

Blast-proof high sound pressure microphone

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1. Introduction

Microphones have been in use for over one century [1,2]. Various microphone types have been developed for different purposes during its long history. Electrodynamic microphone and condenser microphone are the usual types available on the market [3]. At present, there are many choices of microphones for recording in most situations. However, there are some objects which standard microphones cannot record, e.g., extremely minute sound and high sound pressure. If such sounds are needed, it is necessary to extend a microphone performance for recording them [4,5].

Advances in the media technology in the coming years are expected to provide entirely new watching and listening experience in homes [6,7]. The content of this media is expected to make a sense of being there on users. This content often deals with unusual objects, such as close range at a rocket launch or firework displays. However, it is difficult to record these events using standard microphones because the sound pressure level (SPL) is usually far higher than their maximum input SPL. Therefore, microphones with exceptional specifications are required to make such recordings.

The National Aeronautics and Space Administration (NASA) ended the space shuttle mission program in July 2011 [8]. NHK had the opportunity of shooting and recording the last two launches [9] using Super Hi-Vision (SHV) 8K images [6] with a 22.2 multichannel sound [7]. To capture more evocative sounds that describe the overall launch process in detail, we asked NASA for permission to place microphones at close range. The permissible microphone position was only 150 m from the launching pad. Thus, we were confronted with an SPL problem because the recording position was calculated to receive an SPL of around 160 dB. The maximum input SPL for a professional microphone is approximately 130 dB, which was not suitable for this recording. The target input SPL of the previously developed microphone for the high sound pressure was 150 dB [5] so that it cannot be used for the space shuttle launch. Moreover, protective measure against blast of the launch was also needed.

This paper proposes a blast-proof condenser microphone with maximum input SPL of 160 dB. We developed a method that could withstand high sound pressure. The microphone's

specifications have been measured and the results of location recordings were reported.

2. Method for resisting high sound pressure

The most important task was to suppress the distortion caused by the high sound pressure. We had to set the target input SPL at 160 dB to record the space shuttle launch without distortion. To resist this high sound pressure, we developed the following three procedures for modifying a standard condenser microphone capsule.

- i) Reduce the sensitivity by lowering the terminal bias voltage
- ii) Prevent the diaphragm from sticking to the backplate by extending the gap between the diaphragm and the backplate
- iii) Relieve any fluctuations in the atmospheric pressure due to very low frequency sound by making holes in the diaphragm

3. Fabrication of the blast-proof high sound pressure microphone

Figure 1 shows the fabricated blast-proof high sound pressure microphone with its windscreen. The inset shows the layout of the two microphone capsules within the wind screen. The total size was 390 mm (W) × 330 mm (D) × 123 mm (H), and it weighed 5 kg. We designed it as a boundary microphone, which was driven by a 48 V phantom power supply.

We installed two microphone capsules, where the maximum input SPL differed by 7 dB. This allowed us to select the appropriate capsule based on the SPL in the recording position, after considering the appropriate balance between the level margin and the S/N ratio.

To install two microphone capsules, we made the base microphone capsule from an omnidirectional lavalier microphone COS-11D (Sanken Microphone) because it is one of the most miniature standard microphone capsules. The base microphone capsule is a condenser type with an electret backplate. Its sensitivity level is -35 dB re V/Pa, and it has a maximum input SPL of 127 dB with 1% distortion. In the proposed method, we modified the microphone capsule as follows:

- i) We reduced the charge voltage of the electret from 100 V to 50 V.

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Fig. 1 The fabricated blast-proof high sound pressure microphone. The inset shows the layout of the two microphone capsules within the windscreen.

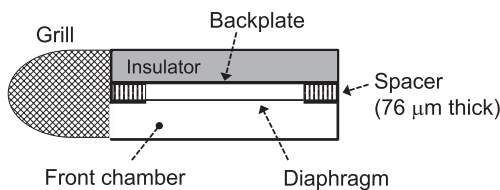


Fig. 2 Structure of the microphone capsule.

