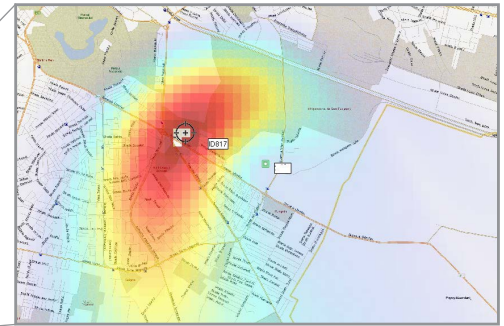


Keysight Technologies

N6854A RF Geolocation Server Software License

Technical Overview



The Keysight Technologies, Inc. N6854A geolocation server software extends the capabilities of a wide area network of N6841A RF sensors with integrated real-time RF emitter geolocation and mapping. This software computes the estimated position (EP) of emitters based on several unique geolocation methods. It is tightly integrated with the N6820ES Signal Surveyor 4D software that provides advanced RF search and signal isolation functions for monitoring, survey and interference detection. The Geo Server Software can be tipped automatically or manually from Surveyor 4D. Results are logged to the database and may also be displayed in real-time in the user interface.

Improve Detection and Geolocation of Modern Signals

New methods for quickly detecting and locating modern wireless transmitters are now possible with the N6854A geolocation server and multiple N6841A RF sensors. Modern signals and interference can be intermittent, short-duration, low power, at higher frequencies, with wider signal bandwidths and more complex modulation – making them especially challenging to detect and locate. Traditional approaches to spectrum monitoring and direction finding against modern communication signals is either ineffective due to siting constraints or cost prohibitive due to higher initial capital and ongoing calibration and maintenance expense..

