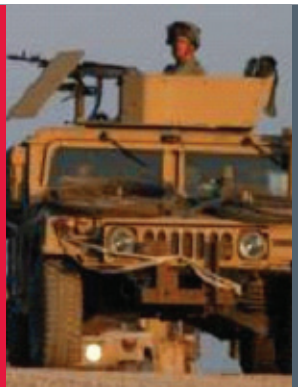

Improving IED Countermeasure Technology

Using RF Capture and Playback Systems

Tackling the IED Challenge

In modern warfare Improvised Explosive Devices (IEDs) are a major challenge for our military personal. US Army reports document that through 2007 in the Iraq and Afghanistan conflicts 80% of soldier casualties and fatalities were caused by IEDs.

Many IEDs are activated remotely with low cost commercial wireless devices such as cell phones, cordless phones and garage door openers. While multiple methods are being used to mitigate the use and effectiveness of IEDs, this application note focuses on the use of electromagnetic countermeasures and their interoperability with mission critical services. By combining the Tektronix spectrum analyzer and X-COM Systems long duration RF signal storage system, a unique tool results for the recording, analyzing, and creating of new waveforms and complex RF environments to help tackle IED countermeasure technologies.

Developing New Jamming Solutions

In 2006 the Joint Improvised Explosive Device Defeat Organization (JIEDDO) was established. JIEDDO is attacking the IED threat using a combination of intelligence, training and technology. Originally formed as the Army's IED Task Force, the group has transformed into a combined joint service, interagency, multi-national program with a goal of leveraging all available resources and technologies in a coordinated campaign to defeat the IED threat.

Major investments have been made to develop and improve jammers for a variety of platforms including:

- Ground vehicles
- Man portable systems
- Unmanned Airborne Vehicles (UAV)
- Unmanned Ground Vehicles (UGV)

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The challenge of defeating IEDs must address many considerations. For example, while very high RF power levels can disrupt IED communications, this can create an environmental hazard for vehicle personal and overload vehicle power systems. In addition, minimizing the disruption of radio communications, GPS navigation capabilities, and other RF sensing systems must be addressed to ensure mission system interoperability.

Early Efforts to Evaluate Jamming Solutions

Initial efforts to evaluate the performance of IED jamming solutions were relatively simplistic, as shown in Figure 1. Jammer performance was determined by the system's ability to prevent wireless activation from different distances and geometries between the jammer, IED, and detonating device. This basic pass/fail test approach, while effective at establishing a benchmark for a system's capability, did not provide the information needed to understand why a system would not work under certain conditions or what improvements would be most effective in enhancing performance other than by adding more power.

To understand jammer effectiveness and reduce system development time several questions must be answered:

- What jamming to noise ratio is needed for different signals?
- What jamming waveforms are most effective?
- Where, in the communication of the device being jammed is the signal being disrupted?
- How can jammer effectiveness be maintained while maximizing interoperability with other mission critical assets?

