• GRAPHICAL SYSTEM DESIGN •

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MACHINE CONTROL AND MONITORING

Performing Aircraft Jet Plume Noise Measurements Using LabVIEW Software and PXI Hardware

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Figure 1. NAH Ground Run-Up Measurements of an F-22 at after Burner Power

Products Used
LabVIEW
Sound and Vibration Measurement Suite
PXI-4496 Data Acquisition Modue
MXI-4 link to PXI remote controller
PXI-4462 Data Acquisition Module

The Challenge

Developing a portable near-field acoustic holography (NAH) system for measuring high-amplitude jet noise from current and next-generation military aircraft to provide model refinement and benchmarking, evaluate performance of noise control devices, and predict ground maintenance personnel and community noise exposure.

The Solution

Developing a system based on cost-effective NI PXI dynamic signal acquisition (DSA) devices to take advantage of portability, flexibility, scalability, and accuracy; scale the number of data channels; and move the microphone array to increase the area under test and decrease measurement time while integrating the technical requirements for NAH with the environmental conditions and safety constraints associated with jet noise measurements.

Why the Air Force Research Laboratory Needed to Measure Jet Engine Noise

Military jet aircraft expose both ground maintenance personnel and the community to high levels of noise. Thus, the U.S. Department of Defense is funding research to develop advanced modeling tools for noise reduction techniques and community noise exposure. For these tools to achieve their full potential, innovative measurement and analysis methods are necessary to characterize the jet noise source region. NAH offers the best general method to measure the magnitude, directivity, and spectral content as well as the spatial distribution of the noise emitted from a jet.

Figure 2. NAH Measurement Team with the F-22

The Air Force Research Laboratory chose Blue Ridge Research and Consulting (BRRC) to develop innovative measurement and analysis methods to characterize and map the noise emitted from jet engines. BRRC, an acoustical engineering consultancy focused on solving critical noise and vibration challenges, partnered with The Brigham Young University (BYU) Acoustics Research Group to develop this application.

Challenges of Performing NAH

The application of NAH processing to the characterization of a full-scale jet plume environment and the development of an appropriate measurement array pose several technical and logistical challenges. Accurate characterization of the near field of a military jet aircraft requires the ability to record sound pressure levels up to 170 dB and frequencies from 5 Hz to 30 kHz. In addition, measurements must be made along the entire length of the plume. The NAH system must also be semiportable because of the limited number of locations where military jets can perform static high-power engine run-ups.

One major requirement for this high-channel test rig was design and packaging simplicity to minimize set-up time and cost. To measure a surface large enough to characterize the entire jet noise source while minimizing the number of microphones, we proposed a scan-based microphone array with stationary reference microphones.

Using the NI PXI Platform to Build a Multichannel Data Acquisition System

We record the time waveforms from the microphones on a multichannel data acquisition system built on the NI PXI platform. The PXI chassis includes nine 16-channel NI PXI-4496 modules and two 4-channel NI PXI-4462 data acquisition modules with simultaneous sampling to ensure correct phasing of all 152 channels. With 24-bit analog inputs per module and integrated electronic piezoelectric (IEPE) constant current signal conditioning, the PXI modules are ideal for making precision microphone measurements.

The PXI-4496 modules deliver 113 dB of dynamic range and simultaneous sampling on all 16 channels at rates up to 204.8 kS/s. In addition, the modules include built-in antialiasing filters that automatically adjust to the sampling rate and software-selectable input gains of up to 20 dB. The 113 dB dynamic range and software-selectable gain adjustments allow for precise measurements of both low and high power conditions. In addition, the data are AC coupled at the recorder using a high-pass filter with a 0.5 Hz corner frequency.

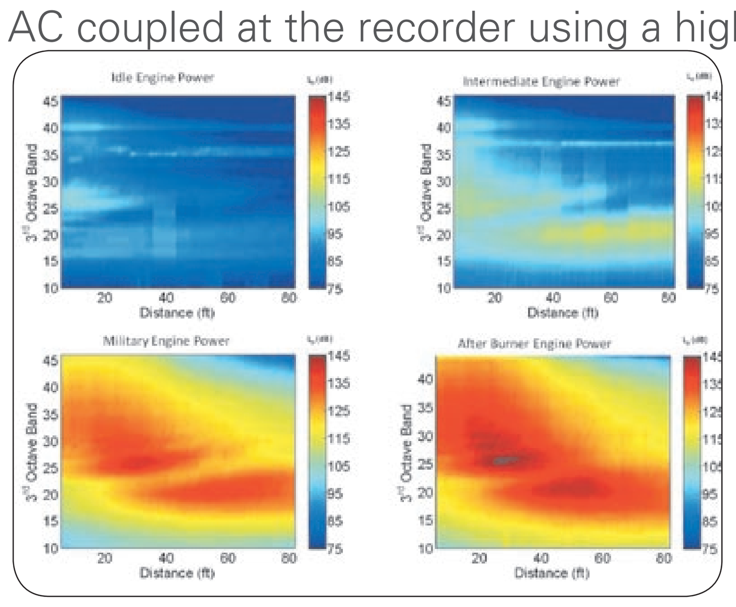

Figure 4. NAH Multichannel Data Acquisition and Monitoring Measurement System User Interface

We can take the high-amplitude pressure measurements with a quarter-inch G.R.A.S. 40BE free-field microphone with a 26CB preamplifier. This allows a frequency response of 4 Hz to 100 kHz ±3 dB. Additionally, we made two design modifications to customize the sensors for this specific application. The microphones were designed to have a nominal sensitivity of 1 mV/Pa, which permits measuring levels of up to 170 dB. We also extended the preamplifier neck from the quarter-inch microphone to a half-inch female BNC connector to minimize cable connections, prevent reflections, and increase ruggedness
in the array mounting. IEPE conditioning onboard the data acquisition system powers the constant current preamplifiers.

The NAH measurement system uses a 2D microphone array, which consists of 90 microphones, that moves along the jet plume on a plane parallel to the sheer layer through the use of four wheels and a guide rail. The required measurement area is broken up into multiple patches the size of the 2D microphone array. The guide rail allows us to precisely locate the test rig along the plume. Also, the wheels of the test rig may be locked in place.

Figure 3. NAH Multichannel Data Acquisition and Monitoring Measurement System

The data from all the channels are streamed over a single coaxial cable to a remote 1 U controller via a MXI-4 link. The controller contains an Intel Core 2 Quad processor with four 250 GB hard drives in a RAID 0 configuration, which enables streaming to a disk over 150 channels while running data monitoring and analysis software.

In addition, adequate storage is important considering one measurement patch of 152 channels of data collected at 96,000 Hz over 30 seconds results in more than 1.75 GB of data. We can take measurements at multiple patches along the jet plume for several engine power conditions to fully characterize the plume; therefore, the data are saved in a nonproprietary binary format. We can control and monitor data acquisition using a daylight readable laptop running a Windows OS remote desktop either wirelessly or wired to the controller.
The data acquisition system is housed in a MIL-SPEC shipping case.

The system is located approximately 61 m from the jet nozzle with custom-made InfiniBand cables running from it to the test rig. This length helps minimize the vibration of the hardware from the harsh jet plume environment while the test rig travels the entire length of the plume. With the flexibility of LabVIEW software, we were able to customize the monitoring and data verification functions.

We successfully tested the data acquisition system with all 152 channels simultaneously sampled at a rate of 100 kHz. We will conduct future benchmarks with the introduction of additional visualization tools.