Telecommunications Engineering, Analysis, and Modeling

The Telecommunications Engineering, Analysis, and Modeling Division conducts studies in these three areas for wireless and wireline applications.

Engineering work includes assessment of the components of telecommunications systems; evaluation of protocol and transport mechanism effects on network survivability and performance; and assessment of the impact of access, interoperability, timing, and synchronization on system effectiveness in a national security/emergency preparedness (NS/EP) environment.

Analysis work is often performed in association with Telecommunications Analysis (TA) Services, which offers analysis tools online via the Internet. In addition, ITS can provide custom tools and analyses for larger projects or specialized applications.

Modeling has been one of ITS' greatest strengths for many years. Propagation models are incorporated with various terrain databases and data from other sources, such as the U.S. Census. Adaptations of historic models, and those for more specialized situations have been developed and enhanced.

The **Wireless Networks Research Center** (WNRC) opened in May 2001. ITS is noted for its expertise in wireless communications, in particular the ability to measure, predict, and analyze various wireless communication systems. The WNRC was designed to accommodate studies of emerging technologies and PCS, analysis of wireless protocols, and studies of wireless network effects such as congestion and capabilities such as priority access. (See the Tools and Facilities section, p. 81, for more information about the WNRC.)

Areas of Emphasis

ENGINEERING

PCS Applications The Institute helps the Telecommunications Industry Association (TIA) committee TR46.2.1 develop an inter-PCS interference model and handbook. ITS also serves as editor for this committee. The project is funded by NTIA.

Wireless Network Discovery The Institute's tools are used to analyze wireless networks by collecting network protocol messages and physical RF link measurements to identify wireless network behaviors such as usage patterns, channel resource allocation and network topology. This project is funded by the National Communications System (NCS).

Wireless Priority Access Service The Institute assists the Office of the Manager, National Communications System (OMNCS) in developing a wireless priority access service (PAS) capability, critical to NS/EP communications. This project is funded by NCS.

ANALYSIS

Telecommunications Analysis (TA) Services The Institute provides network-based access to its research results, models, and databases supporting applications in wireless telecommunications system design and the evaluation of systems. These services are funded by fee-for-use and fee-for-development charges.

Geographic Information System Applications The Institute has developed a menu-driven propagation model using geographic information system (GIS) formats. The power of the GIS format allows for the use of any spatial database, such as aerial photo imagery. This work was funded by the Dept. of Defense and ARINC.

MODELING

Propagation Model Development In coordination with NTIA's Office of Spectrum Management, the Institute develops enhancements to existing propagation models and works to harmonize related models. The technical products from this effort are presented on behalf of the U.S. at the ITU. The project is funded by NTIA.

Tactical Communication Deception System The Institute analyzed communication systems operated by tactical units, including the existing communication deception system, and developed an improved performance model. This project was funded by the U.S. Army CECOM.

PCS Applications

Outputs

- Interference models for the PCS technologies currently in use as well as proposed third generation (3G) systems.
- Contributions to an industry-developed inter-PCS interference standard for predicting, identifying, and alleviating interference related problems.

Personal Communications Services (PCS) has become the choice for mobile voice and data communication and is a significant resource during emergency recovery of telecommunication services following a natural disaster. PCS networks of varying technologies from many providers cover a majority of this nation's area. Most areas are serviced by multiple, independent, non-interoperable systems which use the same radio frequency bands and infrastructure (base station sites and towers), contributing to one source of interference. Another source of interference occurs when damages occur to the terrestrial telecommunication system and users migrate to cellular resources. This sudden influx of traffic by private, commercial, civil, and Federal users results in wireless system overloads, a decrease in signal quality, and disruption of service in the affected area. National security/emergency preparedness (NS/EP) planners and network operators must understand these interference effects to operate effectively in an overloaded environment. To aid in their understanding, the interfering environment caused by large numbers of active users and competing technologies must be characterized.

Several standard propagation models are accepted by industry members (for example: Okumura and COST-231/Walfish/Ikegami) but no interference models have been developed or accepted. In 1997, ITS developed a PCS interference model (Ferranto 1997*). The initial development covered system-specific interference models to determine co-channel interference from the immediate and adjacent cells, for two licensed PCS technologies: PCS 1900, which is a narrowband time division multiple access (TDMA) system based on Global System for Mobile (GSM), and code division multiple access (CDMA) based on IS-95. The model takes into account system considerations and management functions (such as power control in IS-95) that are affected by the dynamic nature of the interference.

The generic model involves a hexagonally arranged circular cellular geometry, with each cell having six adjacent cells. A single base station is located in the center of each cell and any number of mobile stations are randomly located within a cell's radius. The interference model consists of four components:

- Base-to-mobile link:
  - ❶ victim base station is interfered with by mobile stations in adjacent cells.
  - ❷ victim base station is interfered with by mobile stations in the same cell.
- Mobile-to-base link:
  - ❸ victim mobile stations are interfered with by base stations in adjacent cells.
  - ❹ victim mobile stations are interfered with by the base station in the same cell (for IS-95 systems only).

The output of the model is an aggregate interference waveform, examples of which can be seen in the figure on the next page for two different scenarios. This waveform can be input to a hardware simulator or a software modeling program to evaluate system designs or can be used in an actual hardware implementation. It also can be used to characterize one-on-one, one-on-many, and many-on-one interference. As a result, potential solutions can be proposed; these solutions can be used by field personnel to solve existing problems or to anticipate and avoid potential problems.

Since the development of the model began, the communications industry has proposed and developed new technologies to address system limitations such as system capacity, coverage, and data transfer rates. 3G systems have been proposed to support the goals established by the International Telecommunication

