by older, legacy radio systems. Advocates of these new spectrum management approaches often assume that signal processing algorithms in the legacy radio systems, such as error correction, will mitigate the effects of the undesired signal from the new radio system. Others maintain that the signal processing algorithms were designed to mitigate channel characteristics different than those created by the new systems and are unlikely to be effective.

ITS has applied its extensive experience in undesired signal characterization to this problem. In addition, it has developed hardware test beds with off-the-shelf legacy radio equipment from satellite digital television, global positioning satellite, and land mobile radio systems to measure interference

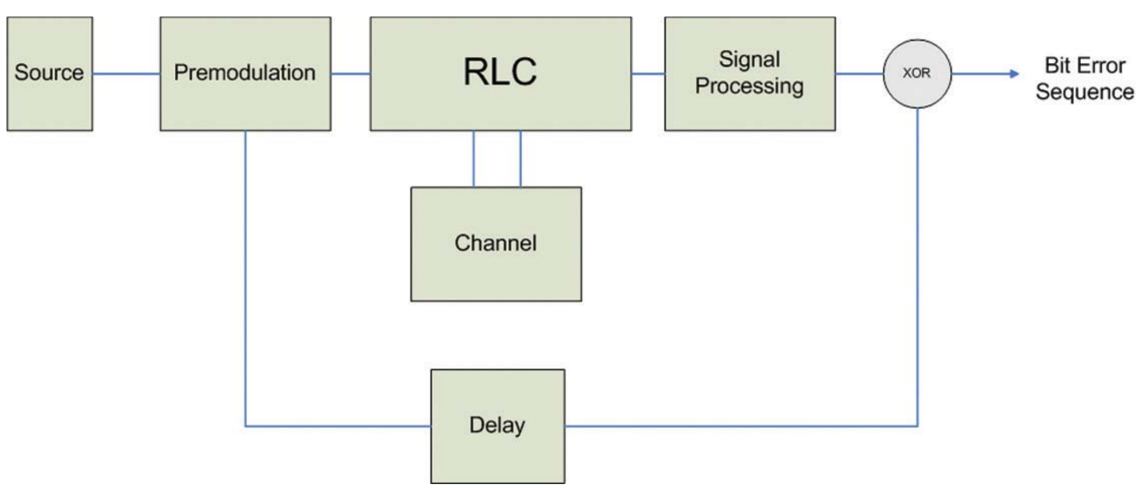

Figure 1. Radio link model with subsystems. The bit error sequence needed for receiver performance analysis is generated by comparing source bits to received bits with a logical exclusive-or (XOR) operation.

susceptibility. The tests were effective for evaluating end-to-end interference susceptibility. However, in many cases, signals within the receiver were difficult to acquire or entirely unavailable. Without these signals, it was difficult to fully evaluate the susceptibility of individual signal processing algorithms. The computer simulated radio link model was conceived to overcome this problem.

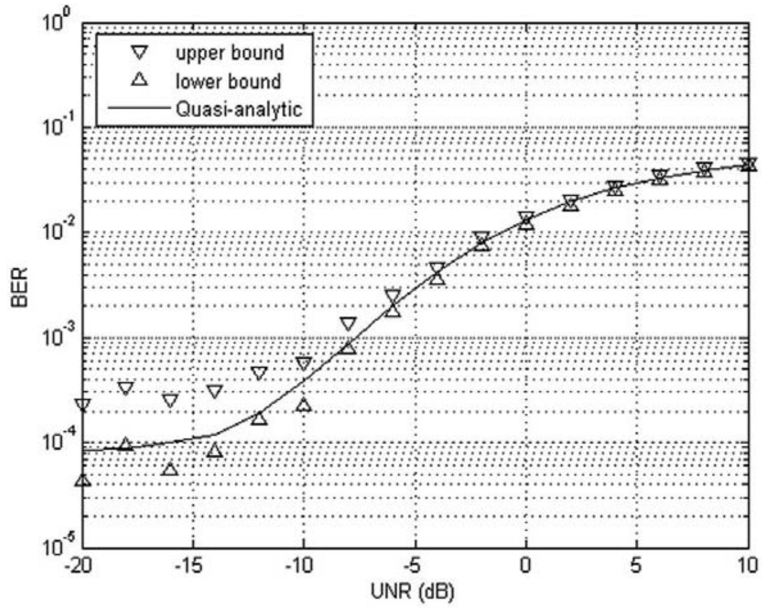

Figure 2. Upper and lower bounds of the simulated BER confidence interval are plotted with quasi-analytic BER for BPSK radio system using threshold detection and subjected to gated Gaussian noise.

The radio link model will also be used to translate new multipath and undesired signal measurements directly to receiver performance measures such as bit error rate (BER). ITS has recently performed an extensive set of mobile to mobile propagation measurements. Currently, ITS is preparing for new man-made noise measurements. Previously, these measurements were only reported in terms of parameters such as multipath root-mean-square delay spread or undesired signal mean and peak powers, which under certain conditions, can be used to estimate BER. The radio link model will allow engineers to translate these measurements directly to BER.

Conceptually, the model is built around a radio-link-core (RLC) to which various signal processing algorithms and channels are attached. The RLC, which includes the modulator and demodulator, must be highly characterized so its effects on signal processing algorithm test results are minimal. The effect of the channel on signal processing algorithm performance is evaluated by measuring BER over a range of channel model parameter values. More detailed evaluation is supported by its ability to collect various signals and sequences present while the receiver is performing poorly.

In FY 2007, the basic radio link model was designed, implemented in software, and validated. Validation compared simulated BER of a binary phase-shift keyed (BPSK) radio system using threshold detection to BER from a quasi-analytic model over a range of undesired signal power to receiver noise power (UNR) ratios. The quasi-analytic model efficiently computes BER from the first-order statistics of the undesired signal. Figure 2 shows such a comparison for a gated Gaussian-noise undesired signal. The BPSK radio system was operated at a signal to noise ratio (SNR) of 8.4 dB with a BER of 1.0e-4. The gated Gaussian noise had a 100 microsecond period with a 12.5 microsecond on time. The upper and lower bounds represent the confidence interval of the simulated BER for a 0.95 confidence level. Inclusion of the quasi-analytic BER in the simulated BER confidence interval indicates the results are statistically consistent.

In FY 2008, we will begin to test the effect of undesired signals on widely used signal processing algorithms. The signal processing algorithms will include Viterbi detection, least-mean-square equalization, and spread spectrum correlation. We are particularly interested in understanding the effect of gated Gaussian-noise on Viterbi detection. As part of this work we will investigate ways the quasi-analytic model and a hardware test bed based on a legacy satellite digital television equipment can be used to validate simulated Viterbi detection BER.

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1.7 GHz Advanced Wireless Systems Compatibility Testing

Outputs

- Measurements to determine effects of interference between proposed Advanced Wireless Systems devices and incumbent radio systems.
- Compatibility analysis between proposed devices and incumbent radio systems.

In May 2003, the Presidential Spectrum Policy Initiative brought forth a plan to improve efficiencies in radio spectrum use and provide incumbent systems greater protection from interference. A second goal of the policy is to promote timely integration of new, emerging technologies while preserving national security, public safety and scientific research. In April 2004, a Presidential Executive Memorandum demanded that affordable broadband access be made available to all Americans by 2007. Both of these memorandums paved the way for a spectrum auction in June 2006 for 90 MHz of radio spectrum for advanced wireless (including third generation or "3G") telecommunications services to meet the demand for new wireless services. The aforementioned 90 MHz of spectrum lies between 1710 to 1755 MHz and 2110 to 2155 MHz.

ITS was tasked by NTIA's Office of Spectrum Management (OSM) to examine the electromagnetic compatibility between new Advanced Wireless Services (AWS) devices and incumbent radio systems in the 1710 to 1755 MHz AWS band. The primary concern was whether incumbent systems would experience interference from new AWS devices, and if such potential existed, what the coordination distances and frequency separations would need to be to allow both types of systems to share the same band.

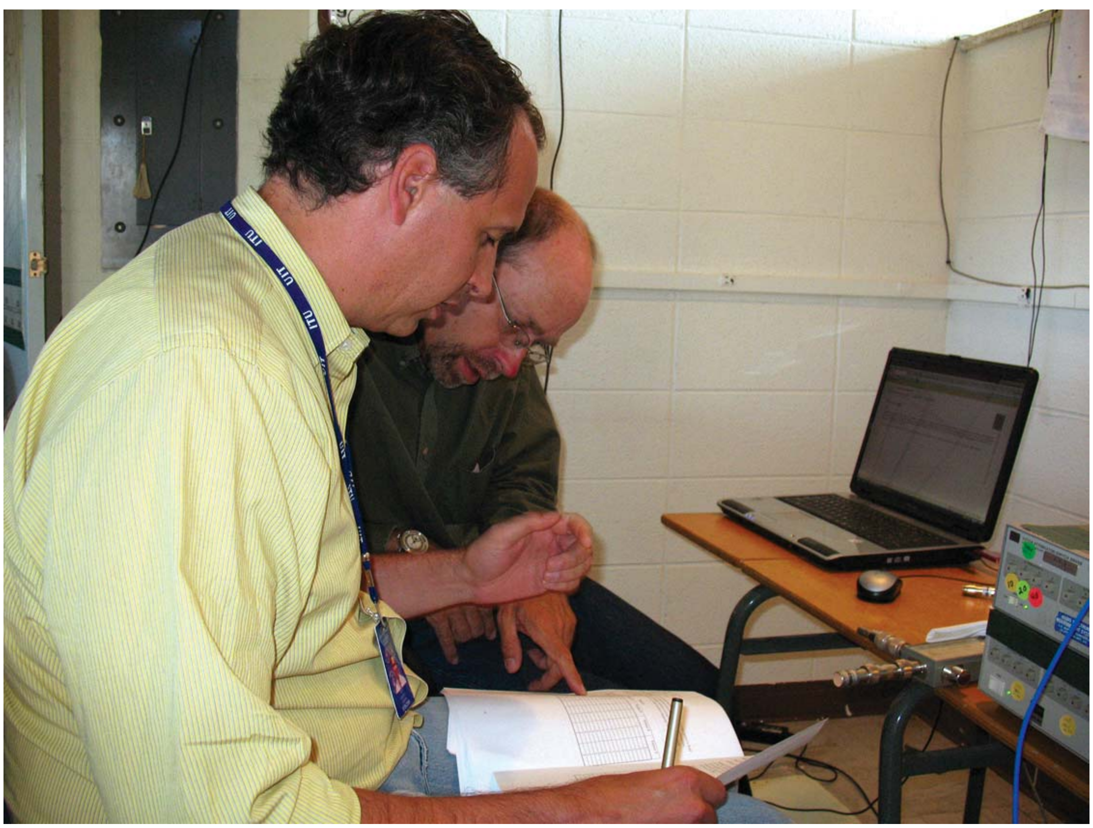

Figure 1. ITS and OSM engineers reviewing data collected during the AWS testing (photograph by J. Carroll).

