Spectrum Monitoring Pilot Program

Docket Number:
130809703-3703-01

RIN 0660-XC007

General Response and comments from:

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General systems already exist to monitor spectrum usage in real time and have already been fielded by a number of DoD and US Commercial organizations – these companies will be better able to provide testimonials on the system capabilities:

EPG Ft Huachuca, AZ

JSC Annapolis, MD

Aberdeen Proving Ground, MD

Microsoft Seattle, WA

Boeing Seattle, WA

Comsearch Ashburn, VA

The systems already in use consist of remote, rugged, SDR outdoor sensors. The sensors report spectrum occupancy or signal strength back to a central system if connected through the internet or are able to store data locally if remote from the internet. All data is recorded with GPS location and time precision.

Data format is compressed using a number of techniques; however the resulting information can be provided in a standard format for use with other existing databases such as csv, png or Mancat.

A database server is available that keeps results from all sensors and can be set up to automatically poll the network of sensors hourly or over any other preconfigured period of time. Should the network be lost data is saved locally on the sensor for collection at the next connection.

Critical to this system is the ability to move sensors around quickly with minimal technical knowledge, even placing the sensors into vehicles and driving around on a daily basis, examples of gathering mobile information are: postal service, garbage collectors, utility readers – each of these services travel to every home and business in a specific geography over a regular period of time.

A sensor could be placed at every freeway camera providing extra security and implemented on an already constructed IT infrastructure.

This system is described in the CRFS Monitor documents provided.

More specifically, NTIA invites comment on the following questions:

1. How should a measurement system be designed to measure a variety of emissions, including weak or intermittent signals, airborne platforms, and radar systems, while keeping incremental costs in check?

To achieve the necessary coverage the receivers have to be sensitive, mounted at the antenna so losses are minimized and capture the spectrum extremely fast. Tradeoffs will have to be made between sweep speed, capture bandwidth and cost. The concept to be considered should be no different than the way we monitor traffic flow on freeways or gather weather data around the country. If the sensor and system costs can be kept low enough then sensors can be easily located in clusters around communities of interest.

2. What types of measurement/monitoring techniques should be used for the different types of radio services

Typically the various radio services are already operating in defined bands so for example it may not be necessary to sweep the broadcast bands as fast or as often as other bands that have intermittent usage, using this technique with a high speed receiver allows for monitoring and measuring techniques to be configured based on a specific spectrum. Intelligence inside the sensor can then be used to zoom in on a signal of interest; I/Q data can then be captured should a signal not be of the correct format on a specific frequency. This data can then be used to further analyze the signal. Receivers all working together in a cluster have a higher probability of seeing the same signal at the same point in time this allows for geolocation of the signals using TDOA or POA techniques.

Despite this, even high speed; swept receivers have a limit on their POI (Probability of intercept). To improve the POI, one or more swept receivers can be combined with a single wideband receiver which is able to command a receiver to analyze sub-bands more closely when radar and other fast pulse signatures are captured.

3. What frequency bands should initially be measured during the pilot phase of the program?

All frequencies from 30MHz to 6GHz should be measured, limiting the spectrum capture is not necessary and is critical to spot harmonic, sub harmonic or spurious signals. Military comms and radar have been known to cause garage doors to open due to harmonic or out of band distorted signals. Receivers exists that can sweep the full 6GHz spectrum 10 to 100 times a second so why limit the captures? Limiting the frequency range will also allow a geographically broader spread of equipment, as to cover bands up to 20GHz and beyond requires a more dense population of receivers due to the transmit powers possible and the more significant effects of propagation loss.

4. How should measurement and monitoring parameters (e.g., resolution and video bandwidths, sampling rate, dwell time, detector selection, antennas, pre-selector filtering, dynamic range) be specified?

This depends on the band or frequencies being monitored. However to cover the range of all possibilities the receiver should be able to measure power or occupancy in a bandwidth of as little as 5KHz as this is the present narrowest comms bandwidth, if there is a need to measure adjacent channel or adjacent noise power from signals then this may need to be narrower. Sample rate needs to be coupled with bandwidth, the full spectrum can be sampled extremely fast if the bandwidth is 1MHz but is proportionally slower for a narrower bandwidth.