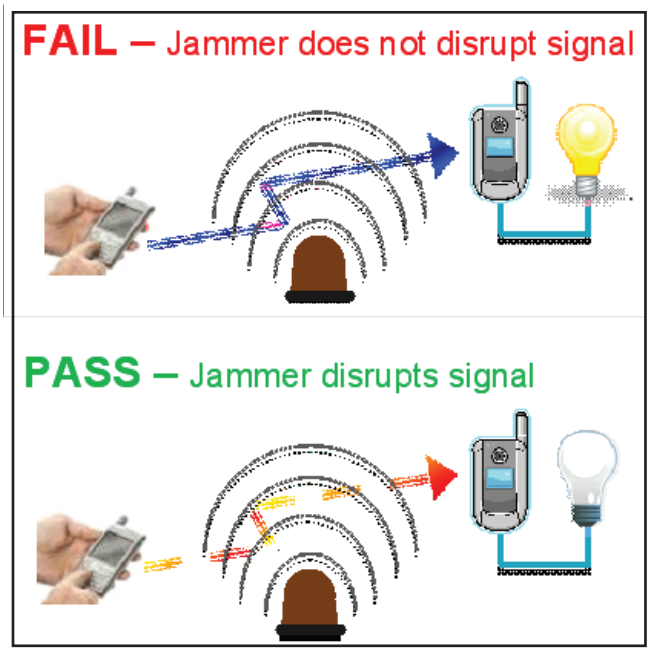

Figure 1. Early testing was effective at determining a jammer's ability, but did not provide insight into optimizing and improving the technology.

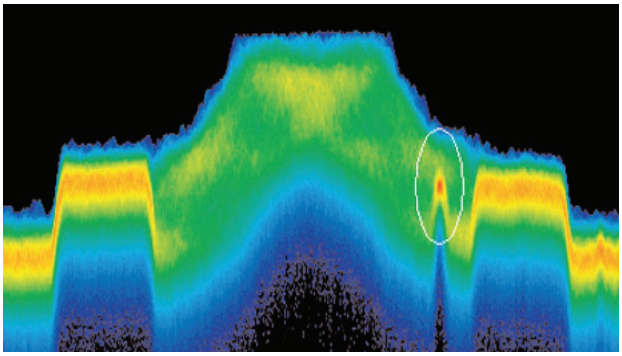

Figure 2. Tektronix' DPX Live RF displays time varying signals at different power levels. Finding small signals in the presence of large signals is key to improving IED jammer technology. The circled signal shows a narrowband transimission buried in a spread spectrum signal.

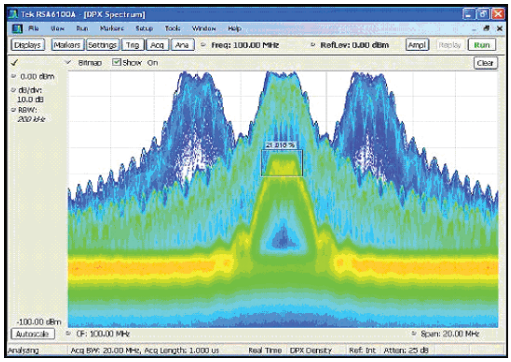

Figure 3. DPX Density measurements and triggering, shown above the box in the center of the image, can quantify and isolate signals within time varying signals based on statistical occurrence.

The Value of an RF Capture/Playback Approach

Tektronix and X-COM have been partnering for several years to provide customers with fully integrated RF Capture /Playback solutions. The combined system provides unprecedented capabilities to document analyze and re-create complex RF environments.

Tektronix' RSA6000 series spectrum analyzer offers the combined widest calibrated acquisition bandwidth and dynamic range available on the market and a digital output that includes the full 16 bit I & Q digitized RF signal data stream. Combined with the unique real-time frequency triggering functionality, the Tektronix RSA6000 user can use frequency or statistical event markers to identify spectrum of interest.

X-COM's IQC2110™ long duration RF signal storage system can continuously record the RSA6000 signal stream without gaps or interruptions for hours or days. The ability to time-stamp data and place event markers in the data stream works hand-in-hand with the RSA6000 to provide unique insight and rapid signal of interest collection.

X-COM's RF data analysis tools rapidly analyze information using the event marker functionality, locate intermittent and hard to find signals, extract and export signals for detailed analysis, create signal libraries, and create repeatable custom dynamic spectrum loops for testing and evaluation.

All data is stored in a non-proprietary format to facilitate easy integration with a wide range of signal analysis techniques. The Tektronix RSA6000 series analyzers and X-COM IQC2110 systems combine to provide an unmatched tool for reducing the time needed to develop effective countermeasure solutions.

