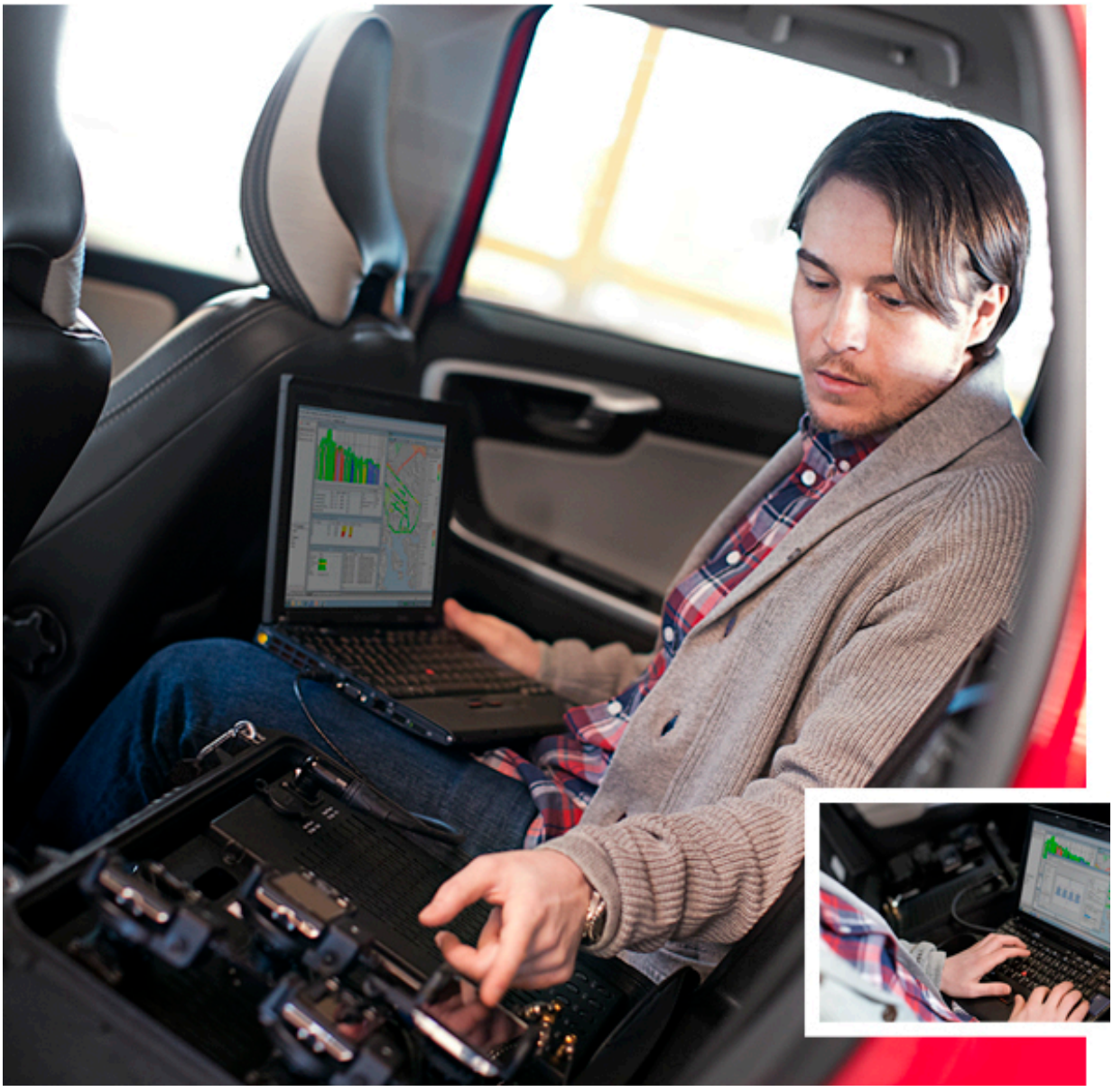
TEMS Investigation 14.1 Technical Product Description



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Contents

1 Introduction

1.1 The Network Challenge

Mobile operators depend crucially on their networks' performance: for the satisfaction of their customers and for the revenue that fuels their business and future growth. Operators around the world face the same challenges. The latest technologies must be implemented without delay, customer demand for new services is constantly expanding, and market forces hold down subscription rates. Yet despite these stresses, consistent high-quality performance is indispensable for success.

A number of tools and monitoring systems allow operators to measure, evaluate and improve the performance of their networks. Geographically positioned field measurements are critically important here, because no other category of metrics can match their precision in pinpointing the exact location and nature of problems. For example, while data sources such as network counters do provide significant information on performance, drive testing delivers targeted information on network failures before network launch and the entry of commercial traffic. Equally importantly, drive testing evaluates network performance from the end-user's perspective, delivering the information needed to improve customer satisfaction.

The capabilities of drive-test and troubleshooting tools can be applied to many activities that are required in the course of a network's life cycle:

- Site verification and acceptance
- Initial tuning (RF optimization)
- Network acceptance
- Service quality monitoring
- Optimization and maintenance
- Troubleshooting
- Network verification
- Benchmarking

Surveys show that bad user experience is the primary reason why subscribers change service providers, and that very few users report their complaints to customer care. Consequently, it is essential to measure performance in a way that captures users' perceptions, and continuous network monitoring to locate and eliminate problems at an early stage is necessary in order to maintain quality and grow the customer base.

1.2 What Is TEMS™ Investigation?

Used in more than 180 countries worldwide, TEMS Investigation is the industry-leading tool for troubleshooting, verification, optimization and maintenance of wireless networks. Offering data collection, real-time analysis and post-processing all in one, TEMS Investigation eliminates the need for multiple tools, reducing costs and saving time and effort for operations staff.

Designed for in-vehicle, in-building and pedestrian-area testing, TEMS Investigation's powerful and versatile features are essential throughout the network's life cycle. Using TEMS Investigation, operators can increase accessibility, improve retainability and heighten service performance.

The design of TEMS Investigation is based on these core objectives:

- Improve customer satisfaction by enabling operators to experience networks as their subscribers do.

- Provide powerful functionality that enhances work process efficiency and saves time.
- Provide multivendor and multitechnology capabilities in order to secure investments.
- Support a wide variety of terminals and scanners to meet each operator's unique testing needs.

TEMS Investigation is a complete, cost-effective and conveniently compact solution for the active field engineer. Its highly flexible and intuitive user interface keeps training costs to a minimum and allows users to take full advantage of the product's powerful features. With a solid history of success that serves as a reliable foundation for innovations and advances to come, TEMS Investigation is the number-one choice for operators worldwide.

1.2.1 The TEMS Investigation Concept

TEMS Investigation, a local user application, offers operators the capabilities of data collection with real-time presentation, on-screen post-processing and report generation – all packed into one tool. The software is executed on a standard laptop running Windows 7, Windows Vista or Windows XP.

TEMS Investigation interfaces with an extensive set of measurement devices from all major vendors across multiple technologies. TEMS Investigation uses these devices to collect geographically positioned data from a user's perspective.

An array of robust features makes data collection powerful and efficient. These include automatic device detection; customizable workspaces users can share; advanced device control; strong and intuitive scripting to manage and automate information gathering; event audio indicators; automatic upload of logfiles; and real-time data presentation.

Multiple devices can be connected to the application and can run simultaneously to minimize the time spent collecting data: RF data, L2/L3 messages and IP information.

TEMS Investigation supports testing of circuit-switched (CS) and packet-switched (PS) services including voice, video telephony, FTP, HTTP, TCP, UDP, Ping, email, WAP, MMS, SMS, video streaming and VoIP.

Backpacks containing battery solutions and equipment cases are some of the accessories offered to facilitate in-vehicle, in-building and pedestrian-area testing.

Thousands of information elements and events can be presented in more than 250 predefined presentation windows. These windows can be very flexibly modified, and users can also create their own windows from templates. All of this helps users meet specific analysis requirements and optimize presentation views for the task at hand. Customized events can be defined to locate problem areas. All presentation windows are synchronized, and all settings are saved in workspaces that can be reused or shared between users.

TEMS Investigation can be used to analyze logfiles from TEMS Investigation, TEMS™ Pocket and TEMS™ Automatic.

TEMS™ Discovery, a highly configurable and user-friendly post-processing solution for air interface measurement data, is recommended for use when large amounts of data are to be processed and analyzed, as well as for advanced report creation.

1.2.2 Technologies and Devices

The commitment, experience, strength and future direction of Ascom Network Testing ensure that TEMS Investigation is constantly updated to meet the evolving needs of the wireless industry. Support for LTE (FDD and TDD), GSM, GPRS, EDGE, WCDMA, HSPA, HSPA+, TD-SCDMA, CDMA (IS-95 to EV-DO Rev B) and WiMAX, together with support for a wide range of services, makes TEMS Investigation the ideal choice for network operators.

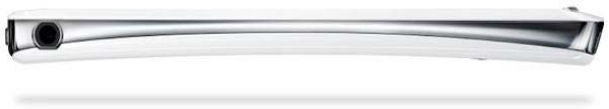
The multimode functionality for system verification, troubleshooting and optimization of radio access networks allows users to:

- Execute concurrent measurements on different technologies, thus saving time.
- Verify compressed mode behavior and optimize intersystem handover and cell reselection.
- Verify and compare coverage and performance between different technologies.

The tool ensures seamless integration among LTE, WCDMA/HSPA and GSM/GPRS/EDGE networks as well as LTE, CDMA EV-DO, CDMA2000 and IS-95 networks.

TEMS Investigation supports a broad portfolio of measurement devices, including phones, smartphones, data cards, USB modems, fixed wireless terminals and scanners from all major vendors across multiple technologies.

Each operator has unique testing needs, and with more than 300 verified measurement devices from over 30 device vendors – phones, smartphones, data cards, USB modems, fixed wireless terminals and scanners –, TEMS Investigation offers the flexibility needed to provide tailor-made solutions. Sony Ericsson, Nokia, LG, Samsung, Sierra Wireless, HTC, Huawei, Option, Novatel Wireless, ZTE, Leadcore, Ascom, PCTEL, DRT, Rohde & Schwarz, Anritsu, Transcom, ST-Ericsson, Qualcomm, GCT, Sequans, Hisilicon, Via, and Altair are a few of the device and chipset vendors supported by the tool. New devices are continuously added.



In addition to the extensive device portfolio, TEMS Investigation offers unrivaled and unique device control capabilities that promote cost-efficient processes and permit measurements that cannot be performed with competing tools.

A large customer base and close cooperation with device and infrastructure vendors enable short leadtimes when introducing new technologies, chipsets and devices. TEMS Investigation has long been established as the leading-edge drive-testing tool for next-generation network rollouts, including HSPA+ and LTE.

1.2.3 Packaging and Licensing

The multitechnology, multivendor approach, together with flexible licensing and packaging, allows advanced customization according to the operator's individual needs and requirements. Features and technologies can be added when required in order to minimize the initial investment. The upgrade paths to new releases and functionality allow customers both to utilize their initial investment and to secure a solution for future needs.

The software allows data collection and analysis for any technologies and devices that have been selected in the purchased product package. It is also possible to purchase TEMS Investigation without data collection capability. Customers who dispense with TEMS Investigation data collection are still able to use the non-real-time functions of the application (single-logfile analysis, logfile reports and logfile export) for troubleshooting and analysis.

Powerful **post-processing** facilities are provided by TEMS™ Discovery.

Licenses for TEMS Investigation can be local licenses (residing in hardware keys) or network-based (licenses managed by and detached from network license server).

1.3 Key Features and Benefits

For two decades, TEMS Investigation has been the originator of features and functionality in the drive-testing area: functions that solve specific problems, promote cost-efficient work processes, minimize human errors and improve productivity – allowing operators to focus on safeguarding network quality.

Maximized return on investment – Complete solution for multimode system verification, optimization, analysis and benchmarking in relation to in-vehicle, in-building and pedestrian-area testing.

Future-proof – Scalable, adaptable and constantly updated to meet evolving needs.

Early availability – New technologies, features and devices can be verified before going live.

Solutions tailored to individual needs – Multitechnology and multivendor support, extensive device portfolio, and flexible licensing and packaging.

Testing from a user perspective – Geographically positioned air interface and service quality measurements taken with devices used by subscribers.

Powerful and easy user interface – Efficient, intuitive, customizable and feature-rich user interface leads to short learning curve and reduced training costs.

Efficient work processes – Quick to set up, easy to use and customize, with unique time-saving capabilities that make a difference.

With its rich feature set, TEMS Investigation offers operators the freedom to perform the measurements and tests that they want to perform without affecting end users.

TEMS Investigation offers a number of **exclusive measurement and control capabilities**:

- Lock on technology and restrict use of frequency bands
- Lock on a PLMN, specified by an MCC and MNC combination
- Manipulate access class settings
- Define voice codecs to be enabled, as well as priorities
- Enable/disable HSDPA and HSUPA capabilities and redefine HSDPA/ HSUPA category support
- Enable/disable EDGE capability
- Alter phone behavior with respect to barred and reserved cells
- Lock on, or prevent use of, one ARFCN or a set of ARFCNs
- Force or prevent handover to a single or a set of specified ARFCNs
- Lock on, or prevent use of, one UARFCN or a set of UARFCNs
- Lock on UARFCN and a single or a set of scrambling codes
- Override the BLER target set for the UE by the WCDMA network
- Discard Layer 3 messages of specified types
- Specify GSM Tx Power to be used
- Measure C/I for all hopping channels in all used timeslots
- Measure C/A on hopping channels
- Perform GSM channel verification to check the availability of GSM traffic channels
- Scan GSM and WCDMA with UEs (alternative to dedicated scanners)

How can you troubleshoot or verify service performance on a second or third WCDMA carrier, evaluate a specific speech codec or perform measurements on GPRS without affecting other network users?

With TEMS Investigation it is easy: Use the exclusive control capabilities to configure the device for a specific measurement scenario. For example, lock the phone to one UARFCN and disable all speech codecs except the one to be verified. This is quick and efficient, with no altering of network traffic preference parameters and no interruptions for regular network subscribers.

With multiple use areas and the resulting substantial cost savings, the tool's unique control capabilities have empowered work processes and given users around the world control of their measurements.

The above is just a sample of the many key features available to the TEMS Investigation user. For more information, please see the subsequent chapters.

1.4 Users and Use Areas

TEMS Investigation is the keystone of the most complete solution for troubleshooting, verification, optimization and maintenance of wireless networks. Designed for in-vehicle, in-building and pedestrian-area testing, and with an extensive array of powerful and versatile features, TEMS Investigation plays an important role for operators who seek to increase accessibility, improve retainability and achieve better service performance.

Operators, consulting companies (contractors), RAN vendors, device vendors, universities and education providers, government agencies and regulatory bodies around the world are TEMS Investigation users.

TEMS Investigation is used for multiple activities for multiple reasons, but the principal use areas are associated with activities that ensure a smoothly operating and high-performing wireless network throughout its life span.

Even before the first site is in place, TEMS Investigation is used to provide pathloss measurements as input to network planning tools and site survey activities.

SITE VERIFICATION AND ACCEPTANCE

Single **site verification** is performed in order to identify problems introduced during site installation and to validate equipment functionality. Measurements are taken in order to verify cell coverage, hardware configuration and RF parameter settings, as well as service accessibility and mobility. If acceptance requirements are met, the site is released for RF optimization. Device control functionality is useful in isolating cells and simplifying measurement procedures. Handheld solutions are preferred, and the TEMS Pocket option adds valuable flexibility to TEMS Investigation.

INITIAL TUNING

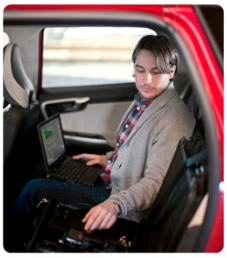
Initial tuning (RF optimization) is a labor intensive network optimization activity, intended to prepare the network for commercial launch. Network design, hardware installation and parameter settings are evaluated and tuned in an iterative manner in order to maximize user experience from day one. Signal coverage, interference situations and neighbor relations are in focus. Powerful and efficient data collection and analysis tools are necessary here in order to achieve cost-efficient work processes.

NETWORK ACCEPTANCE

Before a network is commercially launched it has to meet the stated acceptance criteria. Field measurements from a user's perspective are performed on a cluster basis, and key performance indicators (KPIs) are calculated and reported. Requirements related to signal coverage and interference, as well as service accessibility, retainability, mobility and integrity, have to be fulfilled. With its flexible reporting capabilities, TEMS Discovery combines with TEMS Investigation into an excellent solution for **network acceptance**.

SERVICE QUALITY MONITORING

The **service quality** experienced by users in a network is directly related to the utilization of network resources. Greater numbers of subscribers, altered subscriber usage patterns, new devices and applications, and an ever-changing external environment are all factors that affect service quality and force operators to conduct iterative optimization activities. Continuous **monitoring** to locate and eliminate problems at an early stage is necessary to maintain quality and keep customers. Regular service quality measurement campaigns, conducted with drive-test tools, are important complements to O&M/OSS statistics and customer feedback, and give operators a true view of user-perceived service quality.



OPTIMIZATION

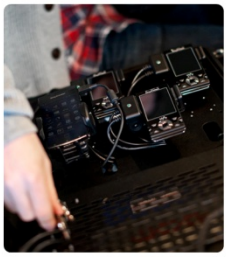
Network optimization is a recurring activity intended to maintain or improve network performance. Field measurements and analysis tools play an important role. Both reported and potential problems should be identified and solved, the utilization of existing resources should be maximized, and potential future changes to the network design should be identified. Network optimization is a multifaceted activity which typically engages the complete range of features of the drive-test and analysis tool.

TROUBLESHOOTING

Troubleshooting is conducted in conjunction with all other activities performed. Users can explore findings related to site verification, initial tuning, optimization and service quality measurement campaigns and present solutions. They can also investigate issues raised by O&M/OSS systems and customer complaints. Efficient troubleshooting demands the very best from data collection and analysis tools. Advanced device control functionality is vital, as are powerful analysis capabilities, when issues are to be detected, reproduced, analyzed and solved.

NETWORK VERIFICATION

Implementation of new RAN features and services must be validated from a user's perspective. In addition, core **network** modifications that might impact end users have to be assessed. **Verification** of new RAN features and services requires leading-edge drive-testing tools that continuously evolve to support today's and tomorrow's wireless networks. The drive-test tool must support the devices that are needed to perform specific measurements. Therefore, a broad device portfolio and rapid integration of new devices are imperative.



BENCHMARKING

The ability to benchmark mobile network performance is an important requirement for many service providers and regulatory bodies. They need to know what coverage and quality of service they can offer compared to their competitors. **Benchmarking** of different devices regarding behavior and performance is of interest for network operators and RAN vendors alike. TEMS Investigation supports simultaneous measurements on multiple devices, and with its multitechnology support, extensive device portfolio, intuitive scripting functionality and fast integration of the latest technologies and devices, it is a tool used for benchmarking worldwide.

Network and device vendors employ TEMS Investigation for multiple activities related to research and development, verification and integration. Universities and training providers utilize TEMS Investigation in their curricula to educate the next generation of engineers.

This exhaustive range of capabilities amply demonstrates why TEMS Investigation is the most complete tool on the market.

1.5 TEMS Product Portfolio

Ascom Network Testing offers the TEMS portfolio, a complete set of trusted solutions for drive testing, analyzing, benchmarking and monitoring mobile network and application performance. Whether used independently or as integrated solutions, TEMS products enable network operators to ensure quality, availability and operational efficiency.

Individual probes to test and evaluate the performance and quality of wireless networks and services:

- **TEMS Investigation** and **TEMS Pocket**: Software to visualize, analyze and report mobile network performance and quality.
- **TEMS Discovery** and **TEMS Visualization**: Dedicated probe systems to benchmark and monitor the performance and quality of wireless networks, services and content.
- **TEMS Symphony**, **TEMS Monitor Master** and **TEMS Automatic**: Experience, knowledge, and a focus on future technologies and services have made the TEMS portfolio the number one choice for operators worldwide.

1.6 Where to Find More Information

For additional information on TEMS Investigation, other TEMS products, or TEMS product training, please visit us on the Web at www.ascom.com/networktesting.

TEMS Bulletins contain updates on new TEMS product releases, events and general information about the TEMS portfolio. You can also obtain up-to-date details on patch releases. To sign up for this free service, go to www.ascom.com/networktesting and, under the heading “TEMS Bulletins,” click the link “Register for TEMS Bulletins.” Along with this material you will also receive our customer magazine, TEMS News.

2 New Features and Functionality

2.1 What's New in TEMS Investigation 14.1

2.1.1 LTE Cell Frame Timing IEs

Inter-cell **synchronization** is a central concept in LTE networks. For TD-LTE in particular with its unpaired spectrum, the same frequency being used on both uplink and downlink, accurate synchronization between cells is crucial. Compared to FDD there is also a more complex range of interference issues to handle, including interference between UEs in adjacent cells and between eNodeBs. Still, even for FDD, synchronization is necessary within a site owing to the overlap between its cells; it is also highly beneficial between sites, since this enables the use of techniques such as CoMP (coordinated multipoint), scheduling traffic in an efficient way among multiple cells.