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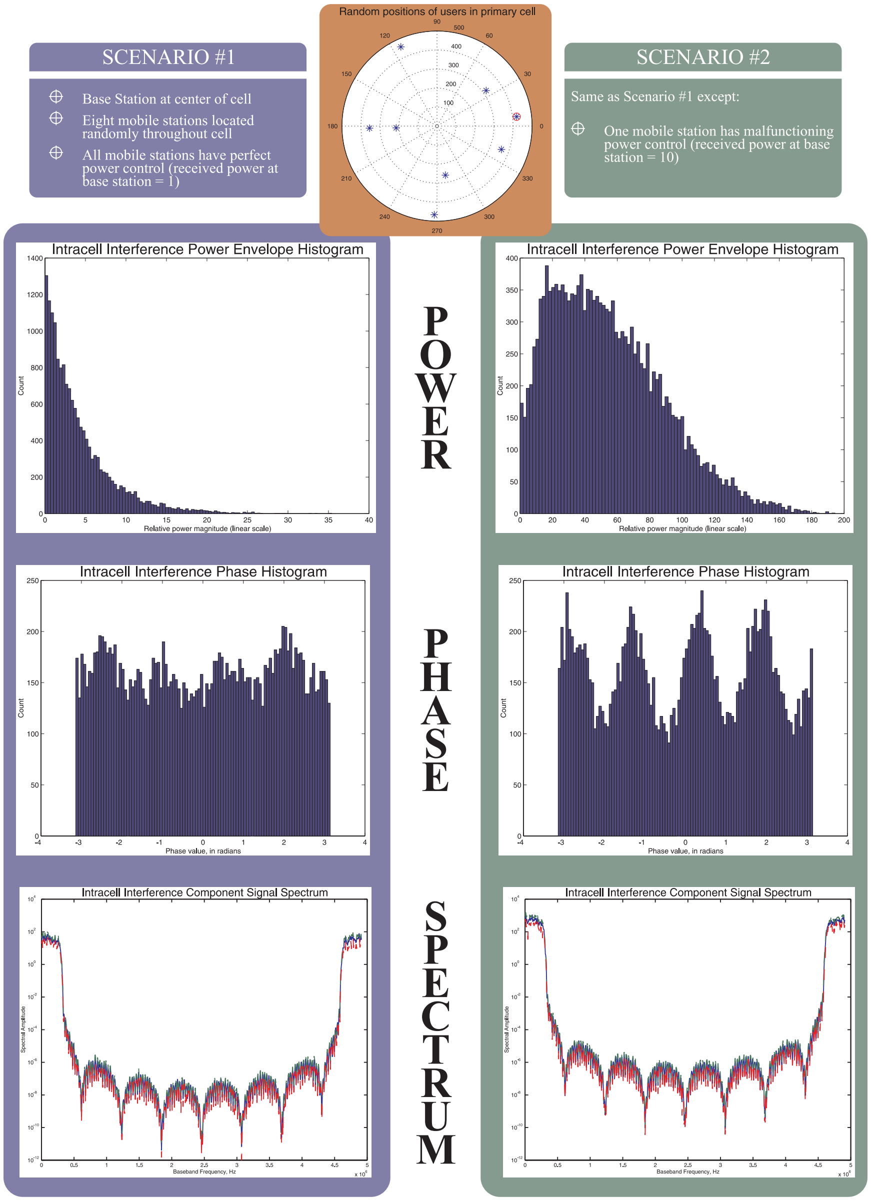
*J.G. Ferranto, "Interference simulation for personal communications services testing, evaluation, and modeling," NTIA Report 97-338, Jul. 1997.

Union (ITU) with IMT-2000. These systems include cdma2000 and W-CDMA, known as UTRA (Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access) in Europe. These technologies present new issues for the existing PCS networks. The new 3G systems will need to coexist with current PCS systems for a period of time. ITS has responded to these changes by upgrading the interference model to the ANSI/TIA/EIA-95B standard adopted in 1999. This is a first step in upgrading the model to the 3G technologies. These upgraded models are being developed such that the output data from the new models will be compatible with the output data from the original models; this will allow users to characterize possible problems between the different technologies as the 3G systems are implemented as well as characterizing interference problems with the existing PCS networks. Some of this work is being performed in the new Wireless Networks Research Center (see pg. 81).



Sample output from the ITS interference model for two different scenarios.

In addition to its model development, ITS continues to contribute to inter-PCS interference understanding through participation in the development of a proposed American National Standard "Third Generation Systems and Licensed Band PCS Interference" as a member of the Telecommunication Industry Association (TIA) committee TR46.2 (Mobile & Personal Communications 1800 – Network Interfaces).

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Wireless Network Discovery

Outputs

- Real-time assessment of wireless infrastructure for emergency communications.
- Wireless link measurements.

Wireless communications networks are evolving away from a simple one-to-one correlation between frequency band and communications channel. A wireless network user's communications channel consists of an aggregate of physical and logical sub-channels. Each sub-channel controls some aspect of a wireless network access session for a user. For example, a typical wireless cellular call must complete a complex series of negotiations between the handset and a base station before allowing a user access to the network. Control channels, once established between a base station and mobile user, facilitate call setup, advanced service requests, air interface resources management, and real-time wireless traffic measurements amongst a myriad of other functions.

In contrast to wired networks, wireless networks exhibit an ephemeral and dynamic relationship between services and resources. At each transaction, the measurable RF and network parameters will change depending on the demands of that particular transaction. It is essential to investigate both of these domains, radio and network, in order to understand the network behavior, i.e., simple RF power measurements alone are inadequate.

Network management protocols insure that RF spectrum is used effectively and efficiently in real time. The low level (data link and network layer) protocol messages that are exchanged between handsets and network contain a wealth of information about the network, but this information is not often readily available. ITS has developed a nascent capability to examine the interaction between link layer messages and radio resources. This capability provides crucial information for Federal emergency communications planning activities in addition to advancing publicly available network characteristics data.

ITS' tools can analyze wireless networks by collecting network protocol messages and physical RF link measurements to identify wireless network behaviors such as usage patterns, channel resource allocation and network topology. This multifaceted viewpoint is necessary since many emerging wireless network architectures rely on spread spectrum techniques to increase user density. Without this real time information about the air interface and the network interface, parameters like channel occupancy would not be obtainable. For instance, in IS-95 networks, the paging channel has to be decoded to gain access to the Walsh code domain which is required to measure traffic channel activity. A similar situation exists in GSM networks, where frequency hopping sequences and time slot allocations from control channels are needed to identify user activity. These kinds of measurements require examination of the integral connection between network protocols and radio resources.

ITS has the capability to peer into wireless networks by using unique tools and techniques that unify the complex relationship between the software and hardware infrastructures of wireless networks. These tools, housed in the new Wireless Networks Research Center (see pg. 81), can be used to identify the behavior of wireless infrastructure topologies on a real-time basis. Figure 1 shows a recent study of IS-95 base station activity in the Boulder County area. The different colors indicate the predominant base station selected by the handset during that portion of the drive test. The base station is identified by information derived from the paging channel. Figure 2 indicates the dwell time at each base station during the drive test. ITS has the capability to decode and process a broad range of parameters that are available in low level messaging for all U.S. cellular and PCS technologies.