Discover the Unexpected with "Live RF"

The Tektronix RSA6000 series spectrum analyzers offer a combined 110 MHz acquisition bandwidth with 75 dB of spurious free dynamic range (SFDR). This provides the bandwidth and dynamic range needed to capture IED communication in even the most cluttered and complex RF environments. The RSA6000's real-time processing engine can provide statistical density triggering, DPX Density™ triggering, or frequency domain triggering. Frequency Mask Triggering allows users to trigger on multiple time varying signals and small signals in the presence of large signals while the DPX Density triggering enables triggering on signals within signals for the purpose of marking events in recorded data. Unlike narrow instantaneous bandwidth scanning mode solutions, the RSA6000 real-time processes have 100% probability of intercept specifications and can capture even the briefest IED communications with certainty.

Another unique feature of the RSA6000 is its DPX® Live RF display and DPX Density™ measurements. The real time Digital Signal Processing (DSP) engine in the RSA6000 can provide 292,000 spectrum updates per second and has a 100% probability of intercept (POI) for signals with a minimum event duration of 5.8 microseconds. As shown in Figure 2, the DPX display clearly shows complex time varying signals, even in the presence of higher power signals. This makes it possible to discern IED signals even if they are short duration and are at frequencies close to powerful emitters.

The RSA6000 has an extensive pulse measurement analysis as well as frequency, amplitude, and phase versus time measurements to help classify signals during the development of countermeasure devices. The DPX Density measurement works well for jammer/IED transmitter analysis.

Acquisition Bandwidth	Data Rate	RSA6000 Record Time	IQC2110 wtih 4 TB Record Time
110 MHz	600 MB/s	1.7 s	1.7 hours
60 MHz	300 MB/s	3.4 s	3.2 hours
40 MHz	200 MB/s	5.1 s	5 hours
20 MHz	100 MB/s	10.2 s	10 hours
10 MHz	50 MB/s	20.5 s	20 hours
1 MHz	6.25 MB/s	81.9 s	6 days, 16 hours

Table 1. Comparison of RSA6000 series maximum capture duration vs IQC2110 RF Capture / Playback Record Times w/4TB configuration.

X-COM IQC2110/CPG: Long Duration RF Record and Playback

The X-COM IQC2110 stores accurate uninterrupted signals captured by the Tektronix RSA6000 for hours or days depending on acquisition bandwidth. The combined RSA and IQC2110 provide an unmatched capability for analyzing complex, wideband, long duration and intermittent waveforms. The IQC2110 continuously records the full 16 bit I and Q data streams from the RSA, up to the full RSA 110 MHz bandwidth. Collecting long duration recordings of IED jammer scenarios makes it possible to conduct detailed analysis of all events leading up to and following an event. The ability to flag data with event triggers or provide accurate time-stamps, enhances the speed of analysis with rapid search on event functionality.

The X-COM Continuous Playback Generator (CPG) makes it possible to replay all or any part of the recorded spectrum with full 16 bit I and Q precision using a Vector Signal Generator. This capability allows segments of spectrum containing signals of interest to be re-created at will. The recreated spectrum can be re-played into the RSA for additional analysis, into another signal analysis system, or used to test system performance in a repeatable environment.

By capturing and recording uninterrupted data streams and event markers, detailed analysis can be rapidly performed on a variety of criteria during the IED remote activation. Collected data can be time stamped with an external IRIG B receiver to very high precision and event markers can be recorded during the data collection process. These capabilities make it possible to quickly find key signals of interest in the captured data files.

Data is stored in a non-proprietary format to allow offline analysis by a wide range of digital signal processing tools including X-COM's Spectro-X and other signal analysis tools.