Figure 2. AWS measurement participants examining the spectrum of a prototype wireless device (photograph by J. Carroll).

ITS and OSM jointly decided to perform a series of field measurements with both the incumbent systems and the new AWS devices, rather than attempting to model the problem and extrapolate the results. AWS vendors worked directly with ITS and OSM to develop a comprehensive test plan to facilitate a series of field measurements. AWS vendors supplied prototype Code Division Multiple Access (CDMA) based AWS devices. The incumbent users made available some examples of their existing communication devices. NTIA provided measurement hardware, test facilities and test and measurement personnel.

The approach to the testing was to couple interference signals from the CDMA devices into the communication systems of the incumbent users. The coupling was done via hardline connections, so as to ensure that the interference levels could be completely controlled. Interference was injected at carefully selected power levels and the effects of interference at each level were noted and recorded. Subsequently, the power levels at which interference effects occurred were converted into equivalent distances between the two classes of devices, so that electromagnetic compatibility studies could be completed. Interference mechanisms that were examined included: on-frequency interference, off-tuned interference and front-end overload in the victim receivers. Possible solutions, including filter-based solutions, were also examined.

The tests were performed at the ITS Table Mountain field site in August 2007 and lasted about a month. The results were collated, thoroughly analyzed by ITS and OSM engineers, and finally presented to all of the involved parties. The test data ultimately provided the key to determining how, and to what extent, this spectrum band can be shared during the transition between users.

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Signal Characteristics, Spectral Emissions, and Interference Analyses

Outputs

- Measurements and analyses showing susceptibility of a wide variety of radio systems to interference effects.
- Technical publications and presentations demonstrating research results.

Historically, radio spectrum bands have been allocated on a service-by-service basis. For example, one band might be assigned to land mobile radios while another would be assigned to radars. That paradigm is gradually changing to one in which multiple services share spectrum bands, even in cases in which such services have not been considered to be electromagnetically compatible. A case in point is the sharing of spectrum at 5 GHz between digital data links and radar systems. Sharing is often thought to provide more efficient use of spectrum, but it also means that radio systems must operate on an *interference-limited* basis. This tends to shift the onus of electromagnetic compatibility between radio services away from traditional spectrum band allocations and frequency assignments and replaces that approach with new engineering designs for entire radio services as well as individual radio systems.

This new emphasis on interference-limited spectrum sharing means that it has now become critical to understand the effects of interference from various types of transmitted signals when they are coupled into a wide variety of victim receivers. As part of its responsibilities as a Government telecommunications laboratory, ITS has undertaken multiple projects in recent years to assess, through direct tests and measurements and also through the development of complementary theoretical models and analyses, the thresholds at which various radio waveforms cause interference effects in a wide variety of radio receivers. These projects have been undertaken using the Institute's direct Government funding, as well as funding from sponsors in other Government agencies and the private sector. These studies have included: interference from ultrawideband (UWB) signals into radars, digital satellite television receivers, land mobile radios, and global positioning system (GPS) receivers; interference from radars into 5-GHz dedicated short range communication (DSRC) devices used in highway environments; interference from communication systems and digital data systems into radar receivers; and interference from radionavigation satellite signals (RNSS) into radars. In all of these studies, ITS has provided detailed technical reports describing the thresholds and manifestations of interference in victim receivers.

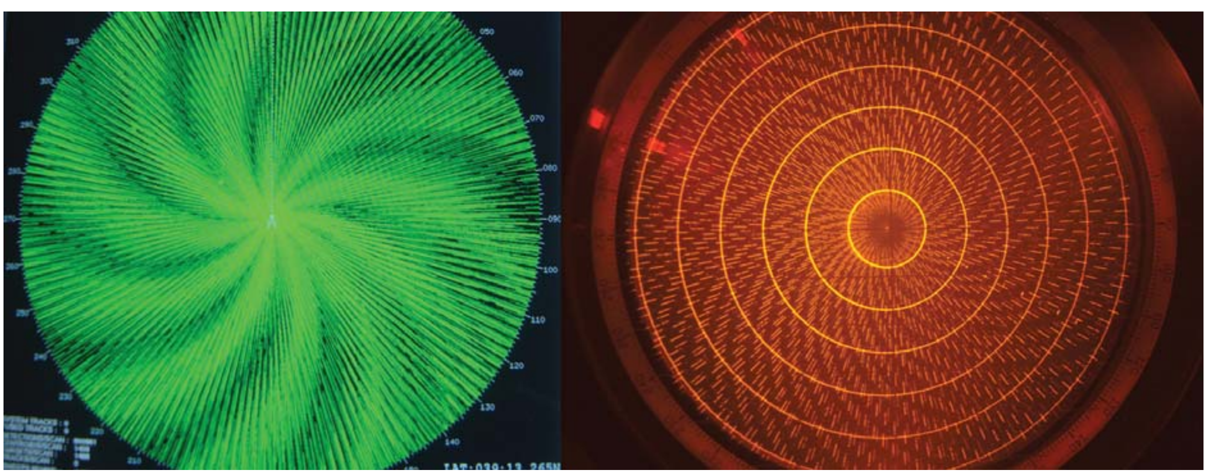

Figure 1. Air search radar display (left) and maritime surface search radar screen (right) with severe interference effects during ITS tests (photographs by F.H. Sanders.

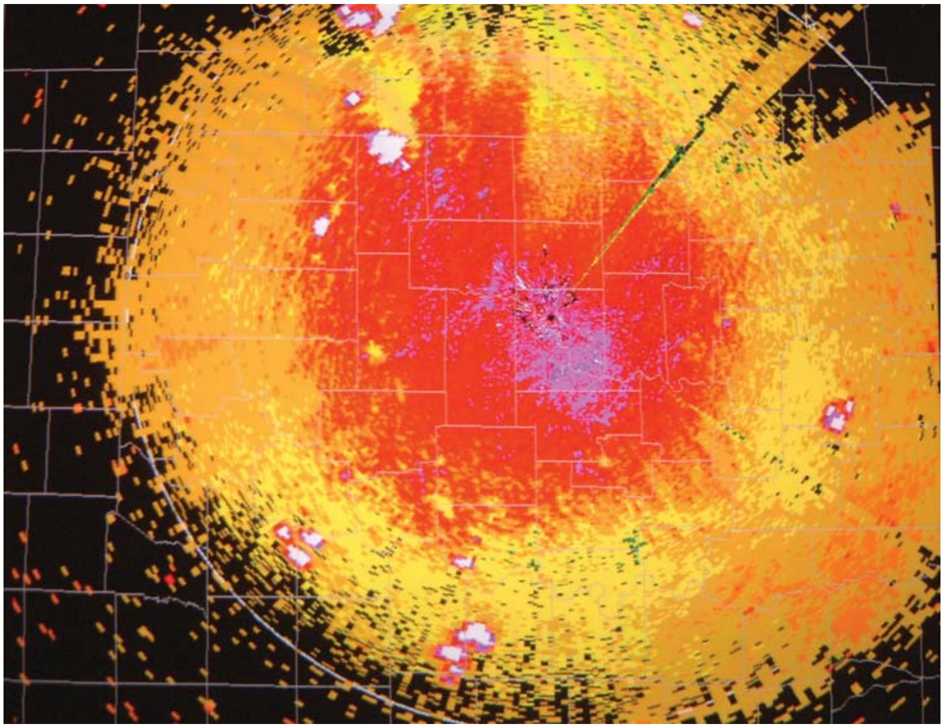

Figure 2. A weather radar display with interference effects at about 1:00 and 4:00 during ITS tests (photograph by F.H. Sanders).

Engineers from throughout the Institute are involved in these studies. The Institute is continually developing new methodologies for generating interference waveforms and testing the effects of the waveforms on victim receivers. The problem is complicated because, on the one hand, test and measurement data are needed to determine the effects of interference on receiver performance, while on the other hand, resource limitations make it impossible to perform hardware tests on all possible interference waveforms into all possible victim receivers. The approach that ITS is taking to solve this problem is to develop theoretical models of receiver performance in the presence of interference, and to validate and correct the models using strategically selected sets of tests and measurements on hardware-generated interference signals that are coupled into key types of victim receivers.

To cite some examples, UWB signals have been mathematically simulated, downloaded into a vector signal generator (VSG), and injected into a digital satellite television receiver. The receiver's performance has then been assessed as a function of the interference levels and pulse parameters. In another ongoing effort, wireless local area network (WLAN) signals have been recorded from actual WLAN transmitters using a vector signal analyzer (VSA) digitizer. The recorded waveforms are then downloaded into a VSG, and the VSG is used as a transmitter that injects WLAN interference into radar receivers.

Interference at high levels may produce easily observed effects that effectively terminate the successful operation of victim receivers, as shown in Figure 1. As devastating as these effects are, they at least are obvious to operators. At lower interference levels, however, the effects of interference may be much more subtle and thus more insidious; interference at these low (but important) levels is an ongoing area of research. Current work in this area includes the effects of interference from digital communication signals on both existing and evolving types of radar receivers and the effects of interference on software-simulated digital radio victim receivers.

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Video Quality Research

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 and maintains 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 the American National Standards Institute (ANSI) and the ITU.

Figure 1. SSCQE-HRR subjective rating device used for HDTV experiment (photograph by S. Wolf).

The first tool, called Command VQM (CVQM), provides a simple command line interface for processing (i.e., calibration and video quality measurements) a pair of video files that have been captured from the source and destination ends of a video transmission system. The second tool, called Batch VQM (BVQM), allows the user to perform Graphical User Interface (GUI) based batch mode processing of many captured video streams, or files. The third tool, called In-Service VQM (IVQM), requires two PCs, one located at the source end and the other located at the destination end of a video transmission system. The two PCs communicate their reduced reference features via the Internet, producing in-service end-to-end video quality monitoring results. Beginning in late FY 2007, source code and executable binaries of these tools were made available royalty free to all interested parties.

