Calibration of High Frequency MEMS Microphones

Understanding and controlling aircraft noise is one of the major research topics of the NASA Fundamental Aeronautics Program. One of the measurement technologies used to acquire noise data is the microphone directional array (DA). Traditional direction array hardware, consisting of commercially available condenser microphones and preamplifiers can be too expensive and their installation in hard-walled wind tunnel test sections too complicated. An emerging micro-machining technology coupled with the latest cutting edge technologies for smaller and faster systems have opened the way for development of MEMS microphones. The MEMS microphone devices are available in the market but suffer from certain important shortcomings. Based on early experiments with array prototypes, it has been found that both the bandwidth and the sound pressure level dynamic range of the microphones should be increased significantly to improve the performance and flexibility of the overall array. Thus, in collaboration with an outside MEMS design vendor, NASA Langley modified commercially available MEMS microphone as shown in Figure 1 to meet the new requirements. Coupled with the design of the enhanced MEMS microphones was the development of a new calibration method for simultaneously obtaining the sensitivity and phase response of the devices over their entire broadband frequency range.

Over the years, several methods have been used for microphone calibration. Some of the common methods of microphone calibration are Coupler (Reciprocity, Substitution, and Simultaneous), Pistonphone, Electrostatic actuator, and Free-field calibration (Reciprocity, Substitution, and Simultaneous). Traditionally, electrostatic actuators (EA) have been used to characterize air-condenser microphones for wideband frequency ranges; however, MEMS microphones are not adaptable to the EA method due to their construction and very small diaphragm size. Hence a substitution-based, free-field method was developed to calibrate these microphones at frequencies up to 80 kHz. The technique relied on the use of a random, ultrasonic broadband centrifugal sound source located in a small anechoic chamber. Phase calibrations of the MEMS microphones were derived from cross spectral phase comparisons between the reference and test substitution microphones and an adjacent and invariant grazing-incidence 1/8-inch standard microphone.

The free-field substitution method utilized two reference microphones calibrated by electrostatic actuation and a third test microphone with unknown response. The technique relied on the test microphone and one of the calibrated microphones being located at precisely the same location in the test chamber. The third microphone was used as a reference to compare the sound field to which the other two microphones were exposed. For the present study, two commercially available standard microphones, a ¼-inch pressure microphone and a 1/8-inch free-field microphone were used as the references. A custom microphone holder was fabricated that allowed the ¼-inch reference microphone to be placed in the same physical location as the MEMS test microphone (Figure 2). Because of the small size and placement of rear electrical connections on the MEMS device, a custom fixture was fabricated allowing the MEMS microphone to be held, active, in the same plane as the ¼-inch reference. The stereolithography fixture was designed and fabricated with a rectangular recess to set the MEMS device flush with the surface, and provided electrical connections through spring-loaded contacts. The 1/8-inch reference microphone was mounted slightly below and ½-inch to the rear of the plane of the test and ¼-inch microphones and held invariant allowing it to monitor the sound field.

The random field in the test chamber was generated using a commercially available broadband ultrasonic (10-100 kHz) centrifugal source. The microphones were centered in the plane of the source, located 16 inches from the wind screen. The entire experimental rig was placed near the center of a small anechoic chamber such that the source and microphones were well isolated from each other and from the chamber walls. The reference microphones were powered by a dual power supply delivering a 200-volt polarization voltage, while the MEMS microphones were powered via a 3-volt DC source. Data was acquired at a sampling rate of 200 kHz using an instrumentation recorder providing 16 bits of digitization. Lowpass filters set to 90% of the Nyquist frequency were employed in the system to prevent aliasing, and external gains of 40 dB were applied to all microphones to increase the number of usable digitization bits.

A representative plot of the sensitivity and phase response for one of the MEMS microphone as measured by the free-field technique is shown in Figure 3. From DC to 40 kHz a slight oscillatory fluctuation shown in the responses is most likely due to weak standing wave patterns present between the source and microphones. The degradation in the response above 70 kHz is believed to be caused by the anti-aliasing filters employed in the data system. Although the data analysis is continuing, the early results indicate that the proposed technique can be used to simultaneously obtain the sensitivity and phase responses of test microphones with reasonable accuracy. Future research will focus on quantifying the uncertainty of the calibration technique as well as apply it to various classes of microphones.