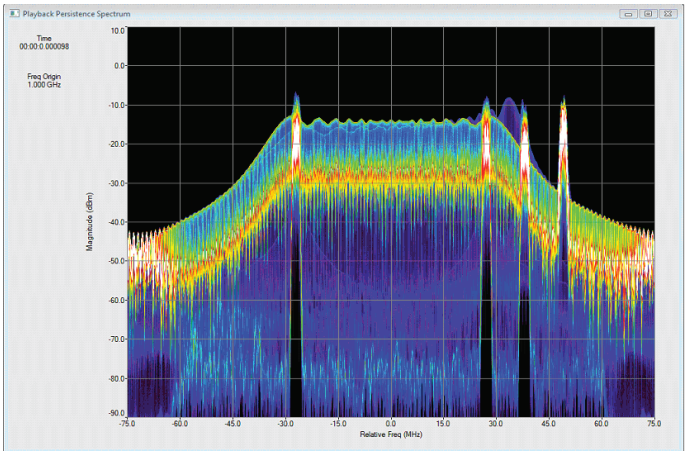

Figure 4. The X-COM Spectro-X signal analysis software easily locates signals near powerful transmitters or hiding in a complex RF environment.

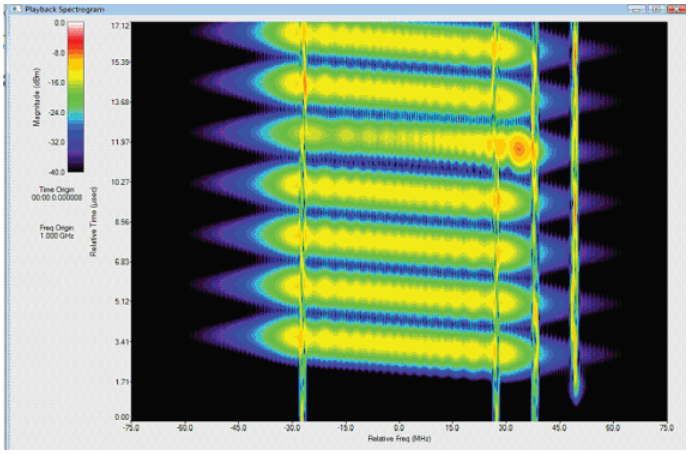

Figure 5. The X-COM Spectro-X spectrogram analysis capability allows signals to be "slowed down" or frozen in time to support detailed analysis.

X-COM Spectro-X, WaveCAFE and RF Editor Signal Analysis Tools

To complement the RSA6000 and IQC2110 system, X-COM has developed a suite of signal analysis tools that are optimized for very large data sets. Unlike some analysis tools, which are limited by workstation RAM, many X-COM tools can be used on datasets of any size. X-COM tools all use open source data formats and are designed to complement existing signal analysis system including MatLab and X-Midas. X-COM signal analysis tool set includes Spectro-X, WaveCAFE, and RF Editor.

Spectro-X, as shown in Figures 4 and 5, is a powerful general purpose signal analysis package that can be used to locate signals, correlate signals with captured or created library signals, evaluate signals using a variable persistence using a temperature gradient color density display similar to the Tektronix DPX Live RF display, and many other analysis and display tools. Spectro-X also provides a unique "Spectrogram" presentation that allows signals to be replayed in "slow motion" or frozen in time to allow precise detailed analysis of transient events and other signal details.

WaveCAFE is used to create, modify and export waveforms. Collected signals can be extracted and exported to other analysis tools, manipulated to simulate impairments and other effects or created from scratch. Complex signals can be easily created, uploaded to the IQC2110 and transmitted at any desired frequency using a CPG and Vector Signal Generator (VSG).

RF Editor is used to create complex time variable spectrum for system test and evaluation. Users can create a library of captured or created signal segments and then, using a simple graphical interface, they can create complex sequences containing multiple individually time varying signals. Individual signals can be modified to simulate impairments such as multi-path effects and noise. IED jammer scenarios can be easily created with a wide variety of wireless signals and test conditions.

Improved Field Testing

The Tektronix and X-COM RF Capture and Playback tools make it possible to achieve a better understanding of jammer technologies and how best to improve effectiveness. The powerful in depth analysis capability allows users to evaluate the effectiveness of different jamming scenarios and to determine how effective different waveforms are at disrupting IED signals. Using more sophisticated waveforms allows better effectiveness to be achieved at lower power levels and helps with system interoperability concerns.

