# DEVELOPMENT OF THE SECOND GENERATION NRC ACOUSTIC SPECTRUM CONTROL SYSTEM FOR HIGH INTENSITY NOISE TESTING

**Anant Grewal[*1], Yong (Eric) Chen[†1], Shahrukh Alavi[‡2], Viresh Wickramasinghe[§1], and Brent Lawrie[¶3]**
[1]Research Officer
[2]Flight Test Instrumentation Engineer
[3]Senior Technical Officer
Flight Research Laboratory, National Research Council Canada, 1200 Montreal Road, Ottawa, Canada, K1A-0R6.

## 1 Introduction

Since 1982, NRC has conducted high-intensity diffuse field noise testing using a reverberant chamber that measures 6.9 x 9.75 x 8m. This is the only facility in Canada capable of supporting full-size satellite and large spacecraft component testing to ensure that they withstand exposure to the intense acoustic launch environment (see Figure 1). Within this chamber, testing at overall SPLs of greater than 150dB with accurate spectrum shaping is routinely performed.

Until 1993, the target acoustic spectrum for test articles was achieved through the real-time manual adjustment of ⅓-octave spectrum shapers. Over time, with ever tighter target tolerances, the ability of human operators to achieve the target spectrum over the duration of tests became severely challenged. In response, NRC developed an in-house closed-loop system for spectrum control. The key components of the first generation controller were a B&K-2131 spectrum analyzer, a Norsonic-731 noise-shaper, and a PC executing the control algorithm. Data flow between the analyzer, computer and shaper was achieved using the IEEE-488 interface (see Figure 2). The system worked extremely well, providing accurate and reliable performance, and was used in the testing of major satellites (RADARSAT-1 and -2, and CASSIOPE amongst others).

In order to eliminate the risk due to the obsolescence of ageing hardware and the reliance on an unsupported operating system and development environment, a plan was developed to migrate the control algorithm to a current generation of hardware and software. After a review of available hardware and software, the National Instruments PXI and Labview-RT development system was chosen for the new spectrum control platform. A control system that provided the baseline functionality of the first generation controller with additional features and performance was developed and benchmarked against the original system as well as two commercial acoustic control systems.

## 2 Spacecraft Diffuse Field Testing

Diffuse field acoustic testing in a reverberant chamber is the principal method used to qualify satellites, as well as their components against the intense acoustic environment present during launch. This approach relies on an accurate re-creation of the launch noise levels in the chamber.

* anant.grewal@nrc-cnrc.gc.ca
† eric.chen@nrc-cnrc.gc.ca
‡ shahrukh.alavi@nrc-cnrc.gc.ca
§ viresh.wickramasinghe@nrc-cnrc.gc.ca
¶ brent.lawrie@nrc-cnrc.gc.ca

Specifications are typically provided in ⅓-octave levels between the 25 Hz and 10 kHz band, and a typical tests lasts between 1 and 2 mins.

**Figure 1:** The RADARSAT-2 Satellite in the NRC Chamber.

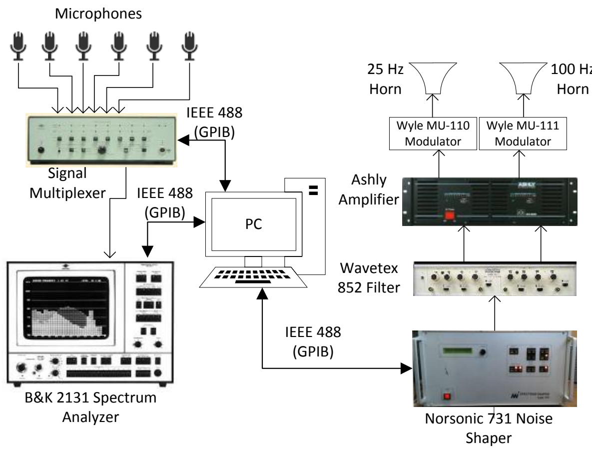


**Figure 2:** Schematic of the First Generation NRC Acoustic Spectrum Control System.

## 3 First Generation NRC Control System

The first generation system architecture and algorithm were developed by NRC staff and the code development was contracted out. In the NRC chamber, noise generation was provided using Wyle WAS-3000 (MU-110/111) airstream modulators for frequencies lower than approximately 1600 Hz. Additional broadband noise between approximately 1 and 10 kHz was generated using a pair of opposed gas jets.

Time-domain multiplexing of 6 microphones positioned around the test article was employed to obtain an averaged noise signal. A B&K analyzer continuously performed ⅓-octave analysis using exponential averaging. Every 0.2 seconds, the current spectrum measurement was transferred to the PC via IEEE-488. In addition to executing the overall supervisory level of control, the PC implemented an integral control loop for each ⅓-octave band between 25 Hz and 1600 Hz to determine the required level of ⅓-octave band attenuation that were communicated to the shaper via the IEEE-488 interface. The output of the shaper was passed through a Low Pass, High Pass Filter network configured using a programmable Wavetek 852 filter. The signals were amplified using a dual-channel Ashly audio amplifier and applied to a pair of Wyle modulator coupled to horns.