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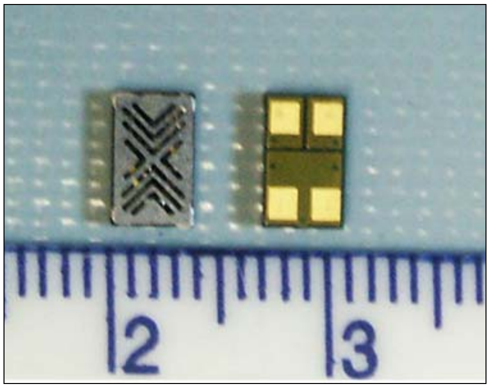

Figure 1. Customized High Frequency MEMS Microphones (Front and Rear Views).

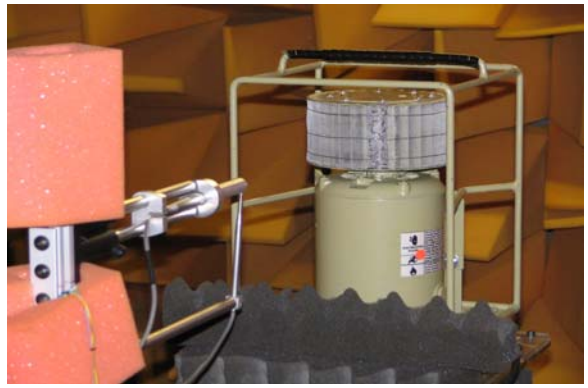

Figure 2. Centrifugal Sound Source and Reference/ Test Microphone

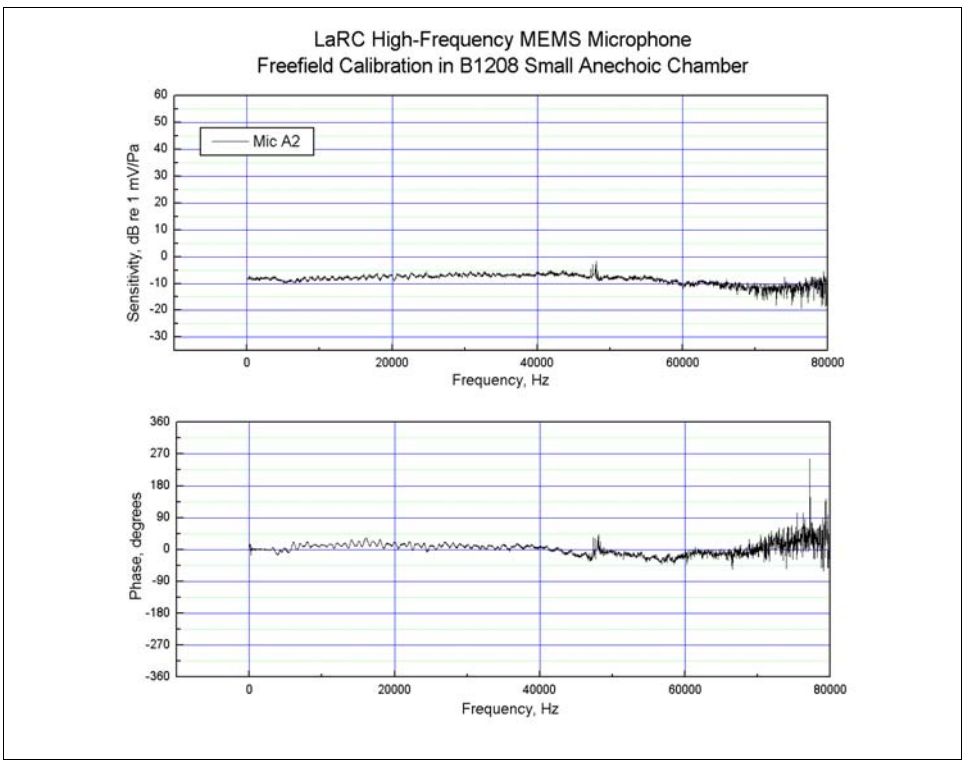

Figure 3. Representative Free-Field Response for MEMS Microphone.