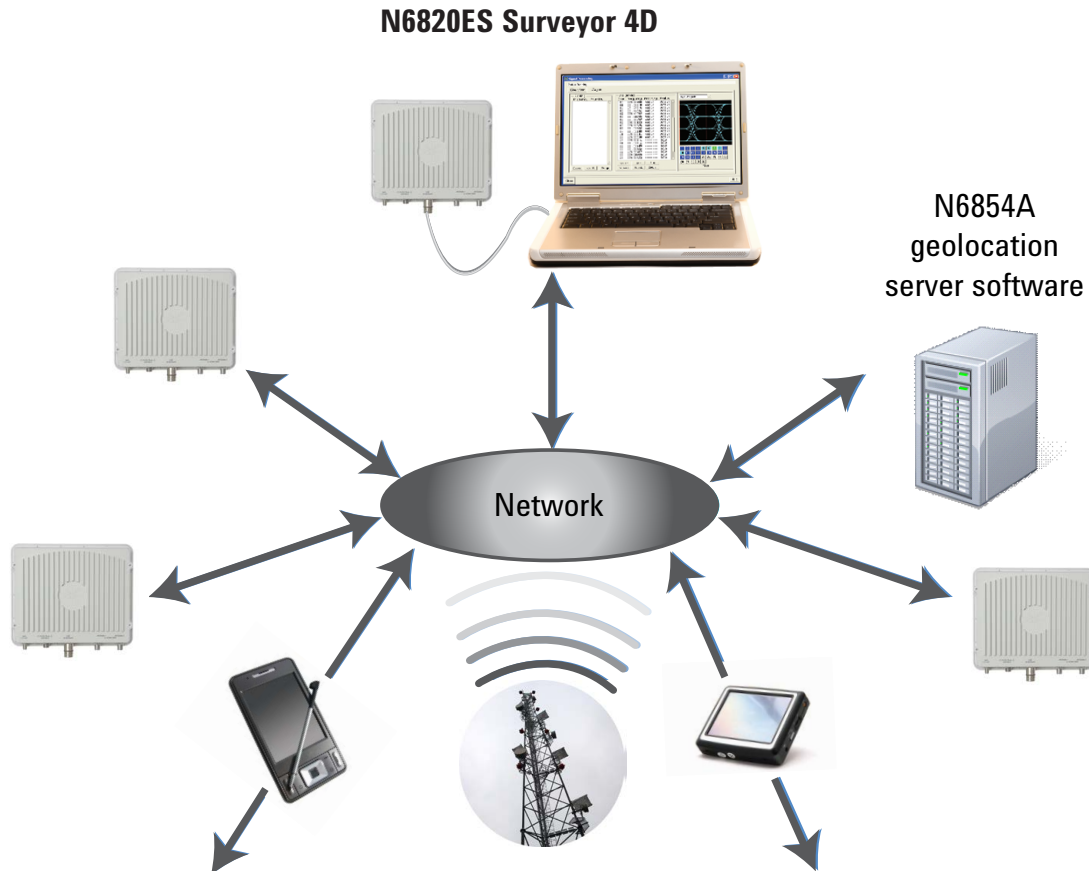


Figure 1. An RF search system, a network of RF sensors combined with the geolocation server software estimates the position of numerous modern signals.

- Geolocation computation for RF emitters from 20 to 6000 MHz
- Locate CW, narrow or wide bandwidth signals including signals below the noise floor
- Supports deployments in indoor, rural, suburban or dense urban monitoring environments from 10 meters to 10's of kilometers
- Use with fixed site or a land mobile network of Keysight N6841A RF Sensors
- Software tasks 3 or more sensors to geolocate signals of interest using the following user-defined techniques:
 - Time-Difference-of-Arrival (TDOA)
 - Relative Signal Strength (RSS) Amplitude Ratio
 - Adaptive hybrid technique combining both TDOA and RSS
- EP results include accuracy and confidence indicators
- Measurement triggering based on RF power level or time-of-day
- Intuitive visual displays of estimated position, signal correlation and propagation characteristics
- Import underlay raster maps in most standard image formats
- Export geolocation results in KML format to Geographical Information Systems such as Google Earth
- Operates in conjunction with Keysight's N6820ES Signal Surveyor 4D software
- API C library for external application interface

Geolocation Methods

Unlike traditional direction-finding (DF) systems which determine the signal's angle of arrival (and thus a line of bearing), the N6854A geolocation server uses a network of RF sensors to locate emitters using several different techniques.

1. Time Difference of Arrival

The TDOA technique is based on the concept that an RF signal of unknown location and time of emission can be located if the precise time of arrival of the signal can be determined at three or more receivers of known location. By precisely time-stamping the signal arrival, the measured time difference of arrival between any pair of sensors form a hyperbolic relationship. Where these multiple hyperbolic lines of position intersect is the resulting EP. For emitters outside of the region covered by sensors, only the TDOA method provides a hyperbola of bearing (HOB). The TDOA approach works well when used outdoors over longer distances (typically > 1 km) and for wider bandwidth signals (> 100 kHz). This method works on signals of interest that are modulated.

2. Received Signal Strength Amplitude Ratio

The RSS amplitude ratio technique is based on the concept that signal power decreases in a predictable manner as the signal propagates away from the emitter. In free space, the power drops off with the square of the distance ($1/r^2$). For actual indoor environments, this has been measured to actually be between ($1/r^3$) and ($1/r^4$). It can be shown that independent of the exponent, the ratio of signal power measured at two different receivers leads to a circle of position. Circles of position from multiple pairs of receivers will (under ideal circumstances) intersect at a single point – the EP. The Keysight RSS technique is well suited for indoor (high multipath) and close proximity deployments. It may also be used for un-modulated CW signals which overcomes a key deficiency of TDOA.

3. Hybrid TDOA and RSS

The Keysight HYBRID algorithm is an adaptive technique that uses both TDOA and RSS information in an optimal approach. When time-of-arrival data is suspect, it relies more heavily on signal power to determine the EP – and vice versa. The HYBRID method is optimal for outdoor, dense urban environments and for narrow bandwidth signals.

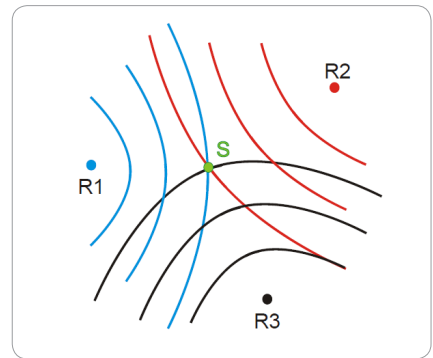


Figure 2. With TDOA method, hyperbolic lines of position intersect at the estimated position of the emitter

Flexible Sensor Network Operation

Operating the sensor network can be either manual, i.e. directly controlled by the user, or automated in a tipped hand-off scheme with a signal search system such as the Keysight N6820ES Signal Surveyor 4D software. The raw measurement data and measurement parameters for each synchronized sensor are logged to the system database and available for later analysis and post-processing.