For spectrum occupancy dwell time should just be long enough to determine there is a signal present, if the signal captured is an interferer then the receivers intelligence can be used to dwell long enough to capture IQ content. The IQ content can then undertake any form of detection. Again, in locations subject to radar or other pulsed signature RF signals, the combined use with a wideband capture receiver will improve POI.

Antennas should be omni-directional and circularly polarized in order to capture any polarization.

In a 6GHz frequency range pre-selection filtering will be a function of the receiving method at a minimum over the 30MHz to 6 GHz range this is 8 but more would be better.

In addition to Dynamic range, receiver Noise Figure is critical as well as AGC or attenuator control. Equipment should be able to AGC on the RTBW (Real Time Bandwidth) captured alone to ensure maximum dynamic range is achieved at every point in a sweep.

5. Which geographic locations within major metropolitan areas or other communities throughout the country would provide the greatest value for the pilot?

Spectrum is probably already being captured on DoD ranges – more ranges should be added. An area of great interest and not likely to have been studied is a quiet non populated area as this will provide information on background signals that are never spotted in the MMA's it may alert us to anomalous propagation that is not easily spotted in a cluttered environment as well as effects from solar radiation.

Additionally, information on propagation across areas bounded by forested areas or vegetation would be significant. The effects of the variation in moisture content due to the change in foliage across winter, summer and fall could show how the effects of interference change seasonally.

6. How should individual measurement units be deployed in each community?

The best approach could be to locate sensors on government buildings with access to a network as well as mobile units that can be driven around and finally a number of sensors with batteries, solar panels and local storage that can be placed for short periods of time in any suitable location.

Remote sensors with no access to a wide area network can be accessed using the cellular network or by storing to local hard drives.

7. How could the long- or short-term placement of multiple fixed units within the same general geographic area improve the accuracy and reliability of the data collected in each community and at what incremental cost?

Multiple sensors in a general geographic area will not only ensure capture of weak signals but also provide the ability to geolocate the signals. As an example a GPS jammer designed to jam a receiver in a vehicle from reporting its location may only generate a few milli-watts, enough to be seen by one receiver in its immediate vicinity, as it moves into range of a second receiver say 1km away then location information can be determined. If the receiver is located with a camera then the license plate of a specific vehicle passing through the geography can be identified and apprehended.

8. How could mobile or portable units be utilized to supplement data collected at fixed sites within a community and at what incremental cost?

Mobile units are essential to supplement fixed units as they allow for “fill in” of signals not seen by fixed units, as an example sensors placed every km will not see every WiFi or low power ISM device that a mobile unit will see. Incremental costs can be very small if the mobile unit is going about its regular day to day activity such as a postal vehicle or garbage collector. Skilled operators are not needed to operate the systems available today.

9. How long should measurement data be collected to provide statistically relevant results, particularly for intermittent operations, at each geographic location?

An understanding of the type of signals expected in a specific geography will determine the answer to this question. Intelligence in the sensor can allow full time spectrum monitoring with results averaged over a specific period of time such as 15 minutes, 30 minutes or 24 hours so that only a small percent will show up for a frequency that only appears for 10 seconds in a 24 hour period.

10. How should the measurement system design take into account variations in population densities, buildings, terrain and other factors within or surrounding selected measurement locations (i.e., in urban, suburban, and rural parts of a metropolitan area)?

As with any radio equipment deployment plan, an analysis of the population’s usage of the ‘local’ radio spectrum as well as a first order model of the surrounding town or city and terrain would be necessary. This would allow estimates of optimum monitoring locations, as well as protection from local and national RF transmitters to be determined. The balance of these sites can then be compared to the available local infrastructure to best place the equipment and thus optimize the expectation of detecting anomalous RF transmissions.

