tcibr.com

# SCORPIO™
# Spectrum Monitoring Software

Scorpio Spectrum Monitoring Software provides complete control and monitoring of TCI's 700 series spectrum monitoring systems; and a full suite of ITU-compliant measurement, analysis and reporting tools. Scorpio runs on MS-Windows compatible devices using a client-server architecture, enabling each Scorpio client to interface with multiple monitoring systems running the embedded Scorpio server application. Each monitoring system can be accessed from multiple Scorpio clients.

Scorpio is able to operate over multiple types of networks, including Ethernet, wireless, and point-to-point microwave links, even if they are slow and unreliable. Scorpio provides a user-friendly, intuitive interface that can be effectively used by staff members who may have limited, or no technical background, ensuring measurement results are independent of operator skill level.

Scorpio provides an interface to TCI's extensive Built-In-Self-Test (BIST) residing on each monitoring system providing remote maintenance, diagnostics and trouble-shooting.

These features combine to provide an extensive set of tools enabling the highest level of operator efficiency, and minimized cost of spectrum monitoring operations.

## Compliant with ITU Recommendations

Scorpio provides comprehensive spectrum monitoring and analysis that meets or exceeds ITU recommendations for the measurement of frequency, field strength, occupied bandwidth, modulation, direction finding, spectrum occupancy, automatic violation detection, and other pertinent measurements.

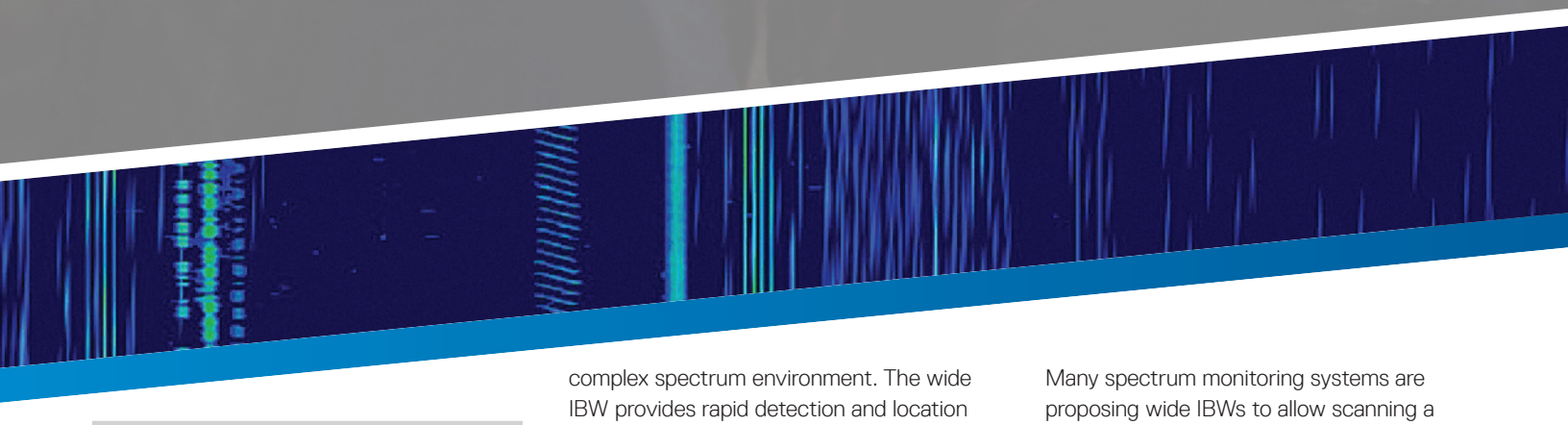
## KEY FEATURES

- ITU-compliant
- Monitoring of traditional and modern signals
- AOA direction finding
- TDOA geolocation
- Hybrid AOA / TDOA geolocation
- Integrated, automated operation
- Supports traditional & modern signals
- User-friendly MS Windows-based GUI

# Supervise the spectrum with software designed specifically for ITU compliance.

## KEY FEATURES

- Supports multi-channel spectrum monitoring solutions in the frequency range from 9 kHz to 8.5 GHz, and extensions above 40 GHz for future 5G monitoring applications.
- Measurements using multiple Instantaneous Bandwidths (IBWs) and Intermediate Frequencies (IFs) provided by TCI spectrum monitoring systems.
- Intercepts, measures, and locates traditional signals and modern digital formats.
- Client-server architecture supports flexible operating modes: local, remote, multiuser, and network operation.
- Client Graphical User Interface (GUI) is intuitive, easy to learn and based on task icons, toolbars, and point and click.
- Real-time signal display and simple single-button-click parameter measurements.
- Tasks scheduled to run on server, with results staying on the embedded server until retrieved by the client, allowing client computers to be disconnected from the network or even shut down while the server runs the scheduled tasks.
- Remote audio capability; audio demodulated at the server location can be transferred to the client for listening and identification.
- Client recording capability; remote audio can be recorded on the local client computer.
- Hybrid geolocation that combines Angle of Arrival (AOA) and/or TDOA measurements.
- Supports multiple languages and calendar types.
- Exports data and reports to MS Office-compatible, ascii and XML formats.



## Instantaneous Bandwidths— The TCI Advantage

TCI's 700-series spectrum monitoring systems employ dual instantaneous bandwidths (IBWs), one wide and one narrow to maximize signal detection, measurements and location in today's complex spectrum environment. The wide IBW provides rapid detection and location of traditional signals, and modern spread-spectrum and frequency-agile signals undetectable by a narrow-bandwidth system, including signals as short as 1 millisecond. The narrow bandwidth IBW enables monitoring of weak and moderate strength signals in crowded portions of the spectrum, especially where powerful emitters may interfere with the broader IBW (e.g. next to a cell tower).

Many spectrum monitoring systems are proposing wide IBWs to allow scanning a wider range of frequencies faster, but wider doesn't necessarily mean "better." TCI's unique approach provides the operator with the best of both worlds — narrowband scanning for congested and/or high-signal-level environments as well as fast wideband scanning. Scorpio also enables for manual gain control to maximize receiver sensitivity and improve reception of signals of widely varying amplitudes.

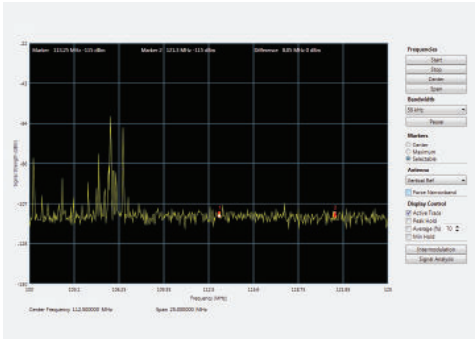
## Network setup

The network setup screen allows the operator to easily select the server or servers to be controlled from the operator's client computer, see Figure 3.

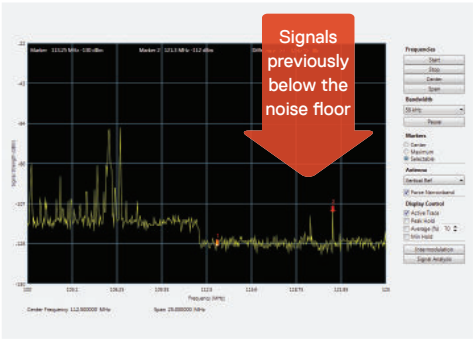
## Fixed-Frequency Operation (Pushbutton DF/Metrics Window)

Fixed-Frequency operation directly controls a Scorpio server and specifies the desired DF or other measurements for a specific signal. DF results are always available, see Figure 4. Other ITU-recommended metrics measurements, including bandwidth, modulation, field strength and modulation depth, can be requested for review and storage, see Figure 5.

