Demonstration of Spectral Sensing & Signal Classification

Robert Newgard, Shubha Kadambe, Zaid Towfic and Christina Conway
Advanced Technology Center
Rockwell Collins, Inc.
Cedar Rapids, IA 52498
ranewgar@rockwellcollins.com, slkadamb@rockwellcollins.com, cmconway@rockwellcollins.com

Abstract— **In dynamic spectrum access systems, it is necessary to have knowledge of the spectral environment. The first step is the detection of RF signals. A potentially beneficial next step is to classify these signals according to modulation type. By utilizing a sensor and classifier, the system can characterize the RF spectral environment and provide actionable information to the end user. We have designed and built a low-power, small-form-factor spectral sensor. In addition we have designed and implemented a robust Gaussian mixture model-based classifier algorithm. In this demonstration, classification is performed on four representative signal modulation types. The classifier engine is linked to an RF spectral sensor that measures the state of the spectrum and provides input data to the classifier. The classifier then extracts features from the sensor input, analyzes the data and identifies the source signal modulation type.**

Keywords – small-form-factor spectral sensor, Gaussian mixture model, signal detection and classification

I. INTRODUCTION

In any dynamic spectrum access (DSA) system the first requirement is knowledge of the spectral environment. The added capability to reliably classify signals while on location provides real-time, actionable information to the warfighter or end user. In the future applications, the sensor and classifier will be operated in conjunction with a policy engine that will enable the DSA system to make decisions about the availability of useable spectrum in accordance with regulatory rules. In this paper, we describe a modulation recognition demonstration that employs the small-form-factor sensor that Rockwell Collins developed for this kind of application (section II) and a Rockwell Collins-developed classifier algorithm (section III).

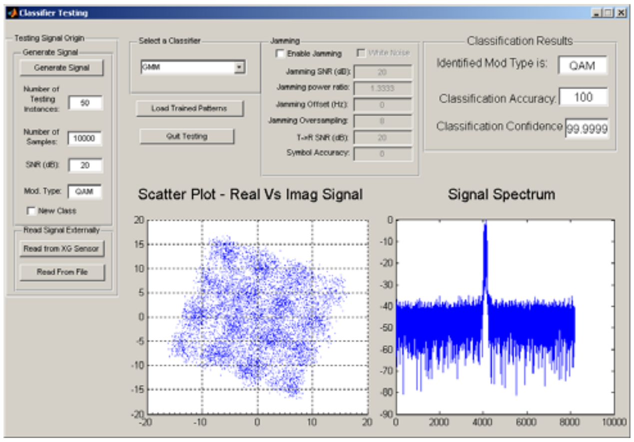
II. XG SENSOR

Under the DARPA neXt Generation (XG) communications program, Rockwell Collins has developed a high-speed, low-power, broadband spectrum power sensor; see Figure 1. The novel sensor architecture is based on a combination of super-heterodyne and digital sampling receiver techniques. The sensor is capable of scanning frequencies from 30 MHz to 3000 MHz at a rate up to 18 GHz/sec. The sensor includes signal-processing capability in the form of a high-speed, programmable, digital signal processor that provides the ability to download a wide range of spectral-processing algorithms. The standard output of the sensor is a Fast Fourier Transform (FFT) of the RF spectrum with an instantaneous bandwidth of 16 MHz. The sensor can also output time domain samples (I and Q) for further post processing. The sensor utilizes a novel, dynamically-reconfigurable frequency architecture to eliminate internally generated spurious signals from the output. An innovative power management control algorithm enables DC power consumption of less than 3.5 watts. The sensor utilizes Ethernet 100BaseT for control and data handling. It is packaged in a small form factor (i.e., 3.5 x 5.75 x .99 in) with an overall volume of 19.9 in^3. The linear dynamic range of the sensor is greater than 100 dB, with a noise floor that is less than 110 dBm in a 25 kHz bandwidth.

Figure 1: Rockwell Collins XG spectral sensor

III. CLASSIFIER ENGINE

The classifier engine is operated through a graphical user interface (GUI) which is shown in Figure 2. This classifier is a hierarchical classifier based on a Gaussian mixture model (GMM), k-means clustering and a Bayesian decision maker. The classifier has been trained for ten different typical modulation types – both analog and digital, radar signals and noise. The classifier recognizes all of these modulation types at various signal-to-noise ratios (SNRs). Simulated signals were used for training and testing in the laboratory.



Number of Testing Instances: 50

Number of Samples: 10000

SNR (dB): 20

Mod. Type: QAM

☐ New Class

GMM

☐ Enable Jamming ☐ White Noise

Jamming SNR (dB): 20

Jamming power ratio: 1.3333

Jamming Offset (Hz): 0

Jamming Oversampling: 8

T->R SNR (dB): 20

Symbol Accuracy: 0

Identified Mod Type is: QAM

Classification Accuracy: 100

Classification Confidence 99.9999

Figure 2: GUI of the Classifier Engine (non-demo version)

The GUI in Figure 2 was used during training and testing. In this GUI, there is an option to read the test signal from either a file or the XG sensor. Average classification accuracy of 97.6% was obtained for ten classes of signals with SNRs of -6 to -3 dB.