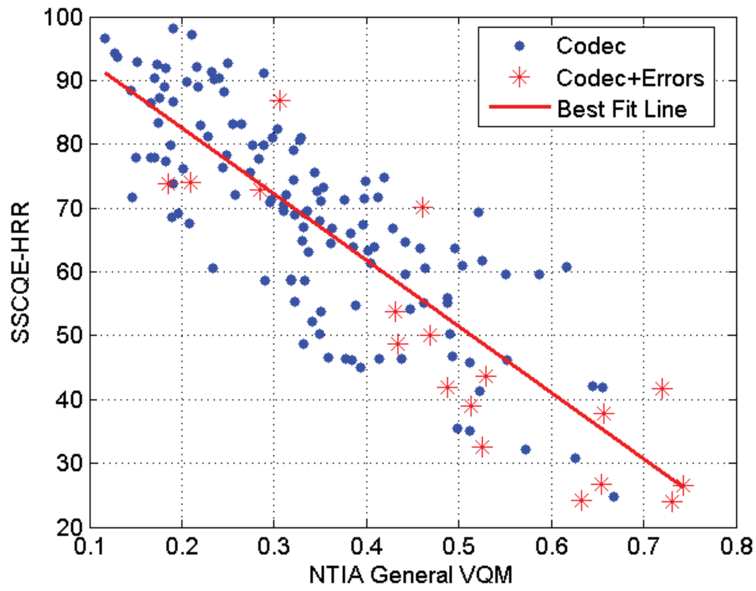

Figure 2. Subjective to objective correlation results for HDTV experiment.

Work is continuing on extending the measurement methodologies to High Definition TV (HDTV) systems. In FY 2007, results were analyzed and published from an experiment whose goal was to assess whether the NTIA General VQM (i.e., the metric standardized by ANSI and the ITU) is an acceptable objective metric for measuring HDTV quality. The HDTV subjective experiment that was performed to evaluate the NTIA General VQM contained sixty 30-second video clips that were rated using the Single Stimulus Continuous Quality Evaluation with Hidden Reference Removal (SSCQE-HRR) method. In the SSCQE-HRR method, viewers move a quality slider in real time (see Figure 1) to express their opinion of video quality. The 60 clips used in the experiment included twelve 1080i HDTV originals and 48 processed versions of these originals from 16 different video systems. The video systems included 5 different HDTV codecs (coder/decoders) running at bit rates from 2 to 19 Mbps and broadcast transmission errors (i.e., RF transmission with poor signal-to-noise-ratio). Excellent objective-to-subjective correlation results for this experiment (see Figure 2) demonstrate the potential application of the NTIA General VQM to HDTV quality monitoring. The graph in Figure 2 plots the slider samples at 10 second intervals versus the corresponding NTIA General VQM for the preceding 10 second interval.

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

Recent Publications

M.H. Pinson, S. Wolf, and R.B. Stafford, “Video performance requirements for tactical video applications,” in *Proc. IEEE Conference on Technologies for Homeland Security*, Woburn, Massachusetts, May 16-27, 2007.

S. Wolf and M.H. Pinson, “Application of the NTIA general video quality metric (VQM) to HDTV quality monitoring,” in *Proc. Third International Workshop on Video Processing and Quality Metrics for Consumer Electronics (VPQM-07)*, Scottsdale, Arizona, Jan. 25-26, 2007.

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Technology Transfer to Industry and Academia

Outputs

- Cooperative research and development agreements with private companies and universities to perform telecommunications research and/or to use the Table Mountain field site for telecommunications-related research.
- Licenses to companies, universities, and individuals to use the patented Video Quality Metric (VQM) software.

Technology transfer is the process by which existing knowledge, facilities, or capabilities developed under Federal research and development (R&D) funding are utilized to fulfill public and private needs. This definition was developed by the Federal Laboratory Consortium for Technology Transfer (FLC), a network of over 700 Federal laboratories including ITS, and the only government-wide forum for technology transfer. Organized in 1974, the FLC promotes and facilitates technical cooperation among Federal laboratories, industry, academia, and State and local governments.

ITS participates in technology transfer and commercialization efforts in a number of ways: through fostering cooperative telecommunications research with industry where benefits can directly facilitate U.S. competitiveness and market opportunities, through making the Table Mountain field site available for research by industry and academia, and also through distribution of our patented software.

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. Under this Act, an agency can implement a cooperative research and development agreement (CRADA) 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 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:

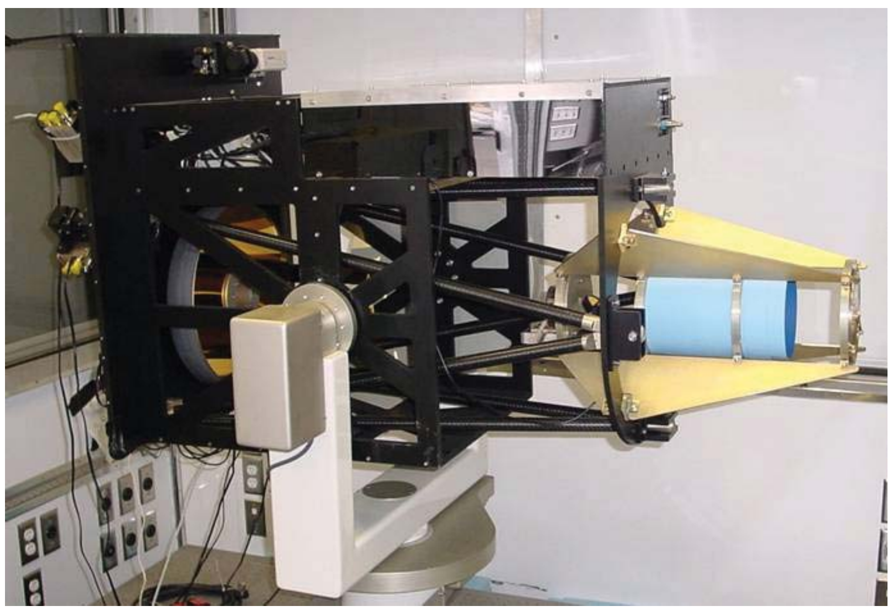
- American Automobile Manufacturers Association
- ARINC
- AudioLogic, Inc.
- Bell Atlantic Mobile Systems
- Bell South Enterprises
- Lockheed Martin/ Coherent Technologies
- East Carolina University's Brody School of Medicine
- Eton Corporation
- FirstRF Corporation
- General Electric Company
- GTE Laboratories 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 Corporation
- 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.

While ITS often participates in technology transfer through CRADAs that involve performing measurements for a private company (thus transferring the Institute's knowledge and expertise), another very common form of technology transfer utilized by ITS is to make the Table Mountain field site available for telecommunications-related research. Federal facilities such as Table Mountain often contain resources (or, as in this case, *are* resources) otherwise unavailable to the general public. Active Table Mountain CRADAs in FY 2007 and publications resulting from them are described on pp. 10-11.

Another major technology transfer mechanism is the use of intellectual property resulting from R&D activities at Federal laboratories. In the past, ITS has made its patented Video Quality Metric (VQM) software available to the public through royalty-based licenses. In an effort to make the software more widely available, in FY 2007 ITS decided to begin distributing the VQM software royalty free. Plans are now underway to put the VQM software into the public domain and thus achieve even wider distribution of this very popular software. Further details about VQM can be found on pp. 56-57.

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.



Lidar system used in the CRADA between Lockheed Martin/Coherent Technologies and ITS (photographs courtesy of LM/CT). LM/CT performed field-testing and characterization of components, subsystems, and systems for eyesafe coherent laser radar at the Table Mountain field site in FY 2007.

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 ITU-R Working Party 8B, the Radar Correspondence Group, and Joint Rapporteurs Group 1A-1C-8B, as well as Study Group 3 (see pp. 42-43).
- Measurements to determine the emission spectrum of an HF ocean-surveillance radar to support the U.S. Administration's position on tightening radar emission criteria for better spectrum efficiency.
- Measurements performed on the effects of interference from signals of radionavigation satellite systems (RNSS) on a long-range air surveillance radar.
- Presentations on the effects of interference in radar receivers for the International Symposium on Advanced Radio Technologies (ISART) in Boulder, Colorado; the Tri-Service Radar Symposium in Orlando, Florida; and the Defense Department Emerging Spectrum Technologies (EST) workshop in Herndon, Virginia.

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 health of the United States, both economically and otherwise. To achieve these goals, the U.S. Administration actively participates in the single 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 communication on a worldwide basis. 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.

Figure 1. Working Party 8B meeting in Geneva, June 2007 (photograph by F.H. Sanders).

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. An area of current debate is the introduction of WiMax systems into radar bands on a worldwide basis. Another area of technical interest is the impact of radionavigation satellite system (RNSS) signals on the performance of long-range air surveillance radars that use the same band.

Figure 2. Test team with a radar that was used in RNSS interference testing in support of the U.S. Administration in ITU-R WP8B (photograph courtesy of Lockheed Martin).

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 examined for electromagnetic compatibility with existing and future radars. To this end, ITS engineers in FY 2007 were leaders in an extensive, multi-agency effort to measure the effects of RNSS signals on a long-range air surveillance radar. Interference signals were injected into the radar receiver while targets were observed. At a variety of interference levels, the effects on target detection were observed. The results of that work have been prepared for submission to ITU-R Working Party 8B (recently re-designated 5B). More generally, interference test results have been used for U.S. Contributions in WP-8B, the Tri-Service Radar Symposium, the International Symposium on Advanced Radio Technologies (ISART), the Defense Department's Emerging Spectrum Technologies (EST) workshop, and NTIA Reports and Technical Memoranda.

To support the U.S. Administration's spectrum efficiency goals in FY 2007, ITS and OSM engineers measured emission spectra from an FM-pulse (chirped) HF ocean surveillance radar and submitted the results to Working Party 8B. 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.

Recent Publications

B. Bedford and F. Sanders, "Spectrum sharing and potential interference to radars," in "Proceedings of the International Symposium on Advanced Radio Technologies, Feb. 26-28, 2007," P. Raush and K. Davis, NTIA Special Publication SP-06-445, Feb. 2007.

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.