TEMS Investigation 14.1 presents **cell frame timing** data in newly constructed information elements for the current LTE serving cell and neighbors. This information can for example be used to:

- Verify and troubleshoot synchronization in the network.
- Compare and evaluate synchronization techniques.
- Optimize heterogeneous cell deployment: for example, adjust timing in a pico cell to a surrounding macro cell, taking into account the propagation delay from the macro cell eNodeB.
- Identify co-sited cells (having identical or nearly identical timing offsets) in an unknown network.
- Estimate distance to a site and determine its position by triangulation.

See also the examples in section 6.1.1.

2.1.2 Extended Control Functionality and Logging for Sony Ericsson Xperia arc S

Sony Ericsson Xperia arc S now supports **audio quality measurement**, including PESQ and POLQA. See also section 2.1.3.

The following additional **control functions** have been implemented for the Xperia arc S phone, taking smart measurements with this device several steps further:

- Access class control – modify access class settings
- PLMN control – lock on MCC + MNC combination
- BLER target control – modify BLER target assigned by network
- Speech codec control – redefine set of speech codecs enabled in phone

The **data collection and presentation** have also been augmented in various respects, notably:

- UARFCN and SC indicated for each SIB
- C/I per TCH computed for GSM circuit-switched services
- SIR target presented

2.1.3 POLQA for CS Voice

The state-of-the-art POLQA algorithm for speech quality assessment, previously introduced for VoIP, is now available also for **circuit-switched voice**. POLQA can be computed for both narrowband and super-wideband speech. POLQA is obtained in the ACU (TerraTec) audio quality measurement configuration.

2.1.4 Cell Whitelists

A common constraint in testing of cellular networks is to restrict tests to a **predefined set of cells**: for example, verifying a new or reconfigured cell cluster, or performing some procedure that would disturb regular network operation unless it is limited to cells that have been specially configured for the purpose.

In this version of TEMS Investigation it is possible to enter a **list of allowed cells** ("**whitelist**") and have it converted into a user-defined event. This event can then be used in a script to trigger some action whenever the tester is in an allowed cell. A "periodic" flag has been added as a new property of user-defined events, so that a cell whitelist event can be generated repeatedly and continuously listened for by a script. Making use of these features lets the user conduct rigorously selective network testing in a minimum of time and without any extra effort in the field.

See also section 5.7.2.

2.1.5 Scripted Scanning

Scanning tasks can be scripted instead of being run manually from the Navigator pane. Controlling scanning from a script brings the same benefits of convenience and automation as for other testing activities.

2.1.6 Manual Pinpointing Mode in Pinpoint Window

In the Pinpoint Window, routes can now alternatively be traced manually while walking, as opposed to being planned in advance and followed during the walk. The manual mode is similar to the pinpointing function in the Map window. Offering both modes in the Pinpoint Window tool adds further to its flexibility and usefulness.

2.1.7 Hisilicon LTE Chipset Support

The accessibility of LTE network testing is further broadened as TEMS Investigation 14.1 adds support for Hisilicon chipset based LTE devices.

2.1.8 Via CDMA/EV-DO Chipset Support

TEMS Investigation 14.1 introduces support for devices equipped with a Via CDMA/EV-DO chipset.

2.1.9 New Connectable User Terminals

- Axesstel MV610VR (Gateway R90, Net1, EV-DO Rev. B)
- Huawei E398S (Hisilicon chipset based)

2.1.10 New Connectable Scanners

A TD-LTE scanner from Transcom Instruments is offered as a cost-efficient solution for scanning of TD-LTE networks. Supported LTE bands are:

- TDD 1900 MHz (Band 39)
- TDD 2300 MHz (Band 40)
- TDD 2600 MHz (Band 38)

2.1.11 LTE RRC Redirection Events

The LTE RRC connection redirection events have been extended to cover redirection to EV-DO (HRPD/eHRPD).

2.1.12 New LTE Information Elements

- PDSCH BLER and ack/nack counters for Transport Blocks 0 and 1 separately, giving a more fine-grained view of retransmission statistics.
- PUSCH ack/nack counters.
- Rank Indication counters showing incidence of values RI = 1 and RI = 2, useful for studies of MIMO channel properties.

2.2 What Was New in TEMS Investigation 14.0

2.2.1 Control Functions for Smartphones

TEMS products have a long tradition of offering unique device control capabilities that rely on advanced measurement capabilities in the device hardware. TEMS Investigation 14.0 continued and reinforced this tradition by adding the Sony Ericsson **Xperia arc S** smartphone as a connectable device. This is a Qualcomm chipset-based device running under Android, and it obeys the following control commands:

- Lock to RAT
- Lock to band (WCDMA and GSM)
- Control cell selection and handover (WCDMA and GSM)
- Set cell barred behavior (WCDMA and GSM)
- Enable/Disable HS capability

The **Samsung Infuse 4G** smartphone (ST-Ericsson chipset based), likewise new as a connectable device in TEMS Investigation 14.0, supports all of the above commands as well as the following:

- Control access class
- Control PLMN
- Control speech codec usage
- Enable/Disable EDGE capability

2.2.2 New Logfile Format

The old logfile format (*.log) was replaced in TEMS Investigation 14.0 by a new format with extension **.trp**. The new format embodies a more flexible and versatile framework for recording of measurement data:

- **Multiple** logfiles can be recorded in parallel, each recording being wholly independent of the others. The activities of one device can be recorded in any number of logfiles simultaneously.
- In logfile recording controlled by a script, you can opt to record only a **subset** of the activated devices.
- At creation time, you can tag logfiles with **metadata** which can serve as an aid to locating, sorting and categorizing the files later on. Some of this metadata is also visible in Windows Explorer.
- The logfile **size** is significantly reduced compared to the LOG format.

When loading a completed logfile into TEMS Investigation later on for analysis, extensive information about the file appears on a new Navigator tab called the **Logfile** tab. Here you can view not only general information (time and space coordinates, descriptive metadata added at recording time, and more) but also:

- A list of the participating **devices** with accompanying key properties (capabilities, hardware identifiers and more), presented in the same way as in live mode. If you wish, you can hide data from selected devices in the logfile presentation.
- A complete **chronology** of the activities performed by all devices, and their outcomes. The chronology can be grouped by device or activity type, or filtered to show only one device or one type of activity.
- Activity **statistics**: Total/succeeded/failed/aborted.

Full compatibility with the old logfile format (*.log) is of course maintained.

2.2.3 Speech Quality Measurement with POLQA

POLQA, defined in the ITU P.863 standard, is the successor of PESQ, being specially developed for HD voice, 3G and 4G/LTE and VoIP. POLQA was introduced in TEMS Investigation 14.0 as a speech quality measurement algorithm for VoIP.

The POLQA (Perceptual Objective Listening Quality Analysis) algorithm is designed along similar lines as PESQ, being a reference-based method that compares the degraded speech with the undistorted original to assess quality. However, it has been refined to eliminate known weaknesses of PESQ, particularly in these areas:

- Handling of new and complex types of distortions that arise from today's convergence and coexistence of voice, data and multimedia application services. One example is the effects of packet loss and of packet loss concealment.

- Performance for higher-bandwidth audio signals (wideband, super-wideband).
- Performance for CDMA speech codecs and hence for CDMA networks in general.

2.2.4 Searching, Filtering and Highlighting in Message Windows

New functions for searching, filtering and visual highlighting were implemented in message windows in order to accelerate analysis. The search functions essentially correspond to the Find in Logfile feature in pre-14.0 product versions, which was removed in TEMS Investigation 14.0. You can:

- **Find arbitrary text** in message headers. Optionally, the full message contents can be searched. Case and whole-word matching is available. A “find next/find previous” feature is included for easy stepping back and forth between hits (can be done with the keyboard arrow keys).
- **Show only** messages of a selected type.
- **Hide** messages of a selected type.
- Highlight selected types of messages in **unique colors**.

2.2.5 Expansion of Scanning Capabilities

- GSM scanning capabilities of Rohde & Schwarz TSMW were made available for use with TEMS Investigation:
  - RSSI scanning, static ARFCN set
  - RSSI scanning: BSIC decoding
  - RSSI scanning: C/I measurement
- LTE: TDD and FDD pilot scans can be run in parallel on Rohde & Schwarz TSMW.
- The handling of scanning configuration sets was relaxed, allowing multiple devices to scan concurrently using different configuration sets.

2.2.6 Improved Service Testing Capabilities

TEMS Investigation 14.0 introduced the option of using **Internet Explorer 9** for HTTP download testing instead of TEMS Investigation’s built-in Web browser. Two new HTTP information elements were provided (regardless of browser used): total **document size** and **download time**.

Flow control in scripting was rendered more powerful with the new **Wait For** activity. You can use this activity to halt execution:

- until a given time of day (with optional subsequent repetition of activities that are placed in a loop with the Wait For activity)
- until a given event (or one event from a defined set) occurs
- until an activity in another workflow branch concludes with a stipulated outcome.

The **Parallel** (workflow branching) structure was amplified in one important respect: Within such a structure you can assign **multiple activities of the same type** to the same device. This means that you can set up, for example, multiple concurrent FTP

download sessions with one device simply by putting the sessions in parallel branches in your script. There is no need to pass special concurrency parameters with the FTP testing activity.

2.2.7 Logfile Export Enhancements

The logfile export tool was repackaged into a **separate executable** which can alternatively be run from a Windows command prompt. Command line switches are provided for all aspects of the export setup that are configurable from within TEMS Investigation. Command-line controlled export can be scheduled with the generic scheduling functionality in Windows. All of these features help you manage logfile export more smoothly and save time.

Cell files can be included when exporting logfiles. This affects exported information elements and events in precisely the same way as cell files loaded in TEMS Investigation enrich the presentation in the application user interface (populating information elements that require cell file data, etc.).

2.2.8 Improved HASP Soft License Handling

A **license manager portal** was introduced, facilitating management of network licenses and adding traceability. In this Web-based portal, which can be installed under Windows 7 or Windows Server 2008/2003, the license server administrator assigns to each TEMS Investigation user the products they are allowed to detach and sets a maximum detach duration. Further constraints such as license expiry dates can be defined. “Category” fields are provided for convenient grouping of users. Reports on license usage can be generated and also exported in comma-separated (CSV) format.

Side by side with the license manager portal, a client license manager with a graphical user interface is provided. From this utility, users detach licenses to their local machines. The client works over a VPN, and the main benefit it brings is that it greatly reduces the risk of detaching the wrong license by mistake.

2.2.9 New Connectable User Terminals in TEMS Investigation 14.0

LTE devices:

- Huawei M920
- LG LS840 (LG Viper)
- LG MS840 (LG Connect 4G)
- LG P936 (LG Optimus)
- Samsung SCH-R920
- Samsung SCH-R940
- ZTE N910

UMTS devices:

- Sony Ericsson Xperia arc S (EU): See also section 2.2.1 regarding control functions
  - WCDMA/HSPA 900/2100 MHz (LT18i)

  - WCDMA/HSPA 800/850/1900/2100 MHz (LT18a)
  - GSM/GPRS/EDGE 850/900/1800/1900 MHz
  - Google Android 2.3
  - Qualcomm Snapdragon MSM8255 (1.4 GHz)
  - HSDPA Category 10 (14.4 Mbit/s), HSUPA Category 6 (5.76 Mbit/s)
- Huawei E353
- LG P505
- LG P509
- Sharp 006SH

2.3 What Was New in TEMS Investigation 13.1

2.3.1 Alternative Mobile-to-mobile AQM Solution

This is a cost-efficient solution for mobile-to-mobile audio quality measurement. Two or four mobile devices, which call each other in pairs, are connected to an Audio Capturing Unit (ACU) which relays the audio to the PC. The PESQ calculation is done by the PC itself, so that no separate processing power is required in the Audio Capturing Unit. Since the voice calls are made between the mobiles, there is also no Call Generator or similar component in this AQM configuration.

The activities of the devices are completely controlled from TEMS Investigation by means of a Service Control script, just as in the existing TEMS Investigation AQM setup.

The mobile-to-mobile AQM solution is in principle RAT-independent. In TEMS Investigation 13.1 it was implemented for the following phones: Sony Ericsson Xperia arc, Sony Ericsson W995, Nokia C7-00 (GSM/WCDMA); Huawei C8600 (CDMA).

See also section 5.4.2.

2.3.2 CS Fallback Events and Information

The “circuit-switched fallback” mechanism allows a user terminal connected to EUTRAN to access the CS domain via GERAN or UTRAN. A number of events – some new, some expanded in scope – report on the resulting interaction between the terminal and networks.

Event categories:

- Call setup events
- Inter-RAT events
- Attach events

2.3.3 Extended Set of LTE RACH Information Elements

A collection of new information elements deals with the RACH procedure in LTE: RACH Type, RACH Reason, RACH Result, Preamble Step Size, RACH Preamble Responses with PUSCH Resource, MME Group Id and MME Code.

2.3.4 Improved Handling of Qualcomm-based LTE Devices

Network connect can be performed for Qualcomm chipset-based LTE devices from within TEMS Investigation, that is, without using an external connection manager.

TEMS Investigation also permits connection of multiple Qualcomm-based LTE devices.

2.3.5 CDMA/EV-DO Rev. B Measurement and Analysis

Rev. B of the EV-DO (TIA-856) standard introduces multicarrier data transfer in EV-DO. TEMS Investigation 13.1 allows connection of devices built on a range of Qualcomm CDMA/EV-DO Rev. B chipsets. The implementation has been verified with the Huawei EC367-2 device.

Presented information elements subdivide into three categories:

- Basic radio parameters
- Multicarrier serving channel information
- Forward link multicarrier RLP throughput

2.3.6 New Connectable User Terminals in TEMS Investigation 13.1

- Sequans TD-LTE USB modem SQN3010A-USB-M1, operating on LTE Band 40 (2300–2400 MHz) and based on TD-LTE-capable chipset SQN3010
- Samsung Galaxy S 4G
  - Android-based
  - WCDMA/HSPA 1700/2100 and 2100 (Bands IV, I)
  - GSM/EDGE 850/900/1800/1900
  - HSUPA Category 6 (5.76 Mbit/s), HSDPA Category 14 (21 Mbit/s)
  - Advanced control functionality
- Sierra Wireless AirCard 319U
  - Dual-Carrier HSPA+ USB modem from Sierra Wireless
  - WCDMA/HSPA+ 850/900/1900/2100 (Bands V, VIII, II, I)
  - GSM/EDGE 850/900/1800/1900
  - HSUPA Category 6 (5.76 Mbit/s), HSDPA Category 24 (42 Mbit/s)
- Other new LTE devices:
  - BandLuxe C501
  - Huawei E392

  - Sierra Wireless AirCard 313U
- Other new UMTS devices:
  - Huawei E367
  - Huawei E372
  - Novatel Option MC996D
- New CDMA devices:
  - Huawei C8600
  - Huawei EC367-2
  - Huawei M860
  - Kyocera S1350
  - LG KV600
  - LG KV755
  - Samsung SCH-R720
  - ZTE AC8710

2.3.7 WCDMA Scanning with Rohde & Schwarz

WCDMA pilot (Top N) scanning can be undertaken with Rohde & Schwarz TSMW scanners. There are no restrictions on supported frequency bands (30 MHz to 6 GHz).

2.3.8 CDMA/EV-DO Scanning with PCTEL SeeGull MX

Support was added for CDMA/EV-DO scanning (PN scan, RSSI scan) with PCTEL SeeGull MX.

2.3.9 New Connectable Scanners in TEMS Investigation 13.1

- PCTEL SeeGull MX LTE 800/900/1800/2600 + WCDMA 900/2100 + GSM 900/1800
- PCTEL SeeGull MX WCDMA 850/1900/2100 AWS + GSM 850/1900 + CDMA/EV-DO 850/1900/2100 AWS
- Anritsu ML8780A

2.3.10 Software Update Service

A TEMS Investigation software update service was introduced. This service checks for new patch releases on a regular basis. The new feature streamlines administration processes and minimizes waiting time.

2.3.11 Enhancements in TEMS Investigation 13.1.1

- Multiple concurrent PN scans can be performed with PCTel MX and EX scanners: for example, one PN scan on a 1x (cdma2000) frequency and one on an EV-DO

frequency. This feature is a time-saver that reduces the hours you have to spend on drive testing.

- Min/max/median versions of HS transport block size IEs introduced:
  - HS Transport Block Size (Min), HS Transport Block Size (Max), HS Transport Block Size (Median), all with arguments for primary carrier and secondary carrier.
  - HS MIMO Transport Block Size (Min), HS MIMO Transport Block Size (Max), HS MIMO Transport Block Size (Median), all with arguments for stream 0 and stream 1.
- Support added for Samsung Galaxy S II LTE (Telia).
- Support added for Anydata ADU-895A (CDMA/EV-DO Rev. B, 450 MHz).
- Support added for Novatel Ovation MC551 4G LTE USB modem (Band 13, Verizon).
- Support added for Huawei U6100 (HSPA, Telenor).

2.3.12 Enhancements in TEMS Investigation 13.1.2

- The existing indoor measurement solution was complemented with a new **Pinpoint Window**, where you create and walk pre-planned indoor test routes. The point of pre-planning routes is to render route walks as simple as possible, promoting an efficient work process and saving time and money. User actions are reduced to the clicking of three buttons: **commit** to a waypoint on reaching it, step **forward** to the next waypoint, and step **backward** to the previous waypoint in case you want to repeat a part of the route. The buttons are generously sized to permit easy and accurate tapping on a touch screen while walking around.

  Indoor map sets, which incorporate building and floor plan information as well as the planned routes you create, are saved in the iBwave Design container format (*.ibwc). Logfiles recorded when walking planned routes are saved in regular TEMS Investigation logfiles.

  Indoor testing with the Pinpoint Window is fully aligned and compatible with TEMS Pocket (which likewise supports pre-planned routes) as well as with post-processing in TEMS Discovery.
- A large number of new LTE information elements were introduced. These relate mainly to: cell reselection parameter settings and measurements (intra-frequency, inter-frequency and inter-RAT); discontinuous reception (DRX); DCI format usage on PDCCH; and sounding reference signals (SRS).
- To the HTTP Get script activity were added two new options: 1) Terminate session after a specified duration; 2) Terminate session after downloading a specified amount of data.
- Support added for Altair FourGee 3100 chipset (TDD/FDD LTE); implementation verified with Altair reference device
- Support added for GSM scanning with Rohde & Schwarz TSMW.
- Support added for the following devices:
  - Datang/Leadcore LC8143

- HTC Vivid (PH39100)
- LG MS695
- Samsung SCH-R920 (Chief)
- Samsung SGH-I727 (Galaxy S II Skyrocket)
- Samsung SGH-I997 (Galaxy S Infuse 4G)
- ZTE X500.

3 Data Handled in TEMS Investigation

TEMS Investigation utilizes data from all of the following sources:

- **Terminals:** GSM, WCDMA, LTE, TD-SCDMA and CDMA air interface measurements
- **AQM modules:** PESQ and other audio quality measurements
- **Scanners:** GSM, WCDMA, LTE, TD-SCDMA, CDMA, WiMAX
- **Data service testing software,** integrated into TEMS Investigation
- **GPS units,** stand-alone or built into scanners
- **Cell files:** GSM, WCDMA, LTE, TD-SCDMA, CDMA, WiMAX, Wi-Fi
- **Logfiles** from TEMS Investigation and a range of other sources

3.1 Information Elements

Information elements are the building blocks of all quantitative presentations in TEMS Investigation. They are gleaned from reports delivered by phones, scanners and GPS units. Being derived from these sources, they contain:

- Air interface measurements (GSM, WCDMA, LTE, TD-SCDMA, CDMA, WiMAX)
- Data service measurements
- Network configuration parameters
- Cell data
- Positioning data

The total number of information elements is well above 1,000.

3.2 Events

Events signify interesting occurrences relating to the operation of the connected equipment. Events are generated by the TEMS Investigation software based on data received from these devices. Some examples of predefined events are:

- Blocked Call, Dropped Call (UMTS, CDMA)
- PDP Context Activation Failure (UMTS)
- Radio Link Addition Failure (UMTS)
- Baton Handover (TD-SCDMA)
- Hard Handoff (CDMA)
- Traffic Handoff to EV-DO (CDMA)

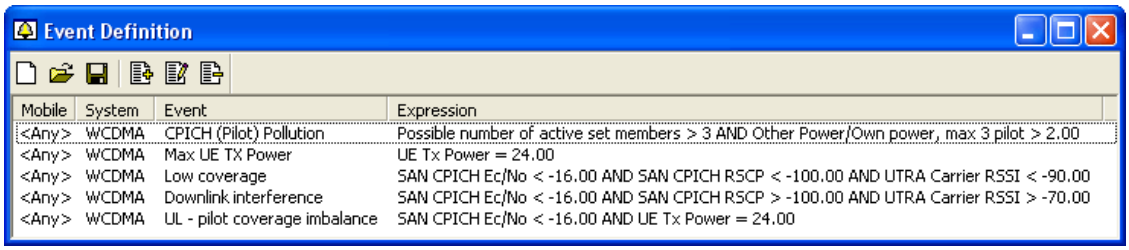
Events are a vital part of TEMS Investigation presentations and are often instrumental in directing the workflow of the network engineer. They can save a lot of time in the troubleshooting and optimization processes, allowing quick identification of problem areas – whether during drive testing or during post-processing.