11. What steps can be taken to eliminate or minimize the possibility of ‘‘hidden nodes’’ when conducting measurements?

In order to prevent “hidden nodes” it would be necessary to perform some modeling of the propagation environment surrounding any deployment. As is seen with GSM/LTE base stations (BS), urban canyons are often formed due to the nature of the buildings on which they are mounted. This is necessary to help isolate one BS from another. The reverse is true for monitoring, as we want to see as much common spectrum as possible. Multiple placements of antennas at a variety of heights can be modeled to show how this can overcome the possibility of a hidden node.

12. What kind of spectrum utilization and occupancy information (e.g., precise received field strength levels, time-of- day occupancy percentages, times that signals are measured above specified thresholds) would be most useful to spectrum stakeholders?

Levels must be set to determine occupancy above a minimum threshold in a specific band, for instance if operating in the cellular bands maybe only signals above -100dbm are relevant, in the broadcast bands only signals above -80dbm may be relevant. Separate occupancy sweeps can be set at a lower level to run less frequently looking for lower level signals and compared to the high level signals. Care must be taken not to set levels too low such that noise triggers the occupancy sensor; this is also a critical point when determining the noise figure of the system. The basis of this analysis of the real-time spectrum is to set masks which can trigger alerts to significant misuses of the spectrum. However, once occupancy data is brought back to a central database for analysis occupancy percentages can be analyzed in a variety of ways. This data can also be looked at historically to identify short or long term rogue transmissions.

13. What detection thresholds should be used to measure and characterize the usage patterns of incumbent systems?

Multiple detection thresholds can be set so that post collection analysis can be used to determine usage patterns based on signal level. Systems do not need to be limited to one threshold level.

14. What data and information would be useful in evaluating potential sharing compatibility with wireless broadband devices?

The most useful measure for this is percentage occupancy. If we can see the occupancy rates for multiple wireless devices, we can also then decide whether there are better algorithms for ensuring maximum band co-existance of such devices. The measure of power transmitted by each device would also ensure all devices are operating at their maximum limits. Where transmit power back-off is implemented due to better link quality, it may be possible to determine whether these devices operate 'fairly' in the presence of devices competing for the same spectrum or adjacent channels of operation.

15. How can the gathered data and analysis better inform spectrum policy decisions, enhance research and development of advanced wireless technologies and services?

Real world IQ data can be captured in a specific band and analyzed for bit error rate and other signal quality factors – this data can then be mixed with other IQ data from a different technology to compare the performance and results with advanced wireless techniques, for instance spread spectrum technology such as COFDM is less susceptible to a single channel narrow band FM signal within its bandwidth than two narrow band FM signals on top of each other.

16. What data formats and evaluation tools should be employed?

As much open source data formats as possible should be used and in line with other standards that have evolved over the years there needs to be a user's group developed to help formulate these standards, bodies such as NDIA for defense interest could be tapped as they have spent a great deal of time in the Test and Evaluation world formulating standards.

17. How can the large amounts of measurement data be effectively managed, stored, and distributed?

All data should be brought back to a central server and be in a format that allows quick database searches by time, location and frequency. RFeye Monitor software combines quick and easy data access with a deep database capable of storing multi-terabyte volumes of data. Data is processed by the embedded Linux system on board each receiver and logged. Logged data is automatically transferred to the database server where it can be queried and filtered using a web portal interface. Data can be viewed as a series of graphs, such as occupancy by time or frequency, or output as CSV. A common data format allows the same data to be transferred to other tools for further analysis and visualization. Multiple users can simultaneously make multiple requests of the receivers and this is managed by on-board intelligence that assigns a relative priority or executes on a “round-robin” basis. For example, users can make background occupancy measurements, whilst at the same time running a range of standard campaigns or user-generated applications on the Node. RFeye Monitor can also run in parallel with other real-time software applications. This flexibility is the key to cost-effective deployment of large receiver networks for serving multiple discrete and diverse spectrum data requirements.

18. What steps can be taken to ensure that sensitive or classified information will not be revealed to unauthorized parties?