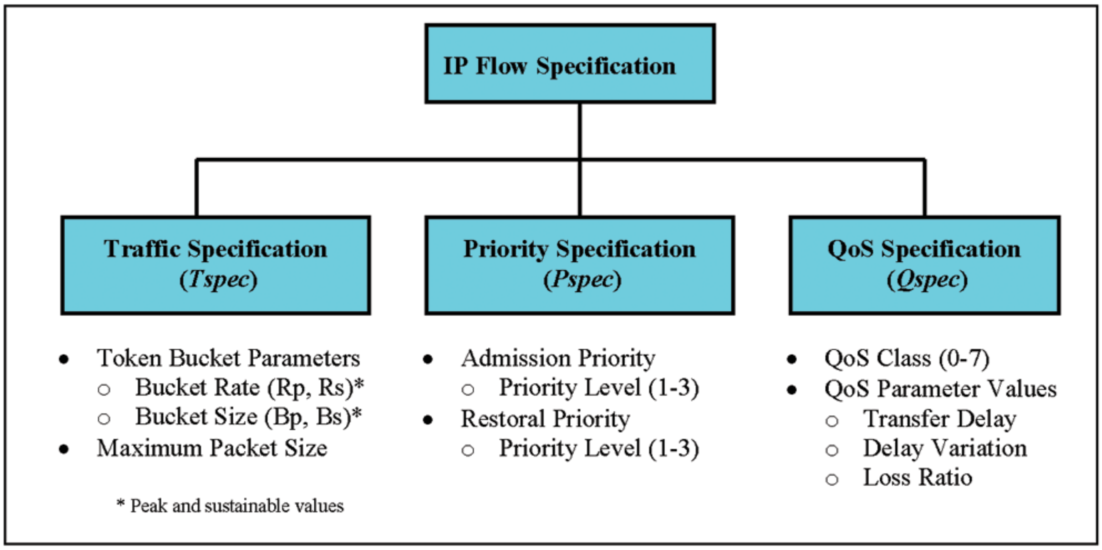
The Institute has a long history of leadership, technical contributions, and advocacy of U.S. Government and industry proposals in the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) and related U.S. standards organizations. ITU-T is a specialized agency of the United Nations, responsible for developing the international standards (Recommendations) that 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 2007, 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 (IPTV) — 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 Operation, 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 that emulate the human visual system. In related work, ITS 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. Institute staff members lead PRQC's QoS and Security Task Forces.

In FY 2007, Institute leaders contributed strongly to management of the Next Generation Network Global Standards Initiative (NGN-GSI), a SG 13-based standards development program that coordinates and accelerates NGN standardization across many ITU-T Study Groups. SG 13's NGN-GSI activities collectively involved over 1200 delegates and produced 21 new ITU-T Recommendations during FY 2007.

The Institute's PRQC leaders organized and managed six PRQC meetings during FY 2007. Among other outputs, the group produced a new American National Standard on availability metrics for transaction-based IP network services, a new ATIS Technical Report (TR) that describes how Emergency Telecommunications Service (ETS) will be given priority treatment in NGNs, a new TR that



IP flow specification parameters.

defines a method of estimating the overall availability of an IP network based on selected point-to-point availability samples, and the text for a new ITU-T Recommendation that defines service prioritization requirements for NGNs. PRQC also produced a new Draft Standard for Trial Use that specifies an algorithm for calibrating (aligning) transmitted and received video streams, enabling them to be accurately compared by objective video quality assessment methods. This calibration technique, which was developed at ITS under the Video Quality Research project (pp. 56-57), will be valuable to video service providers and equipment manufacturers in developing and implementing objective video quality measurements.

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 2007 the number of participants subscribed to this reflector grew to 600. ITS chaired two physical VQEG meetings in FY 2007. 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 2007. ITS is spearheading new ITU-T work on multimedia quality assessment through its leadership in VQEG and the JRG-MMQA.

ITS submitted two technical contributions to ITU-T SG 12 during FY 2007. The first provided complete text for a new Recommendation that defines speed, accuracy, and dependability parameters for call set-up in NGNs that employ the session initiation protocol (SIP) in establishing and terminating media sessions ("calls") between users. The second provided the core text for a new Recommendation that will define IP flow specification parameters (identified in the accompanying figure) and associated decision rules to coordinate NGN admission control, policing, and resources assignment in situations where independently-operated networks must cooperate in providing NGN services.

During FY 2007, the Institute's ITU-T leaders also contributed to the planning and conduct of an ITU-T/IEEE Joint Workshop on Carrier Class Ethernet. An ITS staff member organized and chaired a key workshop session (Ethernet QoS, Timing, and Synchronization) and arranged for the session results to be published in a forthcoming special issue of *IEEE Communications Magazine*. This initiative contributed to mutual understanding and cooperative action among standards groups based in IEEE 802.1 and 802.3 (Higher-layer LAN Protocols, Ethernet) and ITU-T SG 15 (Optical and Other Transport Network Infrastructures).

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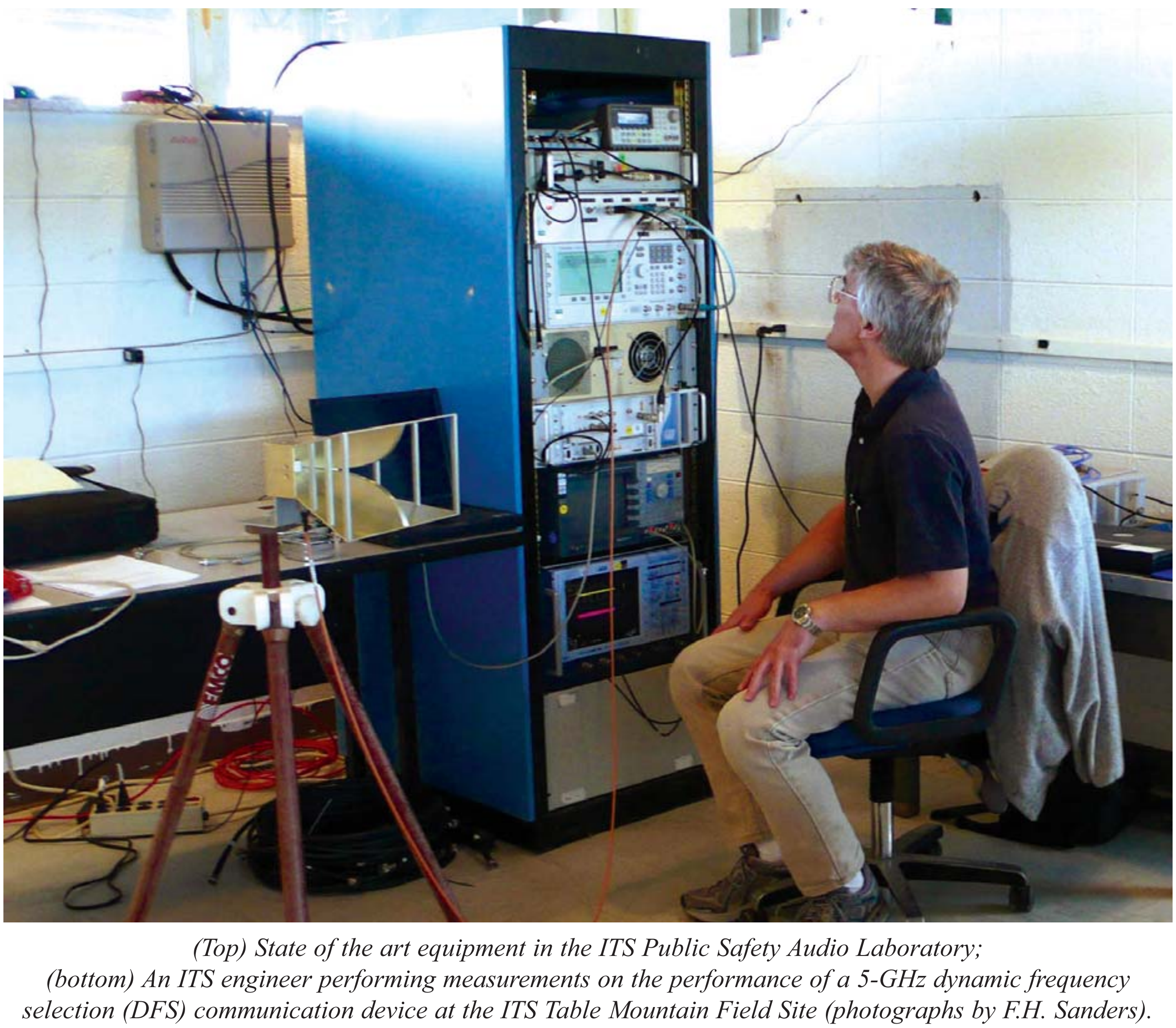

(Top) State of the art equipment in the ITS Public Safety Audio Laboratory; (bottom) An ITS engineer performing measurements on the performance of a 5-GHz dynamic frequency selection (DFS) communication device at the ITS Table Mountain Field Site (photographs by F.H. Sanders).

ITS Tools and Facilities

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 efficient and robust 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 the highest 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 recorders, digital audio tape machines, and CD players. These systems are augmented with several digital audio and video workstations and numerous top 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. Four systems offer the ability to record and play back uncompressed digital audio bit-streams together with synchronized uncompressed SD and HD video bit-streams that conform to ITU-R and SMPTE Recommendations (e.g., SMPTE 259M/272M, 292M). Much audio and video processing is performed on 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, 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. Laboratory staff contribute to the development of all three facets of compliance assessment as defined by the TIA TR-8 Mobile and Personal Private Radio Standards, i.e., performance, interoperability, and conformance, and use these test standards in the lab in support of internal research, outside agency (OA) and interagency agreements (IAAs) as well as cooperative research and development agreements (CRADAs) with other non-federal government entities.

In FY 2007, laboratory staff completed development of the Radio Performance Measurements automated testing software suite and presented the product to the program sponsors at NIST who distributed it to Project 25 (P25) manufacturers. The performance measurement capabilities included in the tool include the usual 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. This is just one of the laboratory's assets.

Interoperability tests are made possible through interactive testing using the laboratory's extensive cache of P25 radios and repeaters, while conformance assessments are accommodated by communications analyzers. The laboratory 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. Common air interface protocol logging and data capture are supported as well.

In FY 2008, the laboratory will be implementing the requirements of NIST Handbook 153 *Laboratory Recognition Process for Project 25 Compliance Assessment* in order to earn formal recognition as a Project 25 Compliance Assessment Program test facility. Additionally, engineering research is underway to develop a mechanism to characterize the effect of RF channel impairments on the comprehensibility of speech demodulated by P25 receivers.

The primary use for this capability is compliance assessment of P25 LMRs, but the underlying general purpose 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 radio channels. 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), transmits it at radio frequencies, receives the signal, down-converts and records it, and finally 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 mobile channels for frequencies up to 5.8 GHz. Historically, the DSCP was employed extensively to support development of analog and digital cellular communication services. ITS subsequently expanded the probe capability to eight channels capable of mobile phased array or multiple-input, multiple-output (MIMO) measurements. Also available is a wide-bandwidth probe, particularly suited for high-resolution measurements to support the deployment of such systems as wireless local area network (LANs) up to 30 GHz. The system is currently being used to support the development of a new, short-range mobile-to-mobile radio propagation model for frequencies ranging from VHF to SHF.

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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. 73). 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. 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 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 listing of ITS staff with contact information. Available at http://www.its.bldrdoc.gov/organization.php.