The user can also define customized events by composing logical expressions, which may contain the following types of trigger conditions:

- Occurrence of other event
- Appearance of Layer 3 message
- Value change of information element
- Value of information element meeting threshold condition (>, =, or <)

Allowed logical operators are AND, OR, XOR and NOT.

Below are some examples of user-defined events (for WCDMA). Their names tell what they are designed to indicate.



3.3 Cell Data

TEMS Investigation can present data on the cell sites of the measurement area: location, power settings, antenna configurations, etc.

Cell data can be provided in several ways:

- in a file with a TEMS Investigation specific format
- in an XML file whose format is common to multiple TEMS products

In either case the files are stored as plain text for maximum flexibility.

Cell files used in TEMS Investigation CDMA (file extension .csv) can be converted to the XML format using TEMS Discovery.

Supplying cell data enables a multitude of useful functions in the application. See section 6.8.

The XML format also supports definition of Wi-Fi access points, which can then be presented in TEMS Investigation in the same way as cells in cellular networks.

4 Vehicles of Presentation in TEMS Investigation

TEMS Investigation is equipped with the following means of presentation:

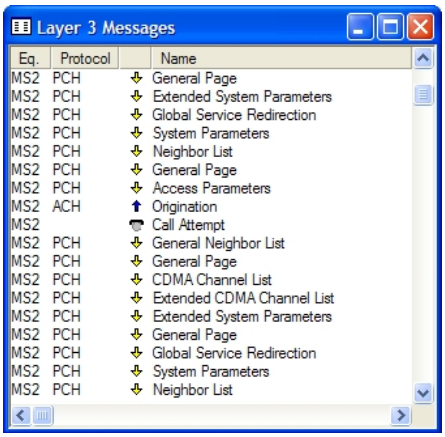
- Message windows
- Line charts
- Bar charts
- Map windows
- Status windows (text-format, tabular)
- Event Counter window

A large set of predefined windows of the above types are supplied, all of which can be freely modified by the user. There are also blank line chart and status window templates which the user customizes from scratch.

Status windows are constantly refreshed, showing the situation at one instant in time, whereas maps and line charts accumulate information and display the whole history of the testing session. All windows are synchronized: When the user selects an arbitrary time instant in a map or line chart, the status windows are automatically updated to show the parameter values current at this point in time.

4.1 Message Windows

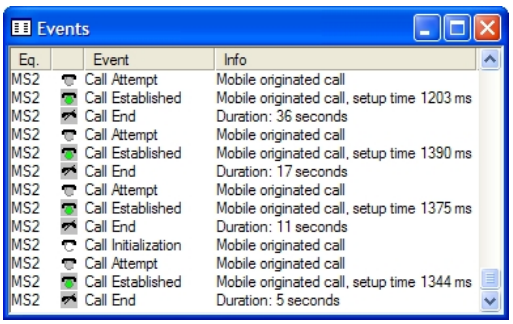
Message windows are used to list Layer 3 messages, Layer 2 messages, mode reports and error reports from external devices, as well as events generated in TEMS Investigation (see section 3.2). Below is the Layer 3 Messages window:



The window displays the name and direction (uplink/downlink) of each message as well as which protocol the message originates from. A filtering function lets the user select precisely which Layer 3 messages to show.

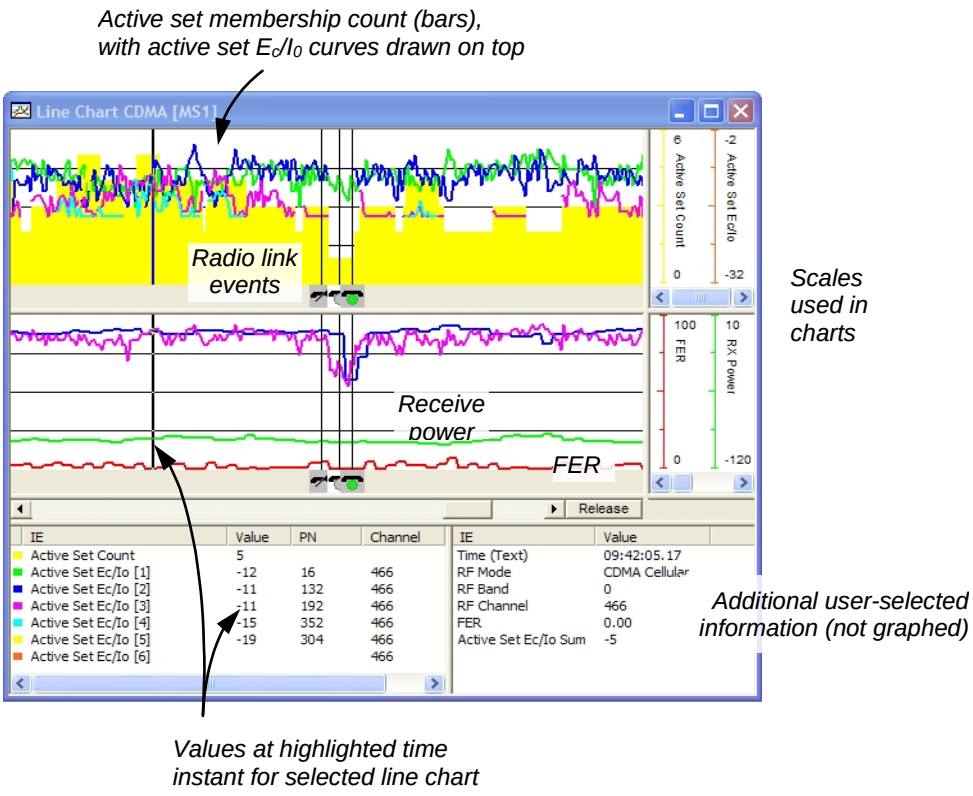
Message windows have a number of useful interactive features. Clicking a message freezes the window, so that the details of the message and its context can be studied at leisure.

A special window is dedicated to the presentation of events; it displays the same event symbols as in maps and line charts and supplies any extra information that may be associated with the events:



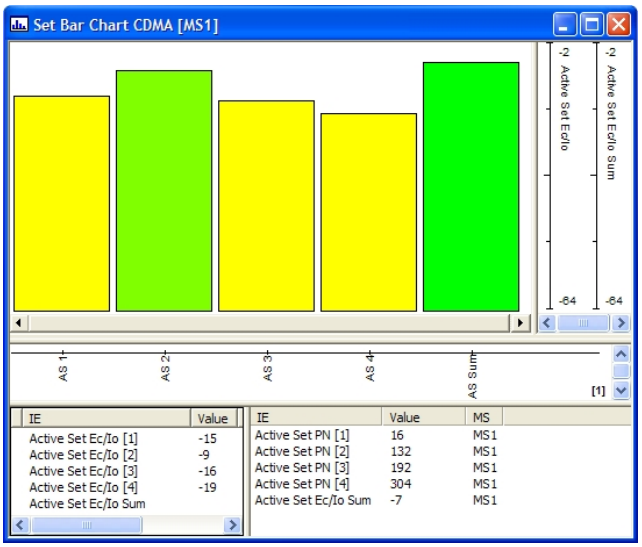
4.2 Line Charts

The line chart visualizes how numerical information elements evolve over time, also displaying at what points events have occurred. The Line Chart window is subdivided into a number of synchronized panes. See the cdma2000 example below.



4.3 Bar Charts

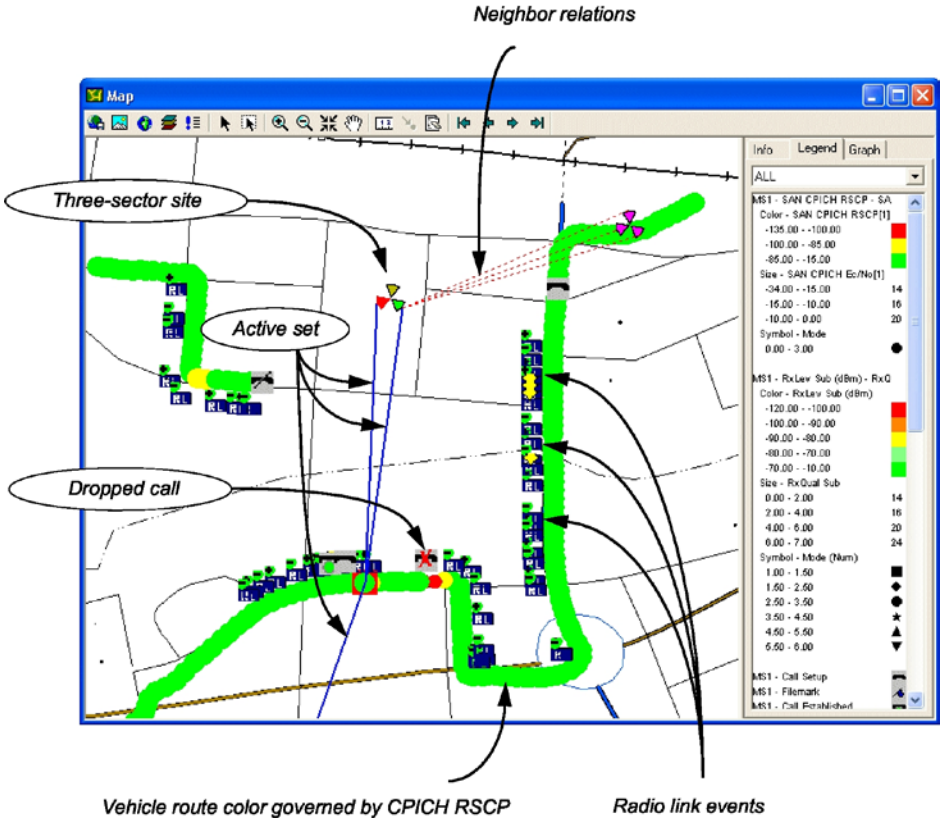
The bar chart is primarily intended for presenting frequency scans (see sections 6.6 and 0), but is by no means limited to that application. Any numerical information element can be presented.



Bar chart showing E_c/I_0 for each member of the active set in cdma2000.

4.4 Map Windows

Drive test routes can be presented graphically on a map of the investigated area. Measurement data and events are plotted symbolically. The positions of cell sites can also be drawn, with the added possibility of indicating the serving cell/active set throughout the test drive by means of successive connecting lines. A separate pane on the right enables the presentation of auxiliary information, such as a map legend.

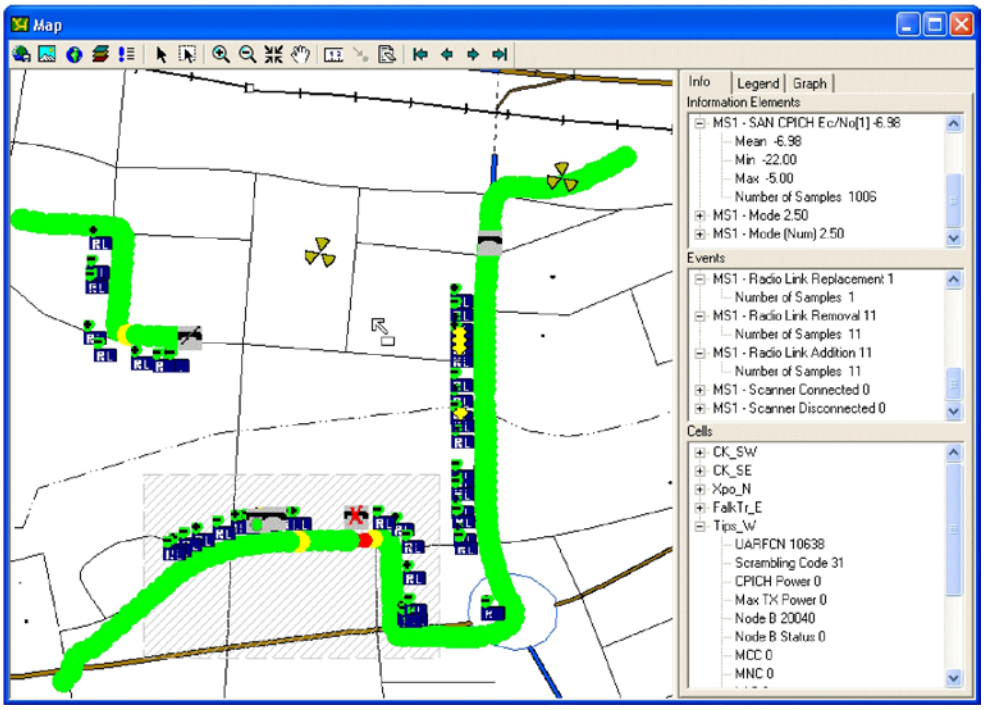


The default settings for route markers (showing, among other things, signal strength) can, of course, be freely modified by the user. Each route marker can code up to three information element values (marker size, color and shape). Several markers can be drawn in parallel in order to show more data.

Clicking a map symbol displays the data it represents in the right-hand pane. Selecting an area enables presentation of statistics for this area, as exemplified below.

A multilayer structure is used for the presentation data, just as for the elements of the map image itself. The visibility of each layer can be controlled separately.

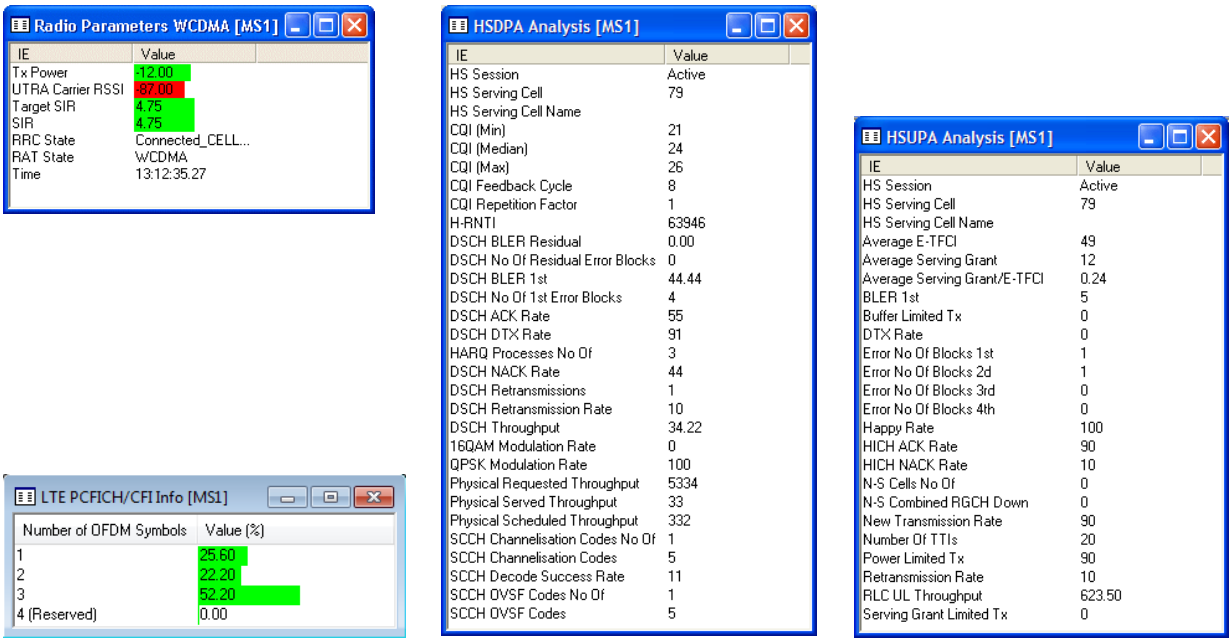
Other map features include panning, zooming, labeling of map elements and choice between different projections (using GeoSet file). Maps can be in MapInfo, uncompressed TIFF, or bitmap format. Note that map plotting requires access to positioning data.



Map window with area selected for statistics computation (dashed gray rectangle). Statistics on information elements and events are shown in the top two boxes on the right. The third box holds cell information.

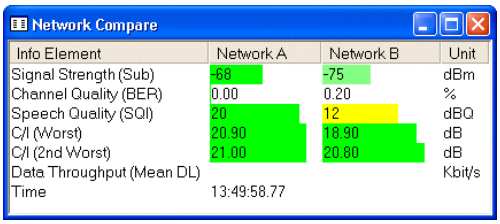
4.5 Status Windows

The status windows present information elements in tabular form. There are a number of ready-made windows designed for presenting particular categories of information (such as signal strength or speech quality). In addition, there is a blank template which can be used to compose status windows of the user's choice.



WCDMA radio parameters (top left), LTE PCFICH/CFI Info (bottom left), HSDPA information (center), HSUPA information (right)

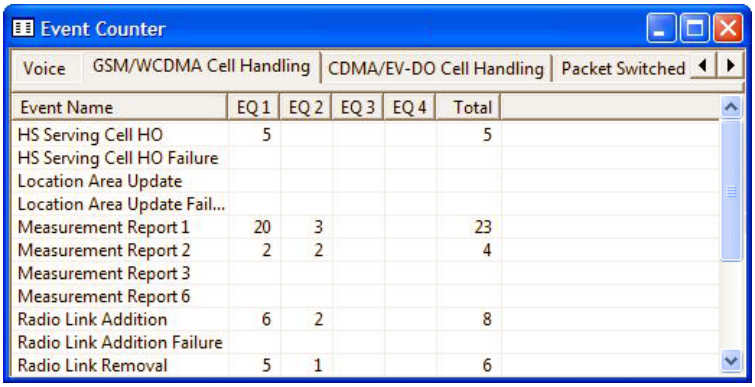
Note that *any* pieces of information available in TEMS Investigation may be viewed together in status windows. The blank status window template permits users to design their own status windows bottom up:



Two UMTS networks, A and B, are compared. A uses the AMR speech codec, whereas B uses the EFR codec. The speech quality, as might be expected, is superior for A at the time instant shown. Also, A uses frequency hopping while B does not (B has no "2nd Worst" C/I, since only a single channel is used). Two phones are used for the measurements, one for each network.

4.6 Event Counter Window

The Event Counter window keeps track of the number of times various events have occurred. The set of events to show is completely user-configurable; a number of default tabs have been set up grouping predefined events into categories (“Voice,” “Packet Switched,” etc. – see image below). Tabs can be freely substituted and renamed; for example, a CDMA user might want to remove the GSM/WCDMA tabs.



Counters can be reset by the user at any time. In both recording and logfile analysis mode, counters are reset automatically when a new logfile is opened.

5 Collecting Data with TEMS Investigation

5.1 Technologies

This section focuses on data collection with user terminals. Regarding scanning, see section 5.6.

5.1.1 UMTS and CDMA

TEMS Investigation covers the whole of UMTS and CDMA.

For UMTS, most of the supported phones can make calls on both WCDMA and GSM networks and perform handover back and forth between the two types of network. When in WCDMA mode, the phone also monitors GSM neighbors in order to enable handover to the GSM network whenever justified. In GSM mode, WCDMA neighbors are monitored in the same manner.

On the CDMA side, EV-DO-capable phones also have cdma2000 (1x) support. When in EV-DO mode, the EV-DO log mask is applied to the handset, and when the phone switches from EV-DO to cdma2000, the cdma2000 log mask is applied.

In both UMTS and CDMA, events are generated in connection with all handovers/handoffs. These include:

- WCDMA inter-frequency as well as inter-system handovers (in the latter case, compressed mode usage is also indicated).
- CDMA hard handoffs as well as handoffs between cdma2000, EV-DO and cdmaOne.

5.1.2 LTE

Data service testing can be done with LTE-capable UEs. CS fallback handover from EUTRAN to UTRAN/GERAN and back can be tested, as can RRC redirection from LTE to any of GSM, WCDMA, 1x or EV-DO (HRPD/eHRPD).

5.1.3 TD-SCDMA

Voice and data service testing is performed with dual-mode TD-SCDMA/ GSM phones.

5.1.4 General Remarks on Data Service Testing

TEMS Investigation is capable of doing data service testing with almost any device. The only requirement is the availability of Windows drivers that make it possible to set up an IP data connection. As a result, a wide variety of phones, smartphones, network cards, USB modems, embedded modules, etc., can be used. Any IP-based activity as well as the video streaming activity in the Service Control Designer can be tested with such a device, and all IP information elements will then be populated.

5.2 Logfile Recording and Transfer

The framework for recording logfiles is highly flexible, with a rich set of options allowing precise scoping of data collection, and an elaborate file format structure that permits extensive storing of auxiliary data.

Logfile recording can be initiated in several ways: **manually**, as a side-effect of starting an indoor **route walk**, or automatically as dictated by a **script** that is executing.

When starting a recording, you can enter **metadata** for the logfile (subject, tags and description), which is useful for categorizing and locating files later on.

Multiple logfiles can be recorded at the same time, each recording being completely independent of the others. The activities of one device can be recorded in several logfiles simultaneously. Conversely, for scripted recording, you can exclude devices you do not want in the logfiles and record data only from a subset of devices.

Filemarks can be inserted in logfiles during recording to tag segments of particular interest.

Data is logged in a manner that minimizes the risk of data loss in case of hardware malfunctions, such as power failure in the PC.