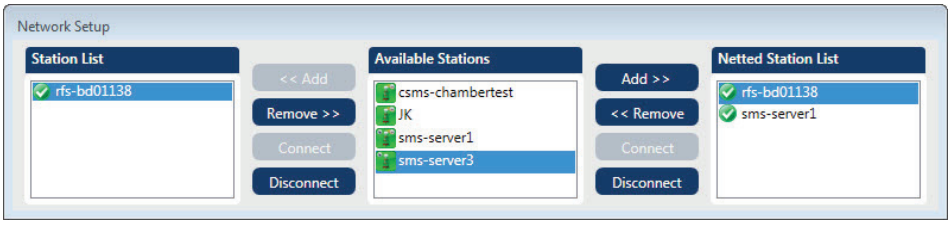
› Example of noise floor reduction using narrower bandwidth



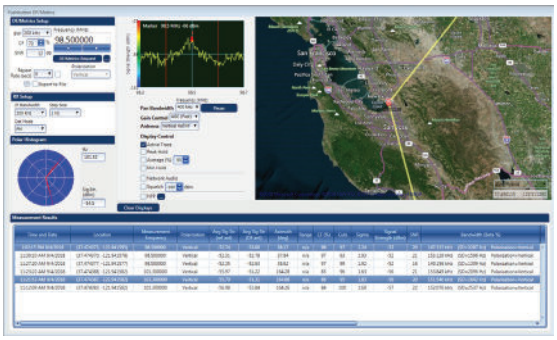
› Fig. 1 – Example using 40 MHz receiver bandwidth




› Fig. 2 – Example using 4 MHz receiver bandwidth




› Figure 3 – Network Setup Window



› Figure 4 – Pushbutton DF/ Metrics Window


› Figure 5 – Pushbutton DF/Metrics Window, Metrics Setup Popup Window

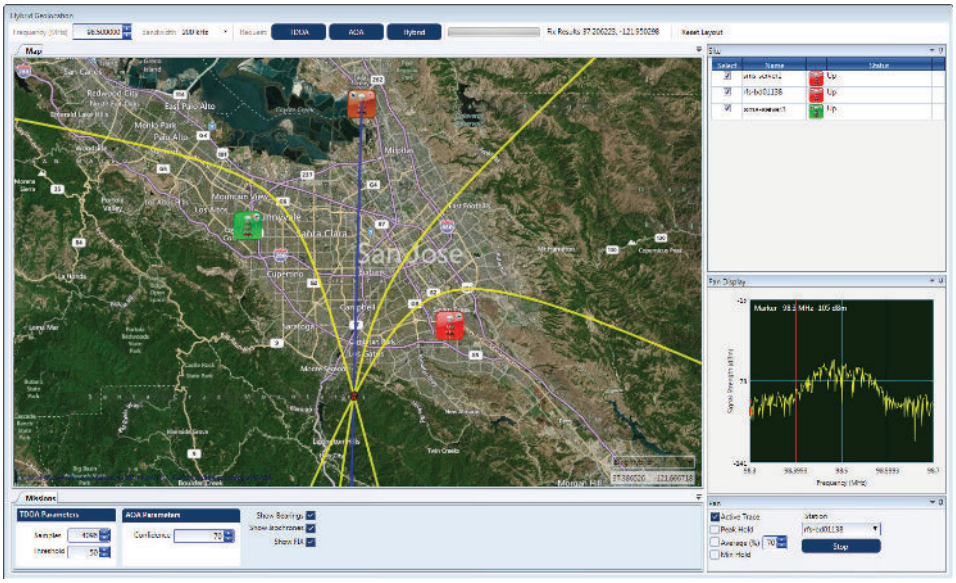
## Location, Location, Location

When it comes to direction finding and geolocating signals of interest, TCI is the proven industry leader. And Scorpio makes full use of TCI's DF/geolocation technology, including:

**VHF/UHF AOA DF** – TCI's VHF/UHF Angle of Arrival (AOA) DF option provides wideband DF from 20 MHz to 3 GHz, with SHF option up to 8.5 GHz. TCI's wideband system capability computes all signals in the scan range. Known as DF First®, DF data is captured for all active signals, enabling search by direction and geolocation.

**HF DF** – TCI's Wideband HF DF options provide line of bearing and elevation, and can use Single Site Location (SSL) techniques to determine range and geolocate HF transmitters. Again, since this is a wideband system, direction is computed for all signals in the scan range, enabling search by direction.

**Triangulated Geolocation** – Multiple AOA DF results are combined to calculate the emitter location. Since the individual AOA sources are wideband systems, geolocation can be performed on multiple simultaneous signals of interest. And since the AOA information is cached in the DF Server, Scorpio operators can compute a fix for past signals of interest.



› Figure 6 - TCI Scorpio Hybrid Geolocation

**Homing Geolocation** – Moving DF platforms can geolocate transmitters by combining multiple AOA measurements gathered over time. Since the AOA information is pre-calculated with DF First® and stored in the signal database, operators can go "back in time" and compute a fix for a signal of interest collected from multiple locations over time.

**TDOA Geolocation** – Leveraging the RF Processor's precision time-stamping, Time Difference of Arrival (TDOA) techniques can be used for precision geolocation of target emitters. In addition, TCI offers a set of outdoor RF Sensors which can be deployed into a wide area to support distributed monitoring and TDOA geolocation.

**Hybrid Geolocation** – TCI's unique hybrid geolocation technology combines AOA and TDOA techniques to achieve directed precision geolocation with a minimum of TDOA assets.

› Typical Fully Integrated TCI Scorpio Spectrum Monitoring Vehicle

## User-Friendly Software

TCI's Scorpio™ software incorporates powerful graphical displays with easy-to-use features, such as drop-down menus, dialog boxes and automatic default values (where appropriate) to enhance understanding and simplify operations. Scorpio software can be operated interactively, giving the operator full control of the mission with instantaneous feedback, or in automatic scheduled mode without operator intervention. In scheduled (calendar) mode for unattended operation, Scorpio automatically initializes and starts operation when power is applied.

## DF Polar Display

On the Pushbutton DF/metrics window, the detailed result of a line-of-bearing measurement is displayed as radial lines on a background map and polar display.

## Homing DF and FIX Window

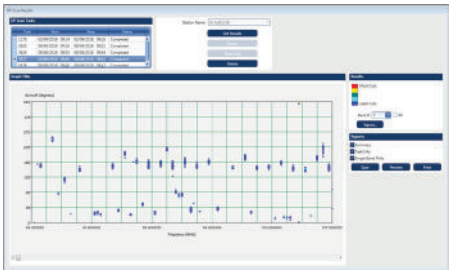
In line with ITU recommendation, the Homing DF and FIX feature enables a mobile unit to "drive down" a transmitter of interest. The DF results are presented with respect to true north and are plotted on a map background. If the mobile unit is moving (DF on-the-move) successive line-of-bearing measurements are displayed over the map background and a FIX result is automatically calculated and displayed for those displayed lines of bearing, see Figure 8. Each line of bearing also shows a color-coded dot at its beginning, indicating signal strength of each measurement.