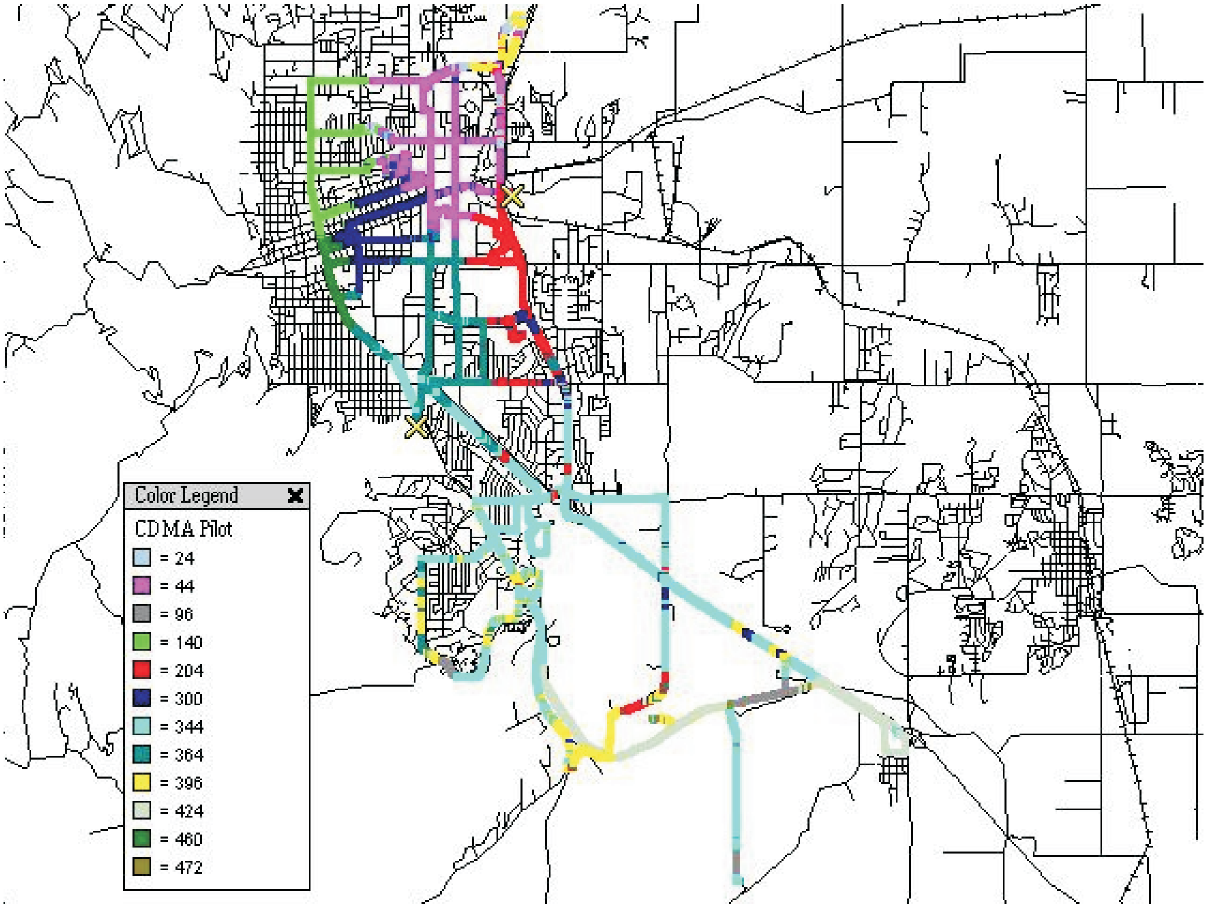

Figure 1. Reception map for Boulder County IS-95 base stations.

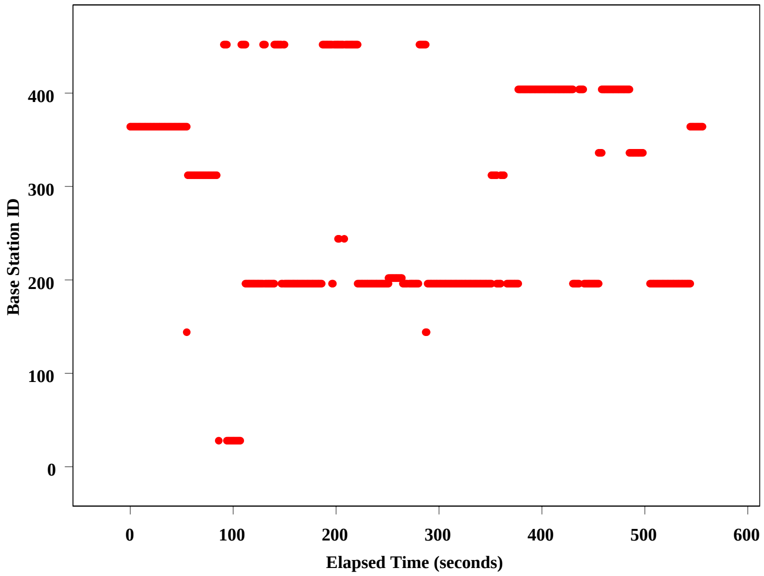

Figure 2. Variation of IS-95 base station versus time during mobile measurement.

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Wireless Priority Access Service

Outputs

- TIA TR45 standard requirements document.
- Technical contributions to national standards organizations.

Government subscribers have become dependent on commercial wireless communications for the performance of their mission, in particular for national security and emergency preparedness (NS/EP) communications. NS/EP responders frequently require wireless connectivity in order to provide communications in a mobile environment when responding to emergencies such as earthquakes, hurricanes, and floods. Commercial wireless service provides a cost-effective capability for NS/EP communications that leverages the use of the public switched telephone network (PSTN) rather than a cost-prohibitive private network. In addition to minimizing costs and deployment time, this arrangement provides broad accessibility.

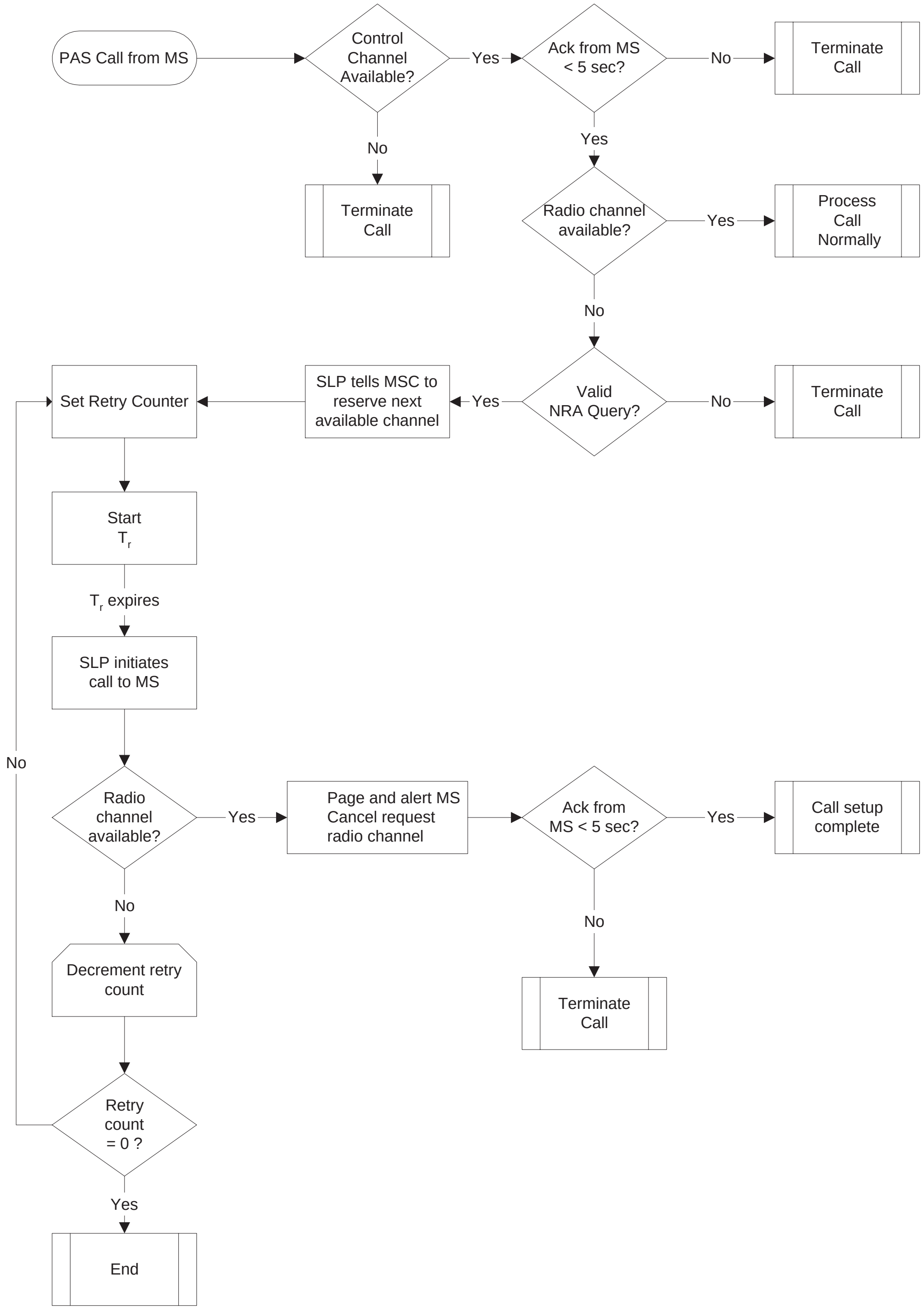
However, following a disaster, severe network congestion in any surviving telecommunication systems can cause high call blocking in both wireless and wireline communications. Thus a priority access service (PAS) is necessary to enable critical disaster relief officials to provide services when they are most needed. A wireline PAS currently exists, the Government Emergency Telecommunications Service (GETS) program, but a wireless capability is still lacking.