When used to support field testing, different IED jammer systems can be evaluated using reproducible environments. The system can also record the entire stimulus-response sequence to allow evaluation of the detailed behavior to aid in optimizing system design.

Bringing Test to the Bench

While it is important to conduct field testing to evaluate the effectiveness of IED jammers, this can be an expensive and time consuming approach. The cost for outdoor test facilities, government vehicles, and multiple personal can quickly add up. Using the Tektronix RSA and X-COM IQC system, test scenarios can be easily created using captured and/or created signal information. Exceptionally flexible and capable bench top or anechoic chamber test and evaluation systems can be created with the capability to simulate virtually any real-world situation.

The ability to bring high fidelity testing into a laboratory environment reduces costs and allows more time to be spent developing improved technology with better reproducibility. For example, the Tektronix RSA and X-COM IQC system can be used to capture, analyze and playback signals from jammers, IED transmitters and receivers individually or at the same time. Other unrelated radio communication, RF sensor technologies, and/or GPS signals can be injected or used to evaluate collateral effects or improve the receiver sensitivity or selectivity in a given environment.

Although field testing remains a critical step for the final verification of technologies and support certification, moving technology development to a more controlled laboratory bench offers a lower cost of test for research of new methods and optimizing jammer performance.

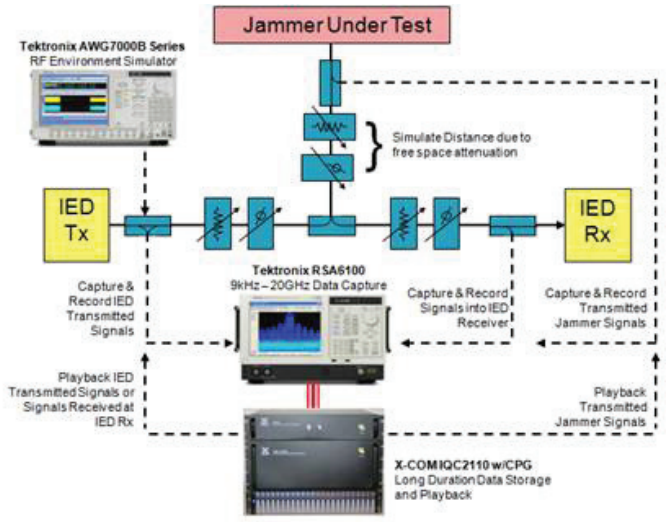

Figure 6. The ability to re-create complex RF environments in a coaxial bench setup provides a very cost effective way to gain a more in depth understanding of different technologies and an unmatched optimization tool.

Improved Jammer Certification

The effects of evolving IED jammer technology has been apparent in both Iraq and Afghanistan. The number of IEDs planted in Iraq has dropped from 23,000 at the peak in 2007 to 3,000 in 2009. Today 50% of IEDs are detected and disarmed and less than 10% result in casualties. Unfortunately, the use of IEDs has been increasing in Afghanistan (2,700 to 8,300 over the same time period). The Tektronix RSA and X-COM IQC system provide engineers tasked with addressing this life threatening challenge the tools they need to save lives and create more effective systems.

The combined Tektronix/X-COM system makes it possible to understand complex RF environments in detail. New waveforms can be easily and quickly created, evaluated and their effectiveness tested. Existing and new jammer systems can be evaluated using repeatable scenarios. Improving jammer performance will reduce casualties and adverse effects on other mission support elements.

To learn more about Tektronix real-time spectrum analyzers visit us on the web at www.tektronix.com/ew.

To learn more about X-COM Systems RF capture/playback solutions visit us on the web at www.xcomsystems.com.

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Contact List Updated 25 May 2010

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