- ii) We extended the gap between the diaphragm and the backplate from $38\mu\text{m}$ to $76\mu\text{m}$.
- iii) We made four holes with a $15\mu\text{m}$ diameter in the diaphragm.

Figure 2 shows a structure of the microphone capsule. We adopted a configuration in which the sound influx direction is parallel to the diaphragm for miniaturization. The diaphragm is rectangular with dimensions of $7.4\text{ mm} \times 3.2\text{ mm}$ made from polyphenylene sulfide. The holes were made at each corner of the diaphragm at 0.5 mm from the longer side and 1.5 mm from the shorter side.

As protective measures against blast and rain, we prepared the windscreen using a nets of stainless steel, which was used to cover the microphone capsules. We lined the inside of the windscreen with water-repellent cloths to withstand the rainy weather because we were not allowed to approach the microphones for several days after they had been positioned.

4. Measurement results

All measurements were performed in an anechoic chamber, which had dimensions of $7.8\text{ m (W)} \times 7.6\text{ m (D)} \times 6.8\text{ m (H)}$, with a lower cutoff frequency of 40 Hz . The measurement distance was 2 m . The measurements were performed using a $1/2$ free-field microphone type-4191 and a pre-amplifier type-2669 (Brüel & Kjær). The microphone was driven by an amplifier, CSP-353 (Current).

4.1. Sensitivity and maximum input SPL

We prepared two microphone capsules with different sensitivities and maximum input SPLs, as described above. The first capsule's sensitivity level was -52 dB re V/Pa , and its maximum input SPL was 157.4 dB with 1% distortion. The second capsule's sensitivity level was -59 dB re V/Pa , and its

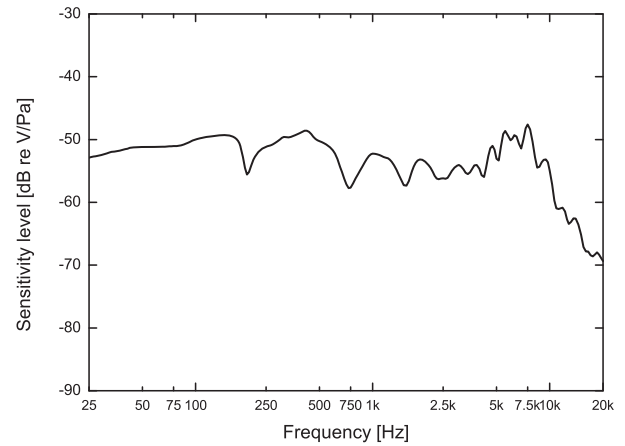


Fig. 3 Amplitude frequency response of the proposed microphone.

maximum input SPL was 163.4 dB with 1% distortion. The maximum input SPL is usually defined as the value at which distortion reaches 1% . We also estimated the maximum input SPL in the usual manner, because an SPL of 160 dB was impossible to generate in the experimental room.

4.2. Amplitude frequency response

Figure 3 shows the amplitude frequency response of the proposed microphone. The result corresponds to the microphone capsule with the higher sensitivity. The measurements were made by directing the microphone's principal axis to the loudspeaker's diaphragm.

The high end of the frequency range was 10 kHz . Sensitivity level deterioration was observed in the frequency range higher than 10 kHz . This was attributed to the loss of the microphone capsule's stiffness [2], which was caused by the extension of the gap between the diaphragm and the backplate.

Peaks and dips were considered to be a consequence of the sound reflection and diffraction caused by the windscreen and the base plate.

4.3. Directivity

Figure 4 shows the polar pattern in the horizontal plane, and Fig. 5 shows the polar pattern in the vertical plane. The direction of the principal axis corresponds to 0° .

Figure 4 shows that the proposed microphone was almost omnidirectional in the horizontal plane at a frequency range lower than 4 kHz . A sensitivity level deviation is shown in Fig. 5, with a frequency range higher than 1 kHz . This was attributed to the asymmetrical layout of the microphone capsules and the output amplifier.