The same DF results are also plotted on a compass rose oriented with respect to the front of the vehicle, so the operator can quickly and easily see the signal's direction relative to his vehicle, and direct the driver's approach to the signal transmitter.

The location of the mobile unit itself is determined by the Scorpio system's built-in GPS, and the orientation of the vehicle to north is determined using combined readings from an electronic fluxgate compass and the system GPS.

## Wideband Signal Detection and DF Operation (DF Scan)

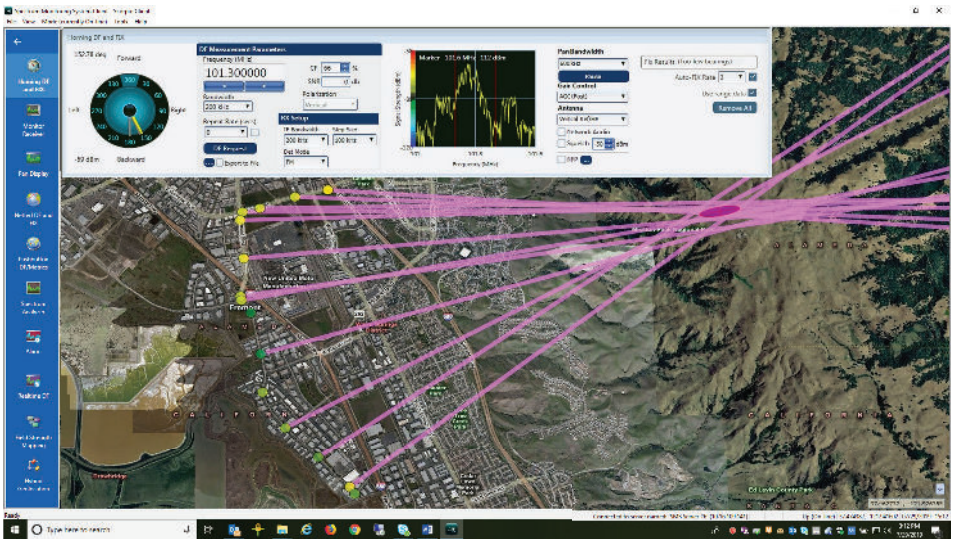
The system scans the frequency range requested by the operator and performs a DF measurement on all signals that meet the requested criteria. Figure 7 shows an example of a DF Scan result window. Bearing is displayed on the y-axis, and frequency on the x-axis. In this example, the bearing of 230˚ at 89.7 MHz is shown in red, as more measurements have been taken on this frequency. This graphic result, as well as tabular results, can be saved as reports.



› Figure 7 – DF Scan Results Window

## Automatic Frequency Scan and Scan from List Functions

For tasking windows that allow ranges of frequency, such as the AVD, DF Scan, and Spectrum Occupancy tasking windows, the operator defines scan parameters, such as: one or many F1-to-F2 frequency ranges, exclusion frequencies, step size, signal activity threshold, and DF and signal-measurement parameters. Alternatively, the operator can specify a set of discrete frequencies of interest for a scan-from-list task. For either the frequency scan or the scan-from-list functions, the server automatically performs the operator-specified activities and stores the results in the database , and are replicated to the operator's client computer database when requested. The results may be displayed on the client computer and/or a report can be generated, if desired.



› Figure 8 – Homing DF and FIX Window

## Built-in Self-Test (BIST)

The Scorpio BIST function enables an operator or maintenance personnel to determine the status of the server using a thorough diagnostic test. The function can create a small text file of test results that can be sent to TCI for assistance or in-depth diagnosis, if desired.

Precision signal sources and control units built into the Scorpio server achieve auto-calibration. Any variations (even those caused by temperature changes) are detected and compensated for in software to assure a high level of measurement precision, as required by ITU recommendations. No special external calibration procedure or instrumentation is necessary.

The BIST sequence tests hardware components in the reverse order of the normal signal flow: processors, digitizers, receivers, antenna switches and antennas, providing a logical and easy-to-understand result, see Figure 9.

## Geographic Map Display

Geographic map displays are available within a number of Scorpio Client windows. ESRI ArcView shape file maps and Internet maps can be selected as the background for DF and FIX results. A low-resolution ESRI shape file digital map of the world is provided, with selectable layers including county name, borders, cities and city names. TCI can provide higher resolution maps as an option, or the customer can install their own compatible ESRI ArcView maps. The ability to overlay data on BING maps (street, satellite, and hybrid) as well as OpenStreetView maps is a standard feature.

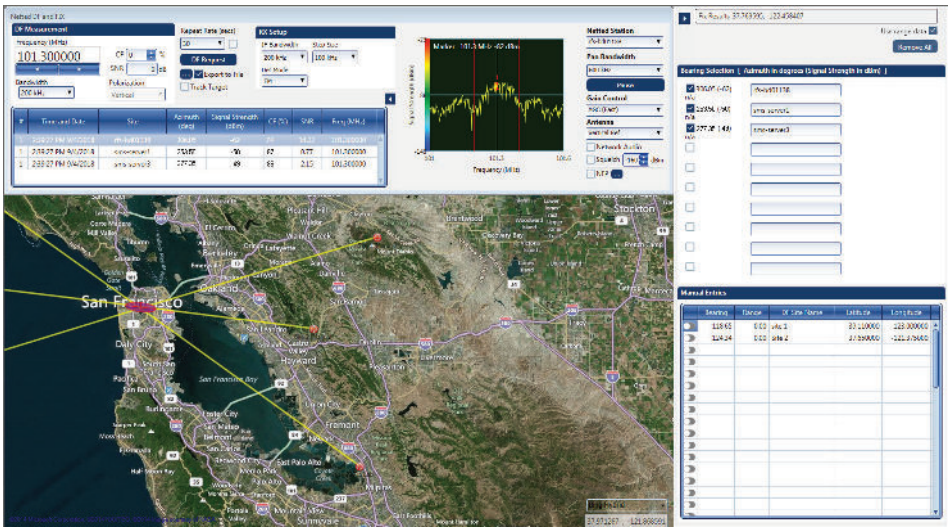
## Netted DF Display

This display shows locations of monitoring/DF stations, measured lines of bearing, and the DF triangulation FIX of the signal of interest, see Figure 10. A single click on the DF button sends a DF measurement request to all stations selected by the operator to be part of the netted DF network. Each tasked station returns a line-of-bearing measurement, displayed on the Netted DF Display. If the lines of bearing intersect, the system automatically calculates and displays a FIX result.