The database server can have different levels of security that control the level of information provided to non-secure users, for instance IQ data associated with a specific collection would not be made available to uncleared users. Alternatively, if the monitoring equipment is placed on a segregated network at each location with its own server, then security could be significantly enhanced this way. Data could be physically moved to a central database with restricted access levels to allow analysis of the data without access to the monitoring equipment. This doe add some complexity, but the level of security required should be implemented according to the sensitivity of the data which the system may capture.

RFeye Monitor

Web-based dynamic spectrum database and management solution using remote distributed monitoring network

Key features

- ✓ Network of fully configurable RFeye Nodes
- ✓ Rugged, compact, lightweight, IP67 rated
- ✓ Wideband 10 MHz to 6 GHz receiver with 20 MHz RTBW
- ✓ Frequency extension to 18 GHz with Block Down Converter
- ✓ Outstanding RF performance and sensitivity
- ✓ On-board GPS for accurate positional and time stamping
- ✓ Full mounting kits for easy installation
- ✓ Integrated RFeye Monitor database software for quasi-real time querying of data from any network Node
- ✓ Node and network status monitoring
- ✓ Fully programmable sweeps and time captures
- ✓ Fully programmable mask and level analyses
- ✓ Fully programmable alarms and alerts
- ✓ Fully programmable campaigns
- ✓ Displays of occupancy by time and frequency
- ✓ Displays of spectral events
- ✓ GSM cell site surveys
- ✓ Data export to RFeye Map for mapping and analysis or processing CSV for further analysis

Introduction

RFeye Monitor is an integrated, fully configurable solution for collecting and managing spectrum data using a network of widely distributed RFeye Nodes.

Remote distributed spectrum monitoring and data management
RFeye Monitor is aimed at national regulators and other spectrum stakeholders who require real and current data to support planning and operational decision-making. The system allows for continuous 24/7 monitoring of the RF environment up to 6 GHz (or 18 GHz with the RFeye Block Down Converter). It provides up-to-the-minute information about spectrum usage, occupancy, events or violations across all measured spectrum, as well as fully programmable alarms and alerts.

Highly efficient database and web portal
RFeye Monitor software combines quick and easy data access with a deep database capable of storing multi-terabyte volumes of data. Data are processed by the embedded Linux system on board each Node and logged using CRFS's proprietary embedded NCP Logger application. Logged data are automatically transferred to the database server where they can be queried and filtered using the web portal interface. Data can be viewed as a series of graphs, such as occupancy by time or frequency, or output as CSV. A common data format allows the same data to be transferred to RFeye Map for further analysis and visualisation.

Multi-user access, multi-mission configuration
Multiple users can simultaneously make multiple requests of the Nodes and this is managed by on-board intelligence that assigns a relative priority or executes on a "round-robin" basis. For example, users can make background occupancy measurements, whilst at the same time running a range of standard campaigns or user-generated applications on the Node. RFeye Monitor can also run in parallel with other real-time software applications such as RFeye Site or Live. This flexibility is the key to cost-effective deployment of large RFeye networks for serving multiple discrete and diverse spectrum data requirements.

- Manage interference
- Monitor spectrum usage
- Run spectrum campaigns
- Inform spectrum planning
- Access up-to-the-minute data
- Measure occupancy and utilization
- Track and log events and violations

Use scenarios, customers and missions

Use scenarios

- National and regional spectrum monitoring
- Cities and other spectrum intensive areas
- Military training grounds and ranges
- Government ranges
- Critical infrastructure
- Airports
- Public arenas
- Sports stadia
- Borders
- Harbors
- Coastlines

Customers

- Spectrum regulatory agencies
- Military spectrum operations
- Government and military range managers
- Spectrum/frequency managers
- Homeland security and intelligence services
- Site security managers
- Border control
- Coastguards and harbor masters

Missions

- Up-to-the-minute occupancy profiling
- Spectrum campaigns:
  - Suspected GPS and other jammers
  - Tetra interference
  - ISM band usage
  - GSM and UMTS band coverage
  - Cellular interferers
  - Other user specified
- Triggers and warnings
- Compliance and interference monitoring
- Spectrum planning and decision-making
- Fast access to individual or aggregated measurements
- ITU compliant spectrum occupancy measurements
- Analysis of spectrum anomalies and events
- Interactive spectrum database applications

Deployments

RFeye Monitor is modular and scalable and can be deployed in networks ranging from a handful of Nodes for a single site to very large regional or national networks.

