ITS Tools and Facilities

Adaptive Antenna Testbed

The adaptive antenna testbed (ATB) is a multi-channel test facility based on ITS digital sampling channel probe technology (see also "Adaptive Antenna Testbed," pp. 56–57). The VMEbus-based system can simultaneously characterize eight wideband radio channels (expandable). The received signals are digitized for flexible post processing. The Table below summarizes the range of permissible values for the ITS channel sounding system, as well as giving an example of a personal communications services (PCS) band configuration.

Data Acquisition and RF Parameters used for Diversity Tests

Configurable System Parameters

Parameter	PCS Band Example	ITS System
Receiver Channels	4	1-8 (expandable to 16)
Carrier Frequency	1.92 GHz	.45 – 6 GHz
Bit Rate	10 Mb/s	.1 – 50 Mb/s
Resolution	100 ns	10 µs – 20 ns
Code Type	Maximal Length	Programmable
Code Length	511 bits	Programmable
Acquisition Mode	Burst	Continuous or Burst
Positioning	GPS/Dead Reckoning	GPS/Dead Reckoning
Transmitters	1	Multiple
Data Processing	Post	Post or Real Time

The ATB provides a common reference for evaluating next-generation PCS antenna systems. Data from multiple channels can be used to test the diversity gain resulting from various signal combining algorithms. Digital beam forming techniques may also be examined.

A well-characterized cell site in Boulder, CO, serves as a known platform for evaluating existing and new PCS components and systems. Alternately, the ATB transmitting and receiving systems may be van-mounted for site mapping studies at any required location.

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Audio-Visual Laboratories

The ITS Audio-Visual Laboratories offer a wide range of audio and video recording, storage, processing, reproduction, objective quality assessment, and subjective testing capabilities. These capabilities in turn support the development and verification of new quality estimation techniques for compressed digital audio and video, and the development of novel subjective testing techniques for audio and video signals. Signals are acquired with high-quality microphones and cameras. Recording and playback devices include studio-quality analog and digital video tape recorders with two to four audio channels, video disk systems, digital audio tape machines, CD players, and analog audio cassette machines. These systems are augmented with several computer-based digital audio and video systems. One system offers the ability to record and playback video streams that conform with International Telecommunication Union, Radio Communication Sector (ITU-R) Recommendation BT.601 and synchronized digital audio streams to and from a high-speed workstation with a 500 GB Fibre Channel disk array. Video processing is performed in the digital environment using several high-performance video workstations. These workstations are supported by storage peripherals that include an 80-GB read/write optical jukebox, a 12-GB 4mm tape drive, an 8 GB 8mm tape drive, and a 40 GB digital linear tape drive. Analog audio mixing, filtering, and equalizing equipment is available, and the most intensive audio processing is done in the digital domain on PC platforms. An array of digital audio and video encoders and decoders are available as well. An audio-video routing switcher and numerous patch-panels allow for nearly arbitrary interconnections between the various pieces of equipment in these laboratories.

Reproduced signals are presented through studio-quality video monitors, monitor loudspeakers, headphones, or handsets. Two separate rooms with controlled acoustic and visual environments are available for the subjective testing of audio and video signals. These environments are specified in International Telecommunication Union, Telecommunication Standardization Sector (ITU-T) Recommendation P.800 and ITU-R Recommendation BT.500 respectively. These specifications address

background noise levels, wall colors, light levels, room dimensions, among others. Finally, the labs feature an array of audio and video signal generators and analyzers to support laboratory measurement and calibration activities. Lab activities are mainly focused on objective estimation of audio and video quality, and subjective testing of audio and video quality. Random access digital audio-video playback systems coupled with electronic data entry systems greatly facilitate many of the subjective testing activities. Because two separate 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++, processes video signals in accordance with American National Standards Institute (ANSI) T1.801.03-1996 and other more recently developed metrics, resulting in estimates of video quality that show good correlation with subjective test results. Objective audio quality estimation is performed by software implementations of the Measuring Normalizing Block algorithms, standardized in ANSI T1.518-1998, and ITU-T Recommendation P.861, Appendix II, 1998. The labs support both batch-mode and real-time objective quality estimation.