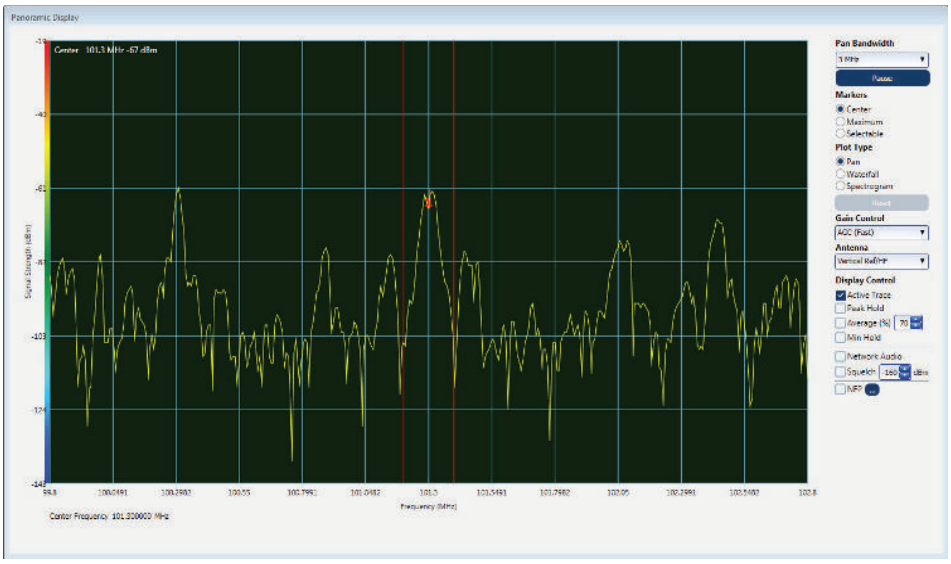
## Panoramic Spectrum and 3D Waterfall Displays

The panoramic display shows a real-time, high-speed panoramic capture of the spectrum, with up to 80 MHz (using CSMS processors) and higher instantaneous bandwidth. This enables rapid identification of modulation characteristics, and identification and correlation of specific signals of interest intercepted at different sites, (Figure 11.) The 3D waterfall and spectrogram displays provide real-time, three-dimensional views of signal amplitude, frequency and time. Signal amplitude is color-coded and appears as the third dimension.

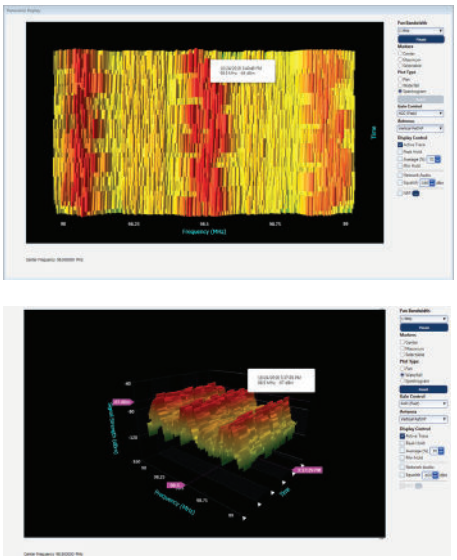

› Figure 9 – BIST Results Window




› Figure 10 – Netted DF screen, showing FIX for two-site bearing measurement




› Figure 11 – Panoramic (or Pan) Display Window

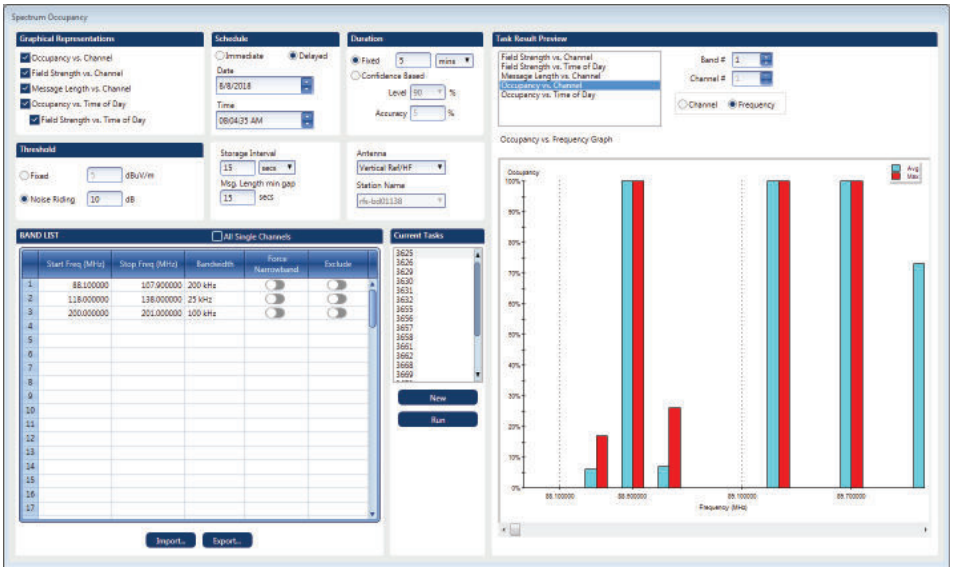


› Fig. 12 – 3D Waterfall, Spectrogram Windows

## Spectrum Occupancy Measurement Tasking and Result Displays

The tasking display enables the operator to easily set the task parameters for either immediate or delayed scheduling, see Figure 13. These measurements are used to identify traffic analysis patterns, and include the maximum and average values of the following measurements, available for display in graphic and/or tabular form:

- Channel occupancy versus frequency/ channel
- Signal strength versus frequency/ channel
- Message length versus frequency/ channel
- Frequency/channel occupancy versus time of day




› Figure 13 – Spectrum Occupancy Tasking Window

Scorpio provides spectrum occupancy measurements to assist in monitoring spectrum usage, tracking down interference, identifying traffic analysis patterns and performing band-clearing activities. These measurements are performed in accordance with the 2011 ITU Spectrum Monitoring Handbook and to the accuracies defined in ITU-R SM 1880. Spectrum occupancy can be measured in a variety of ways. For example, the user can select a “channel scan” to look at specific channels or a “spectrum scan” to scan continuously over a frequency range defined by start and stop frequencies. The system performs statistical analyses of transmissions and spectrum occupancy that are then available in on-screen windows, see Figure 14, and can also be displayed and saved as graphical and tabular reports.

› Figure 14 – Example of On-Screen Spectrum Occupancy Results Windows

## Receiver Control Display

The receiver-control window gives the operator direct control of the settings of the receiver and the built-in digital audio recorder. The display enables selection of receiver parameters such as frequency, bandwidth and detection mode. The window also includes an integral panoramic signal display to assist the operator in fine-tuning the receiver to the signal of interest, see Figure 15.