The RFeye Monitor solution uses both hardware and software. RFeye Nodes are deployed over the area of interest. This could range from a small network on a particular site up to hundreds or thousands of Nodes across an entire country. It can be deployed using a variety of hardware configurations including fixed, man-portable or mobile nodes. An Ethernet or celluar connection provides the link to the database server and internet portal. The system has been designed to be fully scalable and to provide the best possible user experience from small to very large networks.

NCP Logger

Each RFeye Node runs NCP Logger, an embedded application that records spectrum data and makes them available for database interrogation. NCP Logger reads a configuration file to determine which scans to perform, what level of processing is carried out on the resultant data and how those data are presented. As well as performing captures, calculations and analysis, NCP Logger also creates notifications and SMS messages to flag events and warnings.

RFeye Monitor Software

RFeye Monitor software comprises a series of tools for data logging, data transfer, database storage and filtering, and web display of requested results. These tools have been designed to provide a seamless user experience such that the set-up can be easily configured and up-to-the-minute data retrieved via a web browser.

Once logged, data are transferred from the Node into the RFeye Monitor database. This can be done in a number of ways to suit requirements and will normally involve either UDP or TCP data transports. The database is capable of storing several different types of data, including text, spectra, occupancy, time, cell survey, temperature and voltage, as well as information about the network and individual campaigns. It uses a single comprehensive library of scripts able to deal with data provided by any of the possible data transfer mechanisms.

The data from the database are accessed via a web portal which can be configured to provide any appropriate GUI to the data. The portal allows the user to query the data and graph the results, as well as to create individual campaigns to run using NCP Logger. It provides secure logins and varying levels of access based on user privilege.

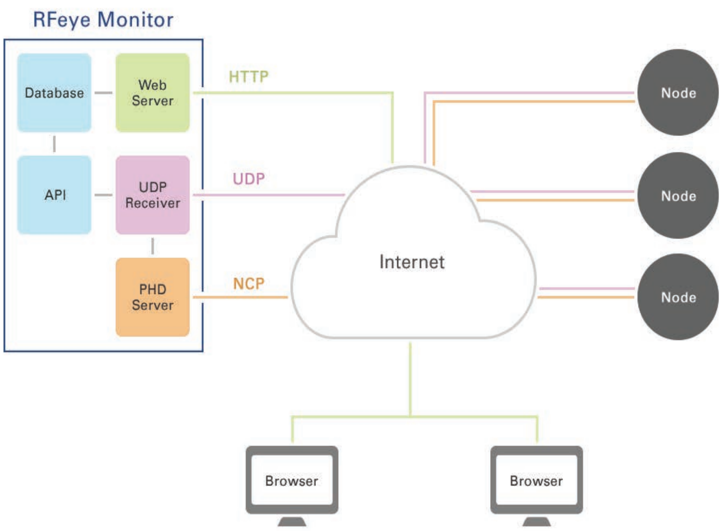
Web Interface

RFeye Monitor provides a seamless user experience through a secure and streamlined web-based application interface.

Powerful backend system behind accessible interface

The RFeye Monitor system architecture consists of several parts which are neatly presented to the user as a single entity through the web interface. The hardware piece comprises a distributed network of RFeye Nodes and a centralized server. RFeye Monitor software combines the spectrum database with data handling processes to present an integrated, convenient and responsive portal to logged data from networks of RFeye Nodes.