Merging the sensor with the classifier engine enables the warfighter to quickly identify and differentiate signals using a compact, man-portable system. By performing real-time assessment of signal types, immediate decisions about appropriate tactical actions can be rendered in response to local activity in the theater of operations.

IV. DySPAN DEMONSTRATION

The DySPAN conference demonstration setup is as shown in Figure 3.

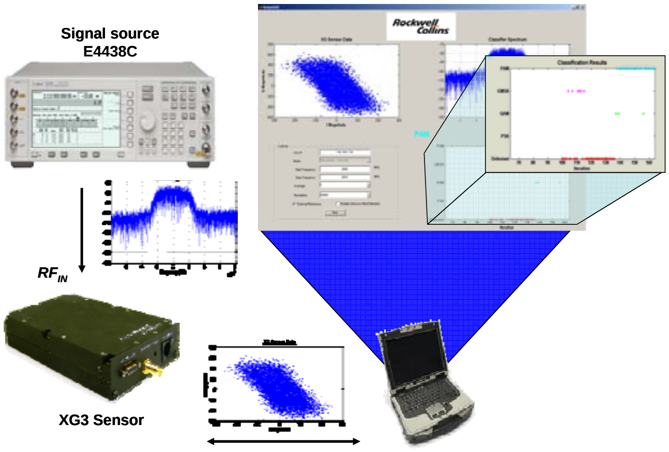
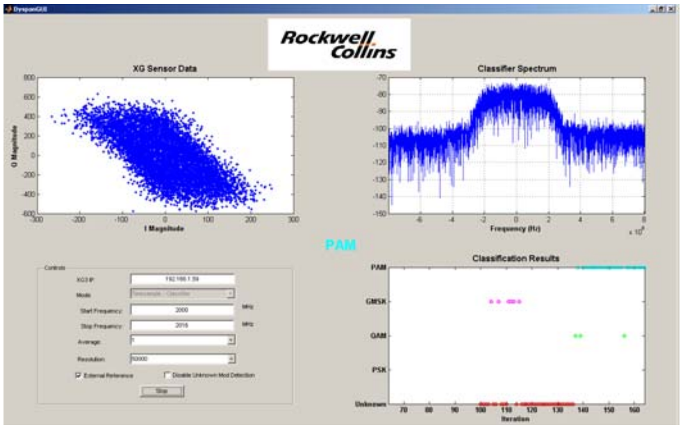


Figure 3: The DySPAN demonstration

In this demonstration, the sensor is interfaced with an E4438C signal generator that provides user-selectable modulated signals representative of modulation types in real-world RF environments. The classifier engine, operated through the GUI shown in Figure 4, uses I and Q output from the sensor supplied through an Ethernet connection. The classifier engine extracts features from the FFT spectrum I and Q data and computes an extracted feature vector. The extracted feature vector is then used by the Baye's decision maker to determine the classification of the sensed signal.

For simplicity during this demonstration, the user can witness the performance of the classifier on a subset of four signal classes – PSK, PAM, QAM, and GMSK.



Start Frequency: 2000 MHz

Stop Frequency: 2016 MHz

☑ External Reference

☐ Disable Unknown Mod Detection

Figure 4: GUI of the demo version of the Classifier Engine

The classifier engine displays the sensed I and Q data in the upper left-hand quadrangle, the sensor control parameters in the lower left-hand quadrangle, the computed FFT spectrum in the upper right-hand quadrangle and the classification results in the lower right-hand quadrangle of the GUI, respectively, as shown in Figure 4.

If no specific modulation type is selected by the user, the classifier engine displays "unknown" as the signal classification type. When one of the four aforementioned modulation types is selected, the engine analyzes the generated signal and displays the identified classification by plotting a circle along one of the four rows that corresponds to that specific signal class. If the modulation type is not one of the four user-selectable signals, the classifier identifies and plots the signal as "unknown".

V. CONCLUSIONS

Combining signal detection with modulation recognition provides the end user with actionable information. By performing real-time assessment of signal types, immediate decisions about appropriate tactical actions can be rendered in response to local activity in the theater of operations.

Rockwell Collins has developed a small-form-factor, low-power spectral sensor and classifier algorithm that provide local spectral awareness and real-time modulation recognition to the end user. A simple demonstration of this capability is documented herein and has been demonstrated at DySPAN 2008.

VI. ACKNOWLEDGMENT

The authors acknowledge the financial support from DARPA for this project (FA8750-05-C-0254) and technical inputs from Preston Marshall, the DARPA Program Manager.