ITS home page: http://www.its.bldrdoc.gov

- 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 and continually develops a pair of measurement vehicles comprising a transmitter-receiver system that characterizes the properties of radio channels over a wide frequency range, from VHF to 30 GHz. The transmitter vehicle has an on-board generator, a pair of telescoping masts, and a set of radio modulators and transmitters. The receiver van is equipped with on-board power, a telescoping mast, azimuth and elevation controllers, and global positioning system (GPS) devices with a dead-reckoning backup. A suite of measurement equipment, much of it designed and hand-built by ITS engineers, is used in the vehicle. These include wideband systems for measuring radio channel impulse responses; impulse response measurement capability at 30 GHz with 2-ns resolution is enhanced with a digital wideband recording system. To support mobile-to-mobile short-range propagation model development, an 8-channel receiver and an 8-channel, 14-bit data acquisition system have been developed. Multi-channel synchronous acquisition can be used for antenna array measurements and multi-frequency broadband measurements. Mobile measurement capability allows space division multiple access (SDMA) algorithms to be implemented using data collected in a wide variety of environments (e.g., urban, rural, and suburban). This data can in turn be used to model and simulate the performance of radio systems in such environments. A suite of analysis software is continuously developed and maintained for calculating mobile propagation metrics from 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 & Video Laboratories

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) and Public Safety Video Laboratory (PSVL) are facilities for investigating the voice and video quality of public safety communication systems in harsh environments. The PSAL 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 PSVL consists of cameras, video capture systems, video coding and decoding systems, network simulators, video editing stations, and props.

An engineering intern at work in the Public Safety Video Laboratory (photograph by F.H. Sanders).

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 more specialized equipment in the PSAL includes the two HATS systems. 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.

The PSAL system provides 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.

The primary role of the PSVL is to support the PSVQ project (see pp. 32-33). In accomplishing this mission, scenes that contain selected vital elements of public safety responder uses are created and filmed on high-definition cameras. These scenes include simulations of surveillance cameras (indoor and outdoor), in-car police cameras, and search and rescue robot cameras, among others. The video is then captured and edited on the PSVL workstations. Selected scenes are processed through controlled versions of the communication systems that might be typical of what a jurisdiction may consider purchasing. The communication systems processing includes compression schemes and simulated wired and wireless networks.

To determine if a system is adequate for use in specified applications, first responders view the video and attempt to perform certain tasks such as identifying an object or reading a license plate. The results of these tests provide data for developing recommendations.

Together, the PSAL and PSVL provide valuable insight into the requirements for public safety audio and video 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 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 on 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 in the field, and they can be mobile or stationary; 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 4th generation 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 can result 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 actual or 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. This includes situations such as laboratory investigations of possible interference from ship or aircraft-mounted radars or communication systems. In these sorts of situations a system is needed that simulates the spectral emissions of other devices with a wide range of latitude and fidelity. An example of these needs 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 would be to determine the ability of dynamic frequency selection (DFS) wireless communication devices to detect various types of radar energy without actually obtaining access to a wide variety of real radars for tests.

Sign at the west entrance to the Table Mountain field site (photograph by J.D. Ewan).

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 has used 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 that ITS uses for generating interference is to utilize high-speed digitizers, called vector signal analyzers (VSAs) to record interference waveforms in bandwidths up to 36 MHz, and to then either 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 the requisite mathematical information to create particular waveform modulations, 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 using VSGs to generate interference 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.

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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 agencies currently using the facilities include the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS).

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A denizen of the Table Mountain field site (photograph by F.H. Sanders).

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. 40-41). 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.
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 2007

NTIA S&E Projects

Audio Quality Research
Develop and evaluate new techniques for encoding and decoding speech signals. Provide algorithms, software, and technical expertise to other ITS programs. Provide technical presentations and laboratory demonstrations as requested.
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
Provide leadership and technical support to committees (e.g., ITU-R, TIA TR-8) developing broadband wireless communications standards that affect Federal agencies' use of the services. Continue model enhancement by addressing path-specific propagation prediction models.
Project Leader: Paul M. McKenna (303) 497-3474
e-mail pmckenna@its.bldrdoc.gov

Effects of the Channel on Radio Systems
Identify, model, and characterize a small number of radio systems and use these to predict the effects of the channel on others. Use the results to predict how interference introduced by new spectrum engineering methods impacts legacy systems.
Project Leader: Robert J. Achatz (303) 497-3498
e-mail rachatz@its.bldrdoc.gov

Network Interoperability
Conduct research in multimedia quality research, enterprise architecture planning, and various methodologies that exist in developing and documenting interoperable architectures. Participate in Project 25/TIA TR-8 and other standards organizations (e.g., VQEG, ATIS, IETF). Investigate multimedia applications and undertake research to establish baseline interoperability for multimedia applications.
Project Leader: Arthur A. Webster (303) 497-3567
e-mail awebster@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
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). Develop network-based measurement methods for Voice over IP (VoIP) quality.
Project Leader: DJ Atkinson (303) 497-5281
e-mail datkinson@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
Support RSMS operations through the development and maintenance of software, hardware, systems, and equipment for FY 2007 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. Continue to develop all existing instrument Dynamic Link Libraries (DLLs) and build upon the collection.
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
Maintain and upgrade the Table Mountain Field Site infrastructure, ensure a safe working environment there, and provide logistical support for research activities at the field site.
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/emergency) 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 and high definition video quality measurement algorithms and software. Transfer the technology to agencies, standards bodies, and the U.S. telecom 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 that should be used in analyses to determine EMC between antennas using the same radiocommunication service or operating in 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 on Interference Rejection
Determine the feasibility of using a commercially available computer capability to simulate the signal processing for a range of different error correction schemes. Implement this capability to evaluate the performance of a radio system subjected to signals from other radio links.
Project Leader: Robert J. Achatz (303) 497-3498
e-mail rachatz@its.bldrdoc.gov

Examination of Short-Range, Low-Height Propagation Prediction Model
As part of a multi-year effort to address the need for an under-1 km propagation prediction model, continue looking at this specific scenario and its unique environmental influences. Continue model development and a field measurement campaign to verify and validate those models. Bring the results of the project to the ITU-R and IEEE, as appropriate.
Project Leader: Paul M. McKenna (303) 497-3474
e-mail pmckenna@its.bldrdoc.gov

Initial Spectrum Testbed and Antenna Harmonic Characterization
Perform technical planning and analyses on the spectrum testbed effort, and provide those outputs for Working Level Group E (WLG-E). Also perform measurements of the electrical characteristics and beam-forming properties of a variety of antennas at their harmonic frequencies.
Project Leader: Michael Cotton (303) 497-7346
e-mail mcotton@its.bldrdoc.gov

Methodology for Statistical Combinations of Noise and Interference
Develop guidance/guidelines as to when an interfering signal that is combined with a noise signal can be considered "noise-like." Document the guidance and guidelines in a technical memorandum that will be incorporated into the Best Practices Handbook.
Project Leader: Michael Cotton (303) 497-7346
e-mail mcotton@its.bldrdoc.gov

Radar Support Tasking
Support USWP8B, USJRG, and the U.S. Administration's positions in ITU-R WP8B and JRG 1A-1C-8B by providing position papers, technical reports, and attendance in these forums. Also support the Radar Correspondence Group (RCG) and the JRG 1A-1C-8B and RCG websites.
Project Leader: Frank H. Sanders (303) 497-7600
e-mail fsanders@its.bldrdoc.gov

Spectrum Efficiency of the Radiodetermination Service
With OSM, develop a report on the basic parameters and trade-offs to consider in an analysis of spectrum efficiency of the radiodetermination service, and provide example calculations of spectrum efficiency for some simple radars. Develop an analytical approach to radar spectrum efficiency in general.
Project Leader: Frank H. Sanders (303) 497-7600
e-mail fsanders@its.bldrdoc.gov

Wind Turbine Interference Assessment
Provide an independent, objective assessment of the effects of wind turbines on air traffic control radar operations. Suggest methods for mitigating any harmful effects. Review a study by the British Ministry of Defence on Air Defence and Air Traffic Control radar systems to determine if the conclusions are relevant to FAA radar systems.
Project Leader: Frank H. Sanders (303) 497-7600
e-mail fsanders@its.bldrdoc.gov

Other Agency Projects

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

Public Safety Telecommunications Interoperability
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 video quality tests to assist public safety agencies with telecommunications systems and equipment selections. Gather information on these technologies and applications relevant to, and useful in, applications in NS/EP environments.
Project Leader: Dr. Carolyn Ford (303) 497-3728
e-mail cford@its.bldrdoc.gov

Department of Commerce / National Oceanic and Atmospheric Administration / NOAA Weather Radio Program Office

NOAA Weather Radio Receiver Tests
Compile the characteristics and responses of NWR receivers to various simulated NWR transmissions, under the same conditions as in a previous study.
Project Leader: Raian F. Kaiser (303) 497-5491
e-mail rkaiser@its.bldrdoc.gov

Department of Defense

Enhancements to Communication System Planning Tool (CSPT) for DOD
Enhance the ITS CSPT model through improvements in the incorporated models and addition of models, as well as user support.
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. Gather information on the technologies for 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 engineering support to FPIC for public safety radio standards development and testing in the ITS test facility. 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

ETS Standards Development
Facilitate the standardization of NS/EP specifications, protocols, and mechanisms. Develop and/or verify emergency telecommunications service (ETS) mechanisms. Assist NCS in support of PDD-63 and associated CIP initiatives.
Project Leader: Arthur A. Webster (303) 497-3567
e-mail awebster@its.bldrdoc.gov

Department of Homeland Security / Office of the CIO

Standardization of Measurement Methods for Investigative Devices
Provide engineering and technical support to the OCIO Wireless Management Office for development of standardized measurement methods of investigative devices. Conduct measurements on new and/or proposed investigative devices defined by DHS.
Project Leader: DJ Atkinson (303) 497-5281
e-mail datkinson@its.bldrdoc.gov

Federal Highway Administration

ITS EMC for HA-NDGPS
Perform interference analysis for the High Accuracy Nationwide Differential GPS (HA-NDGPS) system to ensure compatibility with existing systems and sufficient spectrum. Determine locations and characteristics of 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 Association of American Railroads' (AAR) Wireless Communications Committee (WCC).
Project Leader: John M. Vanderau (303) 497-3506
e-mail jvanderau@its.bldrdoc.gov

Various Federal & Non Federal Agencies

Telecommunications Analysis Services
Develop, maintain, and make available to other Agencies, and the public, engineering models, scientific and informative databases, and other tools.
Project Leader: Robert O. DeBolt (303) 497-5324
e-mail rdebolt@its.bldrdoc.gov

Cooperative Research and Development Agreements (CRADAs)

First RF Corporation

Installed Performance of Antennas
Support First RF in testing antenna system performance on a number of vehicles including UAVs, using the turntable facility at the Table Mountain Field Site.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

Lockheed Martin Coherent Technologies

Laser Testing at Table Mountain
Support Lockheed Martin Coherent Technologies' tests at the Table Mountain Field Site to demonstrate test readiness of customer-sponsored eyesafe laser radar sensor systems.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

RF Metrics

A Study of the Use of a Novel Antenna Pattern Collection Technique for Radar Emissions
Support RF Metrics' attempts to measure a radar system using the test procedures outlined in the ITU-R M-1177 standard and measure the antenna pattern using the technique described in NTIA Report TR-06-436.
Project Leader: J. Wayde Allen (303) 497-5871
e-mail wallen@its.bldrdoc.gov

University of Colorado

Ad hoc UAV Ground Network Test Bed
Support CU's experiments 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

ITS Publications and Presentations in FY 2007

NTIA Publications

N. DeMinco, "Propagation loss prediction considerations for close-in distances and low-antenna height applications," NTIA Report TR-07-449, Jul. 2007.