5.2.1 Recording Indoor Measurement Routes: Pinpointing

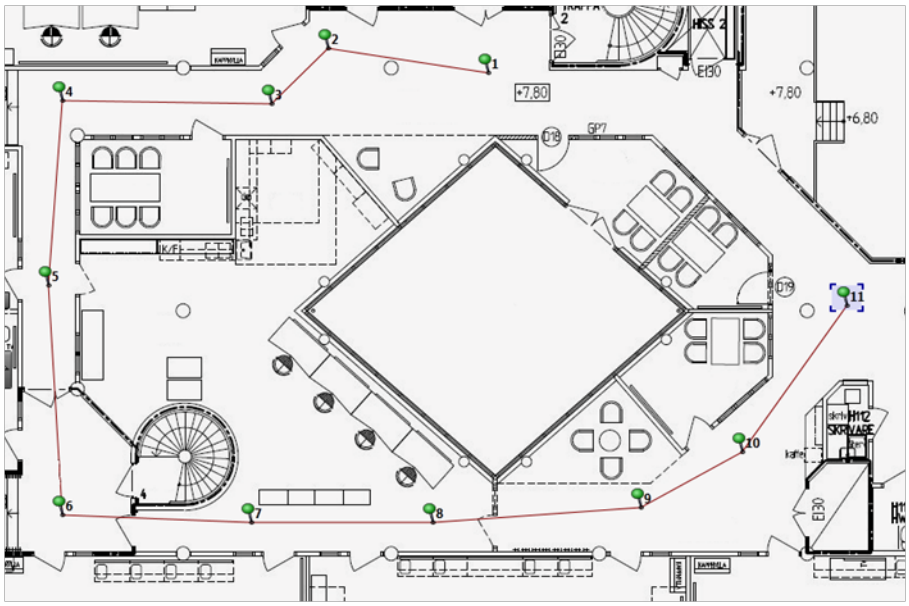
In indoor environments, where there is normally no line-of-sight to GPS satellites, data must be positioned by other means. With TEMS Investigation this is achieved by **pinpointing** geographical positions on a floor plan or other background image.

The mechanics of pinpointing can be approached in different ways. One method is to plan your route in advance, then walk it and mark (“commit to”) each waypoint as you reach it. Another method is to walk around without constraints, just as in a drive test, and mark your positions on the map as you go along.

In either case, TEMS Investigation defines the route by joining consecutive waypoints with straight lines, and the measurement data is assumed to be distributed evenly along each route segment. Therefore, to have data positioned with maximum accuracy, you should walk your routes at a steady pace.

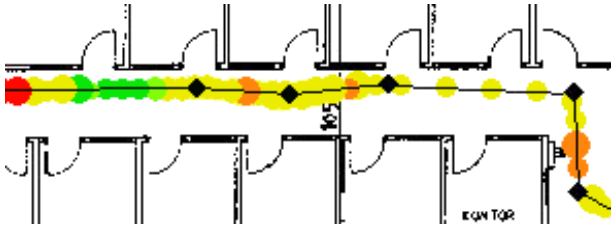
5.2.1.1 Pinpointing Along Pre-planned Routes

Planned routes are created and walked in the Pinpoint Window. First you **create** your route by clicking consecutive spots on the floor plan loaded, saving the route as part of the indoor map set. See the image below, which shows a route (red line) defined by waypoints (pins). You can then **walk** the route and record your walk in a very simple way: For each waypoint, click the “Commit” button (labeled with a plus sign) to indicate that you are currently in that spot. Then click “Forward” to advance to the next waypoint.



5.2.1.2 Freehand Pinpointing

In “free-ranging” indoor testing, you indicate your route by regularly clicking or tapping your current position on the screen, creating waypoints as you go. This can be done either in the Pinpoint Window or in a Map window. Below is a Map window screenshot showing a testing route with waypoints in the form of black diamond-shaped markers. The signal strength along the route is indicated by the color of the circle-shaped markers.



In the Pinpoint Window, a manually pinpointed route can optionally be saved with the map set for later reuse, just like a pre-planned route.

5.2.2 Automated Logfile Transfer

You can set up TEMS Investigation to automatically **transfer** recorded logfiles to a designated FTP server, over the air or via an Ethernet connection. This mechanism serves to simplify ways of working and reduce lead times, always providing quick access to the latest logfiles throughout the organization.

In setting up the FTP transfer, you enter FTP server and login details and configure a number of parameters. The file transfer can be either manual (initiated by the user on each occasion) or automatic (triggered when the recording of a logfile ends). Logfiles are automatically compressed prior to transfer so as to minimize the amount of data to upload.

5.3 Service Control Scripts: Test Automation

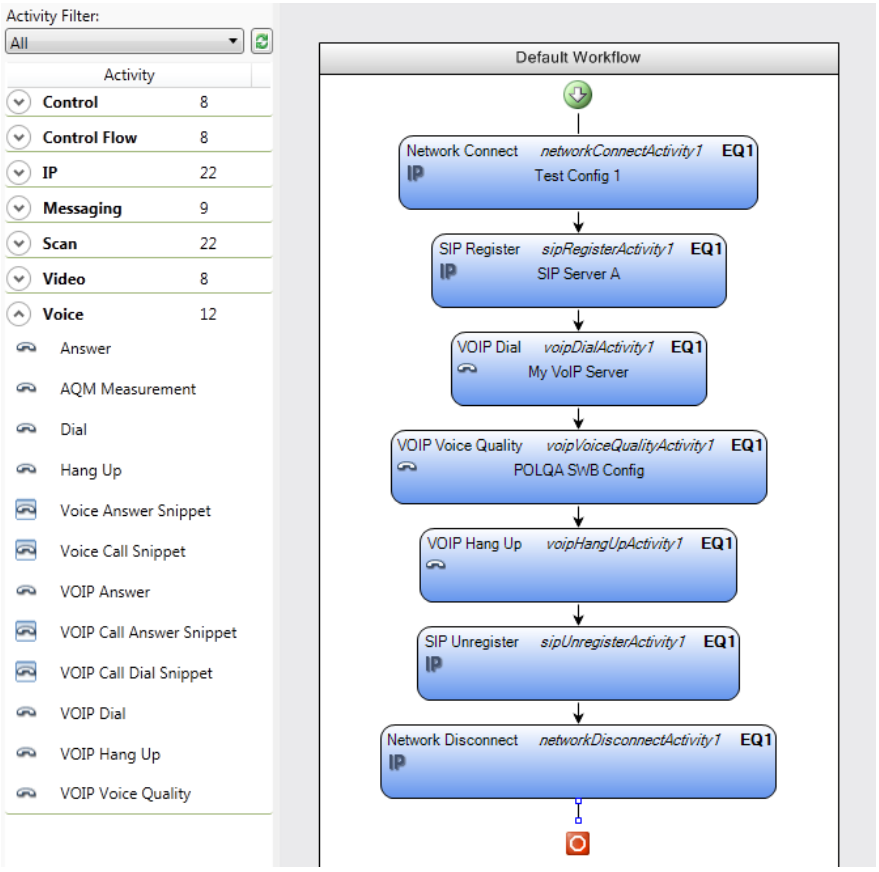
The service control tool is used to compose **scripts** that automate service testing – PS as well as CS. Scripting guarantees consistency of measurements, with tests executed in a uniform and rigorously controlled manner. Scripts also allow you to create advanced testing setups that would be awkward or impossible to manage by operating devices manually.

Scripts are assembled in the Service Control Designer, where they are visualized in an intuitive **flowchart** format, as shown in the screenshot below. Activities are picked from the left-hand pane and inserted by drag and drop at the desired position in the workflow.

Scripts can be structured using **control logic**: loops, branching, if-else conditions, sequences and more. Synchronization of devices is implicitly done wherever workflow branches converge.

Details on servers, call recipients and other entities to interact with are encapsulated in separate **configuration sets** which can be reused across scripts. Scripts can be saved with or without the configuration sets – the former being handy if you want to distribute the script for use on a different PC.

Predefined building blocks ("**snippets**") are provided for all supported services, speeding up script building. Snippets can of course be freely modified to suit your individual needs, just like any other components of a script.



Service control script for VoIP testing (calling party). A similar script (with Dial replaced by Answer) is assigned to the called party.

5.3.1 Testable Services and Protocols

Service testing can be scripted for:

Voice and video calls over CS		E-mail
Voice over IP (VoIP)		WAP
FTP download/upload		MMS
HTTP download		SMS
Video streaming (live/on-demand)		UDP
Ping		TCP
All scanning tasks		

Further valuable service testing features are as follows:

- **Multiple concurrent** data service sessions can be run on the same device. This extends to multiple instances of the same service: for example, parallel FTP downloads.
- Special script activities are provided for **network connect**/disconnect, **PS attach/ detach** and **IP sniffing**.
- The execution of a script can be monitored, step by step, in the separate **Service Control Monitor** window.

5.3.2 Some Service Testing Features of Particular Interest

Please note that the parameters mentioned below are just a small sample of the full set of configurable parameters.

CS Voice
PESQ or POLQA for **audio quality** measurement.
HTTP
Choice between built-in HTTP client and Internet Explorer 9 as **Web browser**.
The client can use **multiple concurrent threads** in handling the HTTP session. The main URL specified in the activity is downloaded only once, regardless of the number of threads.
The HTTP session can be set to **end** automatically after a user-specified **length of time**, counted from the moment the first HTTP packet is received from the server.
The HTTP session can be set to **end** automatically after a user-specified **amount of data** has been downloaded.
TCP and UDP
The **Network Bandwidth** activity gauges maximum TCP and UDP bandwidth performance by interacting with an Iperf server. Either Telnet or SSH2 is used as connection client. Unlike the Telnet protocol, which sends logins and passwords in plain text, SSH2 uses cryptography to authenticate the remote computer and therefore renders the Iperf server less vulnerable to hacker attacks.
A further **UDP** testing activity, independent of Iperf, is also provided.

VoIP
Choice between PJSIP and CounterPath as **VoIP client**.
Speech codec and speech **codec rate** selection.
PESQ or POLQA for **audio quality** measurement.
Extensive set of VoIP **jitter buffer metrics** computed.
Video Streaming
Both **on-demand** streaming (downloading a video clip of known length) and **live** streaming (tapping into a live stream or repeating playlist) are supported.
WAP-based streaming is also testable.
Configurable **prebuffering** and **rebuffering** durations.
VSQI/MTQI for **quality** assessment.
E-mail
Configurable **security** settings: No security/SSL or TLS used during whole session/Initial communication not encrypted, but SSL or TLS applied later on.
Ping
Configurable Ping **packet size**, **interval** between Pings, **number** of Pings to send and maximum **time to wait** for each Ping response.
MMS
MMS messages can be sent to **multiple recipients**.
The sending device and receiving device can be **identical**.
A wide variety of **file types**, including plain-text files and frequently used image file formats, can be sent.
SMS
When sending an SMS, a **delivery report** can be requested from the SMS Center.
A custom **SMS Center** can be specified, different from that indicated on the SIM.

5.4 Obtaining PESQ and Other Audio Quality Measurements

Audio quality measurement (AQM) in TEMS Investigation can be done in a number of contexts and hardware configurations. A summary of the possibilities is given in the following table:

Service	Call Parties	Auxiliary Components	AQM Computed By	Algorithm	Section Ref.
CS voice	Mobile-to-fixed	Call Generator; AQM modules	AQM modules	PESQ	5.4.1
	Mobile-to-mobile	Mobile Receiving Unit (MRU); AQM modules			
	Mobile-to-mobile	Audio Capturing Unit (ACU)	PC(s)	PESQ or POLQA	5.4.2
VoIP	Mobile-to-mobile	(2 PCs used)			5.4.3

Irrespective of scenario, audio quality measurement is always controlled by a Service Control script in TEMS Investigation.

The AQM output encompasses PESQ or POLQA, both of which are estimates of listener-perceived speech quality, as well as a suite of further measurements.

5.4.1 AQM for CS Voice with Call Generator or Mobile Receiving Unit

In this setup, audio quality measurements are collected by TEMS Investigation during mobile-originated voice calls. The call may be received by a **stationary** component known as the Call Generator, connected to the fixed telephone network, or by a Mobile Receiving Unit (MRU) housed in a **mobile phone**. In the following, the Call Generator setup is described. The MRU setup is broadly similar, except that only downlink quality is measured.

The actual AQM computation is done in dedicated hardware units called AQM modules: one connected to the phone and to the PC, handling the downlink; and one housed in the Call Generator, taking care of the uplink. These modules contain DSP hardware.

The speech segments to be used as references are loaded into the AQM modules and into the test terminal. The terminal and the Call Generator then take turns calling each other, playing the reference sentences. The received signals at either end are forwarded to the respective AQM modules, where the signals are compared with the originals and uplink and downlink AQM scores are computed.

The downlink AQM data is written to regular TEMS Investigation logfiles. The uplink AQM data is stored in XML files. To merge the uplink AQM data into the logfiles, a special export function is used.

5.4.2 AQM for CS Voice with Audio Capturing Unit (ACU)

This AQM configuration differs considerably from the ones in section 5.4.1. Here, all measurement is conducted during **mobile-to-mobile** voice calls; up to four mobile devices, which call each other in pairs, are connected to an Audio Capturing Unit (ACU) which relays the audio to the PC.

The AQM computation is done on the PC in this setup, so the audio capturing unit is not equipped with any DSP hardware of its own. Since the voice calls take place between the mobile devices, no Call Generator or similar component is needed either.

The mobile-to-mobile AQM solution captures the audio in analog format as it is output from the mobile devices. This means that the quality score is affected by the phone's internal processing (speech and channel coding, etc.), which is to some extent device-specific. In other words, the quality score obtained in this way is characteristic of a particular phone make and model. This is in contrast to the existing TEMS Investigation AQM solution, where the audio is extracted digitally prior to these processing steps, so that the quality score becomes (more) independent of the device used. The latter score is in a sense more general, but it is also more abstract in nature.

5.4.3 AQM for VoIP

Audio quality measurement can also be performed in connection with VoIP testing, in which case the measurement setup is again different. The VoIP caller and callee are

connected to two different PCs, each running an instance of TEMS Investigation. No auxiliary hardware modules are used in this case.

5.5 Control Functionality for Phones

From TEMS Investigation many aspects of phone behavior can be customized. The available settings vary from one phone to another. Below is a list of control functions that exist in the application.

- Lock on **radio access technology**
- Lock on **frequency bands**
- Lock on a **PLMN**, specified by an MCC and MNC combination
- Manipulate **access class** settings
- Define **voice codecs** to be enabled, as well as priorities
- Enable/disable **HSDPA/HSUPA** capabilities and define categories to be used
- Enable/disable **EDGE** capability
- Alter phone behavior with respect to **barred and reserved cells**
- Lock on, or prevent use of, one **ARFCN** or a set of ARFCNs
- Force or prevent **handover** to a single or set of specified ARFCNs
- Lock on **UARFCN**
- Lock on **UARFCN and scrambling code** or a set of scrambling codes
- Override the **BLER target** set for the UE by the WCDMA RAN
- **Discard Layer 3** messages of specified types
- Specify GSM **Tx Power** to be used
- Inspect and modify settings in any Qualcomm chipset-based UMTS device by sending queries and commands over the Qualcomm **NV interface**.

5.6 Scanning

Scanners are dedicated measurement devices which are indispensable for verifying a network under construction or newly deployed, at a stage where no UEs are yet available.

TEMS Investigation supports scanning with a wide range of devices across all supported technologies. Several types of scan can run concurrently; only the scanner's measurement capacity limits the possibilities of conducting multiple scans in parallel.

Andrew i.Scan	Rohde & Schwarz TSMW
Anritsu	SRU
DRT	PCTEL SeeGull MX/EX/LX, PCTEL PCT

Supported scanning device brands: top-level summary. A very large number of models with differing technology and frequency band specifications are connectable in TEMS Investigation.

For examples of scan presentations in the TEMS Investigation user interface, see sections 6.5, 6.6 and 6.7.

5.6.1 Scanning Methods: LTE

- LTE signal scan
  - Top N Sync Signal scan: Detects P-SCH and S-SCH synch signal presence.
  - Top N Reference Signal scan: Detects sector-specific reference signals.
  - Enhanced Top N Signal scan: Measures multiple RF paths and subband reference signals (used in MIMO transmission).
- RSSI scan: Measures narrowband or wideband channel aggregate power.
- Enhanced Power scan: Higher-performance scan providing selective time/frequency power measurements.
- Spectrum analysis: Measures power with user-selectable resolution bandwidths.

5.6.2 Scanning Methods: WCDMA

- CPICH scan (coverage verification, pilot pollution detection), also including primary and secondary synchronization channels (P-SCH, S-SCH)
  - Top N scrambling codes
  - User-defined set of scrambling codes
  - Decoding of System Information blocks
- SCH timeslot scan
- RSSI (Continuous Wave) scan
- Spectrum analysis
- BCH scan
- Network scan

TEMS Investigation supports simultaneous scanning of up to 12 UMTS frequencies with one scanner. This is useful for multifrequency network configurations as well as for operator benchmarking.

5.6.3 Scanning Methods: GSM

- RSSI scan
  - The set of carriers to scan can be either all channels (as many as the scanning device can manage) or a preselected set of channels (this can be an entire GSM band).
  - Decoding of BSIC
  - Decoding of System Information messages
- Spectrum analysis

5.6.4 Scanning Methods: CDMA

- Pilot scan
  - All pilots
  - User-specified pilot list
  - Top N

  Up to 12 RF channels can be scanned at a time, bringing the same benefits to multifrequency network testing as in UMTS.
- Spectrum analysis
- RSSI (Continuous Wave) scan
- Narrowband interference scan
- Follow phone mode: The scanner always scans the same RF channel and PN offset that a CDMA phone is using.

5.6.5 Scanning Methods: TD-SCDMA

- Pilot scan
  - Midamble Top N: Scanning of Primary Common Control Physical Channel (P-CCPCH)
  - SyncDL Top N: Scanning of Downlink Pilot Timeslot (DwPTS)
- RSSI scan: Narrowband or wideband channel aggregate power scan

5.6.6 Scanning Methods: WiMAX

- Preamble scan
- RSSI scan
- Spectrum analysis

5.7 Network Cell Related Functionality

5.7.1 Loading Cell Site Data

TEMS Investigation can load data on the cell sites of the measurement area. All of the following technologies are supported: GSM, WCDMA, LTE, TD-SCDMA, cdma2000, EV-DO, WiMAX and Wi-Fi (access points).

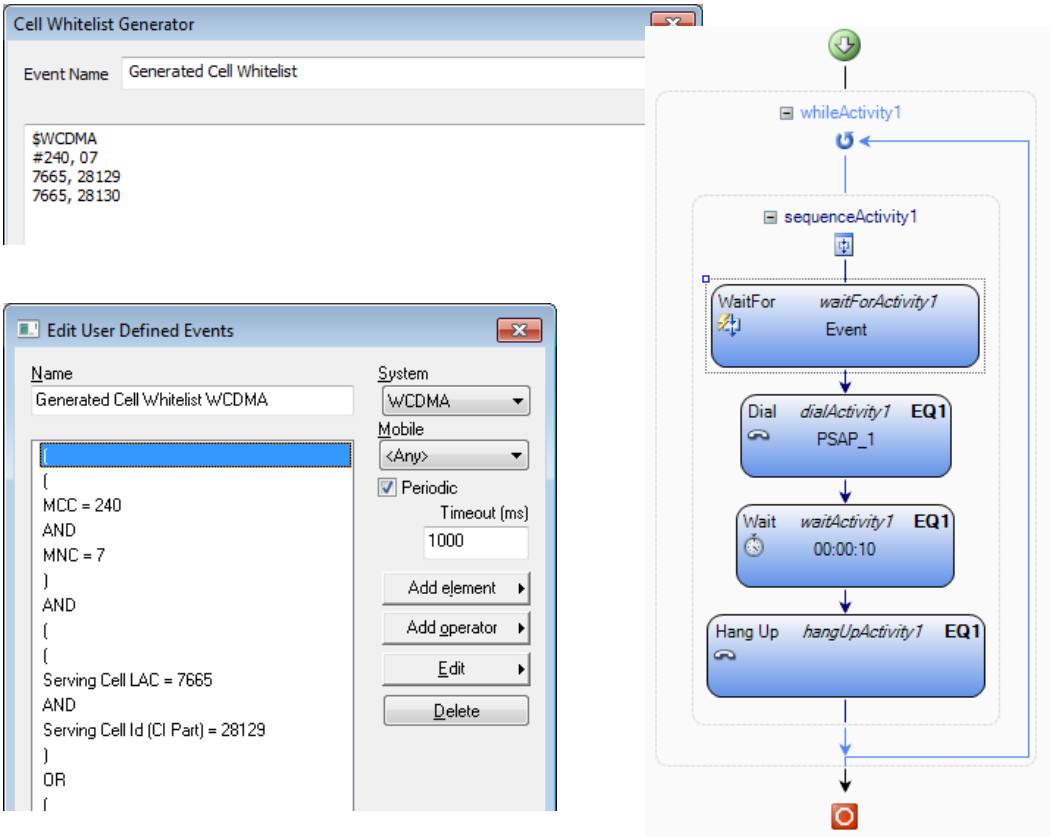
Cell files follow a tab-separated plain-text format or an XML format. The latter is shared with Mentum CellPlanner and spans all of the supported cellular technologies. All cell site information is merged into a single XML file.