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Digital Sampling Channel Probe

The digital sampling channel probe (DSCP), designed and patented at ITS, is used to characterize the wideband propagation characteristics of the radio communication channel. The probe, consisting of both a transmitter and receiver, is used to make complex impulse response measurements. Unlike the analog sliding correlator equivalent, the DSCP digitizes the received signal at an IF frequency and then processes the data, thus providing the advantages of digital processing. Relative to the sliding correlator, the time over which the impulse is generated is also less, and therefore, can characterize the communication channel over a shorter period of time. Historically the DSCP has been employed extensively for channel characterization of cellular and personal communications services. ITS has included new features such as a quad channel capability used to perform spatial and polarization diversity experiments. Recently developed is a wide-bandwidth, high-frequency probe, particularly suited for high resolution requirements such as indoor wireless local area network (LAN) applications. For a more detailed description of the measurement systems and applications, see the following ITS web site: http://flattop.its.bldrdoc.gov/rcirms/

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ITS Internet Services

ITS provides public Internet access to NTIA/ITS publications, program information, and on-line Telecommunications Analysis Services 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 ANSI T1 standards committees. Some highlights of ITS Internet Services include:

- Information about ITS programs and projects. Available at http://www.its.bldrdoc.gov/home/projects.html
- An ITS organization chart and a complete listing of ITS staff with contact information. Available at http://www.its.bldrdoc.gov/home/organization.html
- Recent ITS publications including NTIA Reports, special publications, and journal articles. Available at http://www.its.bldrdoc.gov/pub/pubs.html
- The on-line version of FED-STD 1037C, Glossary of Telecommunication Terms featuring over 5800 technical definitions linked together in hypertext. Available at http://glossary.its.bldrdoc.gov/fs-1037/
- Telecommunications Analysis Services. Available at http://www.its.bldrdoc.gov/tas/
- Information about ITS-sponsored symposiums such as ISART. Available at http://www.its.bldrdoc.gov/meetings/art/index.html
- Anonymous FTP distribution of some ITS developed software programs. Available at ftp.its.bldrdoc.gov

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ITS Local Area Network

ITS maintains a highly flexible local area network (LAN) to support intranetworking services and laboratory interconnection. A structured cabling system interconnects all offices and laboratories with both optical fiber and Category 5 twisted-pair cabling to support high-bandwidth communications on demand. Over 200 devices are supported on 10Base-T and 100Base-TX ethernet segments. Connections can also be made to laboratory test beds featuring synchronous optical network/asynchronous transfer mode (SONET/ATM). This provides ITS with great flexibility and rapid reconfiguration capability for new programmatic needs.

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Mobile Radio Communication Performance Measurements

ITS maintains a test capability for determining the performance of land-mobile radio systems that comply with the Telecommunications Industry Association's TIA-102 and TIA-603 series of specifications.

The measurement capabilities include the usual TIA-603 type of measurements for analog systems, such as receiver sensitivity, adjacent-channel and cochannel interference. In addition, with TIA-102 (Project 25) capable test equipment, various aspects of the link control format information, such as network access code, talk group identification, emergency bit and message opcode, can be viewed. Demodulated speech samples can also be collected for an assessment of audio clarity by ITS' audio laboratory.

The primary use for this capability is interoperability testing between TIA-102 radios of different manufacture and backward-compatibility testing between TIA-102 radios and legacy analog FM systems. Other applications may be possible, such as routine performance measurements. This capability is available on a first-come, first-serve basis by both NTIA and other agencies.

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Mobile Radio Propagation Measurement Facilities

ITS maintains a measurement vehicle capable of radio channel characterization over a wide frequency range. The vehicle is equipped with on-board power, a telescoping mast, azimuth elevation controllers, and global positioning systems with dead-reckoning backup. A suite of measurement equipment also is available for use in this vehicle. This includes wideband systems for measuring radio channel impulse response at 450 MHz, 1350 MHz, 1920 MHz, 5.8 GHz and 30.3 GHz. Impulse response measurement capability at 30 GHz with 2ns resolution has been enhanced with the addition of a digital wideband recording system. During the past year ITS increased its mobile channel measurement capability with the addition of a phased array antenna system. Multi-channel synchronous acquisition can be used for antenna array measurements or multi-frequency broadband measurements. Mobile measurement capability allows space division multiple access (SDMA) algorithms to be studied using data collected in typical mobile environments. This data can then be used to simulate and model radio systems.