An investigation of different propagation modeling methods to meet the special requirements of a short-range propagation model with low antenna heights was performed, and has resulted in the development of approaches to be taken to accurately model radio-wave propagation loss for these types of scenarios. The basic requirements for the Short-Range Mobile-to-Mobile Propagation Model include: separation distances between the transmitter and receiver from one meter to two kilometers, a frequency range of 150 MHz to 3000 MHz, and antenna heights of one to three meters for both transmitter and receiver sites. It is necessary to develop alternative methods for accurate predictions of propagation loss to provide a propagation model that will simultaneously meet all of these requirements. This will require special considerations that currently available models do not include in their methods of analysis. Several analytical approaches were investigated to develop propagation loss prediction methods that take all of these considerations into account. Analysis efforts have determined that the development of this model will require the use of mutual-coupling predictions and should also include the effects of the surface wave. Conventional far-field antenna patterns and gain of the antennas may also not be valid at close separation distances, since one antenna may not be in the far field of the other antenna. Analysis efforts have also determined that these issues and effects become more significant for the lower frequencies (900 MHz and below). For low antenna heights the effects of the close proximity between the Earth and the antenna produce a strong interaction between the antenna and the ground. The antenna pattern performance is vastly different than if the antenna were in free space.

J.R. Hoffman, R.J. Matheson, and R.A. Dalke, "Measurements to characterize land mobile channel occupancy for federal bands 162-174 MHz and 406-420 MHz in the Washington, D.C., area," NTIA Report TR-07-448, Jul. 2007.

This report describes field measurements to characterize Land Mobile Radio (LMR) channel occupancy of Federal bands 162–174 MHz and 406–420 MHz at a single central location in the Washington, D.C., area. This is part of the National Telecommunications and Information Administration effort to evaluate the spectrum efficiency in the Federal frequency bands. Measurements of the received signal levels in LMR frequency bands 162–174 MHz and 406–420 MHz were performed over an eight day period for the purpose of determining channel usage within the measurement system's coverage area of approximately 100-km radius for base stations, 50-km radius for mobile units, and 25-km radius for portable units. The measurements were made using new equipment and techniques that digitize as much as a 5-MHz segment of spectrum and process it to obtain simultaneous signal levels of up to 400 individual LMR channels. These techniques provided faster measurements, but also allowed enhanced postprocessing of the data to remove effects of impulsive noise.

P.J. Raush and K.E. Davis (Eds.), "Proceedings of the International Symposium on Advanced Radio Technologies, February 26-28, 2007," NTIA Special Publication SP-06-445, Feb. 2007.

No abstract available.

Outside Publications

Articles in Conference Proceedings

R.J. Achatz, "An overview of the Institute's role in determining effects of the radio channel on radio system performance," in "Proceedings of the International Symposium on Advanced Radio Technologies: February 26-28, 2007," P.J. Raush and K.E. Davis, Eds., NTIA Special Publication SP-07-445, Feb. 2007, pp. 94-99.

> This paper provides a brief overview of the Institute for Telecommunication Sciences' role in understanding and predicting the effects of the channel on radio system performance. The overview describes relevant deleterious channel conditions, channel measurement equipment, and channel measurements made by the Institute. It then discusses how measurement data is used for channel characterization, channel modeling, and radio system performance prediction. It concludes with a description of current work in the design of a tool that will quantify the effect of deleterious channel conditions on receiver signal processing algorithms.

B. Bedford and F. Sanders, "Spectrum sharing and potential interference to radars," in "Proceedings of the International Symposium on Advanced Radio Technologies: February 26-28, 2007," P.J. Raush and K.E. Davis, Eds., NTIA Special Publication SP-07-445, Feb. 2007, pp. 72-77.

> This paper describes the results of interference tests and measurements that have been performed on a wide variety of radar receivers. 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. The results indicate that radar receivers are potentially very vulnerable to interference from communication signals if such systems share spectrum with radars.

N. DeMinco, "Propagation model development considerations for short-range and low-antenna height applications," in "Proceedings of the International Symposium on Advanced Radio Technologies: February 26-28, 2007," P.J. Raush and K.E. Davis, Eds., NTIA Special Publication SP-07-445, Feb. 2007, pp. 86-93.

> This paper describes an analysis effort for determining the technical considerations for developing radio-wave propagation models to assist electromagnetic compatibility analysis and spectrum management efforts of mobile wireless devices. After performing an exhaustive review and evaluation of currently available radio-wave propagation models, ITS determined that none of the currently available models were suitable for performing radio-wave propagation loss computations to facilitate electromagnetic compatibility analyses of mobile wireless devices. ITS initiated an analysis effort to determine how to develop alternative models that would be valid in this parameter range. This analysis effort involved investigating various propagation loss prediction methods that would be valid for close separation distances (one meter to two kilometers), low antenna heights (one to three meters), and frequencies of 150-3000 MHz. This paper describes the preliminary analysis and investigation that will later be used to develop the radio-wave propagation models that would meet the requirements of the short range mobile-to-mobile (MTOM) propagation model. It was determined that a combination of the complex two-ray method and a method that computes mutual coupling would meet the requirements.

P. Papazian and P. McKenna, "Short range propagation measurements for interference model development," in "Proceedings of the International Symposium on Advanced Radio Technologies: February 26-28, 2007," P.J. Raush and K.E. Davis, Eds., NTIA Special Publication SP-07-445, Feb. 2007, pp. 94-99.

This paper summarizes preliminary work on a short range propagation measurement program. The objective of this program is to create a measurement data base which can be used to develop an empirical short range propagation model which can be used in inference studies of proposed short range wireless systems operating in existing communication bands. This paper describes the impulse response measurement, the propagation environments to be studied, and the frequency ranges proposed for measurements.

M.H. Pinson, S. Wolf, and R.B. Stafford, "Video performance requirements for tactical video applications," in *Proc. IEEE Conference on Technologies for Homeland Security*, Woburn, Massachusetts, May 16-27, 2007.

The Public Safety Statement of Requirements (PS-SoR) for Communications & Interoperability focuses on the needs of first responders to communicate and share information as authorized, when it is needed, where it is needed, and in a mode or form that allows the practitioners to effectively use it. PS-SoR Volume I defined functional communication and interoperability requirements. Published in September, 2006, PS-SoR Volume II identifies quantitative performance metrics, including minimum video performance requirements for public safety's tactical video applications. The goal was not to identify what is achievable with current technology but rather, looking towards the future, to investigate the minimum level of performance that first responders need in order to effectively use their video equipment.

On behalf of the SAFECOM Program and the Office of Law Enforcement Standards, the Institute for Telecommunication Sciences (ITS) conducted subjective video quality testing to estimate the level of video quality that first responders find acceptable for tactical video applications. This subjective testing utilized source video content that is typical of public safety operations in structured subjective viewing experiments with 35 first responders. The evaluations from these first responders, in viewing high quality video (original video) and purposefully degraded video (using video compression and transmission equipment), allowed determination of basic quality thresholds for public safety tactical video applications. These perceptual quality thresholds have been translated into technical parameters for use by video equipment designers, manufacturers, and customers. This paper summarizes those findings. Other testing to evaluate requirements for other public safety applications is underway.

S. Wolf and M.H. Pinson, "Application of the NTIA general video quality metric (VQM) to HDTV quality monitoring," in *Proc. Third International Workshop on Video Processing and Quality Metrics for Consumer Electronics (VPQM-07)*, Scottsdale, Arizona, Jan. 25-26, 2007.

This paper summarizes results from an experiment whose goal was to assess whether the NTIA General Video Quality Metric (VQM) is an acceptable objective metric for measuring High Definition TV (HDTV) video quality. The HDTV subjective test that was performed to evaluate the NTIA General VQM contained 60 30-second video clips that were rated using the Single Stimulus Continuous Quality Evaluation (SSCQE) method. The 60 clips included twelve 1080i HDTV originals and 48 processed versions of these originals from 16 different video systems. The video systems included 5 different HDTV codecs running at bit rates from 2 to 19 Mbps and broadcast transmission errors (i.e., RF transmission with poor signal-to-noise radio). Excellent objective-to-subjective correlation results for this experiment demonstrate the potential application of the NTIA General VQM to HDTV quality monitoring.

Unpublished Presentations

R. DeBolt, "Developing a Geographic Information System (GIS) based propagation tool," talk and demonstration given at GIS Day, Washington, DC, Apr. 12, 2007.

S. Voran, "I called to tell you about the clouds," Art in Science/Science in Art exhibit, Denver Museum of Nature and Science, Jan.-May 2007.

Conferences Sponsored by ITS

International Symposium on Advanced Radio Technologies (ISART 2007)

The International Symposium on Advanced Radio Technologies (ISART 2007) was held February 26-28, 2007, 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 2007 was "Propagation Modeling for Efficient Spectrum Management." The keynote, "Science, Engineering and Regulation: Support for Future Radiocommunications, an Australian View," was given by Carol Wilson of Wireless Technologies Laboratory, Australia. The proceedings were printed as NTIA Special Publication SP-07-445.

A workshop on path-specific propagation prediction models for the 3-K.1 Correspondence Group of ITU-R Study Group 3 was held in conjunction with ISART 2007.

ISART brings together 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.

ISART 2008 Call for Papers

The ISART technical program committee is soliciting papers for the 10th annual International Symposium on Advanced Radio Technologies (ISART) to be held in Boulder, Colorado, June 2-4, 2008. In conjunction with ISART 2008, NTIA/ITS will be hosting ITU-R Study Group 3 meetings, to be held June 5-13. The deadline for submission of draft papers is January 25, 2008.

For more information, see:
http://www.its.bldrdoc.gov/isart/.