The tab-separated format used by TEMS Investigation CDMA (file extension .csv) can be converted to the XML format using TEMS Discovery and can then be read by TEMS Investigation.

5.7.2 Cell Whitelists: Limiting Testing to Designated Cells

A common constraint in testing of cellular networks is to restrict tests to a **predefined set of cells**: for example, verifying a new or reconfigured cell cluster, or performing some procedure that would disturb regular network operation unless it is limited to cells that have been specially configured for the purpose.

To ease the execution of such tests, TEMS Investigation lets the user specify a **list of allowed cells** ("**whitelist**"). The list is converted into a user-defined event, which will be generated repeatedly whenever the user is camping on an allowed cell. The event in turn can be used in a script as a condition for triggering some action.



Top left: Entering a cell whitelist. The "#" line indicates MCC and MNC, while each line beneath it specifies one cell in terms of LAC and cell identity.

Bottom left: User-defined event constructed from cell whitelist.

Right: Whitelist event used as Wait For trigger in a script. When the event occurs, the script proceeds to dial a call. It then returns to the top of the while loop, waiting for the whitelist event to be generated once more to verify that the user is still in an allowed cell.

6 Analyzing Data with TEMS Investigation

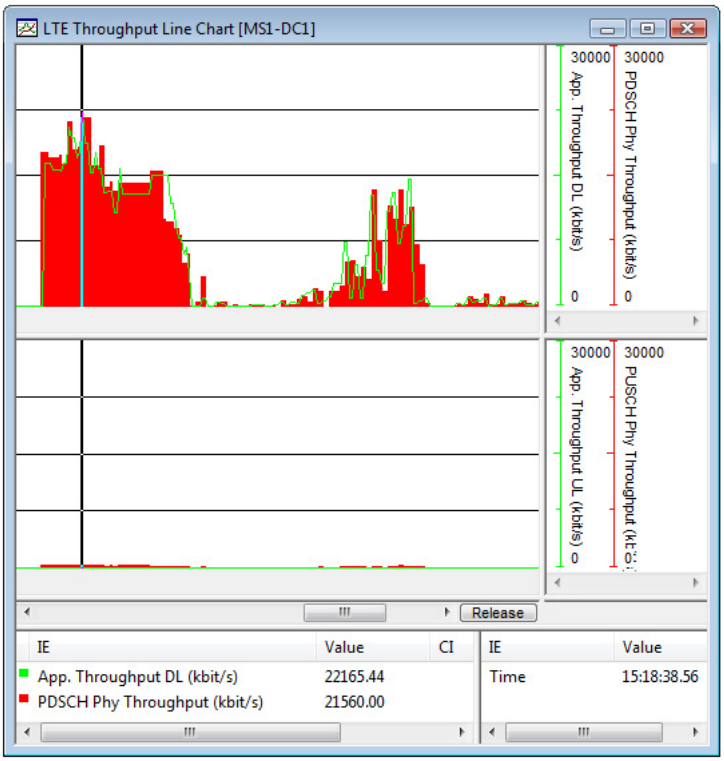
This chapter spans a large number of data presentations offered by TEMS Investigation. Together they exhibit the power of the TEMS Investigation concept, where simple building blocks – information elements and events – can be freely selected and combined into almost every conceivable kind of presentation, where all windows are synchronized. The windows that display the data can be reconfigured at every step to suit the purpose at hand, and any customizations that you do can be saved in the workspace.

Note once again that logfile data from TEMS Automatic and TEMS Pocket can also be loaded into the application.

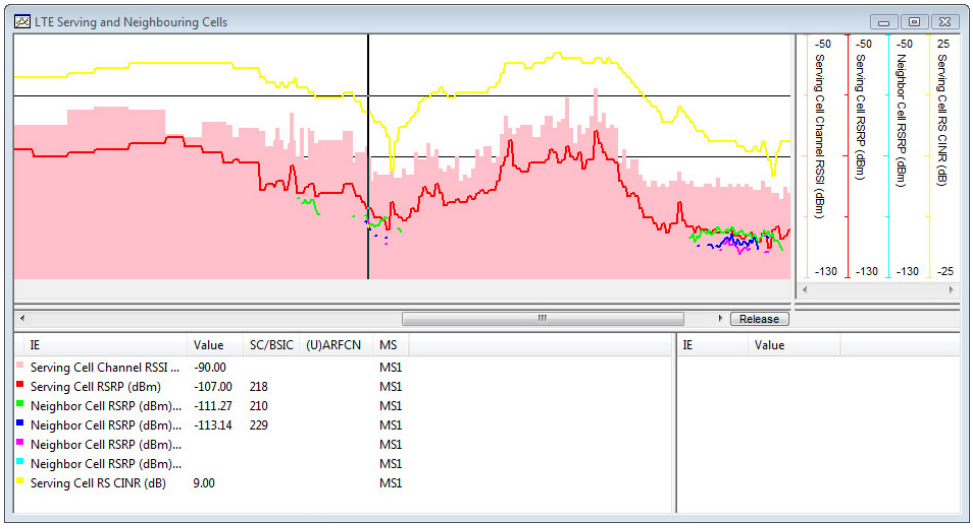
Regarding the far-ranging data presentation and analysis capabilities of TEMS Discovery, please consult the Technical Product Description dealing with that product.

6.1 Monitoring Data Services

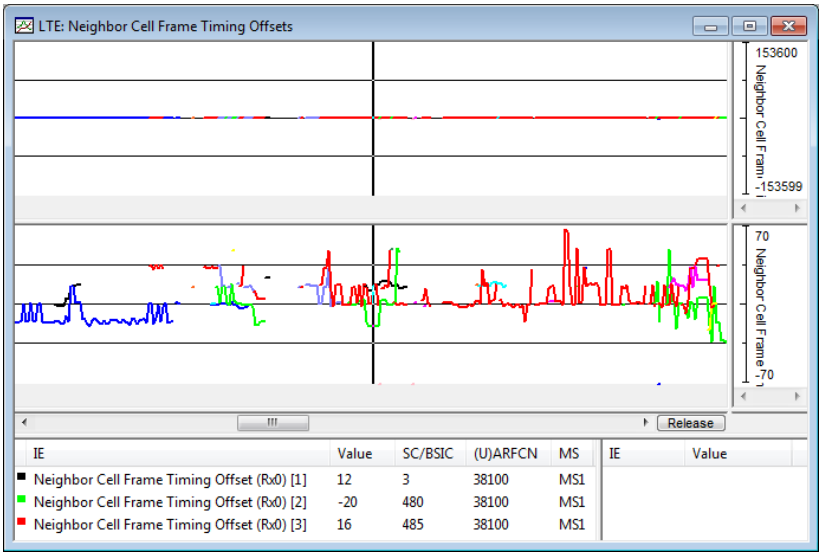
6.1.1 LTE



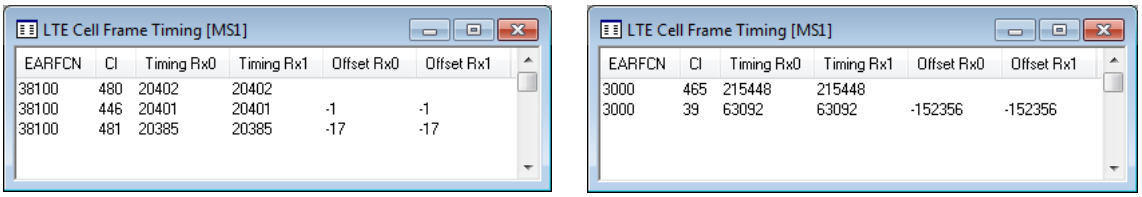
LTE throughput line chart. The green line tracks the application throughput, while the red bars represent PDSCH/PUSCH physical throughput.



LTE serving + neighbors line chart showing serving cell RSSI, serving and neighbor RSRP and serving cell RS CINR.

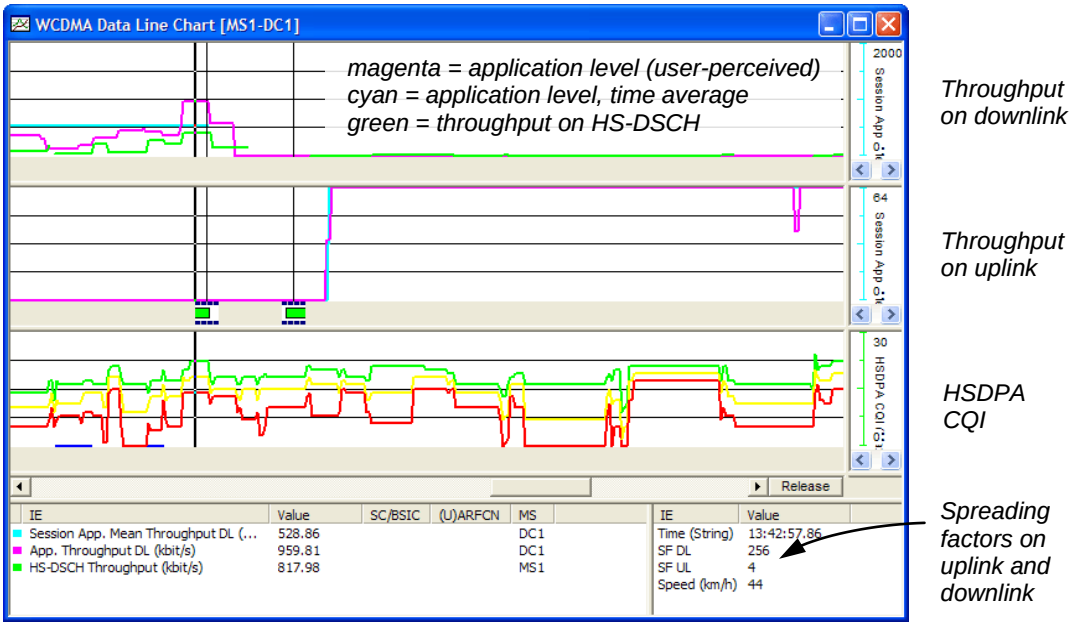


Cell frame timing in a synchronized LTE network. The two charts show the same data at different resolutions: cell frame timing offsets of neighbors relative to the serving cell. In the top chart, where the y-axis spans a very large range of possible offsets (measured in LTE T_s units = 1/30.72 × 10^6 s), we can see that the timing for all cells is very nearly the same. This shows that the cells are synchronized. In the bottom chart, the y-axis is zoomed in to +/– 70 T_s units to exhibit the small offsets that do appear. These are due to propagation delay arising from device-to-cell distance and from reflections.



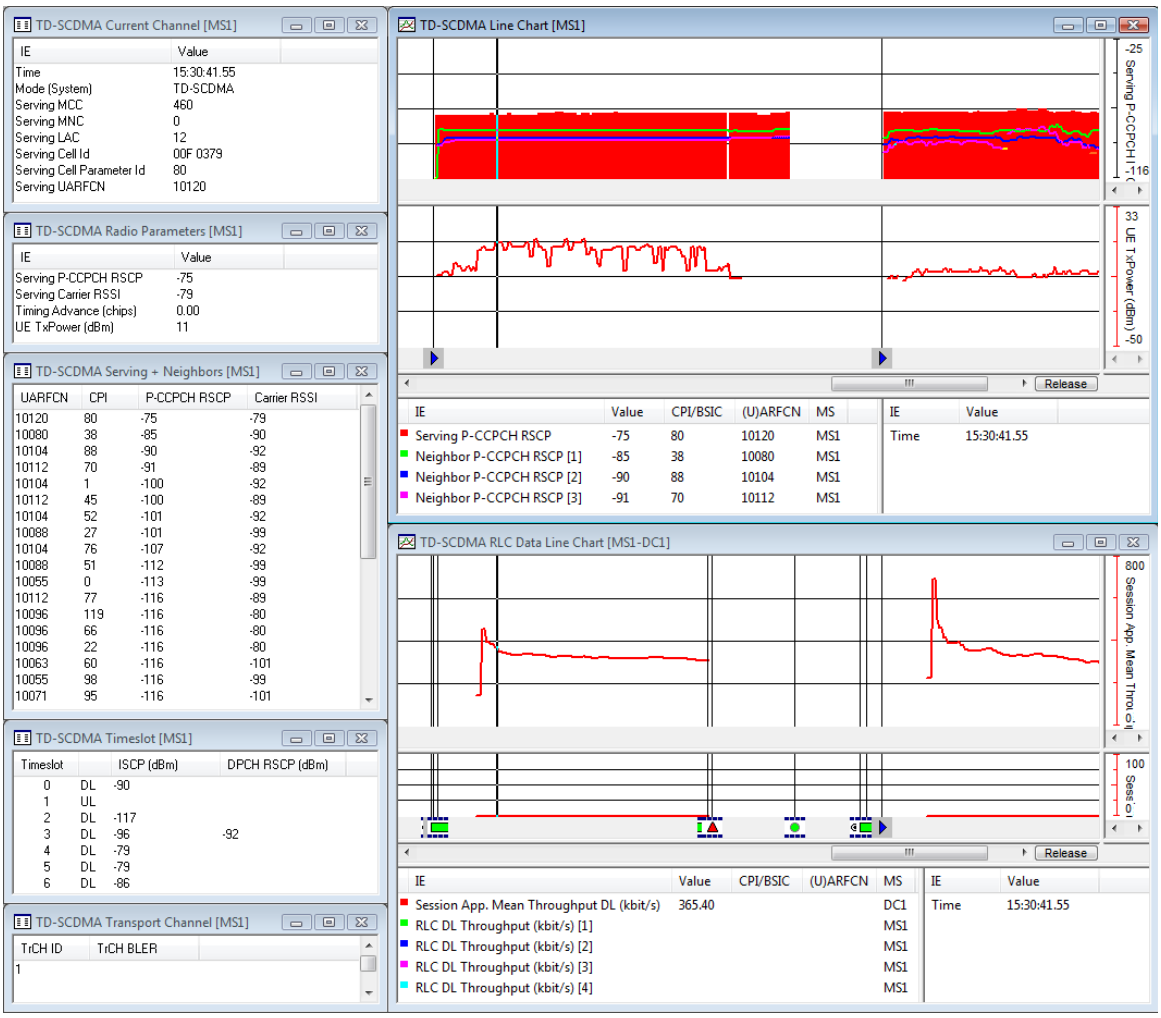
Comparison of synchronized and unsynchronized LTE networks. In both windows, line 1 represents the serving cell, and subsequent lines represent neighbors. The left-hand window shows synchronized cells, whose timing values are near-identical (just as in the line chart above). In the window on the right, on the other hand, the neighbor's timing is completely different from the serving cell's, demonstrating that this network is not synchronized.

6.1.2 HSDPA

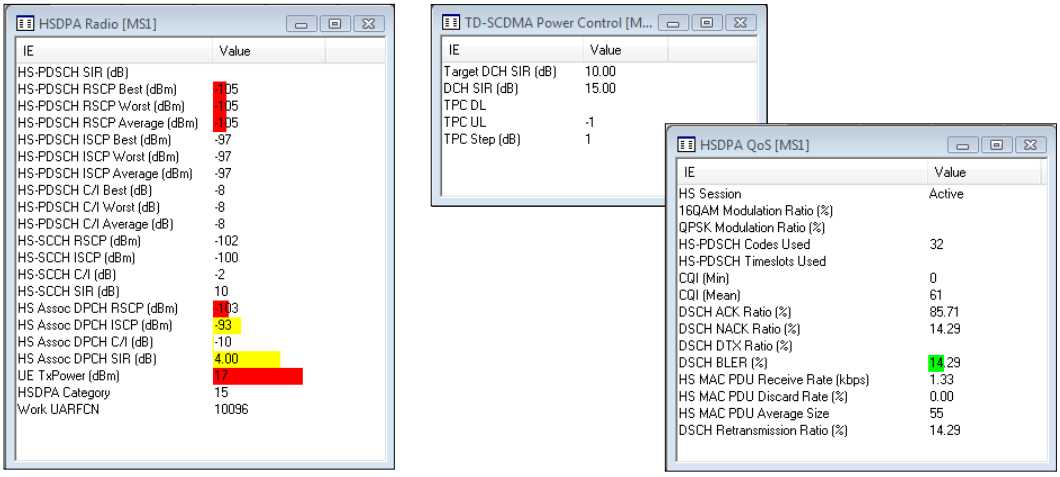


Data line chart depicting FTP data transfer over WCDMA with HSDPA. The user-perceived downlink throughput approaches 1 Mbit/s toward the end of the download (top subchart). An upload follows (middle subchart). Short-time maximum, median and minimum values of the HSDPA Channel Quality Indicator (CQI) governing the radio link adaptation are plotted in the bottom subchart. The spreading factors are 4 on the uplink and 256 on the downlink.

6.1.3 TD-SCDMA

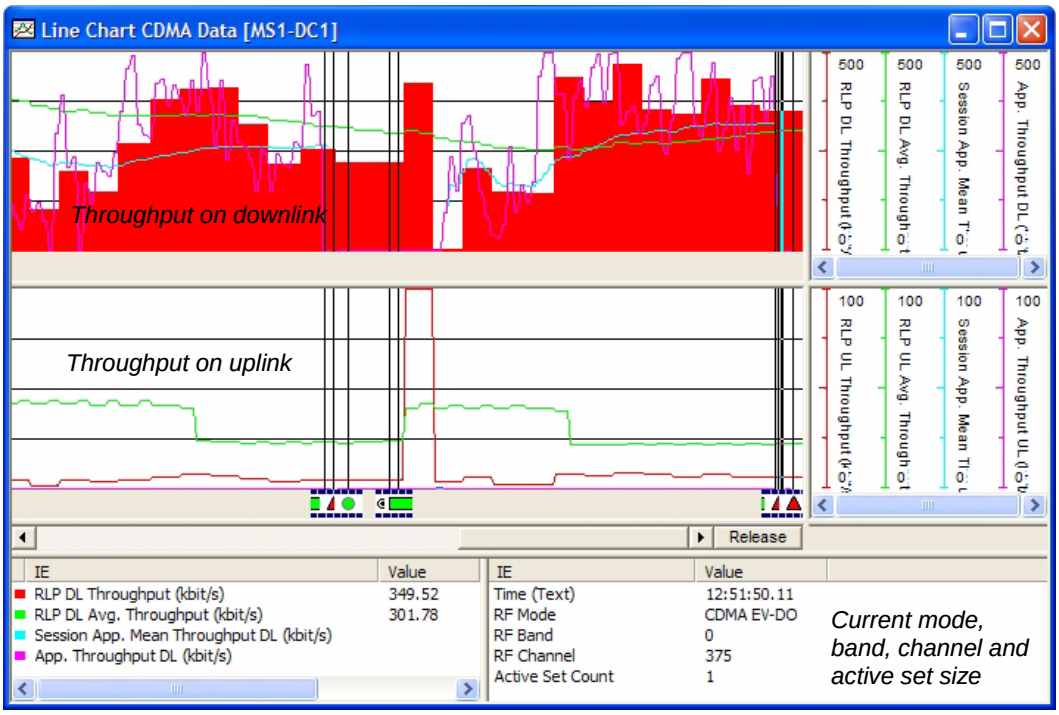


FTP download session over a TD-SCDMA network. The P-CCPCH is the Primary Common Control Physical Channel, functioning as the preferred reference channel in TD-SCDMA.



HSDPA parameters in a TD-SCDMA network.

