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DEVELOPMENT OF A LOUD SPEAKER TYPE REFERENCE SOUND SOURCE

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ABSTRACT
Demands for sound power level measurements of noise sources are increasing. Reference sound sources are very useful for the sound power level measurements by the comparison method. We are developing a loudspeaker type reference sound source. It has six loudspeakers on the surface of a quasi- hemispherical enclosure. It is very easy to obtain a flat power response when loudspeakers are used as the sound source. Six independent noise signals are fed into six loudspeakers through six different amplifiers. This improves the directional characteristics of the source significantly compared when identical signals are fed to six loudspeakers. A monitoring microphone is placed near the center of the enclosure and the sound pressure in the enclosure is monitored. The signal level in each frequency band of each channel is adjusted automatically so that the pressure inside the enclosure, and consequently the radiated power into the external space, is kept constant. Some of the measured results will be presented.

1 - INTRODUCTION
Recent years have seen the adoption of sound power level as a means of measuring machinery and equipment noise, in addition to the conventional sound pressure level.
For measurement of sound power levels in disciplines dealing with sound fields, the comparison method based on reference sound sources is generally employed for the simplicity of measurement it provides. Furthermore, the application of reference sound sources will also be viable for measuring equivalent sound absorption area in the design of sound insulation and for measuring sound propagation characteristics. The authors are routinely involved in developing reference sound sources and have recently fabricated a prototype loudspeaker-type reference sound source and evaluated improvements over conventional loudspeaker-type sound sources.

2 - OBJECTIVE OF PROTOTYPE REFERENCE SOUND SOURCE
The prototype reference sound source system we designed and fabricated for the experiments consists of six loudspeakers arrayed in one half of an equilateral dodecahedron (Fig. 1) and the associated drive system (Fig. 2). The drive system consists of six independent channels, each including a pink-noise generator and power amplifier, to enable the sound-source loudspeakers to be driven by independent signals, differing from the conventional way, which is driven by identical signals. We considered that this arrangement would improve the directivity disturbances that are often a problem chiefly at high frequencies in a hexahedron sound source with conventional equiphase drive, and that this would also help suppress the rise in system minimum resonance frequency due to insufficient cabinet volume. Moreover, this also enables constant sound power level by placing a microphone inside the cabinet and using its output to control the cabinet internal sound pressure.

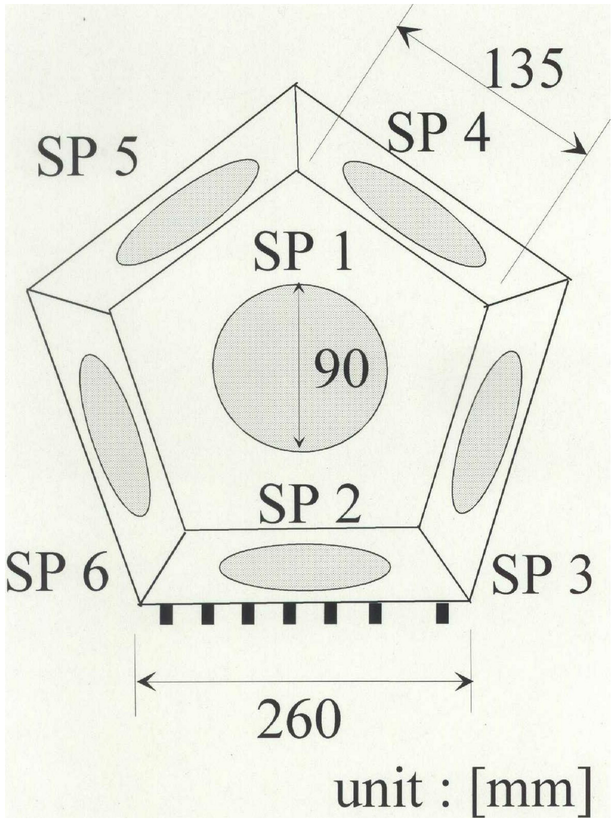


Figure 1: Prototype reference sound source.