ITS is assisting the Office of the Manager, National Communications System (OMNCS) in the development of a wireless PAS capability. The PAS program was developed by the Federal Communications Commission (FCC) and is managed by OMNCS. The FCC rules do not require PAS to be implemented, they merely permit service providers to offer PAS to public safety personnel at the Federal, State and local levels.

The wireless PAS capability leverages the use of existing commercial wireless networks to provide NS/EP users priority access to the next available voice channel in a wireless path in the event that network congestion is blocking call attempts. PAS is activated on a per call basis and is applicable to mobile-to-wireline, wireline-to-mobile and mobile-to-mobile links. When an NS/EP user places a PAS call and the service is activated, the mobile set (MS) requests a voice channel via the control channel messaging. In non-congested environments a voice channel is allocated to the mobile set and the call is connected. In congested environments a voice channel may not be available, so the network will not be able to grant one. In this situation PAS is invoked: the NS/EP caller is placed in a queue and will be given the next available voice channel. PAS does not preempt calls in progress and is to be used only in emergency situations where network congestion is blocking call attempts.

PAS can be implemented over cellular, PCS, specialized mobile radio (SMR) and other commercial wireless technologies as ascertained by the FCC. Per the FCC Second Report and Order, the OMNCS is tasked with managing the PAS program. As PAS evolves, several implementations may be proliferated. One solution that is currently being pursued employs the Wireless Intelligent Network (WIN). This approach is being standardized via the Telecommunications Industry Association (TIA) and the 3rd Generation Partnership Project 2 (3GPP2) standards bodies. WIN builds on existing wireless architectures, which enables a graceful evolution to an intelligent network without making current wireless infrastructures obsolete. Examples of WIN services include radio controlled services, incoming call screening, prepaid charging, and global roaming.

As part of the TIA standards development process, a standards requirements document (SRD) is being developed, which contains a description of PAS with possible technical scenarios. The flow chart in the figure on the next page shows one of the proposed radio access queuing solutions.



PAS radio access queuing flow chart.

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Telecommunications Analysis Services

Outputs

- Internet access 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 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 some 1-arc-second (30 m) and 3-arc-seconds (90 m) resolution for much of the world and GLOBE (Global One-km Base Elevation) data for the entire world; the US 1990 census data with the 1997 population updates; Federal Communications Commission (FCC) databases; and geographic information systems (GIS) databases such as the land use/land cover (LULC) database. For more information on available programs see the Tools and Facilities section (p. 79-81) or call the contact listed below.

The TA Services computer was recently upgraded and is now ten times faster than before, with about 210 gigabytes of storage capacity (three times the previous capacity). We have also obtained 1-arc-second (30 m) terrain data for CONUS with some data at 10 m resolution, which will become available later in FY 2002.

TA Services is currently assisting broadcast television providers with their transition to digital television (DTV) by providing a model for use in

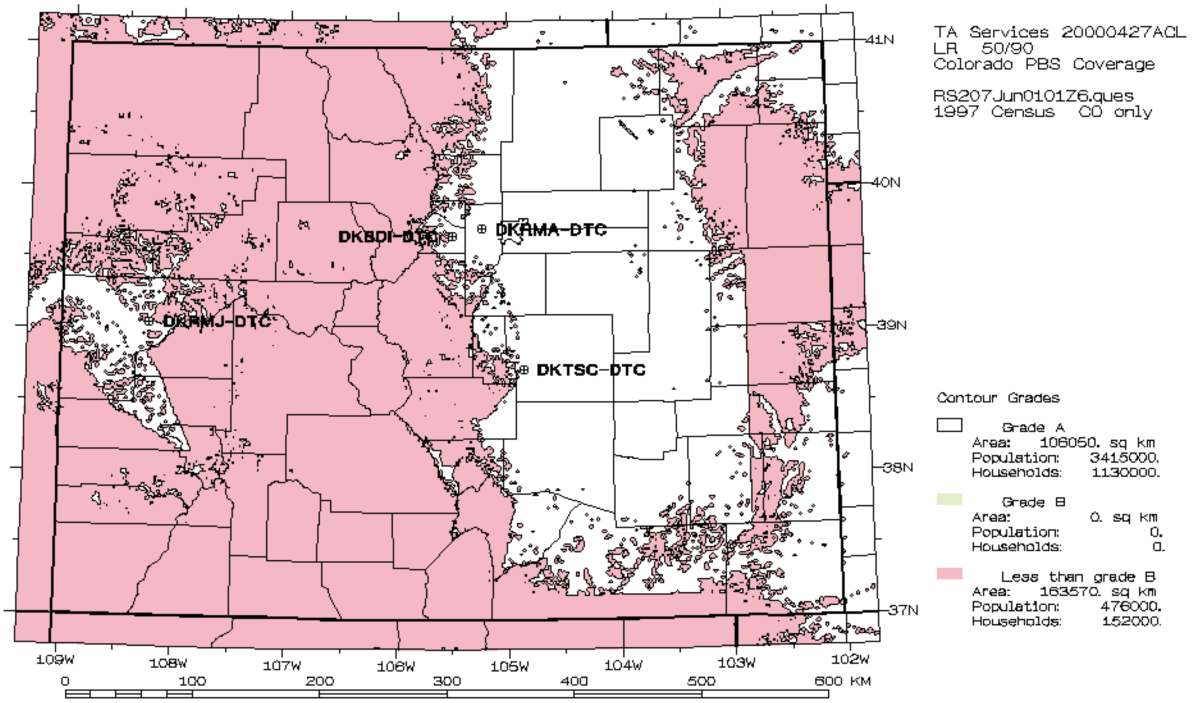

Figure 1. Interference analysis for proposed PBS digital coverage in Colorado.