6.1.4 EV-DO

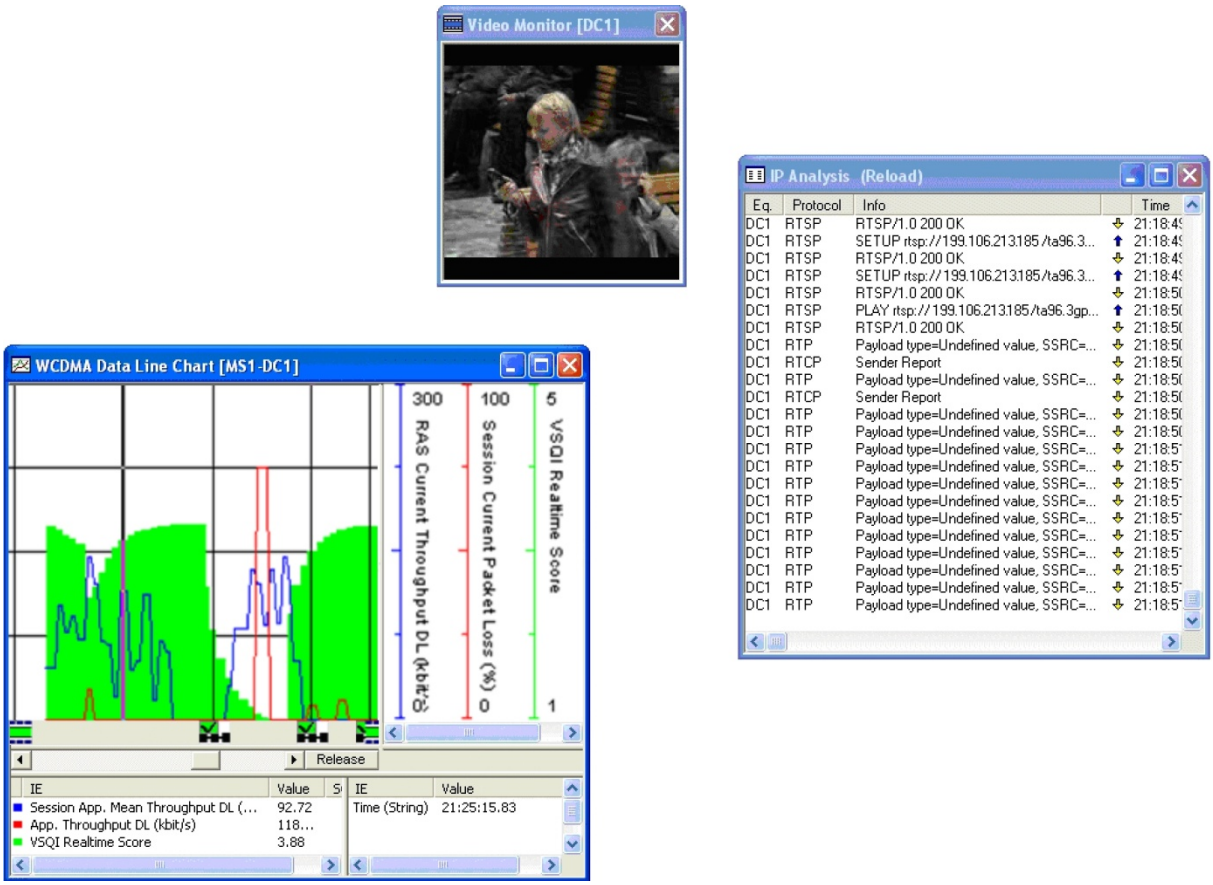


Data line chart depicting FTP data transfer over CDMA EV-DO. The user-perceived downlink throughput approaches 500 kbit/s (top subchart). The uplink is used for TCP Acks and FTP control (middle subchart). Instantaneous values of the short-time and average throughputs are shown (left-hand text pane), as are relevant RF parameters (right-hand text pane).

6.1.5 Video Streaming with VSQI and IP Analysis

The following example shows how to evaluate the performance of video streaming with TEMS Investigation. Note that the IP Analysis window is a highly versatile tool that reveals the traffic over a large number of protocols (see listing below) and is thus useful for studying and troubleshooting any service in minute detail. The full set of protocols supported by the IP Analysis window is as follows:

- **Application layer:** BOOTP, DNS, FTP, FTP-DATA, HTTP, NBDS, NBNS, RTCP, RTP, RTSP, SNMP
- **Transport layer:** TCP, UDP
- **Network layer:** ICMP, IPv4, IPv6
- **Data link layer:** PPP CC, PPP CHAP, PPP IPCP, PPP LCP, PPP PAP



The streamed video clip is replayed in the video monitor (top). The WCDMA Data Line Chart (bottom) tracks the application throughput (blue curve) and evaluates the streaming quality in terms of the VSQI quality measure (green bars). Note how the VSQI score drops; this is because the initial buffering takes slightly too long to complete. During the replay, VSQI stays high as long as the throughput is sufficient. Halfway through the segment, VSQI slumps disastrously, indicating that the streaming client has been forced into rebuffering mode and has halted the replay. In the IP Analysis window (right) we monitor the message traffic over the RTP, RTCP and RTSP protocols that are used for streaming. The IP Analysis window also supports a large array of further protocols, as listed above.

6.1.6 Some Data Service Status Windows

6.1.6.1 HSDPA Analysis MIMO

This window shows vital parameters for a HSDPA session making use of MIMO. The first column applies to the case where only one transport block is transmitted at a time (CQI Type B or single-block Type A). The second column applies in case of simultaneous transmission of two transport blocks (CQI Type A).

6.1.6.2 HSUPA Analysis

This window shows HSUPA performance. The presented data includes: average E-TFCI (E-DCH Transport Format Combination Indicator, each value corresponding to a data transfer rate); average serving grant; UE happy rate; HARQ block error rate; how

often the transmission was limited by the current serving grant; and how often the transmission was limited by the available Tx power.

HSDPA Analysis MIMO [MS1]

Element	1st	2d
HS Session	Active	
HS Serving Cell	140	
HS Serving Cell Name		
MIMO Type	MIMO configured	
MIMO Type A CQI Rate	0.00	100.00
MIMO Type B CQI Rate	0.00	
MIMO CQI (Min)		9
MIMO CQI (Median)		12
MIMO CQI (Max)		13
MIMO Multi TB Rate	12.00	88.00
MIMO DSCH ACK Rate	2.60	94.79
MIMO DSCH NACK Rate	1.56	1.04
DSCH DTX Rate	91	
DSCH Pre Rate	0.00	
DSCH Post Rate	0.00	
MIMO 16QAM Modulation Rate	2.04	93.88
MIMO 64QAM Modulation Rate	0.00	0.00
MIMO QPSK Modulation Rate	0.00	4.08
DSCH Throughput		
CQI Feedback Cycle	8	
CQI Repetition Factor	1	
H-RNTI	64201	
HARQ Processes No Of	0	
SCCH Decode Success Rate	100	

HSUPA Analysis [MS1]

IE	Value
HS Session	Active
HS Serving Cell	79
HS Serving Cell Name	
Average E-TFCI	49
Average Serving Grant	12
Average Serving Grant/E-TFCI	0.24
BLER 1st	5
Buffer Limited Tx	0
DTX Rate	0
Error No Of Blocks 1st	1
Error No Of Blocks 2d	1
Error No Of Blocks 3rd	0
Error No Of Blocks 4th	0
Happy Rate	100
HICH ACK Rate	90
HICH NACK Rate	10
N-S Cells No Of	0
N-S Combined RGCH Down	0
New Transmission Rate	90
Number Of TTIs	20
Power Limited Tx	90
Retransmission Rate	10
RLC UL Throughput	623.50
Serving Grant Limited Tx	0

6.1.6.3 GPRS: Data Timeslots Window – PDCH Utilization

With a Sony Ericsson phone connected, TEMS Investigation is capable of measuring GPRS parameters at the timeslot level. In the Data Timeslot window, the C/I ratio, bit error rate and block error rate are given separately for each timeslot in use, enabling the user to pin down the extent and also the causes of interference problems with greater precision.

The utilization of the timeslot is broken down into own data, other users' data, and control signaling. These statistics shed light on throughput figures; for example, if the throughput is low, one can see whether this is due to frequent retransmissions or to strong competition for network resources. The statistics on the uplink are the same, except that no distinction is made between unused blocks and blocks occupied by other users.

At the bottom of the window, coding scheme usage is presented.

Data Timeslots [MS1]

Element	UL 1st TS	DL 1st TS	DL 2nd TS	DL 3rd TS	DL 4th TS
TS used	TS7	TS5	TS6	TS7	
TS Channel Type	PDCH	PDCH	PDCH	PDCH	
C/I Worst		20.50	2.60	17.40	
BER/TS (%)		0.00	6.30	0.00	
BLER/TS (%)		0	2.00	0	
Own Data (%)	93	55	23	38	0
Other Data (%)		36	31	31	95
Control (%)	7	9	44	31	5
CS-1 Data (%)		0	0	0	0
CS-2 Data (%)		100	100	100	0
CS-3 Data (%)		0	0	0	0
CS-4 Data (%)		0	0	0	0
MCS-1 Data (%)		0	0	0	0
MCS-2 Data (%)		0	0	0	0

Data Timeslots window monitoring a GPRS connection. The performance of timeslots TS5 and TS7 is good, with excellent C/I readings of 20 and 17 dB and consequently a zero bit error rate. However, conditions are less favorable on TS6, where a shaky C/I of 2.6 dB announces a problematic

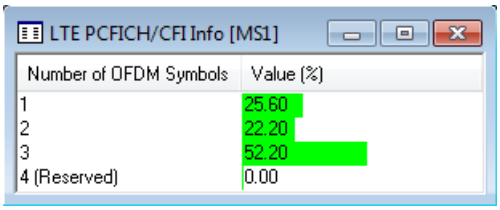
interference situation. Here, the bit error rate is much higher, as expected (6.3%), forcing some retransmissions (nonzero BLER).

Lines 6–8 show what each timeslot is used for. Together with the retransmissions (BLER figure), these numbers add up to 100%.

Lines 9–12 show GPRS coding scheme usage. If an EGPRS phone had been used, the corresponding MCS (modulation coding scheme) distribution would have been shown instead (only the first two MCS lines appear in the above screenshot).

6.1.6.4 LTE: Cell Load Evaluation in PCFICH/CFI Info Window

The PCFICH/CFI Info window displays the number of OFDM symbols allocated for PDCCH (control signaling) during one second, as indicated by the CFI value on the PCFICH channel. The distribution of symbols used gives an indication of the number of active users in the cell.



A higher number of allocated symbols means more active users in the cell and thus higher cell load.

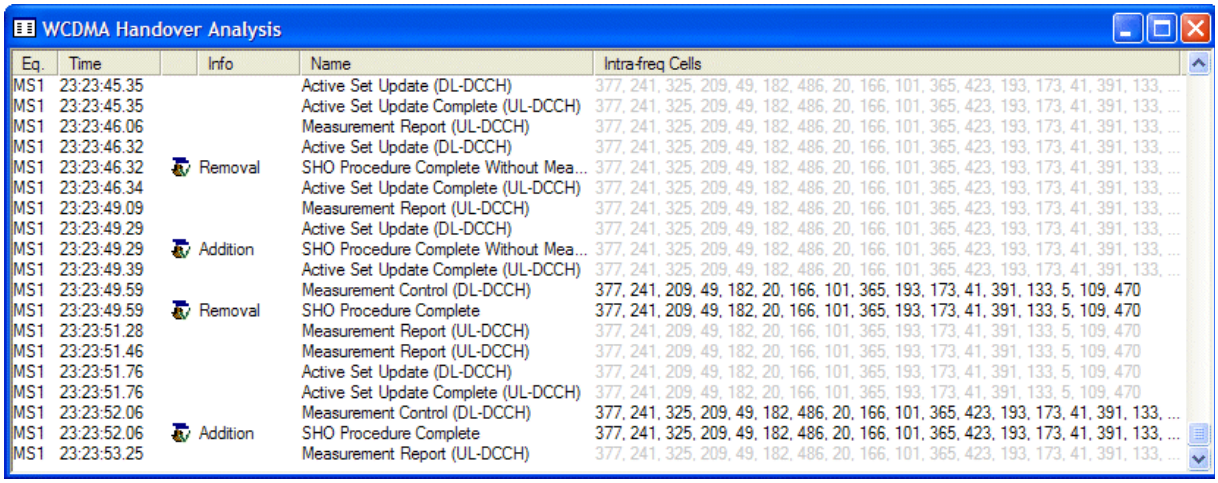
6.2 Monitoring Handovers

TEMS Investigation enables monitoring of all kinds of handover occurring in UMTS:

- GSM handover
- WCDMA intra-frequency handover
- WCDMA inter-frequency (“hard”) handover
- Inter-RAT handover (GSM–WCDMA)

Similarly, TEMS Investigation keeps track of the various types of handoff employed in CDMA networks, including:

- Hard handoff (to another frequency, a different band, a different pilot set, or another frame offset, or a combination of these)
- Handoff between cdma2000, cdmaOne and EV-DO



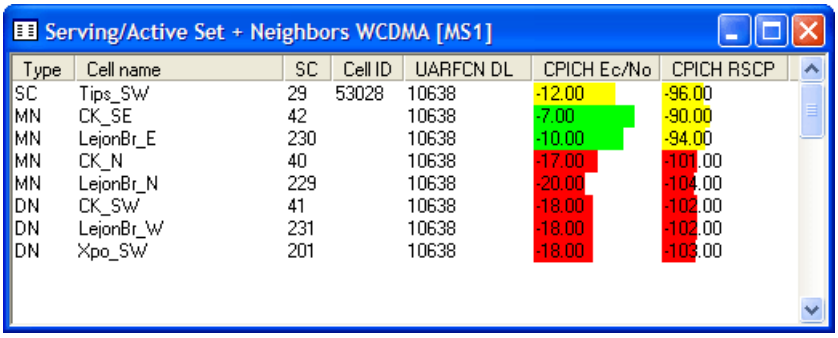
WCDMA Handover Analysis window. This window shows in minute detail how the WCDMA active set evolves over time and specifically in the course of soft handover procedures. In the Intra-freq Cells column is displayed the neighbor list of the currently strongest cell. This list is obtained from System Information blocks (SIBs).

6.3 Monitoring Voice in UMTS

Below is shown a small selection from the range of presentation windows available for studying GSM and WCDMA voice calls.

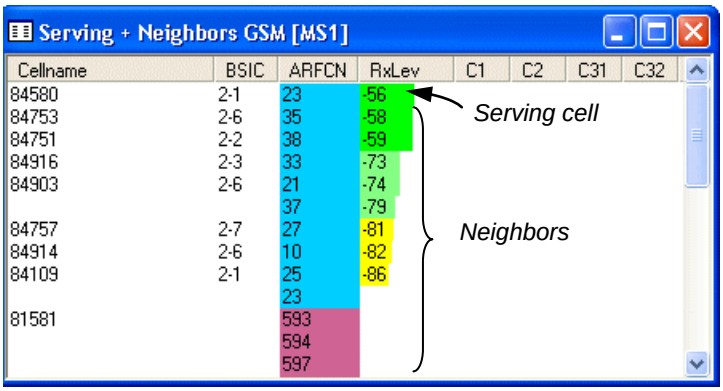
6.3.1 Serving/Active Set + Neighbors WCDMA

The Serving/Active Set + Neighbors WCDMA window lists all members of the active set as well as monitored (“MN”) and detected (“DN”) neighbors. The strength of each scrambling code is presented in terms of CPICH E_c/N_0 and CPICH RSCP.



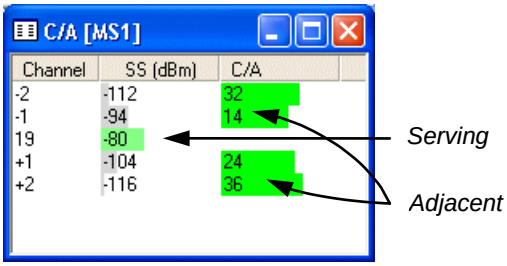
6.3.2 Serving + Neighbors GSM

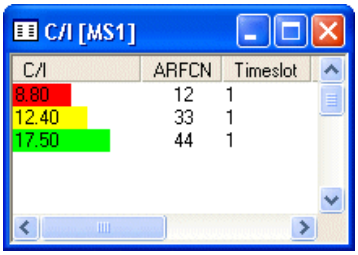
The Serving + Neighbors GSM window presents the BSIC and ARFCN of the serving cell and of up to 32 of the strongest neighboring base stations. The window also presents the path loss and cell reselection criteria (C1 and C2) as well as the GPRS signal strength threshold and cell ranking criteria (C31 and C32). A second version of this window is also provided where cells are sorted by frequency band.



6.3.3 C/A, C/I (GSM)

These windows show the results of adjacent channel and carrier-to-interference ratio measurements.

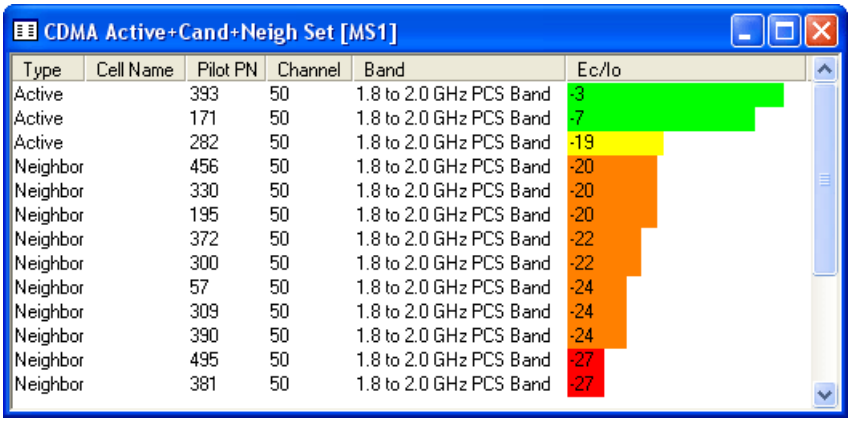




6.4 Monitoring Voice in CDMA

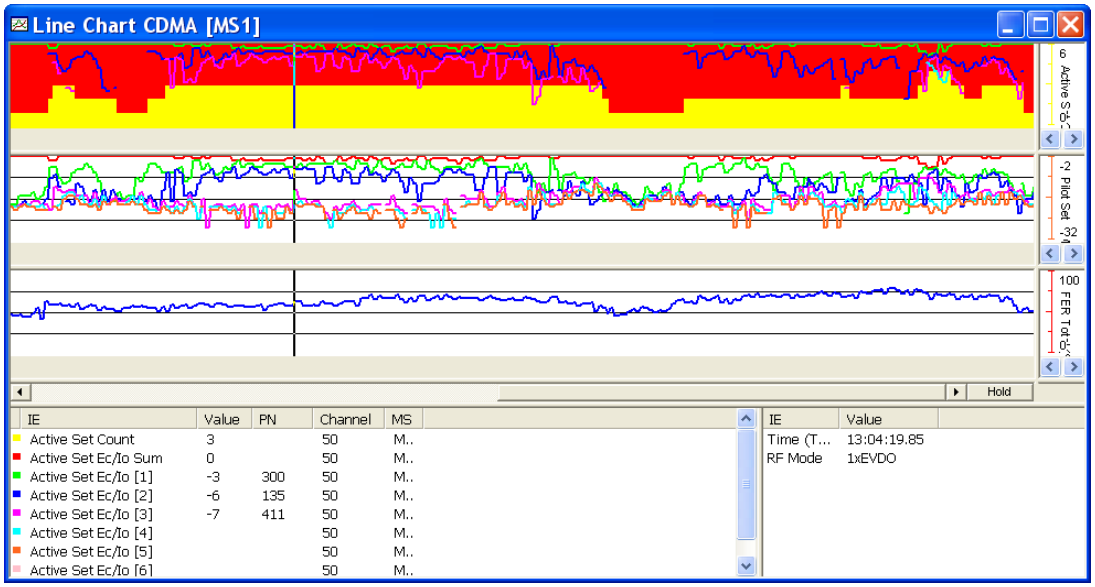
6.4.1 Active/Candidate/Neighbor Sets

The CDMA Active + Cand + Neigh Set window lists all members of the active, candidate and neighbor sets. The strength of each pilot is presented in terms of E_c/I_0.



6.4.2 Coverage Analysis

In a heavily loaded CDMA system, coverage testing is essential to ensure that voice quality is not being sacrificed for system capacity. The pilot strength or E_c/I_0 and frame error rate are measured to analyze coverage area. The pilot channel is a good indication of the coverage area because it always broadcasts with a consistent energy. TEMS Investigation can present this indicator as plain text or in a line chart.



Line chart showing CDMA active set member count and E_c/I_0 for each member (top subchart), pilot set E_c/I_0 for each pilot set member (middle subchart) and frame error rate (bottom subchart).

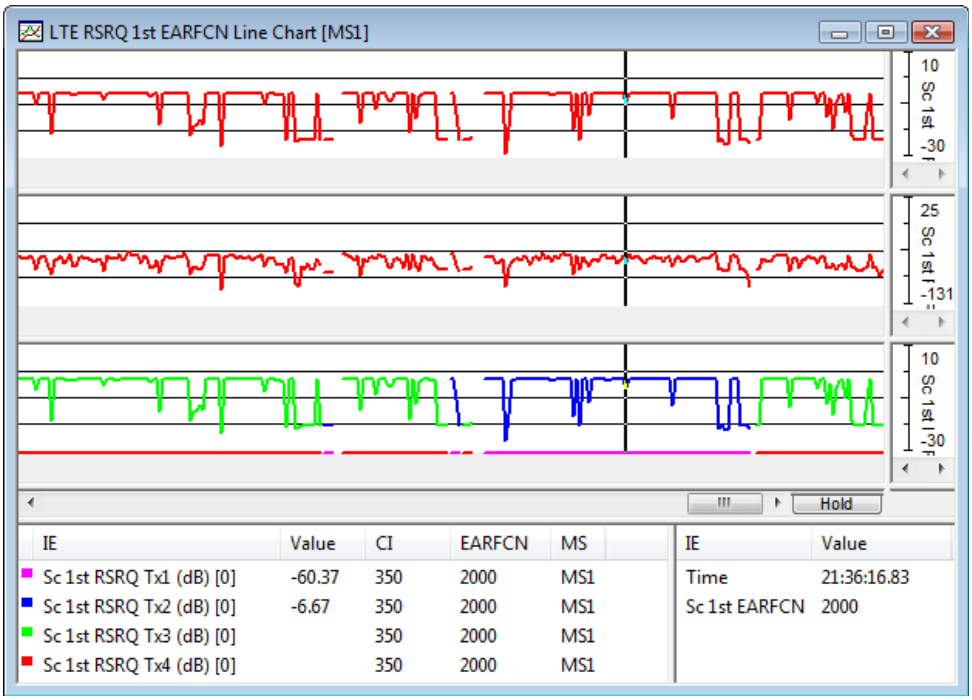
6.5 Scanning: LTE

6.5.1 LTE Reference Signal Scan

Reference Signals in LTE are used for channel estimation. The line chart that follows tracks measurements of Reference Signals. The following quantities are plotted:

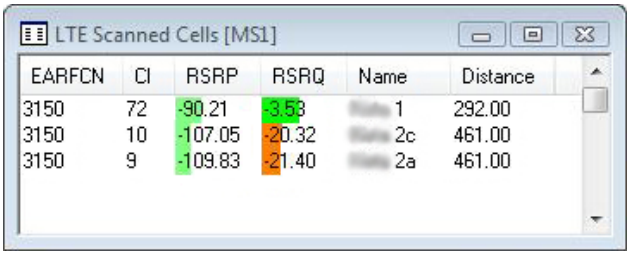
- **RSRP –** Reference Signal Received Power
- **RSRQ –** Reference Signal Received Quality. Defined as *N* × RSRP / RSSI, where *N* is the number of resource blocks across which RSSI (Received Signal Strength Indicator) was measured.