3 - EXPERIMENT

3.1 - Changes in response frequencies of loudspeakers

A speaker system consisting of multiple loudspeakers mounted in a single cabinet and driven with equiphase signals is incapable of supplying sufficient power radiation, because insufficient cabinet volume suppresses variations in cabinet internal air pressure in the low frequencies around the lowest resonant frequency. Conscious of this problem, the authors looked closely into the changes in system resonance frequency by measuring the impedance of SP2 in the two cases of loudspeakers driven with equiphase signals and with independent and unrelated signals. Figure 3 compares the case in which SP2 alone was driven, the case in which all six loudspeakers were driven with equiphase signals, and the case in which the six loudspeakers were driven independently. When the loudspeakers were driven with equiphase signals, system resonance appeared at a higher frequency (approx. 125 Hz) than that at which resonance appeared (approx. 60 Hz) in the case of a single driven loudspeaker. When the six loudspeakers were driven independently, the resonance peak was flattened. This affirms that driving multiple loudspeakers with independent signals effectively suppresses the rise in system resonant frequency.

3.2 - Improvement of directivity

Directivity was measured in a hemi-anechoic chamber and compared for two different cases, namely, the case in which multiple loudspeakers were driven with independent signals, and the other case in which they were driven with equiphase signals. Measurements were taken on a horizontal plane (microphone placed on the floor with a 0.9-m radius) and a vertical plane (1.8-m radius). Figure 4 shows the directivities in the 2 kHz 1/3 octave band obtained in the cases in which the loudspeakers were driven with equiphase signals and in independent fashion. The disturbance in directivity caused by interference appears smooth in the case of independent drive. This leads to the conclusion that smoothing the directivities by means of independent drive will be effective in radiating energy evenly throughout a room.

3.3 - Relationships between internal sound pressure and sound power level

To determine whether control of internal sound pressure would make it possible to maintain constant sound power, the writers measured the sound power and the cabinet internal sound pressure in a hemi-anechoic chamber by varying the input power to the loudspeakers and then investigating their pro-

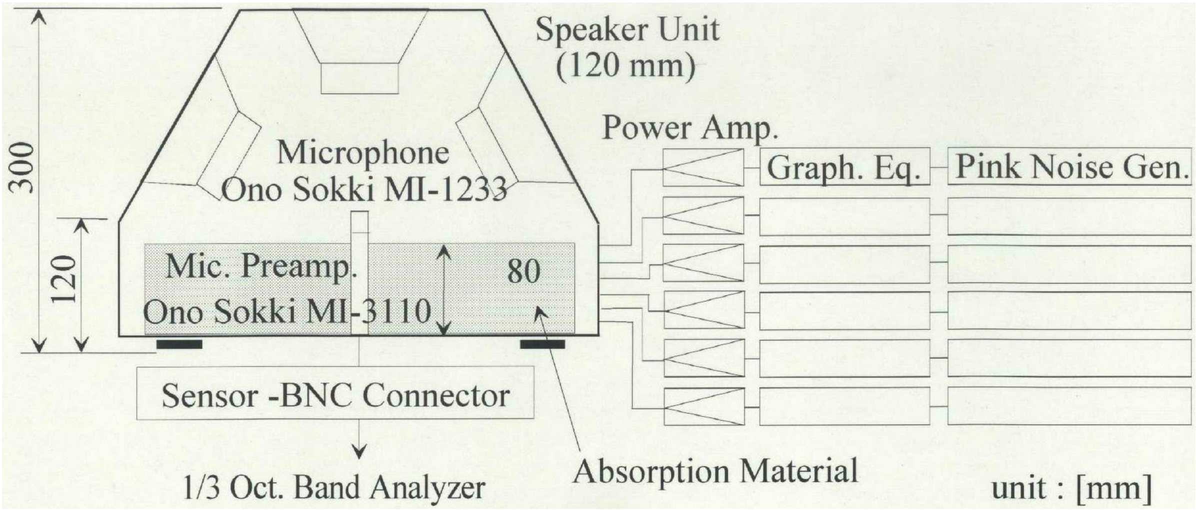


Figure 2: Drive system for reference sound source.

portional relationships. Moreover, to study the influence on sound power when reflected sound in the proximity of the loudspeakers was varied, we also measured sound power with a reference sound source installed in the center and corner (0.8 m from the wall) of a reverberation chamber. Prior to measurement, the loudspeakers were adjusted with a graphic equalizer in an anechoic chamber to flatten their radiation characteristic. Sound power was measured in compliance with the following standards:

1. Hemi-anechoic chamber ISO3745:1977

2. Reverberation chamber ISO3742:1988

Figure 5 shows the results of hemi-anechoic sound power measurement with input power varied from 0.25 W to 1 W to 4 W. The sound power increased roughly within a 5 to 7 dB range, except in the low-frequency range of 80 to 125 Hz. It is likely that the small diameter of the loudspeakers accounts for the loss in linearity at low frequencies as input power increased.
Figures 6 and 7 compare the increases in sound power and internal sound pressure. The way in which the internal sound pressure rose exhibits a similar tendency to that observed in the increase of sound power, which seems to indicate that control of internal sound pressure can be effective for calibrating sound power.