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Radio Noise Measurement System

The ITS noise measurement system hardware consists of an omnidirectional antenna mounted on a ground plane, preselector filter, low noise preamplifier, off-the-shelf spectrum analyzer, digitizer, and computer. Noise samples are digitized prior to spectrum analyzer detection just after spectrum analyzer log amplification. Spectrum analyzer demodulation circuits are used for aural noise identification during measurements. The measurement system noise figure is nominally 2 dB above kT_0b. Noise is measurable approximately 15 dB below and 60 dB above system noise. The noise measurement system uses custom data acquisition software written and maintained at ITS. The software graphical user interface allows the user to customize and notate each measurement. It also displays noise samples and their corresponding first-order statistics. The statistics are shown as an amplitude probability distribution (APD) function (complement of the amplitude cumulative distribution function). The APD is plotted on a Rayleigh graph that represents the amplitude statistics of Gaussian noise as a straight line with a negative slope. Non-Gaussian noise is easily

identified during measurements as a deviation from the straight line or a change in slope. Non-Gaussian noise exists throughout the radio spectrum. ITS has used the noise measurement system to measure noise at 137.5 MHz, 402.5 MHz, and 761.0 MHz. The noise measurement system can also be used to measure noise at higher frequencies. For example, the noise measurement system can be used to measure noise at 2.4 GHz in spectrum occupied by unlicensed Part 15 low power communication devices such as wireless local area networks and Part 18 industrial, scientific, and medical devices such as microwave ovens. The noise measurement system can be run from a building or a measurement van. A direct current converter with noise suppressor is used to power the van mounted equipment if 120 V alternating current is not available. Calibration measurements in radio quiet zones have shown that noise contributed by the noise measurement system and power conversion equipment is negligible.

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Radio Spectrum Measurement Systems

ITS has designed, constructed, and currently operates a number of automated spectrum measurement systems. The Radio Spectrum Measurement System (RSMS), ITS' primary system, is a vehicularly mounted, self-contained facility for measurements between 1 MHz and 24 GHz. ITS also has available a number of suitcase-deployable systems called Compact Radio Spectrum Measurement Systems (CRSMS). RSMS and CRSMS facilities incorporate a combination of commercial off-the-shelf hardware, hardware custom-designed by ITS, and control software written by ITS. The RSMS is RF-shielded, and includes two 30-ft masts, an on-board 10-kW generator, air conditioners, four full-height equipment racks, and storage space. CRSMS capabilities utilize the same software but typically include only as much hardware as is required for any given measurement task. Local arrangements must be made for CRSMS shelter and power. Both RSMS and CRSMS rely extensively upon computer control of measurements. These systems can be operated in fully automatic, semi-automatic, and fully manual modes. Mobile radios, fixed communication links, radars, personal communication systems, earth station uplinks, industrial, scientific, and medical devices, broadcast signals, and special-purpose transmitter systems can be measured. For a complete description of the RSMS, go to ITS on-line publications (http://ntia.its.bldrdoc.gov) and download applicable appendices from any RSMS measurement report (e.g., Appendix C of NTIA Report 99-367; see Publications Cited, pp. 102).

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RFIMS Development Lab

The Radio Frequency Interference Monitoring System (RFIMS) Development Lab is a facility that is used to provide support to the Federal Aviation Administration's (FAA) RFIMS program. Under the RFIMS program, ITS personnel analyzed FAA requirements and developed an automated, custom-designed radio frequency measurement system; integrated and tested a prototype mobile system; and have now integrated and tested eleven systems. The lab contains a measurement system that is identical to the measurement system that is found within RFIMS vehicles. The lab is capable of making the same measurements that can be made with the vehicles. These include measurements of spectrum signature, radar prf and spectragraph, among others. In the RFIMS Development Lab, ITS engineers develop and test measurement concepts that will become part of the RFIMS. Newly created software is tested for both functionality and user friendliness by users. If trouble reports are received from the deployed RFIMS vehicles, the lab is used to recreate the situation, analyze the causes, and implement a viable solution. The lab is available to ITS engineers, all nine FAA regions, FAA headquarters and the FAA Technical Center to support the use and future development of the RFIMS.

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Spectrum Compatibility Test and Measurement Sets

The introduction of new systems in close frequency proximity to older ones can cause electromagnetic compatibility (EMC) problems. Real world measurements of a proposed system's effects within its proposed operating environment are often required to determine its impact on other users of the radio spectrum. In such cases, a system is needed which can simulate the spectral emissions of other devices with a wide range of latitude. Such a system is also needed in situations which require the production of

a controlled interfering signal with known characteristics in environments where the suspected interferer may be unavailable for use. These situations include laboratory tests using interference from ship or aircraft mounted radars or communications systems. To meet these needs, ITS engineers have developed two different types of interference generators. The first system is the Broadband Arbitrary Waveform Transmitter (BAWT) that is used to simulate the spectral output of a wide variety of radar and communication systems. These signals can be coupled directly into the system under test or they can be transmitted into the target system's antenna to more accurately gauge its response to a real interference situation. In cases where the exact form and characteristics of the proposed interferer are poorly known, a second type of generator may be used. This device, the Broadband Noise Generator (BBNG) produces a noise-like signal at the frequency of interest with a bandwidth determined by the investigator. This signal is typically directly coupled into the target system for measurement purposes. The BBNG is especially useful for assessment of system performance in the presence of noise-like spurious emissions from adjacent-band systems.

