# Spectrum Monitoring and Geolocation Systems

## CRFS Ltd

An overview of contemporary radio spectrum monitoring practice and the sensor and geolocation technologies to meet the emerging challenges

**White Paper: Spectrum Monitoring and Geolocation Systems**

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## Summary

In the past few years, the exponential growth of wireless devices has created significant challenges for spectrum regulators. As a key piece of the wireless economy infrastructure, spectrum needs to be well-managed and able to transmit data without interference, whether malicious or accidental.

Spectrum monitoring is a critical operation for supporting effective spectrum management. Spectrum use is monitored to obtain technical and operational information such as the frequency and location of transmitters. More importantly, monitoring is needed to detect interference and unauthorized or illegal activity. Monitoring is also crucial for supporting functional spectrum management such as the allocation and assignment of frequency bands, resolution of interference problems and enforcement of compliance with regulations and conditions of authorization.

During the past two decades spectrum monitoring technology has barely kept up with the rapid advances in wireless communication technologies. Traditional methods for spectrum monitoring use an analogue analyzer alongside digital signal intelligence systems to capture and analyze signals in the proximity. These systems were developed for specialist rather than all-purpose use. As a result, they are generally high cost, not sufficiently rugged or flexible enough to deploy in the field and are unsuitable for continuous real-time monitoring. With the recent innovations in wideband digital communication techniques and the need to use spectrum more efficiently, there is a growing and increasingly urgent requirement for new deployable monitoring solutions that will allow users to obtain relevant and comprehensive intelligence on how the spectrum is being used in real-time and to identity all signals present at any point in time and any potential anomalies and threats.

The RFeye™, developed by CRFS in Cambridge UK, is designed specifically to meet modern day spectrum monitoring challenges. It is the first truly practical and scalable solution for remote distributed real-time spectrum monitoring and is a highly cost-effective alternative to traditional analyzer-based systems. With its high performance wideband scanning receiver, on-board Linux processor, high accuracy GPS, Ethernet port and 4G modem, all housed in a compact rugged IP67 enclosure, the RFeye can be easily deployed and networked over large geographic areas.

The RFeye offers excellent RF performance with a broad range of frequency coverage, high-speed channel scanning, high frequency resolution and wide dynamic range. On-board analytics and full system automation enables a real-time response when a signal of interest is detected. The overlay of different radio geolocation techniques such as Time Difference of Arrival (TDOA), Power on Arrival (POA) and Angle of Arrival (AOA) provides a highly effective means for locating sources of interference and unauthorized transmissions. On-board SSD memory allows for continuous 24/7 data logging.

The RFeye is widely deployed in many countries in regulatory, security and military applications. It is the most cost-effective real-time solution on the market.

**Introduction**

Over recent years, we have witnessed the exponential growth in the use of new wireless devices. Cisco estimates that up to 50 billion devices will be wirelessly connected to the Internet by the end of the decade. Radio communication plays a vital role in connecting and making these devices talk to each other. Spectrum is critical to the success of many wireless industries and services including mobile communications, television and radio broadcasting, emergency communications services, radar and many more.

**Why should we care about spectrum?**

Spectrum is a key piece of the infrastructure of the wireless economy. It makes a significant and fast-growing contribution to national economies. Radio technologies are increasingly important for business efficiency and international competitiveness. Radio-based businesses employ large numbers of people and are amongst the most successful and dynamic sectors of the economy [1]. In the UK, the economic value of spectrum usage has increased by 25% in real terms since 2006 to £52 billion (€62 billion) in 2011 [2]. The use of spectrum also generates considerable social value. Wireless spectrum is used in communications and navigation for national defence and public services. GPS services rely on spectrum for geolocation; military and police forces use radio to communicate; airports use radio to manage air traffic.

Spectrum also plays an ever more important part in our everyday lives via entertainment and leisure activities. Today, more and more people browse the Internet and watch online videos on their mobile phones and tablets through high-speed 4G or Wi-Fi networks.

Many recent technologies are emerging rapidly that rely on connectivity to make them work. Radio is an important part of this connectivity. A number of examples include Cloud computing, the Internet of Things, Machine to Machine communications and Smart Cities. Demand for spectrum is expected to continue growing with the rollout of these new technologies.

**Current issues in spectrum management**

With demand for wireless applications on a rapidly upward trajectory, management of spectrum has never been a more pressing challenge for spectrum regulators. The value of spectrum depends crucially on how well it is managed so that as many potential users as possible can benefit. Furthermore, law enforcement and security services have a strong interest in detecting and preventing unauthorized use of the spectrum.

Primarily, spectrum management is the process of regulating the use of radio frequencies to promote efficient use. Spectrum management ensures, as far as possible, that the right kind of spectrum is available for those who need it, when they need it and that it is used efficiently and with as little interference as possible. Spectrum management involves a number of activities including spectrum planning, authorization and billing, engineering and monitoring [3].

Effective spectrum monitoring is an essential element of good spectrum management. Data collection and analysis from spectrum monitoring is required to support the planning, authorization and engineering elements of spectrum management. It enables spectrum managers to plan and allocate frequencies, avoid incompatible use and identify and respond to sources of interference. It also helps the spectrum regulator with monitoring and enforcement of license and technical standards.

Techniques used in spectrum monitoring have not kept up with the rapid advances in wireless communications during the past two decades. The scale and diversity of modern RF use pose ever greater challenges for traditional monitoring techniques. These have been based on technology originally designed for analogue rather than digital transmissions, the latter becoming increasingly prevalent. The traditional systems have tended to be specialist rather than all-purpose, not rugged or particularly flexible to deploy in the field. They have generally used some types of high-cost, widely-dispersed, stationary bench-top spectrum analyzers with very limited geographic coverage especially at higher frequencies.