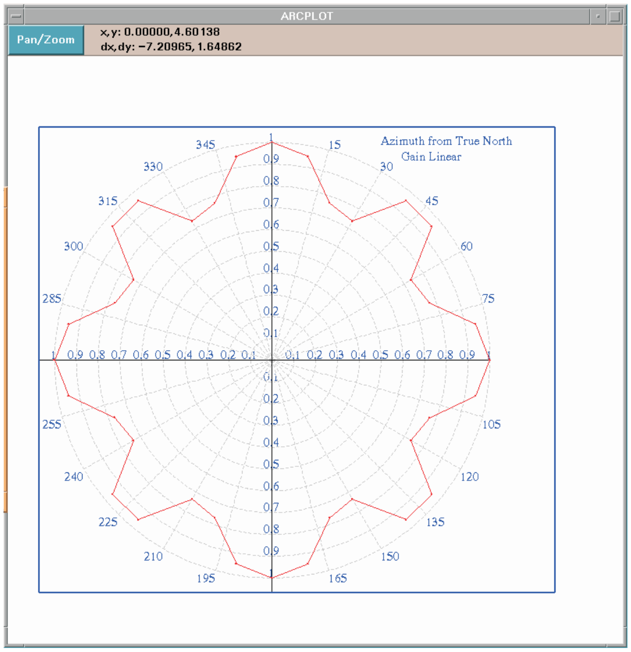

Figure 2. Antenna pattern from the user catalog in the TA Services PCS/LMDS model.

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 advanced television stations updated weekly from the FCC from which these scenarios are made. Results of analyses show those areas of new interference and the population and households within those areas. Figure 1 shows the result of a study done showing the proposed PBS digital coverage for Colorado. The model can also determine the contribution to interference from other stations to a selected station or 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 these modifications have on the interference that station gives other surrounding stations. In addition to creating a plot similar to that shown in Figure 1, the program creates a table which shows the distance and bearing from the selected station to each potential interferer as well as a breakdown of the amount of interference each station generates. This model can be accessed via a network browser.

TA Services continues to develop models in the GIS environment for personal communications services (PCS) and local multipoint distribution systems (LMDS). A GIS efficiently captures, stores, updates, manipulates, analyzes, and displays all forms of geographically referenced information. The use of GIS has grown substantially over the past several years. As a result, databases necessary for telecommunication system analysis are becoming available in forms easily imported into the GIS environment. These databases, including terrain, roads, communications infrastructure, building locations and footprints, land type and use, and many others, can be maintained in commonly used and available relational database management systems (RDBMS) that can be connected to the GIS or placed into the GIS RDBMS. This greatly reduces the amount of database development necessary in PCS/LMDS modeling.

As the frequency increases in a particular application, the level of detail required to describe the path also increases. At PCS and LMDS frequencies, we need to know the location of trees and buildings, the kind of vegetation a signal is penetrating, and the shape and materials used in buildings. Software available at ITS allows us to import digital stereo photographs or other remote sensing data taken from aircraft at relatively low altitudes or spacecraft and convert these images to three dimensional models of the region. This highly accurate surface is then imported into the GIS PCS/LMDS model.

The PCS/LMDS model under development at ITS lets a user select a region of interest with a database generated or imported into the model. These environment and analysis results can be displayed in two or three dimensions. A user can create a database of transmitters and antenna patterns from which to create analysis scenarios. The GIS software reads the location of the transmitter from the map and stores it in the transmitter definition table. Antenna patterns can be imported, entered in table form, or drawn on the screen by a user as shown in Figure 2.

Analysis scenarios consist of a set of transmitters, antennas, and models chosen to produce propagation results for a region of interest. Models include a line of sight (LOS) model, a diffraction model, and a ray tracing model under development by two prominent U.S. universities.

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Geographic Information System Applications

Outputs

- Propagation coverages for one or more transmitters draped over surfaces created by the program or imported by the user.
- Interference and overlap coverages of multiple transmitters.
- Performance predictions in stand-alone or trunked environments.

ITS maintains a suite of Geographic Information System (GIS) based applications which are available to public and private agencies for propagation modeling and performance prediction studies. A GIS efficiently captures, stores, manipulates, analyzes, and displays all forms of geographically referenced information in a user-friendly and flexible manner. Databases for use in GIS systems are becoming more commonly available at affordable prices and include such data as terrain, satellite photo imagery, roads, communications infrastructure, building locations and footprints, land type and use, water bodies, streams, population densities and many others. These are maintained in commonly used relational database management systems (RDBMS) which can be connected to a GIS. The Institute has modified and distributed this tool to several groups with modifications tailored to a specific application. These groups include government agencies, private cellular companies, paging system providers, public and private television systems, private consultants and transportation companies such as the railroads of the United States.

One form of this GIS tool is called the Communication Systems Planning Tool (CSPT). CSPT is a menu-driven propagation model developed for applications at frequencies as high as 50 GHz. The accuracy of the results and the usefulness and flexibility of the presentation of the results are enhanced by the power of the GIS background. CSPT allows the user to import digital stereo photographs or other remote sensing data which have been converted to 3-dimensional models of the region. This environment is then taken into consideration as the model calculates the results of the desired analysis. Contained within CSPT are propagation "engines" valid at frequency ranges used by cellular, personal communications services (PCS), radio, TV, pagers, microwave, and other communication links. New propagation models can easily be connected to the GIS with minimal effort, providing the user with greater flexibility and future growth.

A graphical description of CSPT is shown in Figure 1. The output shows an analysis area in Denver made from an imported digital elevation model and image at 1 meter resolution. There are four transmitters defined for this particular analysis.

The general flow of CSPT 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. Then the user creates or imports transmitter, receiver, and antenna data. This kind of data is now commonly available on the web from such sources as the Federal Communications

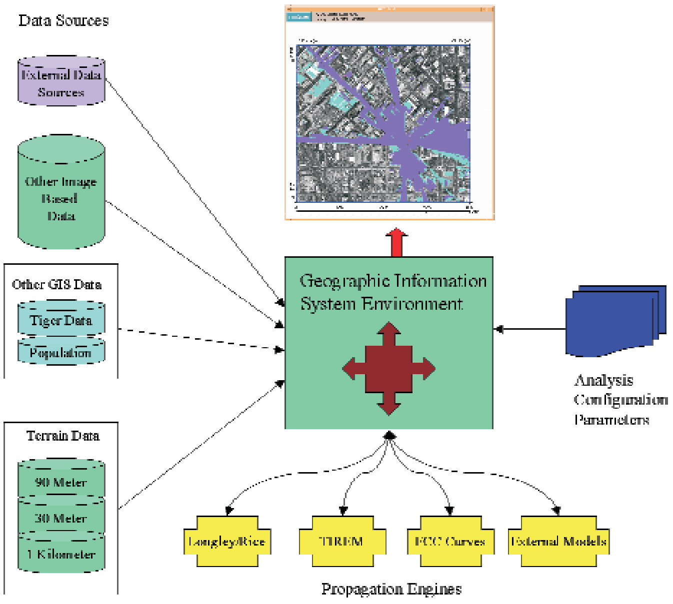


Figure 1. Overview of the CSPT model.