Measurements are executed in a number of different ways. A time-of-day measurement is ideal for most conventional long-duration signals. For short duration and transient signals, once RF energy is above the noise floor of the receiver's IF section, a measurement can be triggered. A peer-triggered measurement is effective when all sensors cannot receive the signal above the noise floor, such as in dense urban or rugged terrain environments. In this case, one sensor will initiate a measurement with several other adjacent sensors. Lastly, there is a free-run mode where the system will make rapid continuous measurements at a specific frequency.

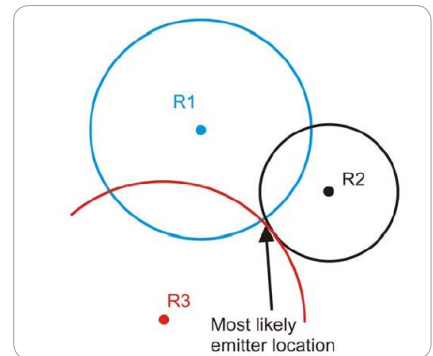


Figure 3. RSS techniques show circular lines of position intersecting at the estimated position of the emitter

Locate Signals Below the Noise Floor

Keysight's TDOA solution in the N6854A software uses a proprietary coherent detection technique for estimating the position of RF emitters. Non-coherent detection schemes require transmitter signal power greater than the noise when comparing measurement results from multiple receivers. When the signal-

to-noise ratio (SNR) is not positive, the noise obscures low-level signals and the receivers cannot detect differences in power. Keysight's coherent detection uses a cross-correlation algorithm between sensor measurements for detecting and locating signals that are not visible in the spectrum data of each individual sensor.

In traditional monitoring stations with non-coherent detection, performance of the system is limited to the performance of the individual receivers. With Keysight's coherent detection of synchronized receivers, the system performance far exceeds that of each individual receiver.