The polar patterns produced by the proposed microphone had a hemispherical directivity. Therefore, we concluded that it was an omnidirectional boundary microphone.

5. Location recording of space shuttle launch

Figure 6 shows the microphone positions during the final mission of the space shuttle (STS-135) at John F. Kennedy Space Center [8,9]. We placed two blast-proof high sound pressure microphones at a distance of 150 m from the launch pad. We successfully recorded the launch sound with a sufficient peak margin and without distortion. No problems

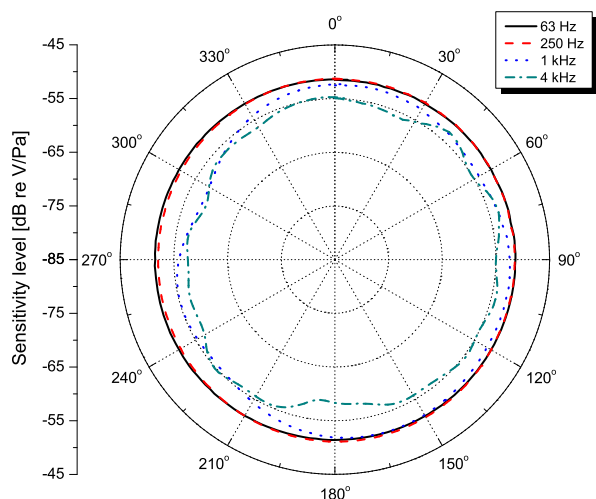


Fig. 4 Polar pattern in the horizontal plane. The direction of the principal axis of the microphone capsule corresponds to 0°.

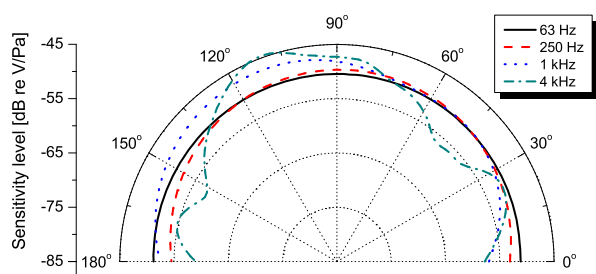


Fig. 5 Polar pattern in the horizontal plane.

caused by the blast or fluctuations in the atmospheric pressure were perceived in the recorded sound.

We confirmed that the sound quality was sufficient for program production. Moreover, the proposed microphone recorded not only the launch but the sand and rock blowing. It provided an evocative sensation of the overall launch process. We produced an SHV program using the recorded sound [9] and showed it at IBC 2011 [10]. Many visitors were satisfied with the program and the launch sound.

6. Summary

We developed a blast-proof high sound pressure microphone with maximum input SPL of 160 dB and successfully

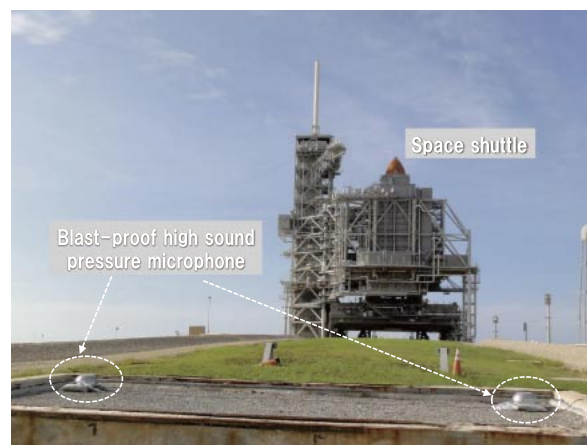


Fig. 6 Microphone positions during the final mission of the space shuttle (STS-135). The microphones were placed at a distance of 150 m from the launching pad.

recorded the space shuttle launch. In future, we will downsize the microphone and widen its frequency range.

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