Commission (FCC) and antenna manufacturers. From this catalog of equipment, the user creates scenarios of transmitters and antennas. Each transmitter within the scenarios can be made active or inactive for any particular analysis calculation.

After creating the transmitter database, receivers, and antennas, the user selects a set of these for a particular study, and defines the type of analysis to be performed. The analysis can be a propagation prediction of one of the following types:

1. Create a line of sight (LOS) coverage only.
2. Calculate signal strength within the LOS region.
3. Calculate signal strength based upon terrain diffraction.
4. Calculate signal strength along a single path.

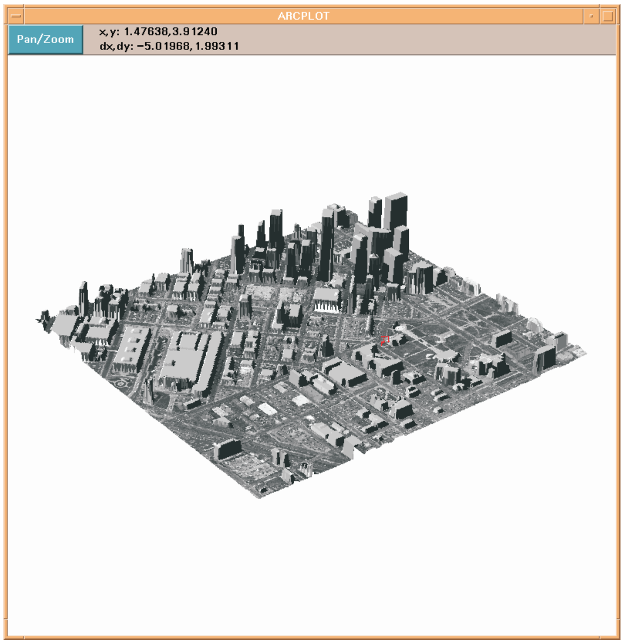
Propagation predictions from multiple transmitters can be overlayed to determine locations of redundant coverage or areas of interference. The output from a propagation prediction analysis can be displayed in any one of the following forms: field intensity (dBuv/m); available power (dBm); basic transmission loss (dB), or signal/ noise power ratio (dB). Signal strength calculations are performed by one of several prediction models according to the user's choice. The models included are:

- Longley/Rice – for analysis options based upon terrain diffraction.
- Tirem – for analysis options based upon terrain diffraction.
- Hata – for urban or suburban environments.
- Cost231 – for urban/suburban environments.
- FCC Curves – for areas larger than 5 km.

Analysis results are draped on top of the analysis area image. These results can be shown in two or three dimensions. Figure 1 shows an area of transmitter coverage for downtown Denver, in 2D. Figure 2 shows the same area of Denver in 3D. Figure 3 shows the transmitter coverage from Figure 1 draped onto the image of Figure 2. The user can zoom into any region of the analysis area and look at individual cell values of signal strength or interference.

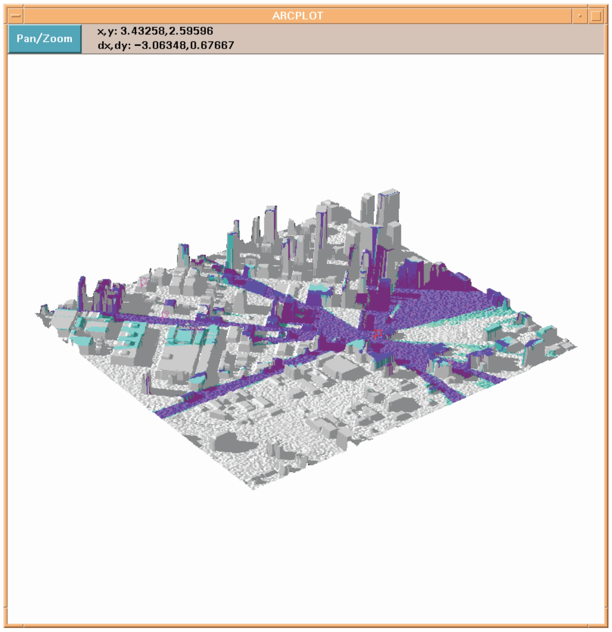
CSPT is available on a UNIX or Windows® NT platform. CSPT contains an extensive help system: most menus have a "help" button which displays an explanation of the options on that menu.

A user's manual is currently being written. We suggest that users have an account with ITS on our TA Services computer so that we may provide phone support.



x,y: 1.47638,3.91240
dx,dy: −5.01968,1.99311

Figure 2. CSPT analysis showing an area of Denver in 3D.



x,y: 3.43258,2.59596
dx,dy: −3.06348,0.67667

Figure 3. Same area of coverage shown in Figure 1, draped onto the image from Figure 2.

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Propagation Model Development

Outputs

- Comparison of algorithms used in ITM and TIREM models.
- Comparison of ITM and TIREM models to various measurement datasets.
- Technical contributions to ITU Study Group 3.

ITS' work on propagation model development in FY 2001 focused on intercomparison and harmonization of the two radio frequency electromagnetic wave propagation models employed by the U.S. Government, the Irregular Terrain Model (ITM) and the Terrain Integrated Rough Earth Model (TIREM). This work was sponsored by NTIA's Office of Spectrum Management (OSM) and by ITS. Progress in each area is described below.

ITM & TIREM Intercomparison

The Irregular Terrain Model (ITM) developed by ITS and the Terrain Integrated Rough Earth Model (TIREM) developed by OSM/IITRI were very similar thirty years ago. Both models are based on the National Bureau of Standards (NBS) Technical Note 101.* The ITM model has remained virtually unchanged since the early/mid eighties, but the TIREM model has undergone many significant changes during the same time period.

In FY 2001 ITS began a project to describe and compare the algorithms used in each of these models. Specifically, the algorithms for the line-of-sight (LOS), diffraction, and troposcatter regions are being examined, in addition to how each model utilizes an effective antenna height for these calculations. Effective antenna heights have a very significant effect on the results of calculations for propagation loss. When the analysis is complete, the final report will contain a summary of the results of the comparison of the algorithms used in ITM and TIREM. This analysis is expected to provide a better understanding of these algorithms, as well as propose explanations for why ITM and TIREM produce different answers, and suggest methods for obtaining the same answers with each model which also agree more closely with measured data.

ITM & TIREM Harmonization

During FY 2000, a study was launched to compare ITM v1.2.2 and TIREM v3.14 predictions to several measured radio propagation datasets. The major goals of this work, which continued throughout FY 2001, are to improve the predictive accuracies of ITM and TIREM, and to reduce or eliminate, where possible, differences between these two models' predictions for circuits with equivalent input values, all while preserving the increased predictive accuracies.