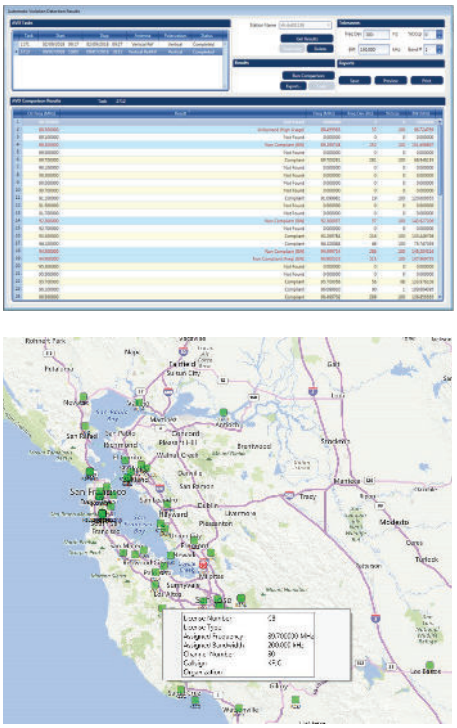

› Figure 15 – Panoramic (or Pan) Display Window

## Automatic Violation Detection (AVD) Tasking and Result Windows

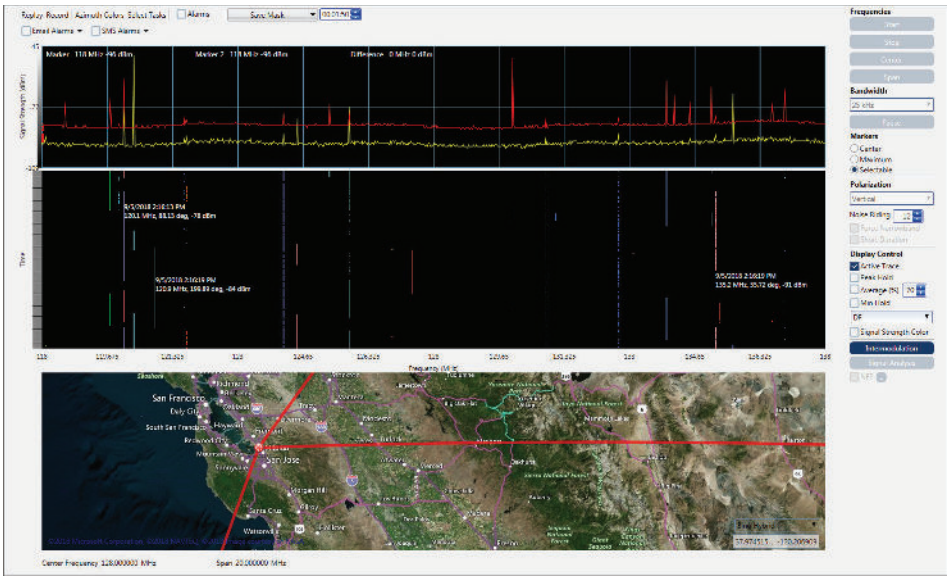
The Automatic Violation Detection (AVD) function is a powerful tool that verifies compliance by licensed emitters and detects unlicensed operations.

AVD operates in conjunction with license data (frequency assignments) downloaded from the Management System database. AVD determines whether a particular transmission complies with tolerances of assigned center frequency and bandwidth, as specified by the operator for the allocated band and service in the National Frequency Plan table. It will also report frequencies operated without a corresponding license in the Management database .

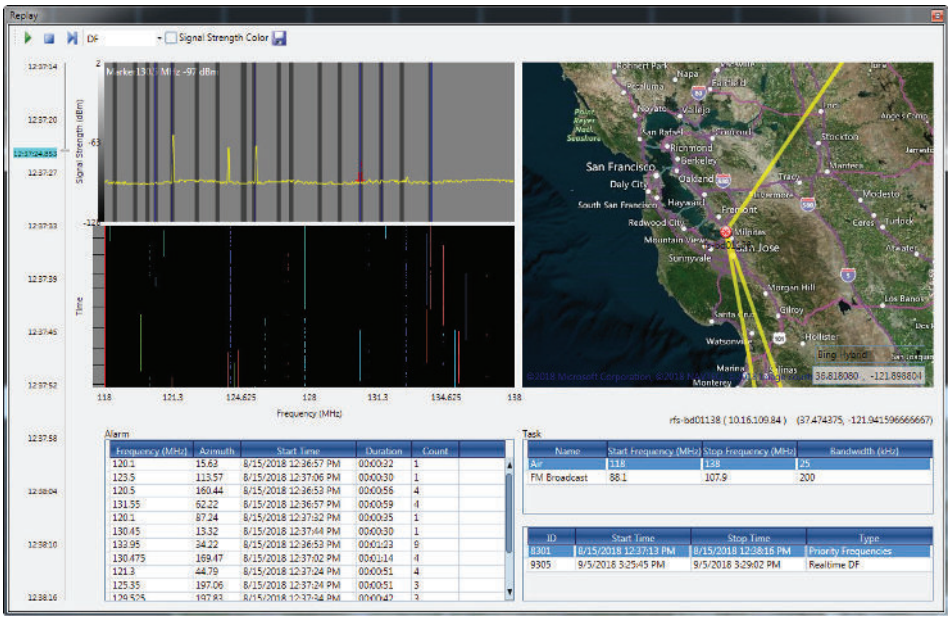
Measurements can be performed on a single frequency or a range of operator-specified frequencies. Figure 16 provides examples of on-screen AVD tasking and results windows.



› Figure 16 – Example AVD Tasking and On-Screen Results Windows



› Figure 17 – Real Time DF/Alarm Window



› Figure 18 – Replay Window for an Alarm

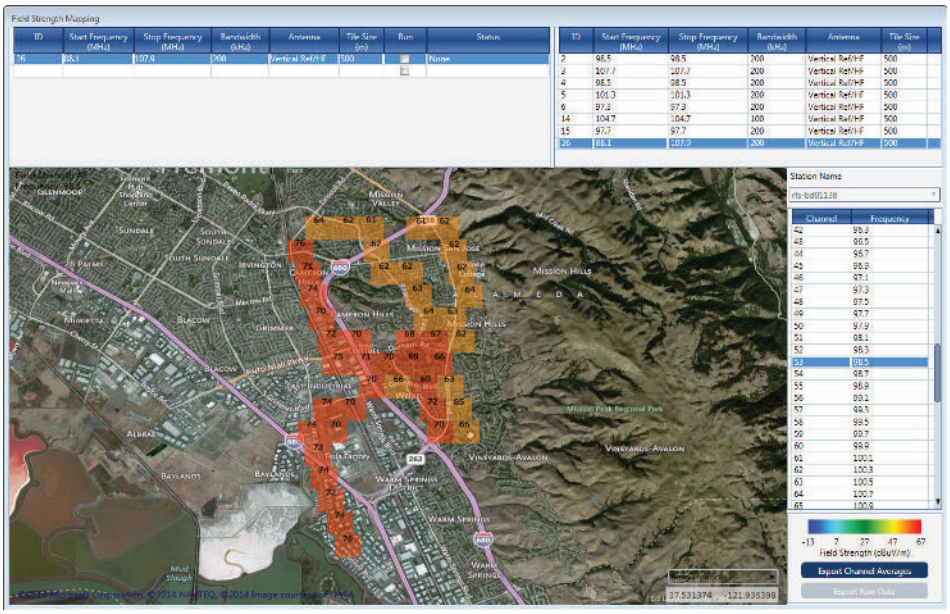
## Real Time DF and Alarm Windows Option

The Alarm/Real Time DF window lets the operator monitor a frequency range, see Figure 17. A typical spectrum-analyzer style display in the top part of the window shows all signals transmitting. A color-coded chart scrolls below this display, with the color indicating the signal direction.

When operating in alarm mode, the operator simply creates a mask. Any signals crossing the mask threshold create an alarm, and have their frequency, azimuth, start time and duration recorded in a replay window for future viewing, see Figure 18. A count trigger displays the amount of times the offending signal has transmitted. Operators have the option to save the Realtime DF of Alarm data for later analysis.