The problem is further compounded by digital modulations with their high carrier frequencies and wider signal bandwidth which result in larger path loss between the emitter and the monitoring receiver, making it even more difficult to detect distant signals using the traditional approach. A more proactive and coordinated method is needed, comprising multiple lower cost networked receivers located more densely over critical areas of spectrum usage.

In addition, the ability to classify signals and identify potential threats amidst legitimate transmissions is becoming increasingly important. The use of human observers is not cost-effective given the sheer scale of RF usage. In order to detect a brief, infrequent transmission from a bugging device, or to find a suspicious signal against the background of large-scale mobile phone use, a smarter technology is needed.

Inefficiencies in traditional spectrum monitoring techniques often result in one or more of the following issues:

- Inefficient spectrum usage and occupancy
- Non-compliance with spectrum regulations in terms of power, location and emission spectrum of transmitters, unexpected user behaviour
- Attempts to interfere with legitimate use of the spectrum by spoofing or jamming
- Suspicious or unexpected transmissions in high security or special event areas, indicating a potential threat
- Covert wireless transmitters
- Intentional or unintentional Electromagnetic Interference (EMI) to sensitive equipment in hospital and testing facility

New types of spectrum monitoring systems, such as the RFeye, are available to help spectrum agencies address these issues. These can be deployed cost-effectively over wide areas to facilitate effective management and efficient use of the radio spectrum. They can also help to identify and classify anomalous transmissions which may represent an attempt to interfere with critical communications infrastructure.

**World Cup use case**

The 2014 Football World Cup was hosted successfully in Brazil in the summer. During the tournament, host cities received hundreds of thousands of visitors on every match day. Radio communications played a critical role in these major sporting events and were, in many cases,

“mission-critical”. Moreover, the football matches took place over a short period within stadia densely populated with electronic devices, resulting in an extremely complex radio environment. All of this represented a major challenge for the spectrum regulators and monitoring engineers to control the risks of inefficient use or intentional misuse of the spectrum.

The Brazilian telecommunications regulator, Anatel, was responsible for ensuring that the use of RF spectrum was effectively managed and policed. In the event of interference, they needed to be able to quickly detect and locate the source. Having understood the challenges, Anatel sought a new approach to spectrum monitoring that could be easily and quickly deployed at each of the key locations across the country.

In 2013 Anatel issued a tender for the purchase of new spectrum monitoring equipment and software. This included a total of 152 fixed location monitoring stations to cover the VHF, UHF and SHF bands up to 6 GHz. Anatel required the receivers to be high-performance, relatively low cost, simple to install and easily networked and managed. The software needed to be capable of integrated analysis of information captured at each station, including geolocation of target transmitters and the ability to distinguish between different transmitters using the same frequency. CRFS was the successful bidder with its RFeye and provided a winning contract price that was less than half that of the second-placed bidder.

During the football tournament, Anatel deployed networks of RFeye nodes at each of the host cities across Brazil. Units were installed on the top of buildings or on towers owned by various public or government agencies, all connected to RFeye software via wired Ethernet or wireless UMTS networks. With its on-board intelligence, the RFeye node was able to continuously detect signals, collect and analyse spectrum data and send alerts based on particular threshold triggers. In addition, the RFeye application software could talk to any or all of the nodes in the network, visualize and analyze spectral events and geolocate sources of interference using TDOA, all in real-time, across the RFeye’s 10MHz to 6GHz frequency range.

The large amounts of data collected by the RFeye nodes were automatically and securely transferred to Anatel’s RFeye server where they could be queried and filtered via the web portal. This provided up-to-the-minute information about spectrum usage, occupancy, events and violations, across all measured spectrum, as well as fully programmable alarms and campaigns.

**Other relevant use cases**

RFeye systems are also widely deployed for various RF monitoring applications in both the private and public sectors around the world.

Pirate radio and illegal cellular base station band transmissions are commonly found in high-rise condominiums, where low-quality repeaters are used to extend 3G services into indoor environments. The out-of-band RF power leaking from poorly designed RF repeaters interfere with adjacent channels. One use case for the RFeye by the Netherlands and Hungarian spectrum regulators (as well as some mobile service providers) is to survey such spectrum usage and geolocate these types of illegal transmitters.

GPS jammers are often used to blind GPS receivers in criminal-related activities. This can affect the legitimate use by other nearby users who rely on GPS signals. RFeye systems have been deployed in

and around airports in Ireland and the USA to detect and locate GPS jammers which may present a critical threat to air passenger safety.

RFeye nodes are deployed in a number of government buildings and secure facilities providing a 24/7 "always-on" alternative to the 'sweep team' approach for technical surveillance counter-measures (TSCM). Compared with the traditional sweep team approach which may miss intermittent transmitters such as bugging devices, the RFeye offers continuous surveillance as well as very high sensitivity thanks to the spectral purity of the receiver.

Today's hospitals have significant quantities of high value electronic equipment and instruments, most of which are sensitive to Electromagnetic Interference (EMI). It could clearly have life-threatening consequences if EMI is not properly controlled. RFeye systems are currently under evaluation as a 24/7 EM-environment monitoring solution in UK hospitals.

**Conclusions**

More than ever, "spectrum intelligence" is a critical and valuable resource both economically and for society at large. This white paper provides a brief overview of the current spectrum management challenges facing agencies across the world and some of the trends in spectrum monitoring. The need for new spectrum monitoring tools that can deal with the growing complexity of the RF environment is clearly understood. Distributed networks of cost-effective real-time monitoring systems, such as the RFeye, offer significant advantages over traditional monitoring equipment and have an increasing role to play in signals detection, analysis and geolocation, in a wide range of high value real-world applications.

**References**

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