4 - CONCLUSION
We found that the loudspeakers comprising a reference sound source driven with independent signals suppress the rise in resonance frequency and improve directivity. Further, we found that control of the cabinet internal sound pressure is effective for calibration of sound power. We plan to study the possible adaptability of these findings to ISO 6926.

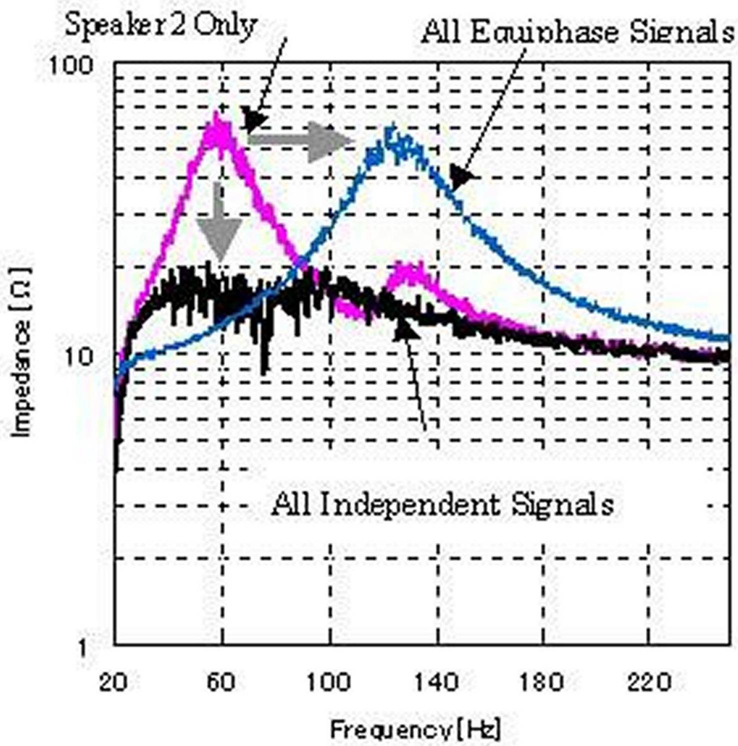
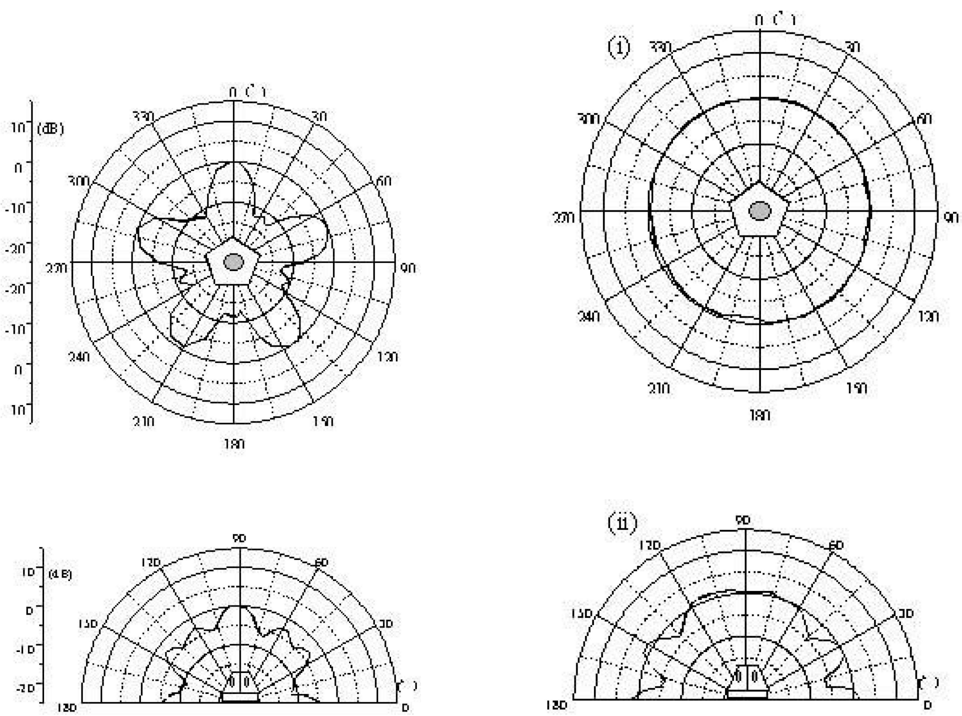


Figure 3: Changes in resonance frequency with multiple driven loudspeakers.