Certain difficulties arose when the results of two previous prediction-and-measurement comparison studies were examined. The two studies considered measurement data from sources (i.e., datasets) that had substantial commonality and both studies found comparable mean and variance statistics for the models' prediction errors, as these applied to the measurement datasets in question. However, careful examination of the results for individual paths revealed large differences in the detailed comparisons of the predictions for a given model (TIREM) between the two studies. Furthermore, there was evidence from the data that both the measurements and

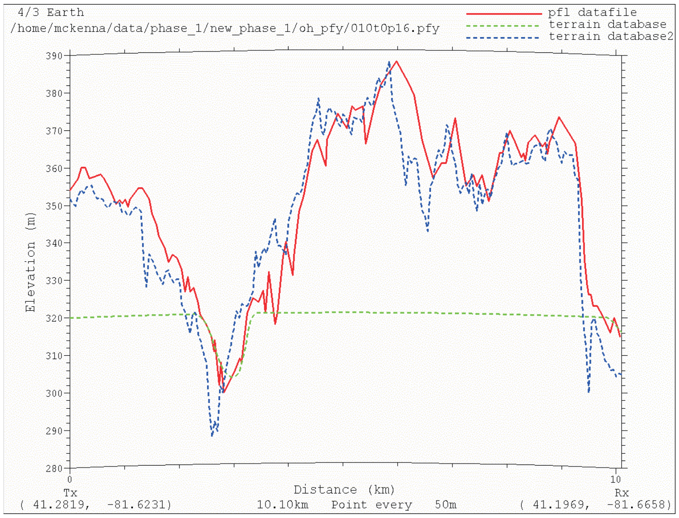

Figure 1. Comparison of profiles for a 10.1-km path in northeast Ohio.

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*P.L. Rice, A.G. Longley, K.A. Norton, and A.P. Barsis, "Transmission loss predictions for tropospheric communication circuits," NBS Technical Note 101, vols. 1 & 2, May 1965 (rev. May 1966 and Jan. 1967).

the predictions, and, hence, the prediction errors, were subject to significant correlation. Therefore, work on this project in FY 2001 was devoted to the resolution of these correlation difficulties.

The first difficulty, differing model predictions on ostensibly identical paths, is related to previously unrecognized discrepancies between the terrain elevation data in two U.S. terrain databases, Database A (shown in green in the figures) and Database B (shown in blue in the figures). Using manually extracted profiles taken from topographic maps (shown in red in the figures), for some of the datasets in question, it is possible to choose one terrain database over the other. Figure 1 shows a plot of the terrain profile for an area in northeast Ohio and Figure 2 shows a similar plot for an area in Virginia. The differences between the two digital terrain databases and the manually extracted profile can be clearly seen in these figures. Figure 3 shows a plot of the terrain profile for a mountainous area of Colorado. For the Colorado data, both datasets agree more closely with each other and with the manual data; however, in view of the Ohio and Virginia data it seems prudent to rely exclusively on Database B.

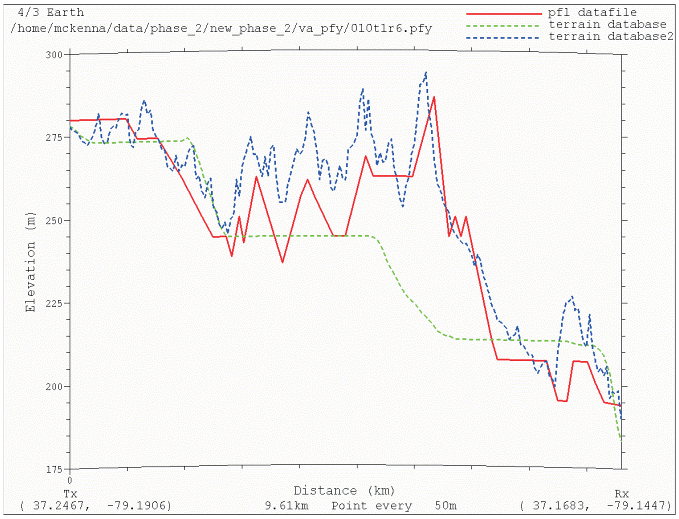

Figure 2. Comparison of profiles for a 9.61-km path in Virginia.

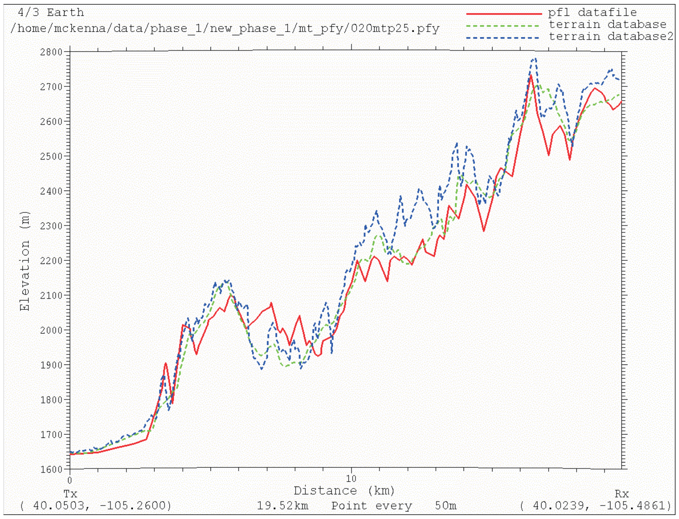

Figure 3. Comparison of profiles for a 19.52-km path in the Colorado mountains.

The second difficulty encountered in this study was the computation of statistics in the presence of correlated data. Stated succinctly, when one infers mean and variance statistics employing correlated data, faulty inferences can occur because these data are neither independent nor identically distributed. ITS has proposed a mechanism for the data correlation and tested it on several measurement datasets. Results show that there is substantial correlation in the data and that the statistics are affected by this correlation. In datasets where multiple measurements were attempted on any given path, the correlation among these measurements gives rise to a concentrated variance that greatly exceeds the variance that would have been estimated for any single measurement series, using standard univariate techniques. There are interesting differences in the contributions of each model's prediction error to these concentrated variances, and this result is expected to lead to useful guidance in the harmonization effort going forward.

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Tactical Communication Deception System

Outputs

- Analysis and specification of previous deception system.
- Inventory and requirements of tactical units' communication networks.
- Model and specifications of an upgraded deception system.

Physical decoys have long been deployed by the military to pose delusory threats. For example, missile decoys may be launched with intercontinental missiles to represent multiple "warheads" where only one exists. Similarly, a tactical communication deception system (CDS) can be deployed to emit radio signals like those from an operational tactical unit. Opposing forces must then decide which signal, if any, is being transmitted by the actual tactical unit. A CDS should be relatively inexpensive, portable, and able to be remotely deployed and controlled.

The U.S. Army tasked ITS to analyze the communication systems operated by its tactical units. The analysis included networks, noise, and the performance of the existing CDS. ITS then proposed a model for an improved CDS.

In an earlier study, ITS characterized the existing frequency hopping-frequency shift keyed (FH-FSK) CDS emulator. Therefore, our original focus in the current study was on the commonly-used FH-FSK radio system and how to improve the existing CDS. Most radio systems employed by the Army use some form of frequency modulation (FM), either analog or digital. A typical wireless FM system model, similar to that used by the Army, is shown in Figure 1. Mathematical models were provided to describe the bandwidth required for these systems with parameters used by the Army. Following a meeting at White Sands Missile Range with U.S. Army personnel that disclosed battlefield scenarios involving other radio equipment unique to the tactical operational unit, the focus was widened to include this other equipment.

Our proposal for a new CDS is shown in Figure 2.