Comparing with WCDMA, RSRP is similar to RSCP (Received Signal Code Power) measured on the WCDMA common pilot, while RSRQ is similar to WCDMA E_c/N_0. Therefore (although the details differ slightly between the technologies), it can be said generally that RSRP measurements tell whether the cell is interference or coverage limited, while RSRQ measurements give indications of excess interference in unloaded or loaded cells.



LTE Reference Signal scanning. The first two charts show RSRQ and RSRP respectively, summed over all Tx ports. The third chart shows RSRQ for each Tx port.

The Map window presentation of LTE cell data includes serving cell indication. Cell names and the distance to each cell are given in analysis windows:



6.6 Scanning: WCDMA

6.6.1 CPICH and SCH Scanning

6.6.1.1 Presentation in Bar Charts: CPICH Scan

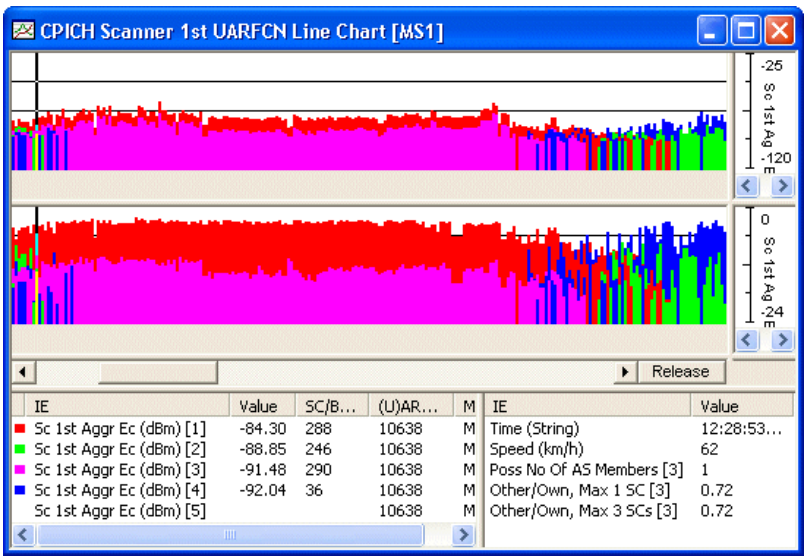
CPICH scan data is presented in the CPICH Scanner bar charts. One predefined bar chart is provided for each UMTS frequency scanned. The bar chart can also be configured to show all scrambling codes scanned, independently of frequency.

The bar chart by default presents peak E_c/I_0 for each scrambling code found. It can be sorted by scrambling code (with bars either drawn at fixed code index positions or simply sorted in order of increasing index) or by code power (increasing or decreasing).

An accompanying status window shows code power parameters and some other parameters associated with these:

6.6.1.2 Presentation in Line Chart: CPICH Pilot Pollution

The CPICH Scanner line charts (again, one chart is provided for each UMTS frequency) are completely user-configurable, like other line charts. If desired, scrambling codes from all scanned frequencies can be presented in the same line chart. The default configuration, however, is as follows:



Line chart depicting CPICH pilot pollution

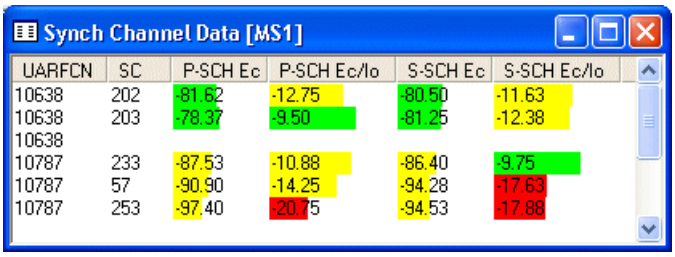
The charts present the five strongest scrambling codes on one UMTS frequency: aggregate E_c (top) and aggregate E_c/I_0 (bottom).

The text pane on the left glosses one of the charts at a time.

The text pane on the right shows the CPICH pilot pollution situation.

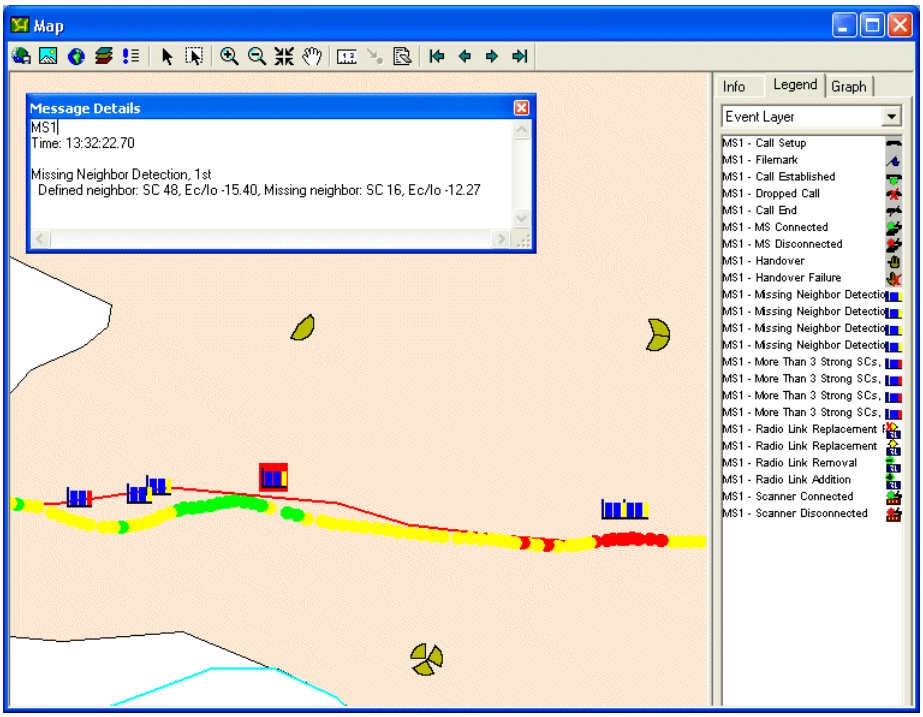
6.6.1.3 Presentation of Synchronization Channels

The Synch Channel Data window presents E_c and E_c/I_0 for code words on the synchronization channels P-SCH and S-SCH.



6.6.1.4 Missing Neighbor Detection: Optimizing Neighbor Relations[1]

If one WCDMA cell which is not defined as a neighbor is found to cause interference with the active connection, it may be a good idea to include that cell in the neighbor cell list. Then, if the cell in question enters into the active set, instead of acting as an interferer it will contribute a useful signal (i.e. add to the soft handover gain). Spotting cells with such properties is referred to as “missing neighbor detection.” An event (based on scanner data) indicating this situation in WCDMA is provided in TEMS Investigation.



Along this route, there are repeated indications of a missing neighbor (the events represented by the “bars” symbol). Event details are shown for the highlighted event.

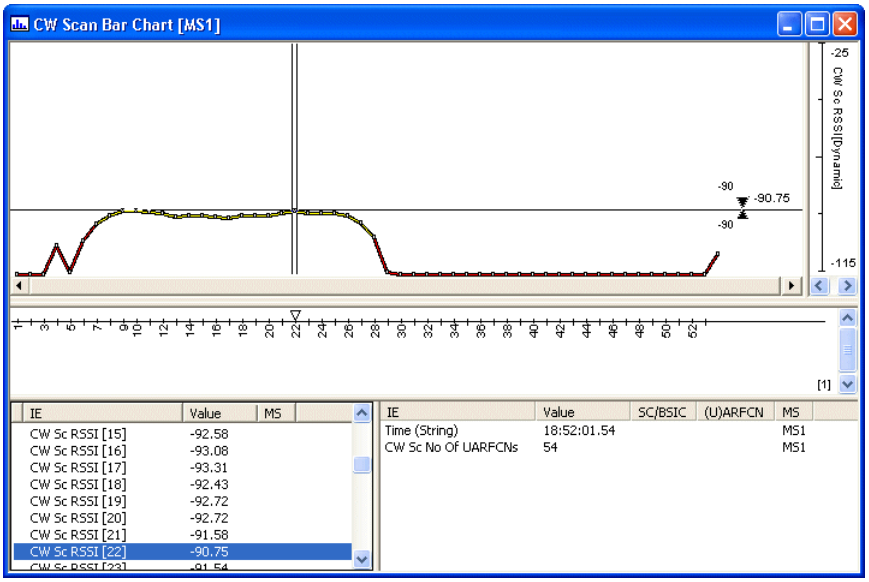
While potentially very useful, addition of neighbors must still be done with caution, since a high number of soft handovers will strain system resources. Also, the distance between the cells must be considered. Cells too far removed from each other should not have a neighbor relation, since terminals far away from a cell site may cause severe uplink interference.

[1] Requires either SIB decoding with scanner or loading of a cell file.

6.6.2 CW Scanning

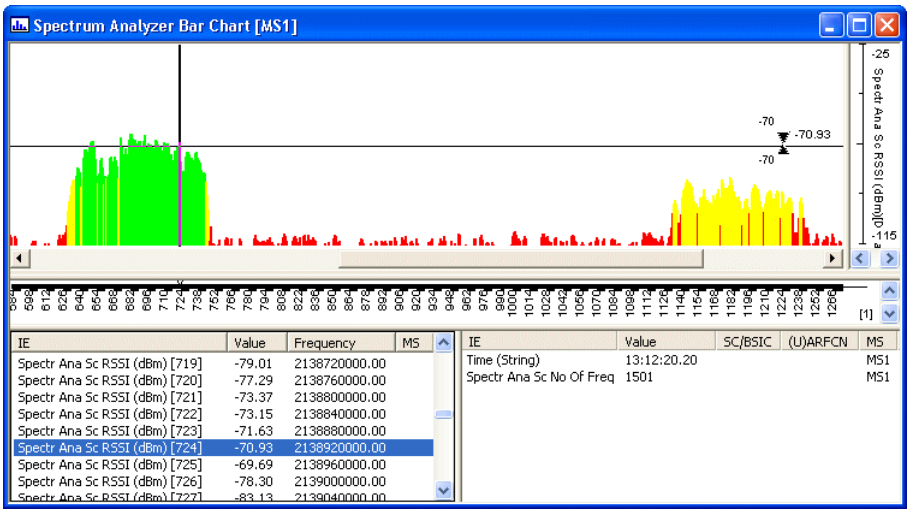
This method scans specified UMTS frequencies, UARFCNs, for a continuous wave (CW) signal. CW measurements (performed in conjunction with a test transmitter) are suitable for tuning of propagation models and for site acquisition.

A bar chart displays RSSI for each UARFCN scanned.



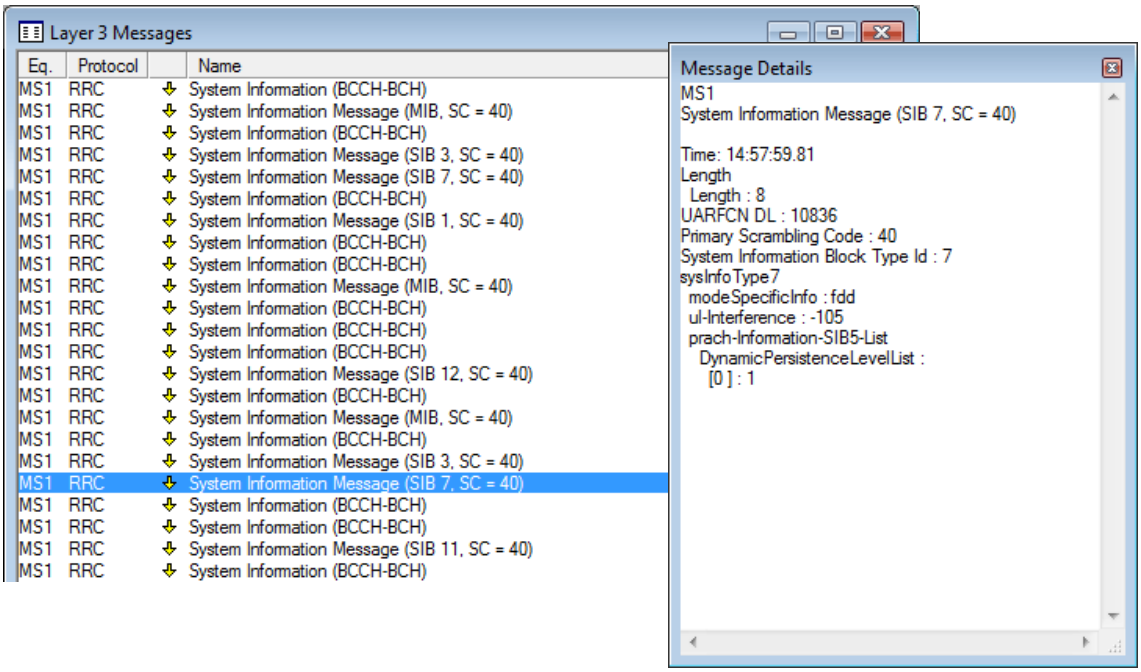
6.6.3 Spectrum Analysis

This method scans the whole of the 3GPP frequency spectrum, or a user-specified segment of it, and presents RSSI as a function of frequency in the chosen band. The spectrum analyzer is particularly useful for spotting external narrowband interferers, and for verifying the characteristics of the wideband signal. The scan resolution is adjusted by the user (maximum sample spacing: 5 kHz).

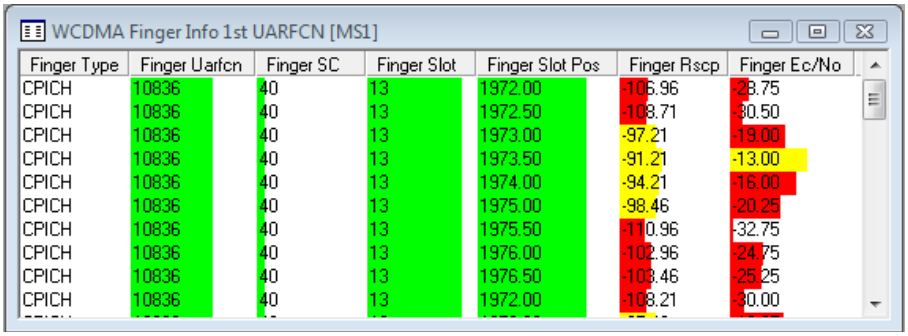


Spectrum scan showing the WCDMA frequency bands used by two different operators.

6.6.4 BCH Scanning



Output from BCH scanning. System Information Messages are continuously scanned and decoded. These messages are listed in the Layer 3 Messages window; one has been opened to reveal the contents of System Information Block 7 (Message Details window). In the WCDMA Finger Info window (see below) are given the RSCP, E_c/N_0 and timing (slot position) of each Rake finger.



6.6.5 Network Scanning

This method searches one or several WCDMA frequency bands for WCDMA carriers (UARFCNs). On each band the search range can be freely customized. The user also sets E_c/N_0 and RSSI thresholds for WCDMA cell detection.

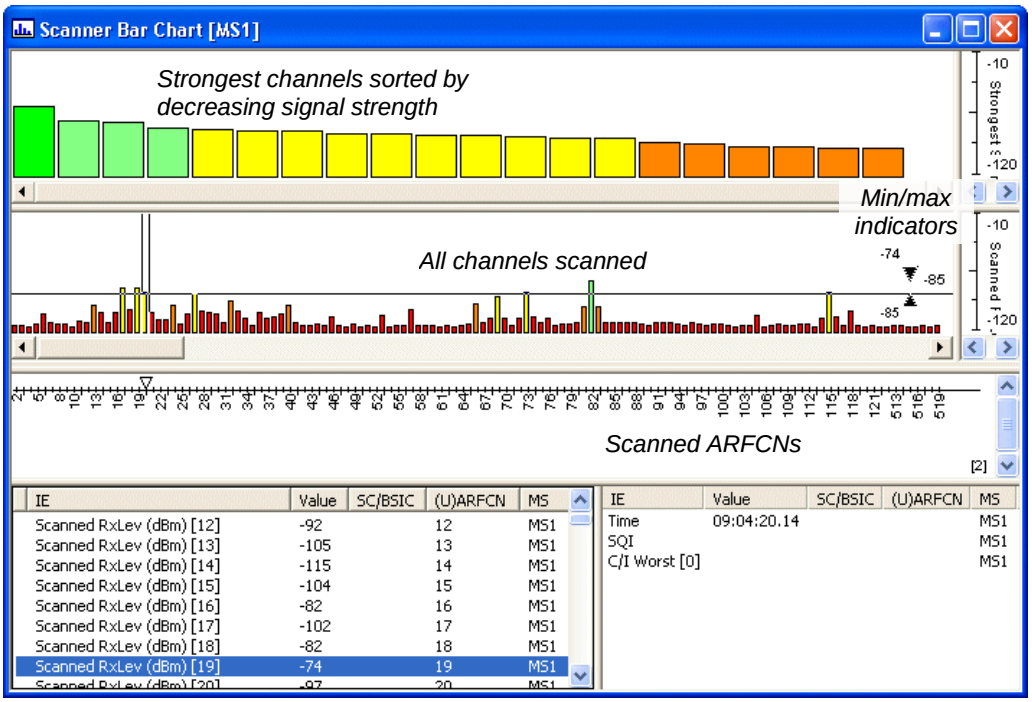
6.6.6 Exporting Scan Data to Mentum CellPlanner

CPICH and CW scan data (sections 6.6.1, 6.6.2) can be exported to Mentum CellPlanner (version 6.2.2), where the data can be used for propagation model tuning or presented in map and status windows.

6.7 Scanning: GSM

6.7.1 Strongest Channels Scan

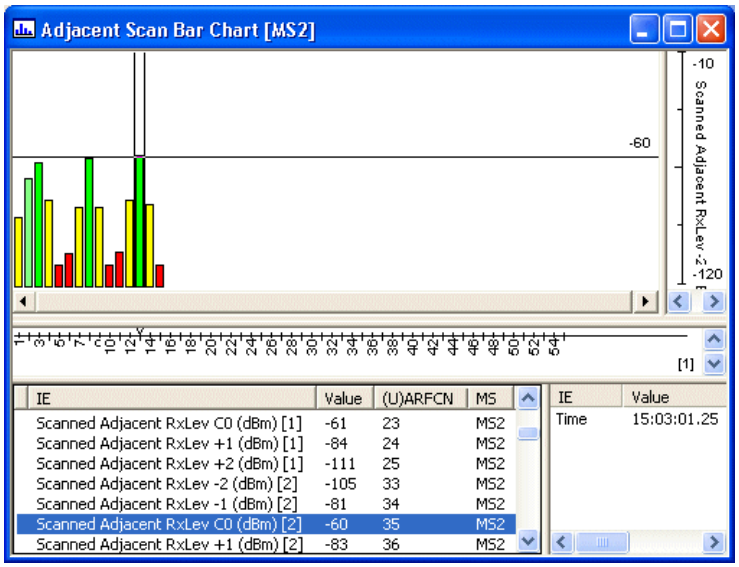
GSM frequency scans are presented in a bar chart, the basic layout being similar to that of the line chart window. The bar chart itself is generic and can be configured to show any data, but a predefined GSM scanning chart is supplied where the appropriate information elements are already in place.



For the selected channel it is possible to display real-time min/max indicators keeping track of the range of signal strength variation for that channel. The two panes at the bottom provide room for a legend (left) and for user-selected additional data (right), just as in the line chart.

6.7.2 Adjacent Channels Scan

The image that follows shows an adjacent channel scan where channels are scanned in groups of five, each group consisting of one C_0 frequency surrounded by two adjacent channels on each side.