## 4 Second Generation NRC Control System

When the decision was made to replace the first generation controller, a number of options were considered including two commercial controllers as well as a array of in-house development options. Ultimately, the in-house option using the Labview RT development environment and National Instruments hardware option was chosen. Many features of the 1st generation system were not available on the commercial systems, nor were a number of enhancements and improvements that resulted from over 25 years of operational experience. The Labview RT environment relies on an intuitive and powerful graphical programming language that permits rapid prototyping and development with excellent real-time performance. The signal analysis, control algorithm, noise generation and cross-over network functions were all implemented within an NI PXI chassis that contained a Pentium i7 processor module along with 24-bit analog input and output modules. The main features are given in Table 1. An early version of the controller was used to perform closed loop control of acoustic modulators from TEAM Corporation in support of a project to design the NASA Glenn Research Center's Reverberant Acoustic Test Facility [1].

## 5 Results

The 2nd generation control system performed very well during a comprehensive validation and commissioning phase and is currently in use for all tests. During commissioning, comparisons were made between the old and new control systems for single and dual horn cases. The errors between the target and measured levels for all bands for the new controller were comparable to those obtained with the old controller in all cases tested. Furthermore, the transition from pre-test to full-test levels exhibited negligible overshoot, and remained steady throughout the test duration. An example of the overall SPL time history for a test is shown in Figure 3. One of the new features of the new controller is the ability of the operator to toggle between automatic and manual control for individual 1/3-octave bands. Another is the ability to specify the controller bandwidth to match the frequency response of the modulator. For example, the new controller can be used to control the Wyle WAS-5000 modulator, which has a frequency range of 25 Hz to 5 kHz. This would not have been possible with the old controller.

**Table 1:** Salient Features of Acoustic Control Systems

| **1st Generation NRC System** | **2nd Generation NRC System** | **Commercial Systems** |
|---|---|---|
| External crossover required for multi-horn control. | Integ S/W multi-horn control via crossover or direct mapping. | External crossover required for multi-horn control. |
| Obsolete Hardware and Software Platform | Proven track record of closed-loop control. H/W & S/W supplier is well-entrenched. | Dependent on continual support from control system vendor |
| "Slam" start for quick convergence | "Slam" start for quick convergence | No "slam" start capability |
| Fixed control range (25 Hz to 1.6 kHz) | Arbitrary control range (25 Hz-10 kHz) | Arbitrary control range (25 Hz-10 kHz) |
| Time-domain multiplexing for multi-microphone averaging. | Various multi-mic averaging strategies (min, max, spectral ave, time multiplex) | Unknown |

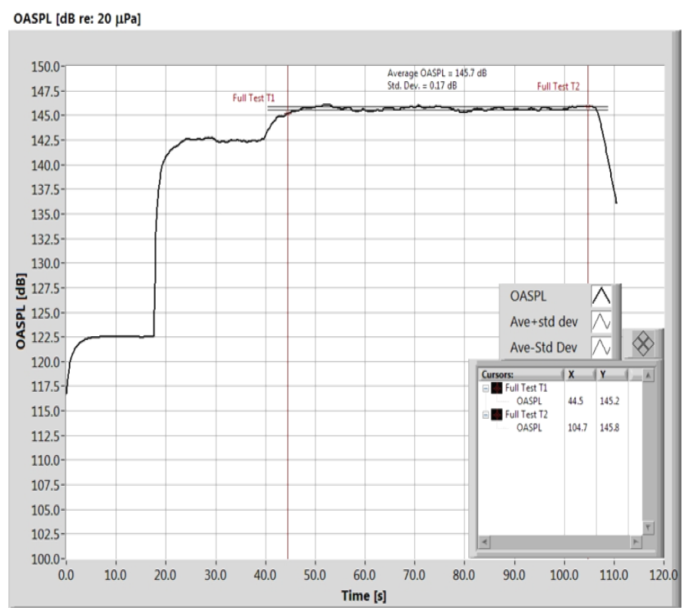


**Figure 3:** Time history of the OASPL for a typical test.

## 6 Conclusions

The original acoustic spectrum control system developed in the 1990s for the NRC reverberant chamber has been upgraded using National Instruments real-time hardware. A control algorithm, encompassing all the features of the old controller along with important enhancements, has been implemented in the Labview RT environment. The performance of the new controller is similar to the old one in terms of accuracy and transient behaviour, and is currently being used for testing of client space hardware.

## References


[1] Grewal, A., Ramakrishnan, R., Hughes, W.O., Woyski, B., Elfstrom, G., Mech, C., and Chen, Y., "High Intensity Noise Generation for Extremely Large Reverberant Room Test Applications," Paper 119, IMAC XXIX A Conference and Exposition on Structural Dynamics, 31 Jan – 3 Feb 2011, Jacksonville, Florida.