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Table Mountain Radio Quiet Zone

This unique facility (one of only two in the nation) is controlled by public law to keep the lowest possible levels of unwanted radio frequency energy within the test area. This allows research concerned with low signal levels, such as from deep space, extraterrestrial low-signal satellites, or very sensitive receiver techniques, to be conducted without the interference found in most areas of the nation. As the use of electronic systems (e.g., garage door openers, computers, citizen band radios, cellular telephones, arc welders, and microwave ovens), the number of radio and television stations, and new uses for the radio frequency spectrum increase, the average level of electromagnetic energy across the spectrum will also increase. This is important to companies that develop sensitive radio receivers and signal-processing equipment, since the equipment is often saturated by the background signal level. This facility is available for use by private parties on a reimbursable basis.

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Telecom Glossary 2000 Web Page

Telecom Glossary 2000 (see pp. 30–31) is available on the web at the URL http://www.its.bldrdoc.gov/projects/telecomglossary2000
The glossary is an update-in-progress of FED-STD-1037C, *Glossary of Telecommunication Terms* (1996). The draft of *Telecom Glossary 2000* provides ~8000 definitions in the disciplines of fiber optics communications, telephony, NS/EP, NII, spectrum sharing, radar, radio communications, TV (UHF, VHF, cable, HDTV), HF ALE radio, facsimile, networks (intelligent networks, next-generation Internet, open network architecture, ISDN, B-ISDN, and network management), communications security, data processing, premises wiring, grounding and bonding, telegraphy, and video. Recently added disciplines include web terminology, T1 Standards, information assurance/security, and photonics. The glossary is presented in hypertext with clickable graphics and hyperlinks to defined terms. The web site contains an ITS-developed search engine with easy-to-follow, menu-driven instructions, to allow a more organized and more thorough review of the entire glossary. The advantages of the search engine include tailored access to the text of all definitions, ranking of results, hyperlinks to all search engine results, and speedy use of the entire glossary.

The glossary is accessible and free to anyone with web access. Typical users include Federal purchasing agents, NS/EP implementors, NII planners, Standards writers and users, R&D workers, O&M workers, technical writers, telecom instructors and telecom vendors. Future plans call for making the completed, up-to-date, hyperlinked, web-accessible telecommunications glossary an American National Standard, available free to the public on the ATIS/T1 web site.

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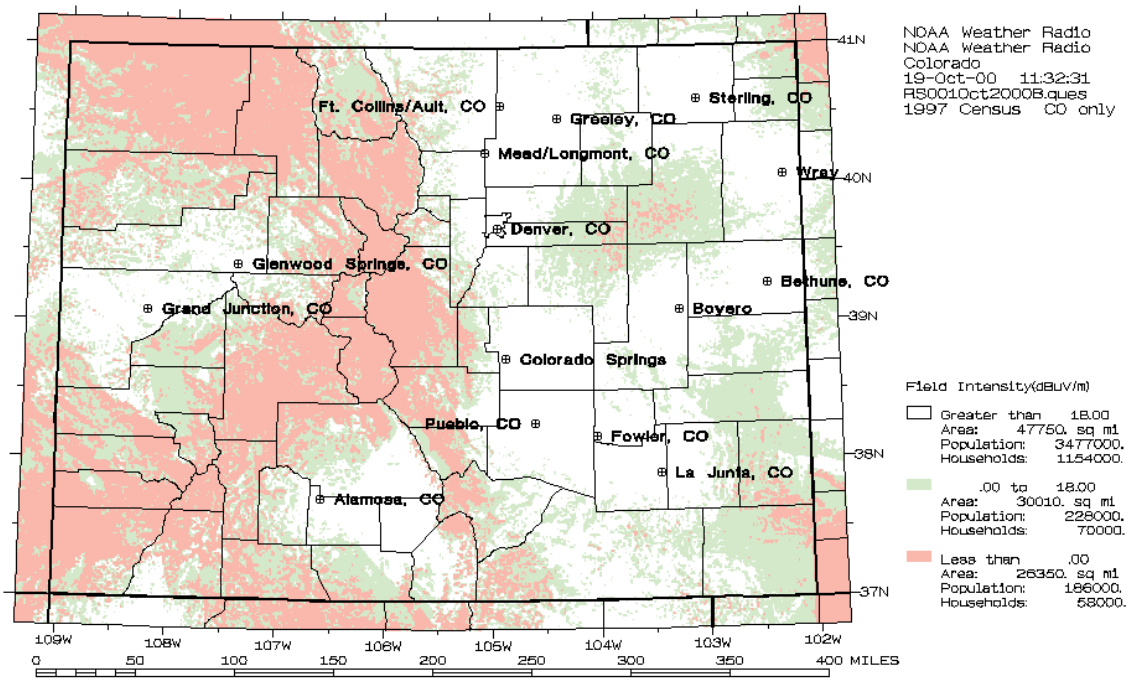
Telecommunications Analysis Services