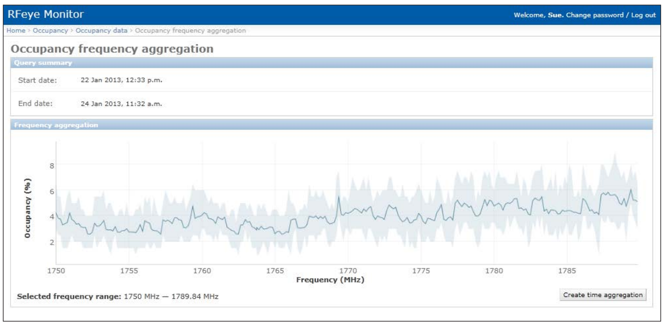
The RFeye Monitor database API provides a further degree of flexibility for users needing to take further control of the spectrum database or integrate with third party systems.



Campaigns

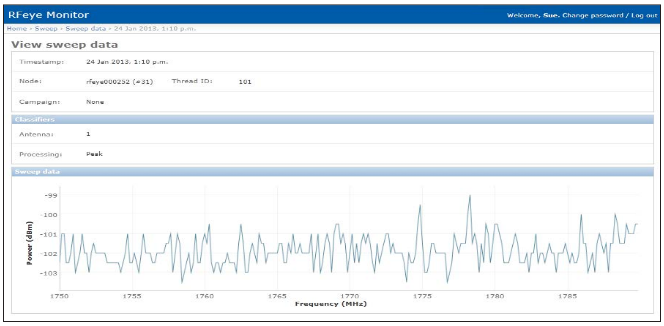
The ability for different users to define and run multiple simultaneous spectrum monitoring campaigns is central to the powerful capability from the RFeye Monitor system. Campaigns can be assigned to the entire RFeye network, sub-groups and regional networks, or individual sites as required. In addition to full range background spectrum monitoring, campaigns are defined for specific missions for example to monitor ISM band usage, TETRA interference, GSM and UMTS band coverage, and suspected GPS and other jammers. The tools available from NCP Logger running on each RFeye Node enable campaigns to be configured based on events such as mask breakages and conditional expressions, which allows targeting of spectral events of interest and data volume management.

Occupancy data aggregation



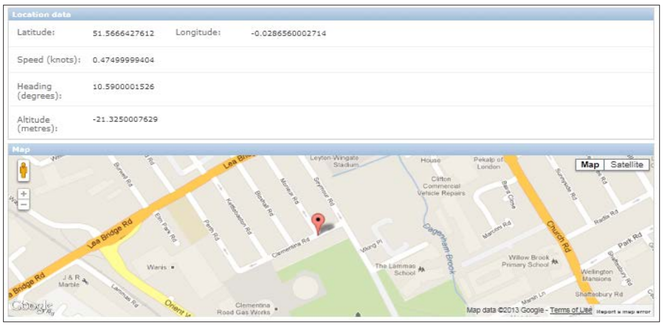
RFeye Monitor allows the user to run queries by individual Node or aggregated groups for occupancy by time or frequency during any selectable period of time. The Nodes take measurements at the requested rate based on power measured above a threshold, in accordance with ITU recommendation SM 1880 for occupancy.

Sweep and time capture data



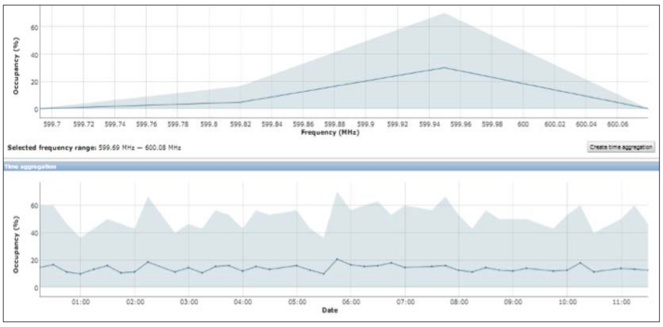
Both frequency and time domain spectral captures can be graphically displayed within the web interface, with controls for scale and range-zoom via simple click and drag. As with other data, the sweep and time data can be filtered by Node ID, campaign, date/time, antenna input and spectral processing, and also output to CSV.