6.8 Role of Cell Data in Presentations

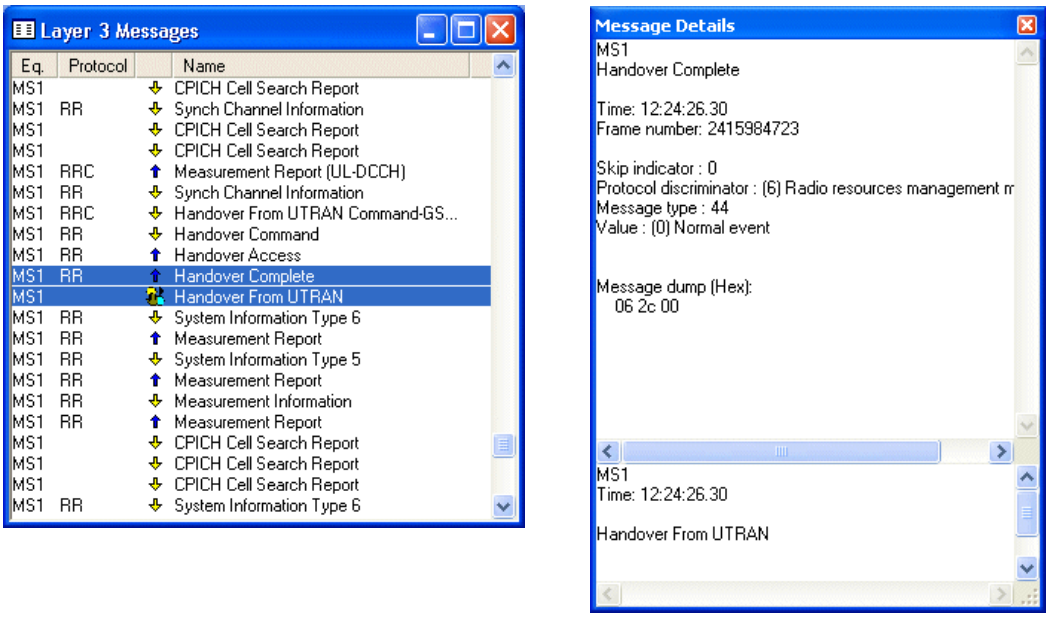
Cell data enables the following functions in TEMS Investigation:

- Drawing of site locations, sector orientations and neighbor relations in the Map window
- Serving cell/active set indication (WCDMA: “Best cell” in active set in Cell_DCH mode)
- Best server indication on the map
- In logfile reports: association of statistics with individual cells; computation of cell ranking based on these statistics
- Sorting of scrambling codes by the neighbor list in the CPICH Scanner bar chart [1]
- Generation of “missing neighbor” event in WCDMA and GSM [1]
- Presentation of cell names in status windows and line charts
- Presentation of distance to cell in status windows (LTE, TD-SCDMA)

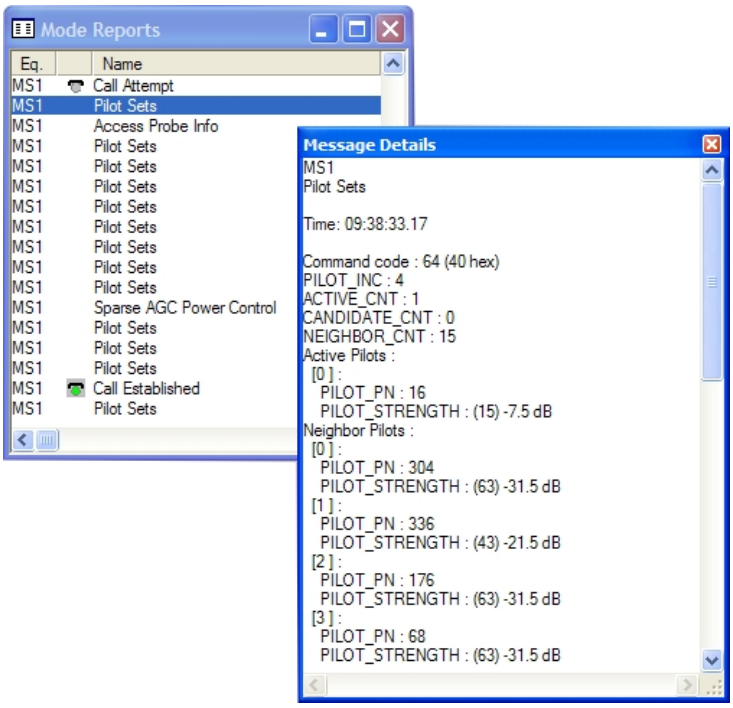
[1] Requires scanner; on the other hand, if the scanner decodes System Information, no cell file is needed.

6.9 Monitoring of Events and Signaling

Layer 3 messages sent and received by the phone are listed in a message window. Individual messages can be inspected in unabridged, plain-text format.



All of the phone's internal reports, used by TEMS Investigation to generate views, graphs, statistical summaries and events, are presented in the Mode Reports browser. Double-clicking a report will launch an associated decode window, showing the parameters in plain English.



7 Logfile Reading Capabilities

TEMS Investigation is capable of loading logfiles from previous versions of the product as well as a range of other sources. It is worth underlining that all these files can be loaded and their contents analyzed on-the-fly in TEMS Investigation, without the need for any awkward import or conversion procedure.

The TEMS Investigation application can load logfiles from the following TEMS products:

- TEMS Investigation 6.x and later
- TEMS Investigation GSM 5.x, 4.x, 3.x
- TEMS Investigation EDGE 1.x
- TEMS Investigation WCDMA 3.x, 2.x
- TEMS DriveTester GSM–TDMA 1.x (GSM logfiles)
- TEMS Pocket 12.x, 11.x[1], 8.x[1], 7.x, 6.x, 5.x [2]
- TEMS Automatic 9.0, 8.x, 7.x, 6.x (any RTU/MTU and TEMS Pocket Remote logfiles)
- TEMS Automatic 5.x (any MTU logfiles)
- TEMS Automatic 4.x (MTU logfiles recorded with GSM-only MTUs)
- TEMS Automatic 3.x, 2.5

TEMS Investigation can also load the following:

- EFEM logfiles from Motorola phones
- MDM logfiles
- Logfiles from Anritsu ML8720 scanners (i.e. files logged by the scanner itself)
- MTR files (GSM)

[1] Please note that logfiles from these TEMS Pocket versions must first be converted using a PC utility that is delivered with that version.
[2] TEMS Pocket 10.x: TEMS Pocket Remote only (logfiles can be loaded following conversion with a PC utility). – TEMS Pocket 9.x logfiles cannot be loaded in TEMS Investigation.

8 Logfile Export and Logfile Report Generation

TEMS Investigation offers a wide range of analysis and post-processing functions. This chapter deals with functions not covered in chapter 6: logfile export and logfile reporting.

Still more advanced and elaborate post-processing can be undertaken with TEMS Discovery; for the full story on this product, see the TEMS Discovery Technical Product Description. Note in particular that KPI reports are now produced with TEMS Discovery.

8.1 Export of Logfiles

Logfiles can be converted to plain-text (ASCII) files with tab-separated columns, conveniently viewed with a spreadsheet program. Logfiles can also be exported in formats that are compatible with MapInfo, ArcView, or Planet. The export can optionally be done from a Windows command prompt and can then be scheduled using the generic Windows scheduling functions.

8.2 Logfile Reports

From one or several logfiles the user can generate a report in HTML format which summarizes the data in the logfiles. When the report is ready it is opened in the default Web browser (Internet Explorer 6.0 or later).

A large set of parameters can be thresholded and graphed.

The logfile report has the following main sections:

- Header: Date and time of report generation
- Logfile information: File names and used equipment
- Thresholds: Detailed statistics on crossing of thresholds (by cell)
- Events: Event statistics
- Quality parameters: Distribution bar charts of quality parameter measurements, and statistics on these measurements

The output involving cell data naturally requires a cell file in order to be generated.

9 Supported Cellular System Versions

For information on the capabilities of individual connectable devices, see chapter 10.

9.1 3GPP

TEMS Investigation is 3GPP Release 8 compliant. Within 3GPP, TEMS Investigation 14.0 supports:

- GSM/GPRS/EGPRS:
  - GSM 850 MHz
  - GSM E-900 MHz
  - GSM 1800 MHz
  - GSM 1900 MHz
- WCDMA/HSPA:
  - Band 1 (2100 MHz)
  - Band 2 (1900 MHz)
  - Band 3 (1800 MHz)
  - Band 4 (2100 MHz)
  - Band 5 (850 MHz)
  - Band 6 (800 MHz)
  - Band 8 (900 MHz)
  - Band 9 (1700 MHz)
  - Band 11 (1500 MHz)
- LTE (with R&S TSMW, any LTE band can be scanned):
  - LTE Band 1 (2100 MHz)
  - LTE Band 2 (1900 MHz)
  - LTE Band 3 (1800 MHz)
  - LTE Band 4 (2100 MHz AWS)
  - LTE Band 5 (850 MHz)
  - LTE Band 7 (2600 MHz)
  - LTE Band 8 (900 MHz)
  - LTE Band 12 (700 MHz)
  - LTE Band 13 (700 MHz)
  - LTE Band 14 (700 MHz)
  - LTE Band 17 (700 MHz)
  - LTE Band 20 (800 MHz)
  - LTE Band 38 (2600 MHz)
  - LTE Band 39 (1900 MHz)
  - LTE Band 40 (2300–2400 MHz)

9.2 CDMA

CDMA standards are supported by TEMS Investigation 14.0 as follows:

- cdmaOne (IS-95)
- cdma2000 (IS-2000)/EV-DO (IS-856) Rel. 0/Rev. A/Rev. B

on the 450, 800 and 1900 MHz bands.

9.3 TD-SCDMA

The TD-SCDMA 2010–2025 MHz band is supported.

9.4 WiMAX

WiMAX (802.16e) scanning can be done on the 2.3, 2.5 and 3.5 GHz bands.

10 Connectable Equipment

10.1 Phones, Data Cards and Scanners Offered with TEMS Investigation 14.1

10.1.1 Phones and Data Cards

- Sony Ericsson Xperia arc (LT15i, LT15a)
- Sony Ericsson Xperia arc S (LT18i, LT18a)
- HTC Vivid (PH39100)
- Nokia C7 (C7-00)
- Samsung Galaxy S 4G (SGH-T959V)
- Samsung Infuse 4G (SCH-I997)
- Sierra Wireless AirCard 319U

AQM support in devices is tabulated in section 10.2.

10.1.2 Scanners

10.1.2.1 GSM, WCDMA, LTE

SRUs:

- WCDMA, GSM

PCTEL scanners:

- PCTEL PCT – WCDMA, GSM
- PCTEL SeeGull LX – GSM
- PCTEL SeeGull EX – LTE, WCDMA, GSM
- PCTEL SeeGull EX mini – LTE
- PCTEL SeeGull MX – LTE, WCDMA, GSM

Notes on PCTEL scanners: BSIC scanning is included in all GSM scanner licenses. GSM C/I scanning requires the purchase of an additional option.

DRT scanners:

- DRT4301A+ LTE

Rohde & Schwarz scanners:

- R&S TSMW Universal Network Analyzer
  - o LTE technology option
  - o UMTS technology option

10.1.2.2 TD-SCDMA

- PCTEL SeeGull EX – TD-SCDMA, GSM
- PCTEL SeeGull EX mini – TD-SCDMA

10.1.2.3 CDMA

- PCTEL SeeGull LX – 1x, EV-DO
- PCTEL SeeGull MX – 1x, EV-DO
- PCTEL SeeGull EX – 1x, EV-DO
- PCTEL SeeGull EX mini – 1x, EV-DO

10.1.2.4 WiMAX

- DRT4301A+

10.2 Selected Capabilities of Devices Offered with TEMS Investigation 14.1

Feature/Device	Sony Ericsson Xperia arc LT15i	Sony Ericsson Xperia arc LT15a	Sony Ericsson Xperia arc S LT18i	Sony Ericsson Xperia arc S LT18a	HTC Vivid	Nokia C7-00	Samsung Galaxy S 4G	Samsung Infuse 4G	Sierra Wireless AirCard 319U
WCDMA 800 (VI)		✓		✓					
WCDMA 850 (V)		✓		✓	✓	✓		✓	✓
WCDMA 900 (VIII)	✓		✓			✓			✓
WCDMA 1700 (X)						✓			
WCDMA 1900 (II)		✓		✓	✓	✓	✓	✓	✓
WCDMA 2100 (I)	✓	✓	✓	✓		✓	✓	✓	✓
WCDMA 2100 AWS (IV)					✓		✓		
GSM 850	✓	✓	✓	✓	✓	✓	✓	✓	✓
GSM 900	✓	✓	✓	✓	✓	✓	✓	✓	✓
GSM 1800	✓	✓	✓	✓	✓	✓	✓	✓	✓
GSM 1900	✓	✓	✓	✓	✓	✓	✓	✓	✓
HSDPA Category	8	8	10	10	14	9	14	14	24
HSUPA Category	6	6	6	6	6	5	6	6	6
GPRS Class	10	10	12	12	12	32	10	10	12
EDGE Class	10	10	12	12	12	32	10	10	10

Feature/Device	Sony Ericsson Xperia arc LT15i	Sony Ericsson Xperia arc LT15a	Sony Ericsson Xperia arc S LT18i	Sony Ericsson Xperia arc S LT18a	HTC Vivid	Nokia C7-00	Samsung Galaxy S 4G	Samsung Infuse 4G	Sierra Wireless AirCard 319U
GSM scanning									
WCDMA scanning									
Control functionality[1]			A	A		B	A	A	
External antenna[2]									
AQM capable	✓	✓	✓	✓		✓			
TEMS Pocket	✓	✓	✓	✓	✓		✓	✓	

10.3 Scanning Support by Device

The tables in this section show what scanning methods are supported with various scanning-capable devices connected to TEMS Investigation.[3]

10.3.1 GSM

Scanning Capability/Device	SRU	PCTEL SeeGull	R&S TSMW
RSSI scan, static ARFCN set	✓	✓	✓
RSSI: BSIC decoding	✓	✓	✓
RSSI: C/I measurement		✓	✓
RSSI: Sys Info decoding		✓	
Spectrum analysis		✓	

[1] A = Advanced; B = Basic.
[2] I.e. external antenna solution offered as option by Ascom.
[3] The devices themselves may possess further scanning capabilities currently not made use of by TEMS Investigation.

10.3.2 WCDMA

Scanning Capability/Device	SRU	PCTEL PCT	PCTEL SeeGull LX	PCTEL SeeGull EX	PCTEL SeeGull MX	R&S TSMW
Pilot scan, static SC set	✓		✓			
Pilot, Top N	✓	✓	✓	✓	✓	✓
Pilot: SIB decoding (continuous)	✓			✓	✓	
Pilot: SIB decoding (snapshot)	✓					
Pilot: P-SCH + S-SCH			✓	✓	✓	✓
Pilot: No. of UARFCNs	12	4	12	12	12	12
SCH timeslot scan			✓			
RSSI scan		✓	✓	✓	✓	
Spectrum analysis		✓	✓	✓	✓	
Network scan	✓					

10.3.3 LTE

Scanning Capability/Device	Andrew i.Scan	DRT	PCTEL SeeGull EX	PCTEL SeeGull MX	R&S TSMW	Transcom
Signal scan	✓	✓	✓	✓	✓	✓
Enhanced signal scan				✓		
RSSI scan		✓	✓	✓		✓
Spectrum analysis	✓	✓	✓	✓		✓
Enhanced power scan			✓	✓		

10.3.4 TD-SCDMA

Scanning Capability/Device	PCTEL SeeGull
Pilot scan	✓
RSSI scan	✓

10.3.5 CDMA

Scanning Capability/Device	Andrew i.Scan	PCTEL SeeGull LX, EX	PCTEL SeeGull MX
Pilot scan	✓	✓	✓
RSSI scan		✓	✓
Narrowband interference scan		✓	
Enhanced power scan	✓	✓	

10.3.6 WiMAX

Scanning Capability/Device	DRT
Preamble scan	✓
RSSI scan	✓
Spectrum analysis	✓

10.4 GPS Devices

TEMS Investigation supports the NMEA-0183 GPS protocol.

Some other GPS units using a different protocol are also compatible with TEMS Investigation, including the GPS built into the supported PCTEL scanners.

This is the full list of recommended GPS units:

- Garmin 10 Mobile Bluetooth (NMEA-0183)
- Garmin 12XL (NMEA-0183)
- Garmin 18 USB
- Garmin 18x USB
- Garmin 35 (NMEA-0183)
- Garmin 60 CSx USB
- GlobalSat BT-359 (NMEA-0183)
- GlobalSat BT-368 (NMEA-0183)
- GlobalSat BU-303 (NMEA-0183)
- GlobalSat BU-353 (NMEA-0183)
- Holux GPSlim 236 (NMEA-HS; Bluetooth or USB)

- Magnetti Marelli RoutePlanner NAV200
- Nokia LD-3W Bluetooth (NMEA-0183)
- Sanav GM-44 (NMEA-0183)
- Sanav GM-158 (NMEA-0183)

10.5 Accessories

In addition to the standard packages, the following optional items can be delivered:

- GPS units
- TEMS Pocket-enabled Sony Ericsson phones
- Equipment cases
- Indoor backpack including battery solution

The indoor backpack contains everything needed to operate phones and scanners in indoor and pedestrian environments. The backpack comes in two sizes, of which the larger accommodates both phones and a scanner, while the smaller is intended for phones only.

Please contact Ascom for further information on the available accessories.

11 Hardware and Software Requirements

11.1 Hardware and Software Requirements for TEMS Investigation Application

TEMS Investigation is designed to run on a standard PC and interfaces with the connected devices mainly through USB or serial ports.

Processor and RAM requirements are strongly dependent on what external devices are connected and what tasks they perform. The recommended minimum configuration is: Pentium T7200 or AMD TL-58 class CPU, preferably with dedicated graphics card from ATI or nVidia; 1 GB RAM. Please note that it is **not advisable** to collect data with more than one device, or to collect data in an LTE or HSPA network, using this configuration.

Windows Experience Index (WEI) scores should meet the following requirements:

- Minimum configuration: CPU > 4.5 and Graphics > 3.0. These are the minimum requirements for doing data collection with TEMS Investigation.
- Maximum configuration: CPU > 5.2 and all scores > 4.0. These are the requirements for maintaining:
  - (GSM, WCDMA Rel. 99 and CDMA/EV-DO) Up to six concurrent voice calls or up to four concurrent data service sessions.
  - (HSPA, LTE) A maximum of four concurrent data service sessions. Limitations apply according to device driver performance and the data rates attained in the network. Note also that the NDIS driver implementation for some devices might limit the number of data service sessions to only one.

LTE data service testing at high throughput rates (above 50 Mbit/s) with a Qualcomm chipset based device requires a very powerful PC processor such as an Intel Core i7.

For testing with a large array of connected devices (for example, 6–8 devices plus GPS), an Intel Core i7-*nnn*QM/XM, Intel Core i7-2*nnn*QM/XM, or equivalent processor is necessary.

11.1.1 Other Hardware Requirements

- One USB port for each user terminal
- One USB port for each stand-alone AQM module
- One USB port for each USB scanner
- USB port, Bluetooth port, or serial port for GPS
- ExpressCard/34 slot or PC Card slot for any data card user terminals
- Sound card and loudspeakers for event audio indications
- Graphics: 1024 × 768 (SVGA) with at least 16 bit colors (High Color)

11.1.2 Software Requirements

- .NET Framework version 4.0 (included on TEMS Investigation CD)

- Internet Explorer 6 or higher required for Report Generator and online help
- Internet Explorer 9 required for HTTP download testing with Internet Explorer
- Microsoft Core XML Services (MSXML) 6.0 required for support of XML-format cell files (not included in Windows XP)
- Microsoft DirectX 9.0c required for video streaming measurements

11.1.3 Supported Operating Systems

- Windows 7 with Service Pack 1 (x86, x64)
- Windows Vista with Service Pack 2 (x86)
- Windows XP with Service Pack 3 (x86)

All the latest Windows updates should always be installed.

In addition, all the latest Windows updates should always be installed.

Supported languages are English (U.S.), Chinese (simplified characters) and Japanese.

11.2 Hardware and Software Requirements for Call Generator

One of the setups for audio quality measurement (AQM) involves the use of a Call Generator: see section 5.4.1. Requirements on the machine hosting a Call Generator are as follows:

- 1.6 GHz processor, 1 GB RAM
- 2.7 GB free space on disk
- Free full-length PCI Express or PCI slot for installing the Dialogic card. For PCI, an adjacent PCI slot must also be free (otherwise there is not enough room for the circuitry on the card).
- Windows Server 2008 (64-bit version) or Windows Server 2003 (32-bit version)

11.3 Requirements for TEMS UDP Server Software

UDP testing makes use of TEMS software installed on the PC that functions as UDP server. This PC needs to have one of the following operating systems installed: Windows Server 2008, Windows Server 2003, Windows 7, Windows Vista, or Windows XP.

12 Note on TEMS Investigation Editions

Please note that the TEMS Investigation product exists in various editions, all of which are covered by the present document but are not differentiated here. This means that descriptions of functionality and external device compatibility are not necessarily applicable in every single respect to the TEMS Investigation edition you have purchased. Any restrictions that apply to your edition are indicated in the Release Note included in the delivery.