Discussion panel at the 2007 International Symposium on Advanced Radio Technologies (ISART) (photograph by F.H. Sanders).

ITS Standards Work in FY 2007

Standards Leadership Roles and Membership in Standards Development Organizations

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

Christopher J. Behm, Member of Working Party 3L and 3K, ITU-R Study Group 3.

Randall S. Bloomfield, 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).

Carolyn Ford, Member of Video Quality Experts Group (VQEG); Member IACP DVS Minimum Performance Specification Project.

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

Margaret Pinson, Independent Lab Group member for Multimedia test and Co-chair of HDTV effort, Video Quality Experts Group.

Patricia J. Raush, Member of Working Party 3J and 3K, ITU-R 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. Member of the US delegation to Working Party 5D (IMT Systems), ITU-R Study Group 5 (Terrestrial Services) (formerly Working Party 8F (IMT-2000 and systems beyond IMT-2000), ITU-R Study Group 8 (Mobile, radiodetermination, amateur and related satellite services)).

Teresa Rusyn, Member of Working Party 3K and 3M, ITU-R Study Group 3; CCV Rapporteur for Working Parties 3J, 3K, 3L, and 3M.

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); Chair of PRQC's Quality of Service Task Force (PRQC-QoS).

Bruce R. Ward, Co-Editor (TIA TR8.19), TIA.102-CACA, "ISSI Measurement Methods for Voice Services," and TIA.102-CACB, "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. Co-Chair of ITU-T Study Group 9's Working Group 5 "Quality Assessment"; Head of U.S. Delegation to ITU-T Study Group 9.

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.

Emergency Telecommunications Service Projects

- "Proposed Draft New Recommendation J.prefrm 'Roadmap for implementing preferential telecommunications in IPCablecom networks' " ITU-T Study Group 9, Contribution 48 (USA) (A. Webster and G. Bain (NCS/DHS))

- "Revisions to draft new Recommendation J.pref – 'Specifications for preferential telecommunications over IPCablecom networks.' " ITU-T Study Group 9, Contribution 49 (USA) (A. Webster and G. Bain (NCS/DHS))

- "Proposed text for inclusion into a new Draft New Recommendation to support Priority treatment in IPCablecom2 networks." ITU-T Study Group 9, Contribution 66 (USA) (A. Webster and G. Bain (NCS/DHS))

- "Draft Revision of T1.TR.79-2003 'Overview of Standards in Support of Emergency Telecommunications Service (ETS).'" ATIS PRQC-2006-014R8 (A. Webster and A. Nguyen (NCS/DHS), editors)

- "Security for Next Generation Networks – An End User Perspective." ATIS PRQC-2007-008, Draft Technical Report (A. Webster, editor)

- Revised T1.523-2001 TELECOM GLOSSARY." ATIS PRQC-2007-009 (A. Webster, J. Colombo (Verizon), editors)

- PRQC Security Task Force Presentation to 3GPP. ATIS PRQC-2007-120 (A. Webster)

High-power Radars and Spectrum Sharing

- "Measuring HF (2-30 MHz) Radars Using ITU-R M.1177 and Time Sampling Techniques," ITU-R Joint Rapporteurs Group 1A-1C-1B on Radar Unwanted Emissions and ITU-R WP-8B (now WP-5B), Feb. 2007 (F.H. Sanders and R. Sole)

- "Comparison of Frequency Domain Measured Radar Emissions to Time- Sampled Waveforms," ITU-R Joint Rapporteurs Group 1A-1C-1B on Radar Unwanted Emissions and ITU-R WP-8B (now WP-5B), Feb. 2007 (F.H. Sanders and R. Sole)

- "The Effects of Zero-Padding FFTs and the Windowing Function on Time- Sampled Waveforms," ITU-R Joint Rapporteurs Group 1A-1C-1B on Radar Unwanted Emissions and ITU-R WP-8B (now WP-5B), Feb. 2007 (F.H. Sanders and R. Sole)

- "Synthetic Airborne Radar (SAR) L-Band Emission Data," ITU-R Joint Rapporteurs Group 1A-1C-1B on Radar Unwanted Emissions and ITU-R WP-8B (now WP-5B), Feb. 2007 (F.H. Sanders and R. Sole)

APCO Project 25

- NIST/OLES Letter Ballot Comments on Draft TIA-102.CACA (ISSI Measurement Methods for Voice Services), TR8-19, Feb. 2007 (R. Bloomfield, B. Ward, N. Walowitz (Protiro for ITS)).

- NIST/OLES Letter Ballot Comments on Draft TIA-102.CACB (ISSI Performance Recommendations for Voice Services), TR8-19, Feb. 2007 (R. Bloomfield, B. Ward, N. Walowitz (Protiro for ITS)).

- ISSI Interoperability Test Procedures Standards Development White Paper: Summary of Conclusions and Recommendations, CAPP TG, Aug. 2007 (B. Ward, N. Walowitz (Protiro for ITS)).

- ISSI Interoperability Test Procedures Standards Development White Paper, CAPP TG, Aug. 2007 (B. Ward, N. Walowitz (Protiro for ITS)).

- ITS Response to Motorola Comments on ISSI Interoperability White Paper, CAPP TG, Oct. 2007 (R. Bloomfield, B. Ward, N. Walowitz (Protiro for ITS)).

- ITS and NIST/ANTD Questions on ISSI Messages and Procedures Document (TIA.102-BACA), TR8.19, Feb. 2007 (B. Ward, M. Ranganathan (NIST/ANTD), N. Walowitz (Protiro for ITS)).

- ITS and NIST/ANTD Comments on ISSI Conformance Test Document (07-019), ISSI TG, Mar. 2007 (B. Ward, M. Ranganathan (NIST/ANTD), N. Walowitz (Protiro for ITS)).

- ITS and NIST/ANTD Comments on ISSI Conformance Test Document (07-019-R3), ISSI TG, Oct. 2007 (B. Ward, M. Ranganathan (NIST/ANTD), N. Walowitz (Protiro for ITS)).

- Working Document – Issue F, Identification of P25 SoR Requirements for Updating of Current (March 9, 2006) P25 SoR, P25 UNS, July, 2007 (R. Bloomfield).

- P25 Statement of Requirements (Approved Aug. 4, 2007), P25 UNS and P25/34 Steering Committee, Aug. 2007 (R. Bloomfield).

Quality of Service

- "SIP-based call processing performance," ITU-T Study Group 12 C 73, Aug. 2007 (N. Seitz).

- "Interworking guidelines for transporting assured IP flows," ITU-T Study Group 12 C 72, Aug. 2007 (N. Seitz).

Video Quality

- "Draft American National Standard for Trial Use: Reduced Reference Video Calibration Estimation Method," PRQC-2007-061R1, Sep. 2007 (A. Webster, S. Wolf, and M. Pinson).

- "Draft New Recommendation J.vcrr, Video Calibration-Reduced Reference." ITU-T Study Group 9, Contribution 50 (USA) (A. Webster and M. Pinson).

- "Proposed changes to Preliminary Draft new Recommendation J.cal 'Calibration methods for constant misalignment of spatial and temporal domains with constant gain offset.' " ITU-T Study Group 9, Contribution 67 (USA) (A. Webster, M. Pinson, and S. Wolf)

- Proposed Draft New Recommendation J.trv "Subjective video quality assessment methods for recognition tasks," Sep. 2007 (A. Webster, C. Ford, M. McFarland).

- "Video Quality Work in ITU-T Study Group 9, JRG-MMQA, and VQEG." ATIS PRQC-2006-160, (A. Webster)

ITS Awards in FY 2007

Department of Commerce Gold Medal Award

In November 2006, several members of the Telecommunications and Information Technology Planning Division were awarded the Department of Commerce Gold Medal, the highest honor given by the Department, for personal and professional excellence (see photo below).

DJ Atkinson, Randall Bloomfield, Jeffrey Bratcher, Eldon Haakinson (retired), Eric Nelson, Val Pietrasiewicz (retired), Andrew Thiessen, Ken Tilley, and Bruce Ward of ITS, along with Dereck Orr of NIST/OLES, received the award for assisting government-wide planning, assessment, and standardization of technologies to achieve interoperable communications among "first responders."

The team addressed technological advancements to improve radio coverage depended upon by police, firefighters, emergency medical personnel, dispatchers, and other first responders during local and national emergencies.

The Gold Medal award specifically highlights the ITS team's leadership in two areas: developing a national strategy for improvement of public safety communications, and assisting the development of technical standards to enable rapid deployment of a new generation of digital land mobile radio systems. Federal, state, and local public safety agencies, including those in Colorado, are widely implementing these systems today.

This work supports the Commerce Department's goal of improving public safety communications to better serve Americans and protect American security.

Recipients of the Department of Commerce Gold Medal Award share the stage with Department of Commerce leaders. Left to right: Secretary of Commerce Carlos Gutierrez, Dereck Orr, Bruce Ward, Ken Tilley, Val Pietrasiewicz, Andrew Thiessen, Eric Nelson, Eldon Haakinson, Jeffrey Bratcher, Randall Bloomfield, DJ Atkinson, and former Assistant Secretary of Commerce for Communications and Information John Kneuer.