## Field Strength Mapping Option

This feature can only be used with a mobile station, and is used to measure and display field. The operator defines and runs Field Strength Mapping task(s). Measurements are taken continuously for the frequencies in all running tasks as the mobile station moves. The average field strength for each frequency is computed and displayed for each grid square as the mobile station moves from grid to grid. The average field strength values for all grid squares and all channels are displayed numerically and color-coded. See Figure 19.



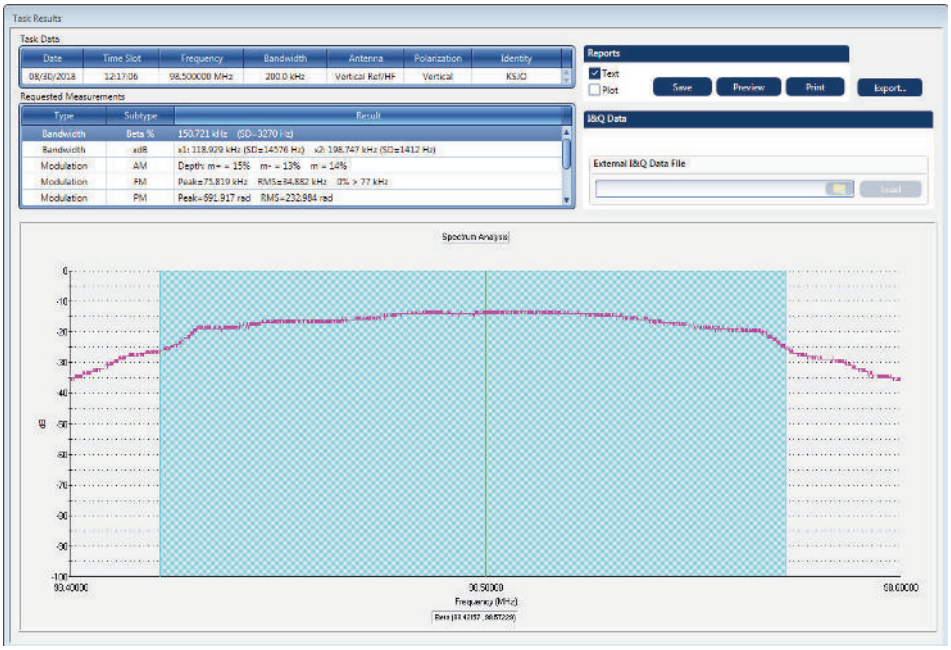
› Figure 19 – Field Strength Mapping Window

## Signal Measurement Tasking and Results Displays

The tasking display enables the operator to easily set the parameters for the task for either immediate or delayed scheduling. These measurements are used to identify the operating characteristics of the signal of interest, and include the peak and average values of the following measurements in graphic and/or tabular form:

- Frequency of operation (Instantaneous & FFT Frequency Measurement)
- Occupied bandwidth
- Signal strength/field strength
- Modulation depth (AM, FM, and/or PM)
- Direction Finding

The results are available for on-screen viewing, see Figure 20, and can be saved in report format, see Figure 21. Scorpio Task Calendar supports multiple languages and calendar types.



› Figure 20 – Scheduled (Calendared) Task Results Window

## Frequency Measurements

Following ITU Chapter 4.2 of the 2011 Spectrum Monitoring Handbook, Scorpio employs DSP processing techniques for the most accurate frequency measurements. The following table summarizes the measurement performance using the two DSP methods — Instantaneous Frequency Measurement (IFM) and Fast Fourier Transform (FFT).

Signal frequencies are measured using the IFM or FFT vector-data-based DSP methods, the ITU's most sophisticated and preferred frequency measurement techniques. This, combined with tying all of the receiver time and frequency bases to the GPS received frequency standard output, ensures excellent frequency accuracy.

The IFM method of estimating modulated-signal frequency examines the phases versus time of each time sample of the input signal. A phase ramp occurs because of the difference between the signal's carrier frequency and the measurement equipment's center frequency setting. A best-fit straight line is calculated for this ramp from which the average carrier frequency is calculated for the time record.

The IFM method is accurate for digitally modulated carriers. The averaging process will converge on the true carrier frequency if the data is random. This random condition is generally met in channels carrying normal data.

The FFT method of estimating modulated-signal frequency examines the power spectrum of the signal in the measurement bandwidth. The spectrum is calculated using the Fast Fourier Transform technique, using a high-performance windowing function. Spectral bins that fall below a dynamically calculated noise threshold are eliminated and a power-weighted frequency average of the spectrum is calculated. This results in a highly accurate average signal frequency value for essentially all signal modulation types.

## Field Strength and Power Flux Density Measurements

Field-strength measurements are one of the most fundamental spectrum monitoring parameters and are referenced in Chapter 4.4 of the 2011 ITU Spectrum Monitoring Handbook. Scorpio performs accurate measurements to ITU-R Recommendation SM 378 over a wide range of signal conditions.

To ensure proper operation and valid measurements to ITU standards, the system is automatically calibrated at every measurement. The instrumentation characterizes signal losses from the RF Distribution Unit to the receiver input. The software automatically corrects the data for path losses to provide accurate measurements.

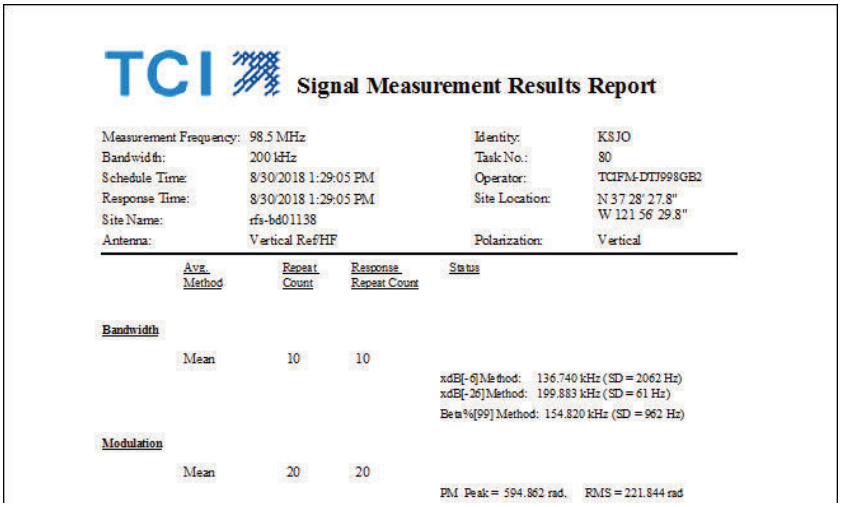
The system also provides measurements of power flux density, which is the preferred emission-strength measurement at higher frequencies.

## Modulation Measurements

Modulation measurements are essential for checking transmitter compliance and ensuring that adjacent-channel interference is minimized. Scorpio can perform AM, FM, and PM measurements simultaneously or individually. The system measures the modulation depth, deviation, or modulation index by examining the In-phase (I) and Quadrature (Q) components of the signal using DSP techniques. These measurements follow the guidelines of Chapter 4.6 of the 2011 ITU Spectrum Monitoring Handbook.