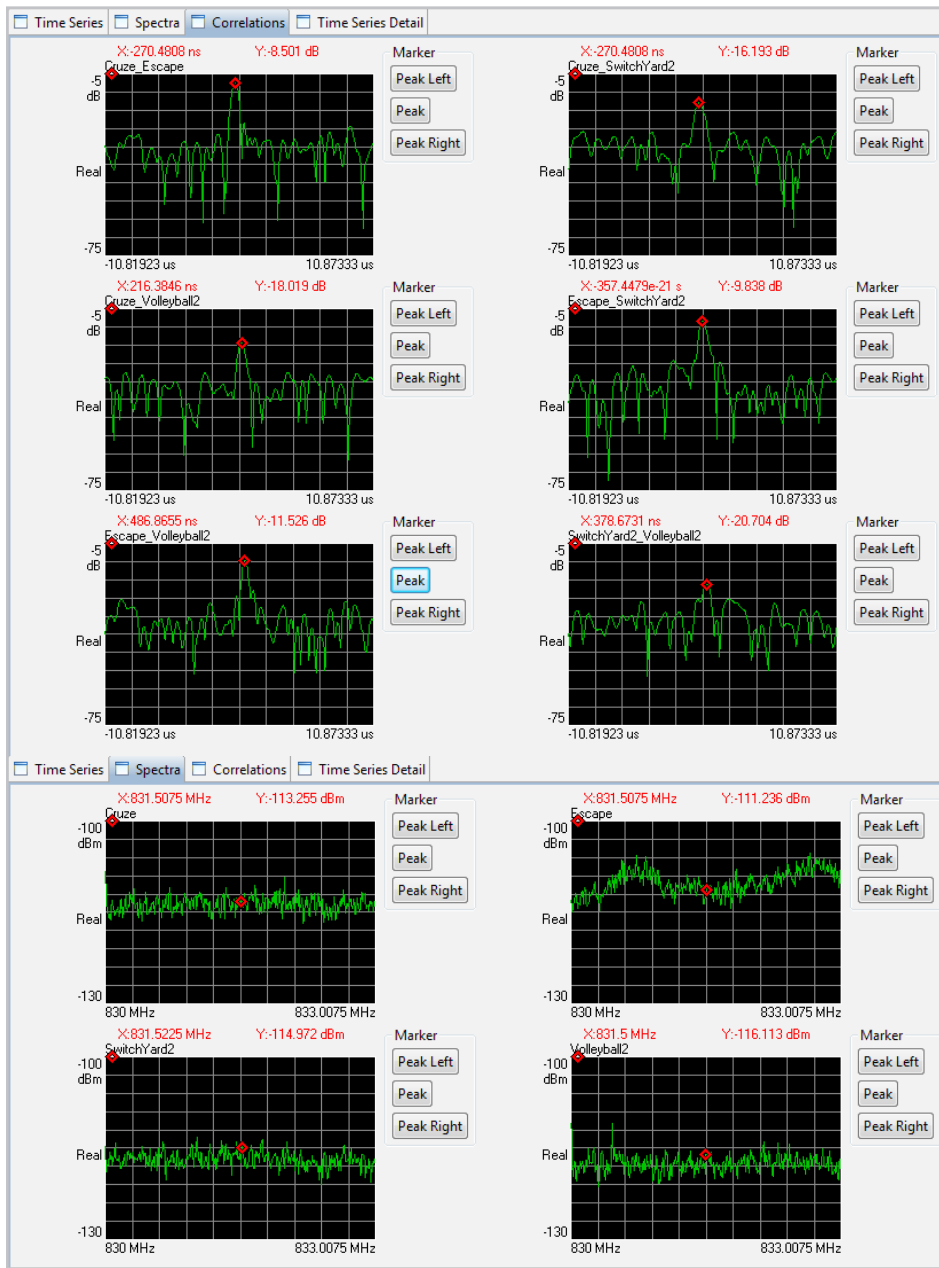


Figure 4. Coherent detection is clearly indicated by the peak in the correlation graphs even though the signal energy is not visible above the noise floor (in the spectrum displays).

Intuitive Geolocation Analysis

The N6854A user interface is implemented as a plug-in application for the N6841A RF sensor management tool and displays data from the system server. This interface integrates all measurement data – raw time-series I/Q data, computed spectrums and sensor cross correlations – into one convenient portal.

An important new tool developed by Keysight is the tentagram display which provides valuable insight into the signal environment. N6854A geolocation software displays include recorded spectrums, signal cross-correlations and sensor location map with the tentagram overlay. When a geolocation measure-

ment is initiated to determine EP, an optional computation of the spatial degree of signal correlation between sensors is also made. This provides additional qualitative information about the measurement itself and can highlight such effects as multipath and multiple emitters on a frequency.