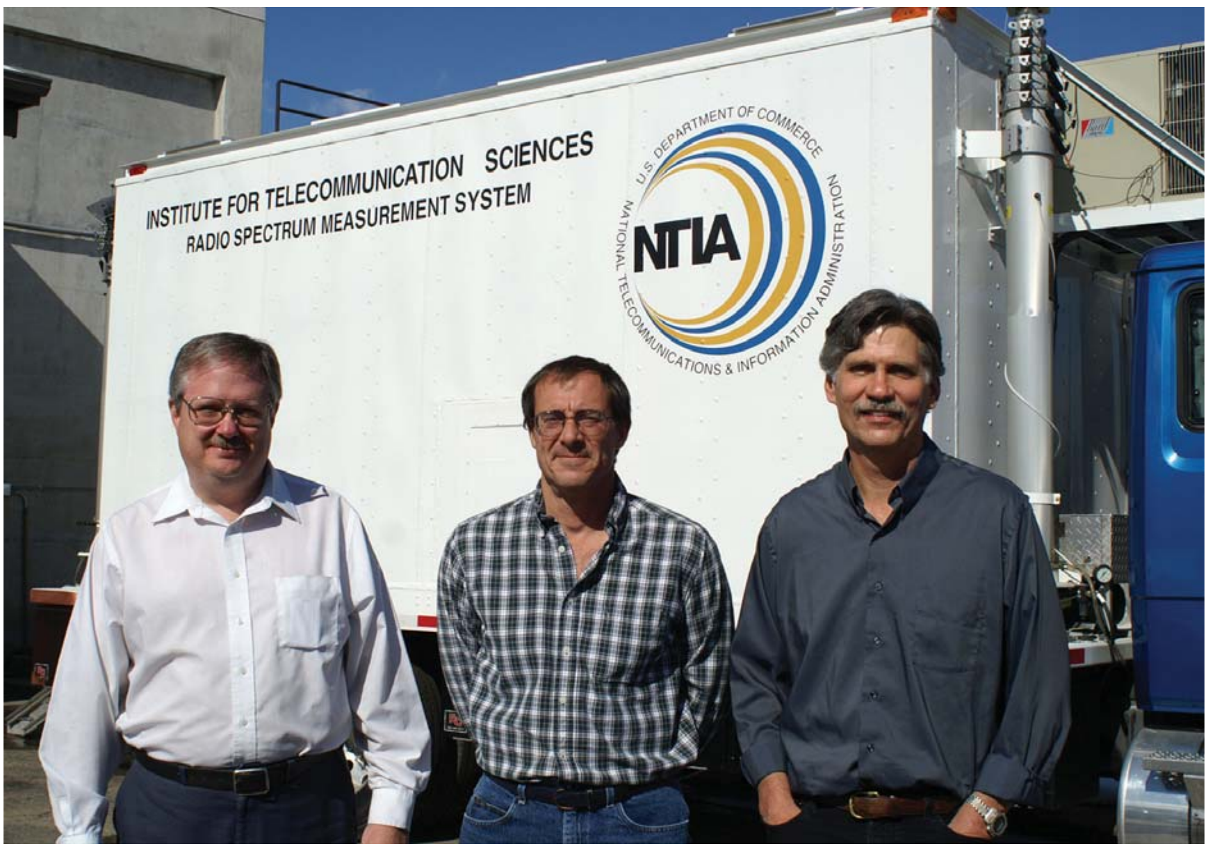
Department of Commerce Silver Medal Award

In November 2006, Brent Bedford, John Ewan, and J. Randy Hoffman were awarded the Department of Commerce Silver Medal, the second highest honor given by the Department, in the category of scientific and engineering achievement (see photo below).

The group was recognized for designing and developing a highly advanced mobile radio spectrum measurement system, capable of measuring the latest complex communications and radar signals. Comprised of a vehicle, measurement hardware, and software, the system can measure how much of the radio spectrum is being used. It can also determine sources of radio interference. It has already aided the Federal Communications Commission, the Army, the Navy, the Air Force, the National Weather Service, and the Federal Aviation Administration.

The Department of Commerce has operated vehicle-mounted radio measurement systems since the 1920s. The first modern system was developed by ITS in the mid-1970s. This year's award-winning design is the fourth generation.

This accomplishment supports the Commerce Department's goal of providing effective management and stewardship of the radio spectrum.



Recipients of the Department of Commerce Silver Medal Award standing in front of the vehicle they designed and developed. Left to right: Brent Bedford, John Ewan, and J. Randy Hoffman (photograph by F.H. Sanders).

Abbreviations/Acronyms

2D	two-dimensional
3D	three-dimensional
3G	third generation
3GPP	3rd Generation Partnership Project
4G	fourth generation

A

AAR	Association of American Railroads
ANSI	American National Standards Institute
ANTD	Advanced Networking Technologies Division (within NIST)
APCO	Association of Public-Safety Communications Officials
APIC	APCO Project 25 Interface Committee
ATIS	Alliance for Telecommunications Industry Solutions
AUGNet	Ad hoc UAV Ground Network
AWS	Advanced Wireless System

B

BBTG	BroadBand Task Group
BER	bit error rate
BPSK	binary phase shift keying
BVQM	Batch VQM

C

CAI	Common Air Interface
CAP	Compliance Assessment Program
CAPP TG	Compliance Assessment Process and Procedures Task Group (a subcommittee under APIC)
CASM	Communication Assets Survey and Mapping
CCV	Coordination Committee for Vocabulary
CD	compact disk
CDA	Code Domain Analyzer
CDMA	Code Division Multiple Access
CEA	Consumer Electronics Association
CIP	Critical Infrastructure Protection
CMRS	Commercial Mobile Radio Services
CONUS	Continental U.S.
CRADA	Cooperative Research and Development Agreement
CRPL	Central Radio Propagation Laboratory
CSPM	Communication System Performance Model
CSPT	Communication System Planning Tool
CSSI	Console Subsystem Interface
CU	University of Colorado
CVQM	Command Line VQM

D

DAT	digital audio tape
dB	decibel
dBm	decibels relative to 1 mW
DFS	Dynamic Frequency Selection
DHS	Department of Homeland Security
DIETS	Department of Commerce ISSI Emulation and Test System
DNR	Draft New Recommendation
DOC	Department of Commerce
DOD	Department of Defense
DSCP	Digital Sampling Channel Probe
DSES	Deep Space Exploration Society
DSRC	dedicated short range communication
DTV	digital television
DVS	Digital Video Systems

E

EBU	European Broadcasting Union
EEEL	Electronics and Electrical Engineering Laboratory
EIA	Electronic Industries Alliance
EMC	electromagnetic compatibility
EMS	Emergency Medical Services
ESSA	Environmental Science Services Administration
EST	Emerging Spectrum Technologies workshop
ETS	Emergency Telecommunications Service
ETSI	European Telecommunications Standards Institute

F

FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FFT	fast Fourier transform
FHWA	Federal Highway Administration
FLC	Federal Laboratory Consortium for Technology Transfer
FM	frequency modulation
FMCW	Frequency Modulated Continuous Wave (type of radar)
FPGA	Field Programmable Gate Array

FPIC	Federal Partnership for Interoperability Communications
FSI	Fixed 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
GMF	Government Master File
GPS	Global Positioning System
GSI	Global Standards Initiative
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
HP	Hewlett-Packard Company

I

IAA	interagency agreement
IACP	International Association of Chiefs of Police
IAFC	International Association of Fire Chiefs
ICEPAC	Ionospheric Communications Enhanced Profile Analysis and Circuit Prediction Program
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IF	intermediate frequency
IMS	IP Multimedia Subsystem
IMT	International Mobile Communications
IP	Internet Protocol
IPTV	Internet Protocol Television
ISART	International Symposium on Advanced Radio Technologies
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

J

JRG	Joint Rapporteur(s) Group

K

kHz	kilohertz
KMF	Key Management Facility
kW	kilowatt

L

LAN	Local Area Network
L-Band	1215-1400 MHz band
LF	low frequency
LFMF	low frequency/medium frequency
LM/CT	Lockheed Martin/Coherent Technologies
LMDS	Local Multipoint Distribution Service
LMR	Land Mobile Radio
LNA	low noise amplifier
LOS	line of sight

M

MAC	media access control (layer)
Mbps	megabits per second
MESA	Mobility for Emergency and Safety Applications
MF	medium frequency
MHz	megahertz
MIMO	Multiple Input Multiple Output
MMQA	Multimedia Quality Assessment
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

OA	outside/other agency
OAM	Operation, Administration and Maintenance
OCIO	Office of the Chief Information Officer
OCTO	Office of the Chief Technology Officer (District of Columbia)
OIC	Office of Interoperability and Compatibility (of DHS)
OLES	Office of Law Enforcement Standards
OMB	Office of Management and Budget
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
PBS	Public Broadcasting System
PC	personal computer
PCAP	packet capture
PCP-TDR	Telecommunications for Disaster Relief and Mitigation — Partnership Co-ordination Panel
PCS	Personal Communications Services
PDA	personal digital assistant
PDD-63	Presidential Decision Directive No. 63 (on critical infrastructure protection)
PDNR	Preliminary Draft New Recommendation
PESQ	Perceptual Evaluation of Speech Quality
PN	pseudo noise
PRQC	Network Performance, Reliability and Quality of Service Committee
PS	public safety
PSAF	Public Safety Architecture Framework
PSAL	Public Safety Audio Laboratory
PSAWG	P25 Systems Architecture Working Group
PS-SoR	Public Safety Statement of Requirements
PSTN	Public Switched Telephone Network
PSVL	Public Safety Video Laboratory
PSVQ	Public Safety Video Quality
PTT	Push-to-Talk

Q

QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying

R

R&D	research and development
RAID	redundant array of independent disks
RC	radio-controlled
RCG	Radar Correspondence Group
RF	radio frequency
RFSS	Radio Frequency Subsystem
RLC	radio link core
RNSS	Radionavigation Satellite Service
ROW-B	Radio Over Wireless Broadband
RPM	Radio Performance Measurements
RR-NR	Reduced Reference – No Reference
RSEC	Radar Spectrum Engineering Criteria
RSMS	Radio Spectrum Measurement Science
RSMS-4G	4th Generation RSMS
RTP	Real-time Transport Protocol

S

S&E	salaries and expenses
SAFECOM	Public Safety Wireless Communications (DHS program)
SAR	Synthetic Airborne Radar
SCTE	Society of Cable Telecommunications Engineers
SD	Standard Definition
SDMA	Space Division Multiple Access
SDO	Standards Development Organization
SDoC	Supplier's Declaration of Compliance
SDR	software defined radio
SDTS	Spatial Data Transfer Standard
SG	Study Group
SIP	Session Initiation Protocol
SIPRNET	Secret Internet Protocol Routable Network
SMPTE	Society of Motion Picture and Television Engineers
SNR	signal to noise ratio
SoR	Statement of Requirements
SSCQE -HRR	Single Stimulus Continuous Quality Evaluation with Hidden Reference Removal

SSMD	Site Specific Model
SU	Subscriber Unit
SV	Systems View

T

TA Services	Telecommunications Analysis Services
TG	Task Group
TIA	Telecommunications Industry Association
TM	technical memorandum
TMOC	Telecom Management and Operations Committee
TR	Technical Report
TR-8	Personal and Private Land Mobile Radio (a TIA standards development committee)
TSB	Telecommunications Systems Bulletin
TV	television Technical Standards View

U

UAV	unmanned aerial vehicle
UHF	ultra high frequency
UK	United Kingdom
U-NII	Unlicensed National Information Infrastructure
UNR	undesired signal power to receiver noise power ratio
UNS	User Needs Subcommittee
URSI	International Union of Radio Science
U.S.	United States
USGS	U.S. Geological Survey
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
WCC	Wireless Communications Committee
W-CDMA	Wideband CDMA
Wi-Fi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WLG-E	Working Level Group E
WNRC	Wireless Networks Research Center
WP	Working Party
WTSC / G3GRA	Wireless Technologies and Systems Committee / Radio Aspects of GSM/ 3G and Beyond

X

XML	Extensible Markup Language
XOR	exclusive-or (logical operation)

Y

YIG	yttrium-iron-garnet