## Occupied Bandwidth Measurements

Occupied bandwidth measurements are referenced in Chapter 4.5 of the 2011 ITU Spectrum Monitoring Handbook. The monitoring system uses two ITU-recommended methods of measuring occupied bandwidth: the X dB and 99% power methods to the accuracies defined in ITU-R SM 443 and ITU-R SM 328. The X dB method uses the total signal power as a reference and the high and low spectral sides are found where the envelope is X dB down, typically 26 dB. The occupied bandwidth is then the difference between the high and low side frequencies. The 99% power method divides the measured signal envelope into bins, each with a corresponding power. Bins are then subtracted one by one from the upper and lower sides of the envelope until the resulting power falls to 99% of the total power, with 0.5% of the power removed from each side.



TCI

**Signal Measurement Results Report**

| | | | |
|---|---|---|---|
| Measurement Frequency: | 98.5 MHz | Identity: | KSJO |
| Bandwidth: | 200 kHz | Task No.: | 80 |
| Schedule Time: | 8/30/2018 1:29:05 PM | Operator: | TCIFM-DTJ998GB2 |
| Response Time: | 8/30/2018 1:29:05 PM | Site Location: | N 37 28' 27.8" W 121 56' 29.8" |
| Site Name: | rfs-bd01138 | | |
| Antenna: | Vertical RefHF | Polarization: | Vertical |

| | Avg. Method | Repeat Count | Response Repeat Count | Status |
|---|---|---|---|---|
| **Bandwidth** | | | | |
| | Mean | 10 | 10 | xdB[-6] Method: 136.740 kHz (SD = 2062 Hz)<br>xdB[-26] Method: 199.883 kHz (SD = 61 Hz)<br>Beta%[99] Method: 154.820 kHz (SD = 962 Hz) |
| **Modulation** | | | | |
| | Mean | 20 | 20 | PM Peak = 594.862 rad. RMS = 221.844 rad |

› Figure 21 – Example Scheduled (Calendared) Task Results Report

## Direction Finding (DF) Measurements

Scorpio provides easy-to-use DF functions for determining the line of bearing of a known or unknown (illegal or noncompliant) signal. When more than one monitoring station is assigned, lines of bearing from each can be automatically combined to calculate a FIX and thus determine the source of the signal.

Scorpio also provides a homing DF function that allows one mobile monitoring station to make successive DF measurements while the mobile station is in motion. When each DF measurement is made, the position of the station is determined by the GPS. Successive lines of bearing and vehicle locations are then plotted on a map in order to determine the location of the emitter.

The system provides a display of DF results as a function of azimuth and frequency. The scatter-plot display visually correlates multiple frequencies with the same azimuth, which is very useful in the case of CDMA, GSM and other frequency-agile signals.

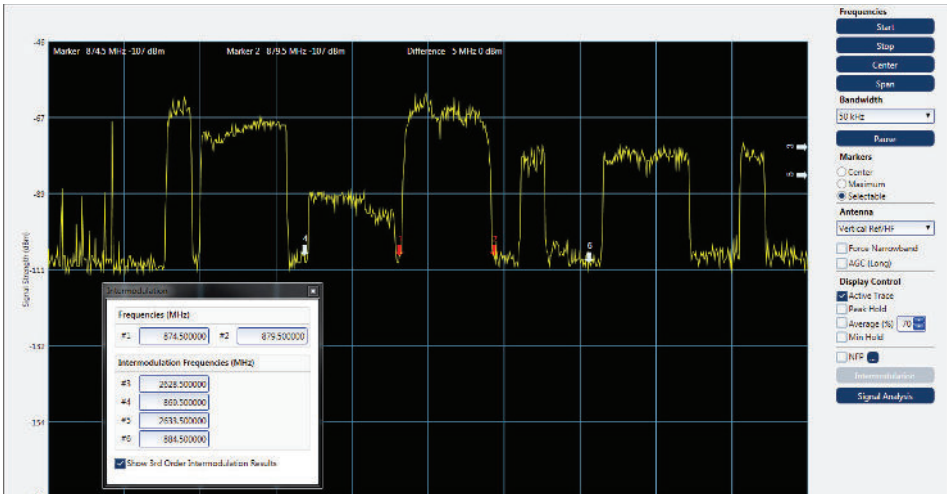
The system's Pushbutton DF function combines a variety of DF functions and displays on one screen. These include a panoramic display, which serves as a useful tuning aid, a map display with zoom and pan functions, a polar histogram display and an alphanumeric display of DF results. DF requests can be issued and results analyzed with a variety of displays on this one screen.

## Spectrum Analyzer Option

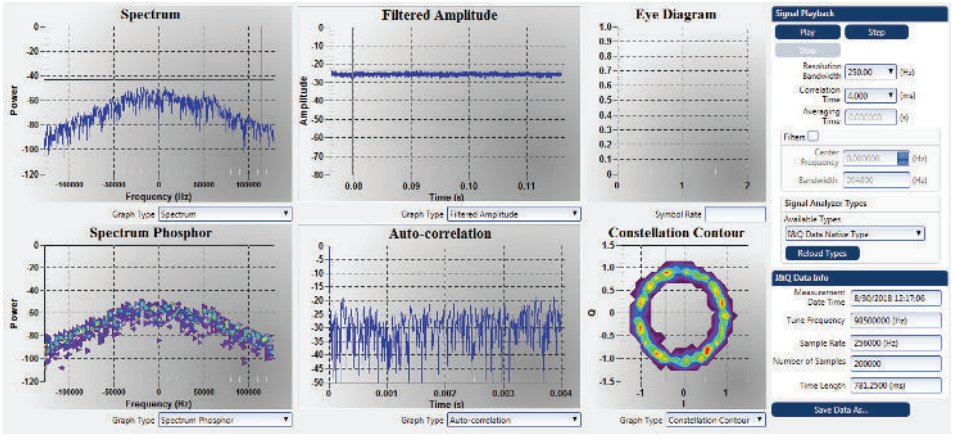
TCI's Spectrum Analyzer Display option can be used in either mobile or fixed stations to visualize signal activity within an operator-defined frequency band.The operator sets a Start/Stop frequency and a bandwidth, and the system immediately starts to shows signal strength by frequency similar to what would be shown by a fast spectrum analyzer. Using this option, an operator can produce 3rd Order Intermodulation results between two frequencies.