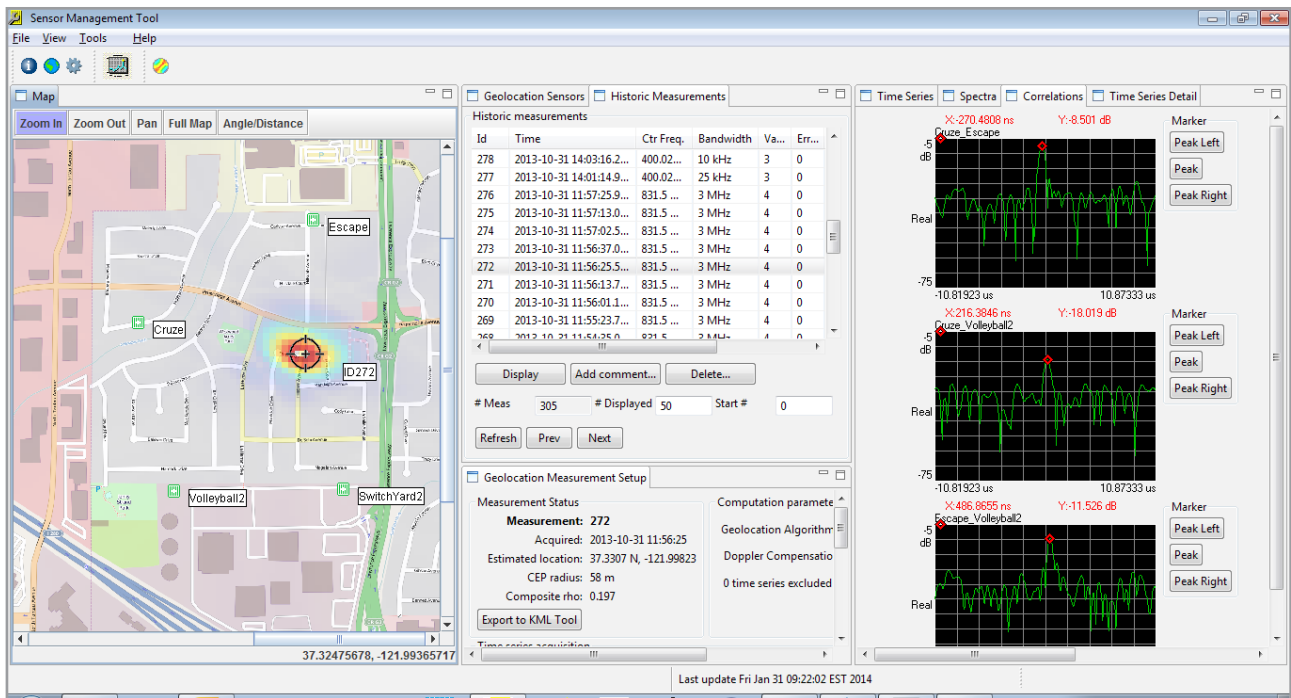


Figure 5. Keysight's tentagram display provides valuable insight into signal propagation characteristics and measurement quality.

Optimize Estimated Position

The accuracy of an estimated position (EP) calculation depends on a number of factors including the relative location of the sensors, the number of sensors used in the measurement, the effects of multipath and the signal bandwidth. The wider the signal bandwidth, the more accurate the EP since it provides a sharper cross-correlation peak.

Multiple RF sensors deployed spatially in an area can be configured to monitor the spectrum coherently and sweep the spectrum synchronously. In such configurations, higher system processing gain is realized derived from measurement redundancy. High precision clock synchronization is enabled by support for Precision Time Protocol (based on the IEEE1588-2008 standard) or by

using GPS - which also provides sensor location for mobile deployments.

Circular Error Probable (CEP) is a common accuracy metric used in geolocation systems. The N6854A software returns a CEP value expressed as distance from the EP based on a 50% probability estimate.