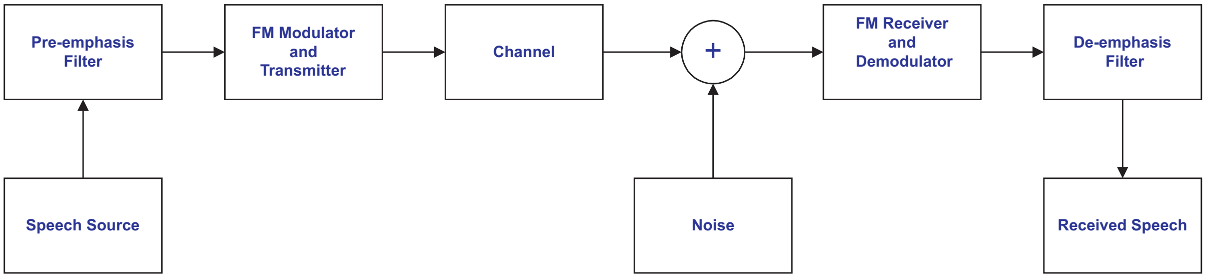

Figure 1. Typical wireless FM system model.

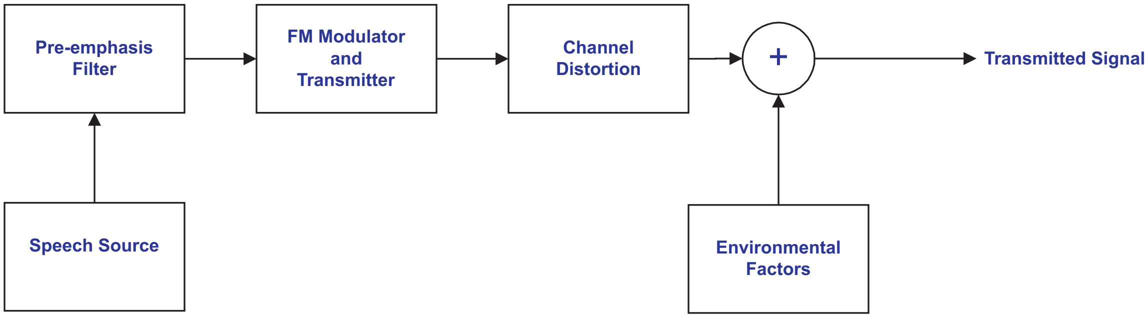

Figure 2. Model of proposed communication deception system (CDS).

In addition to an FM transmitter, it includes a Channel Distortion block and an additive Environmental Factors block at the output. The channel for these applications might be modeled with a Ricean probability model where the probability values are time varying in accordance with the changing environment. By choosing model parameters properly, power in the direct path or line of sight (LOS) can be varied with indirect paths and provide the illusion of mobile or stationary platforms.

The Environmental Factors block was provided for the representation of the man-made or natural noise. Impulse noise from generators and other equipment may be present and provide more realism to the deception signal. Furthermore, these frequencies are generally contaminated by galactic and solar noise in addition to lightning and switching noise. The amplitude of the impulse noise is commonly modeled by a log-normal distribution or a "power-rayleigh" distribution. The interarrival times can be described by a gamma distribution.

Future tasks could include the development of the model shown in Figure 2 and the construction of a prototype system to demonstrate the CDS in the field.

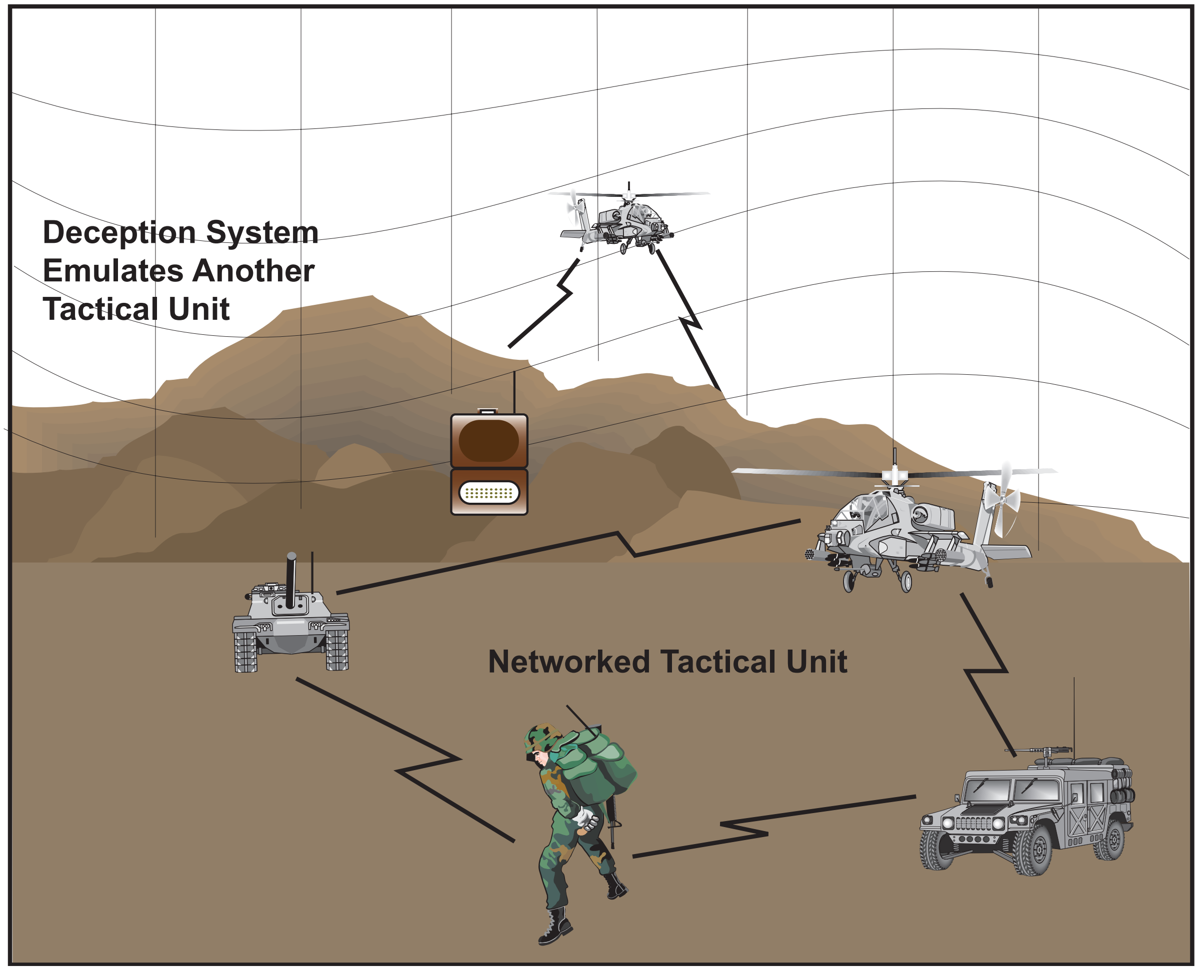

Figure 3. Battlefield communication network with activity and a remote CDS (drawing by A. Romero).

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