RFeye Node location and status management



The location of each RFeye Node in the network can be viewed on a map within RFeye Monitor. Mobile RFeye Nodes will display their historical location according to the data timestamp selected. Full NMEA data along with Node management data including unit temperatures, supply voltages and currents, as well as disk usage statistics are all made available to enable comprehensive status management of the RFeye network.

Temporal Analysis



The interface for graphical reporting provides a simple mechanism to zoom from broad range frequency occupancy data aggregated from the entire RFeye network, into tracking of occupancy by time for specified frequencies of interest at particular RFeye Node locations. This allows the user to quickly drill down from spectrum events spotted in top level overview reports to a detailed localized time line of spectrum activity surrounding the signal of interest. This information can be combined with other features within RFeye Monitor such as spectrum licensee status to provide further layers of context for decision making.

RFeye Node technical specifications

Receiver Performance	
Frequency range	10 MHz to 6 GHz (18 GHz with Block Down Converter)
Receiver noise figure	8 dB typical (10 MHz – 4 GHz) 11 dB typical (4 GHz – 6 GHz)
Input connector	Four switchable signal inputs
Maximum input level	+15 dBm; 15 VDC
3rd order intercept point (IP3)	+20 dBm typical (AGC active)
1 dB input compression	+10 dBm typical (AGC active)
Level accuracy	± 2.5 dB typical
Antenna LO re-radiation	-90 dBm typical
Antenna port isolation	30 dB min. at 2 GHz
SSB phase noise	-90 dBc/Hz at 10 kHz oset -110 dBc/Hz at 200 kHz oset typical, at 2 GHz* (*low noise synthesiser)
Synthesiser switching time	50 μs typical (fast sweep mode)
Spurious free dynamic range	60 dB min.
AGC range	60 dB
Sweep and triggering	
Sweep speed	40 GHz/s (fast synthesizer) 10 GHz/s (high quality synthesizer)
Sweep mode	Fully programmable: Free run continuous, single, timed, delay timed user trigger, adaptive (if-then-else)
Trigger on event	Fully programmable: userdefinable masks, user-definable action when mask exceeded
Signal analysis	
Real-time analysis bandwidth	20 MHz maximum
Equivalent resolution bandwidth	20 kHz min. (max. analysis b/w) 18 Hz min. (reduced analysis b/w)
Operating system and software development options	
Linux OS version	2.6
Development environments	Full SDK C and Python development environment available
Frequency reference	
Selection	Internal, GPS or External
External ref. input	Via expansion port, 10 MHz ± 1 kHz
Reference output	Via expansion port, 10 MHz

Internal frequency reference	
Initial accuracy	better than ±2 ppm at 20°C
Stability	better than ±1 ppm (10°C to 30°C)
Ageing	better than ±2 ppm per year
Timing reference	
GPS	30 ns RMS accuracy typical
RFeye SyncLinc	< 10 ns RMS accuracy typical
Mechanical	
Dimensions (w h d)	170 mm x 60 mm x 125 mm (6.7 in x 2.4 in x 4.9 in)
Weight	1.4 kg (3.1 lb) [Node only] 2.0 kg (4.4 lb) [with environmental protection cover]
Environmental	
Operating temp.	-30 to +55°C (-22 to 131°F)
Storage temp.	-40 to +70°C (-40 to 158°F)
Envrn. protection	IP67 (with environmental cover fitted)
Interfaces	
RF input	SMA (X 4)
DC power	10 - 56 VDC
DC power input	Direct to Node or via Ethernet
Power consumption	15 - 25 W, radio operational 6 W typical, radio idle
GPS antenna	SMA, passive and active (3.3 V nominal DC) antennas supported
Cellular modem antenna	SMA
Ethernet	1 x 1 GigE
USB	2 x USB A (2.0)
Expansion ports	2, configurable to provide: (a) trigger input (b) frequency reference input (c) external (peripheral) control (d) frequency reference output

For more information

To find out more or discuss your specific application, please e-mail us at enquiries@crfs.com or call +44 (0) 1223 815 615. You can also find useful resources on our website at www.crfs.com.

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