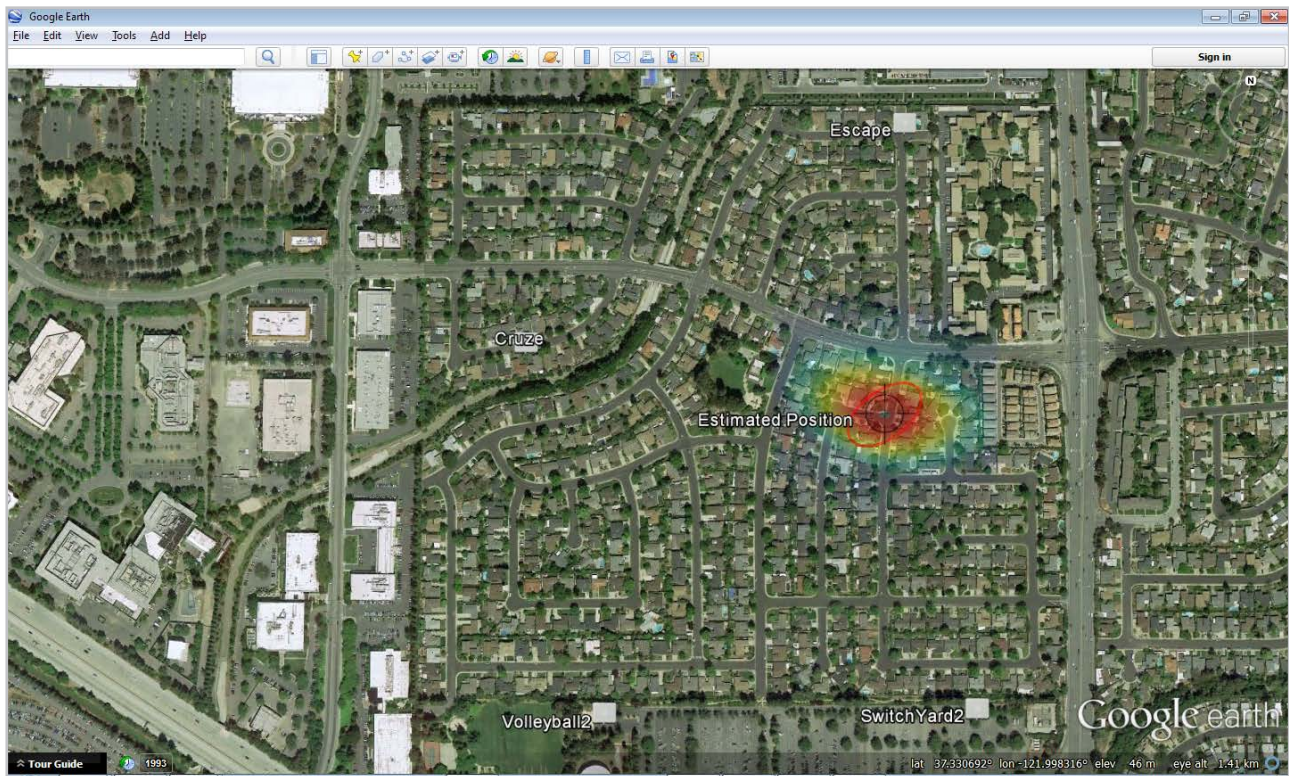


Figure 6. The cross-correlations of signals received by each sensor provide the basis for the time-difference-of-arrival determination. Estimated position is shown in colors with the highest probability location in dark red.

Consulting and Assistance for Successful Deployments

Keysight wants all of your sensor network deployments to be successful. Your first few deployments are likely to need our consulting expertise because of new measurement technology in the N6854A software. Our experts are available and ready to engage with

customers for design and recommendations, including:

- Sensor placement geometry for maximum resolution and sensitivity
- Network infrastructure requirements

- Signal measurement optimization
- Integration assistance with search systems

Our startup assistance is tailored to suit the specific deployment and application requirements.

System Characteristics

Description	Specification
Frequency coverage	20 to 6000 MHz
Measurement bandwidth	Up to 10 MHz ¹
Measurement modes	Manual or remote application control Single or Auto-repeat measurements
Measurement methods	Time-Difference-of-Arrival Relative Signal Strength Amplitude Ratio Adaptive Hybrid (TDOA + RSS)
Measurement trigger modes	RF power in Sensor IF Time-of-Day
Signal data capture	256 to 32k samples of I/Q data (user definable)
Doppler Compensation for moving targets and/or sensors	User enabled up to 100 km/hr ²
Sensor configurations	Minimum of 3 sensors for TDOA and 4 sensors for RSS or Hybrid methods
Measurement history database	User Defined size limit
Programmatic interface	C development library for remote application control

1. The signal of interest may be wider than the measurement BW and still result in an accurate EP.

2. Timing accuracy is degraded when sensors are moving.

Geolocation Accuracy Statement

Geolocation accuracy from an RF Sensor network depends on many factors including:

- sensor density
- placement and geometry relative to the emitter
- sensor antenna height
- terrain and line of sight
- emitter height

For a properly deployed RF Sensor network in a Suburban/Urban terrain in Non-LOS conditions, geolocation accuracy may be as low as 10's of meters to as high as 300 meters depending on the items above and considering signal to noise at the receivers and the signal bandwidth.

Keysight geolocation algorithms rely on discrimination of signals based on frequency, time, or natural signal strength differences based on proximity. They do not support location of same-frequency signals that occur at the same time (e.g. CDMA downlink).

Keysight Geolocation System Configuration Guide
<http://literature.cdn.keysight.com/litweb/pdf/5991-2939EN.pdf>

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