## Scorpio Vector Signal Analysis (VSA) Option

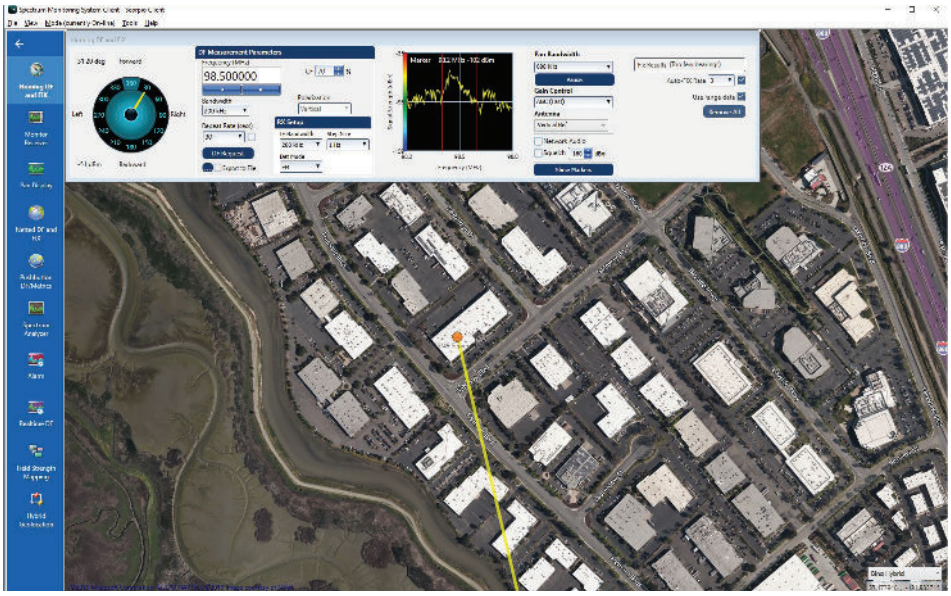
TCI continues to expand the capability of its Spectrum Monitoring System solution by introducing the signal analysis option. With this option, TCI's Scorpio system can capture wideband digital I&Q data and perform vector signal analysis. Scorpio's signal analysis software includes the tools capable of handling a wide variety of digitally modulated signals. The VSA option tools include I/Q recording, vector signal analysis, time domain analysis and bit-level modulation analysis. To further classify signals, the VSA option includes a predefined library of signal templates for easy signal type identification. This function also allows a user to add additional signal templates at any time. VSA was designed to fully comply with ITU-R SM 1600.




› Figure 22 – TCI Spectrum Analyzer



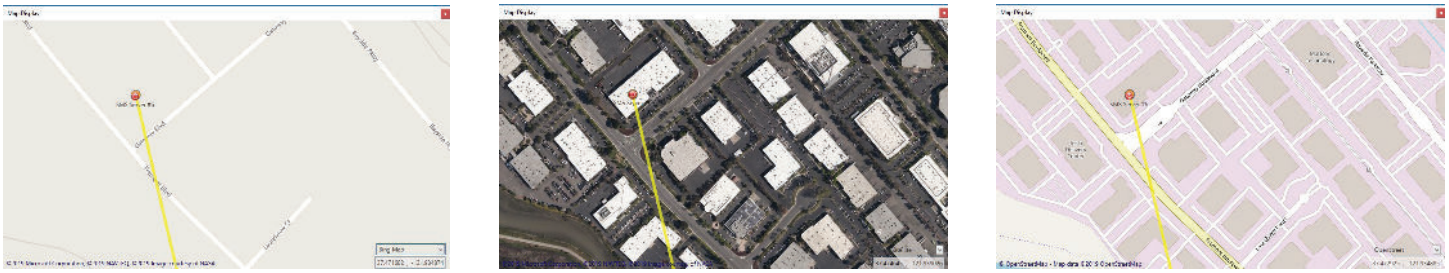

› Figure 23 – Digital Signal Analysis Feature



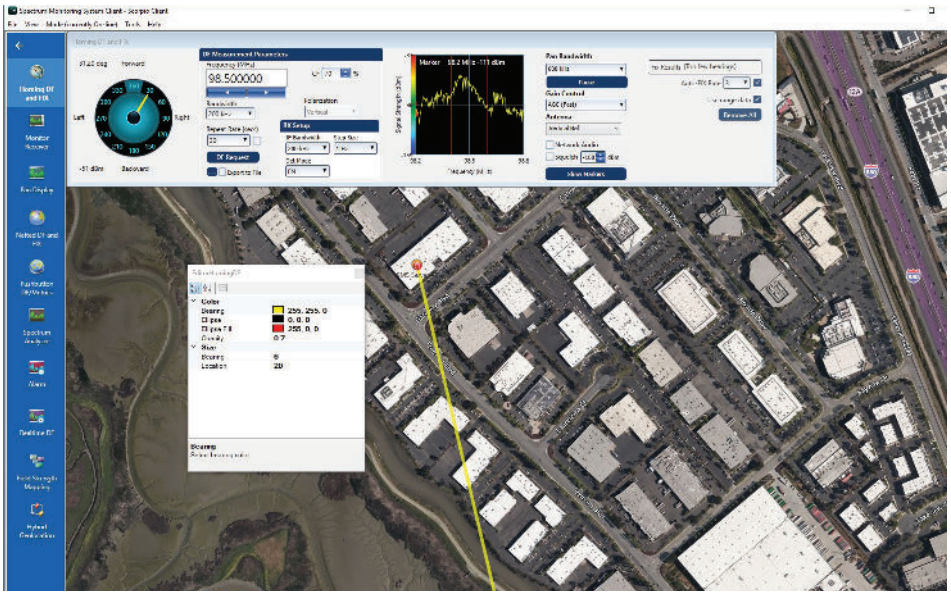
## Digital Maps Online

The TCI Scorpio software is supplied with automatic access to several on-line digital map providers, including Bing Maps, Bing Satellite and Bing Hybrid from Microsoft. This feature can be integrated with Google Earth and offers digital maps at any scale from continental size to the resolution of individual homes and vehicles, including the scale of 1:50,000. The following figures illustrate some typical digital maps offered by the TCI System.

› Figure 24 – Homing DF Screen overlay on Bing Hybrid



› Figure 25 – As well as showing an overlay on Bing Hybrid, Scorpio includes the ability to overlay on BingMap, BingSatellite, and OpenStreetMap



› Figure 26 – The overlay schema can be easily changed for element colors, opacity, and size

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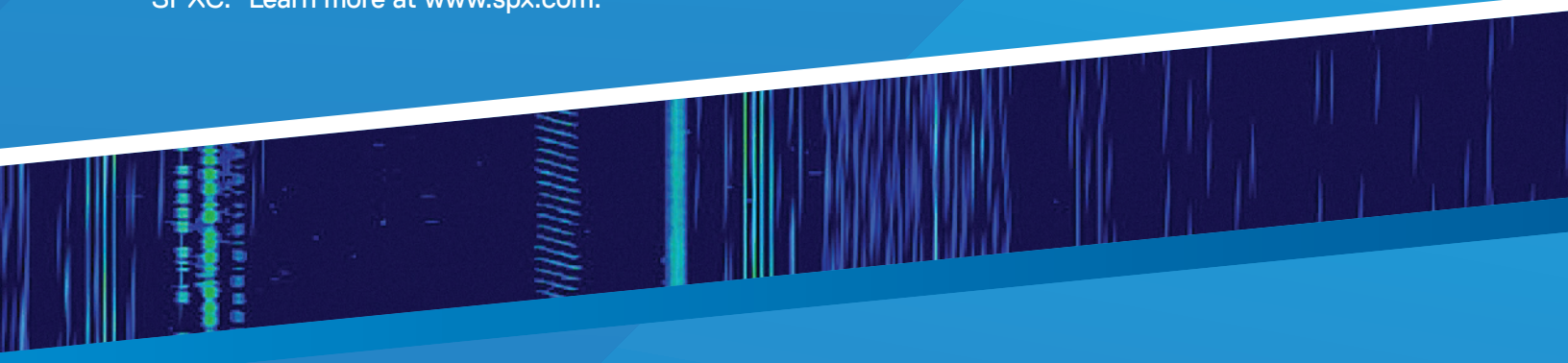

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