Telecommunications Analysis Services (TA Services) provides the latest engineering models and research data developed by ITS to industry and other Government agencies via a web-based interface (http://flattop.its.bldrdoc.gov). It is designed to be both 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 some 1 second and 3-arc-seconds (90 m) resolution for much of the world and GLOBE (Global Land One-km Base Elevation) data for the entire world; 1990 census data (also 1997 updated); Federal Communications Commission (FCC) databases; and geographic information systems (GIS) databases (ARCINFO). TA Services has developed models which predict communication system coverage and interference for many broadcast applications. New models in the GIS environment for personal communications services (PCS) and Local Multipoint Distribution Services (LMDS) have been developed (see Telecommunications Analysis Services, pp. 44-45). The following is a brief description of some 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 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 line-of-sight (LOS) regions around a specified location in the United States using digitized topographic data. It 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.
COVERAGE - Calculates the receive signal levels along radials that are spaced at user-defined intervals of bearing around the transmitter. The program lists the contours of signal coverage of the transmitter along each radial and lists distances to user-specified contours for each radial. Either the FCC broadcast rules or the ITS Irregular Terrain Model can be chosen for calculations.
CSPM - Determines the system performance of mobile and broadcast systems in detailed output plots of signal intensity, as shown in the Figure. 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 ITS's Irregular Terrain Model in a point-to-point mode or other user chosen algorithms for path loss calculation.



Example of a composite coverage analysis using CSPM.

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

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Ultrawideband (UWB) Interference Testing Laboratory

The Ultrawideband (UWB) Interference Testing Laboratory has been developed to evaluate the performance of radio systems exposed to UWB signals. Currently, this fully-automated laboratory is configured for measuring the effects of UWB signals on Global Positioning System (GPS) receivers. Three signal sources — the desired GPS signal, the undesired UWB signal, and white noise — are combined and applied to GPS receivers while certain performance metrics for the receiver are measured. To ensure repeatable measurements, the GPS signals are generated using an elaborate GPS simulator that mimics precise patterns of signals from continuously moving GPS satellites. UWB signals are produced by impulse generators driven by an arbitrary waveform generator and/or by custom driver circuits. A wide variety of UWB signal structures can be generated by varying the average pulse repetition frequency (PRF), the pulse dithering process (pulse spacing modulation), and signal gating characteristics. An aggregate of up to six independent UWB signals can be generated and combined for investigating the effects of multiple UWB signals on radio systems.

While this UWB Interference Testing Laboratory is currently configured for investigating GPS receivers, the signal generation and data acquisition capabilities can be readily reconfigured to test any system or application potentially vulnerable to UWB signals.

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Wireless Link Simulation Laboratory

This ITS laboratory provides an environment to simulate wireless systems and channels for performance prediction of data, and compressed or uncompressed speech and images. ITS specializes in end-to-end results by performing channel characterization measurements, modeling the measurements, imbedding the models in simulation software, and predicting the system performance and spectrum requirements via simulation. Typically, predicted speech and image quality are determined as a function of signal-to-noise ratio, carrier-to-interference ratio, and bit error ratio for a selected radio system and channel parameters. Real-time link bit error generator models are available for each simulation used to study the effects of the link conditions on various sources and may also be employed as a link model in wireless network simulation. These capabilities are useful in determining predicted performance of proposed wireless systems and standards and may be used to determine design and deployment specifications for these systems.

Link software simulation packages and a generic channel simulator software package are available to perform wireless simulations, predict performance, predict spectrum requirements, and perform signal processing. Laboratory hardware consists of workstations to run simulation and signal processing software. An audio cassette, S-VHS recorder and players, and S-VHS TV monitor are available for storing and demonstrating speech, images, and video. Programmable digital signal-processing boards are available to download wireless link simulations for real-time testing of transmitters, receivers, and channel models. A programmable 6-MHz bandwidth hardware channel simulator is also available for testing transmitters and receivers.

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