# UR-409 Enhancing Aircraft Electronic Warfare Testing with Automated RF Spectrum Analysis

## Abstract

Our project, "Enhancing Aircraft Electronic Warfare Testing with Automated RF Spectrum Analysis," addresses the critical need for efficient and accurate analysis in the development of Aircraft Electronic Warfare (EW) Systems. We supersede the traditional manual methods at Robins Airforce Base with our two-model approach: Approach 1 utilizes a custom-trained YOLOv8 detection model for real-time object detection, providing accurate results for Threat System frequency and amplitude. Approach 2 employs an unsupervised Computer Vision model for edge cases with limited data. The resulting application automates the identification of measured signal properties, significantly reducing human interaction, speeding up processing, improving accuracy, and transforming video data into a manipulatable format.

## Introduction

Aircraft Electronic Warfare (EW) Systems are critical components of modern military aviation, providing essential defense mechanisms against electronic threats. The development and validation of these systems necessitate rigorous testing in military flight test ranges. Central to this testing is the evaluation of Radio Frequency (RF) Threat Systems, both real and simulated, which assess the effectiveness of EW Systems during flight tests. Traditionally, engineers at Robins Airforce Base manually have analyzed video data from spectrum analyzers to confirm the frequency and amplitude of specific threat systems, a process that is lengthy and prone to potential inaccuracies.

Our project emerged from the need to streamline and enhance this critical analysis process. Recognizing the limitations of manual analysis, we set out on a collaborative effort with Robins Airforce Base to develop an automated solution for RF Spectrum Analysis. This project aimed not only to reduce human interaction and improve efficiency but also to ensure the accuracy and consistency of data crucial for the development and validation of EW Systems.

## Materials and Methods

### Primary Trained Approach

Our core strategy employs a custom-trained YOLOv8 object detection model, that integrates image segmentation and a deep convolutional neural network (CNN). This approach predicts object bounding boxes and class probabilities for multiple objects within a single image pass, achieving real-time performance by processing the entire frame. Utilizing this model, we retrieve bounding boxes for the spectrum analyzer's grid and measured signal. Because we know the position and dimensions of the boxes, we can derive accurate estimations of the signal's amplitude and center frequency.

### Complementary Unsupervised Approach

In enhancing edge-case coverage and reliability, we introduced an alternative method utilizing classical unsupervised techniques. This approach involves a unique fusion of bitwise summing, differencing, and agglomerative clustering, providing versatility in scenarios with limited training data. By establishing a median background image and employing OpenCV techniques, this approach detects signal movement, captures contours, and clusters signals, allowing for accurate amplitude and center frequency estimation. This complementary approach adapts to edge cases, prioritizing accuracy in signal analysis while accommodating scenarios with shorter videos and limited training data.

## Results

Our automated RF Spectrum Analysis tool has demonstrated significant success in enhancing the efficiency and accuracy of EW testing processes. The primary trained approach, driven by a custom-trained YOLOv8 model, exhibits impressive performance, swiftly and precisely identifying the grid and measured signal of the spectrum analyzer, and by comparing the position and dimensions of the bounding boxes, accurate estimates of the measured signal's amplitude and center frequency are derived. Below are some examples showing its ability to generalize and work on a variety of signals and displays:

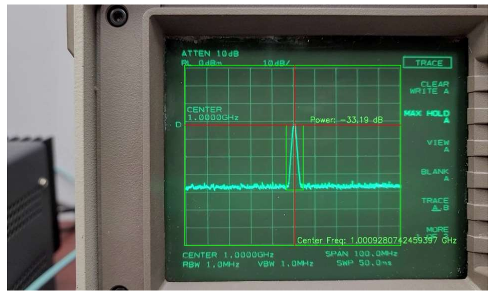


Figure 1. CW Signal


Figure 2. Carrier Signal with Single Sideband Modulation

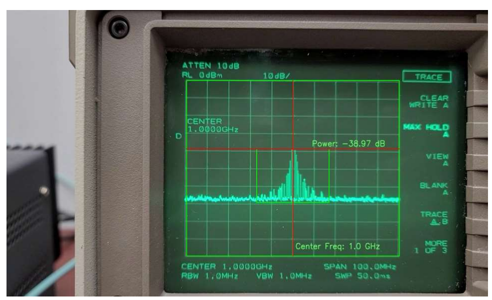


Figure 3. Pulsed Signal

The complementary unsupervised approach, designed for edge-case scenarios, has proven its adaptability and reliability. Using classical techniques like bitwise summing, differencing, and agglomerative clustering, this method is useful in scenarios with limited training data and shorter videos. It captures signal movement, identifies contours, and clusters signals, ensuring accurate estimation of amplitude and center frequency.

In both approaches, the elimination of manual labor not only saves time but also significantly improves the overall efficiency of RF Spectrum Analysis. The tool successfully transforms video data into a digitally manipulatable numeric format, offering valuable insights for military flight testing and electronic warfare system development. Preliminary results on new data are promising, affirming the potential of our technology to revolutionize testing procedures and contribute to the advancement of electronic warfare systems.

## Conclusions

Our resulting application offers the ability to recognize and process signal amplitude and frequency. It provides an automated means to identify a measured signal's center frequency and the amplitude of its peak. This significantly reduces human interaction, enhances the accuracy of RF Spectrum analysis, and conveniently allows for the transformation of video data into a digitally manipulable numeric format.

By eliminating manual labor, our solution saves time, improves efficiency, and ensures the accuracy and consistency of data in EW testing environments. Our results look promising and we anticipate that this technology will be a useful asset in military flight testing and electronic warfare system development.

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