(a): Equiphase signals drive. **(b):** Independent signals drive.

Figure 4: Changes in directivity (2 khz, 1/3 oct. band) with multiple loudspeakers driven with equiphase signals and independent signals; (i) horizontal, (ii) vertical.

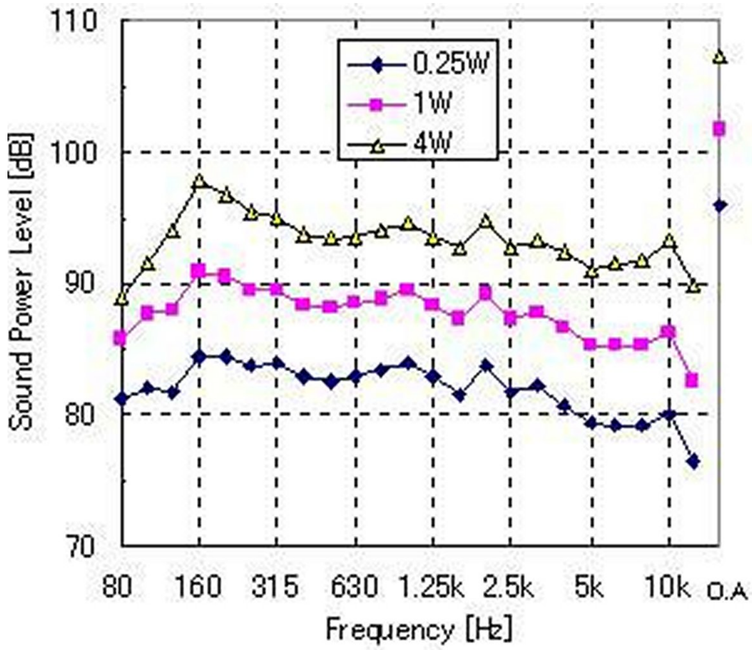


Figure 5: Results of sound power measurement in hemi-anechoic chamber.

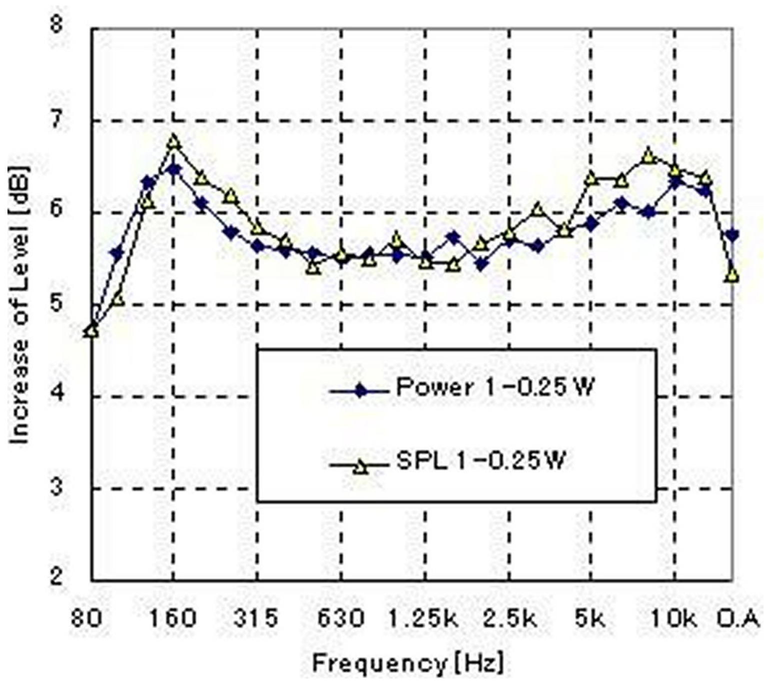


Figure 6: Comparison of increase in the sound power and internal sound pressure.

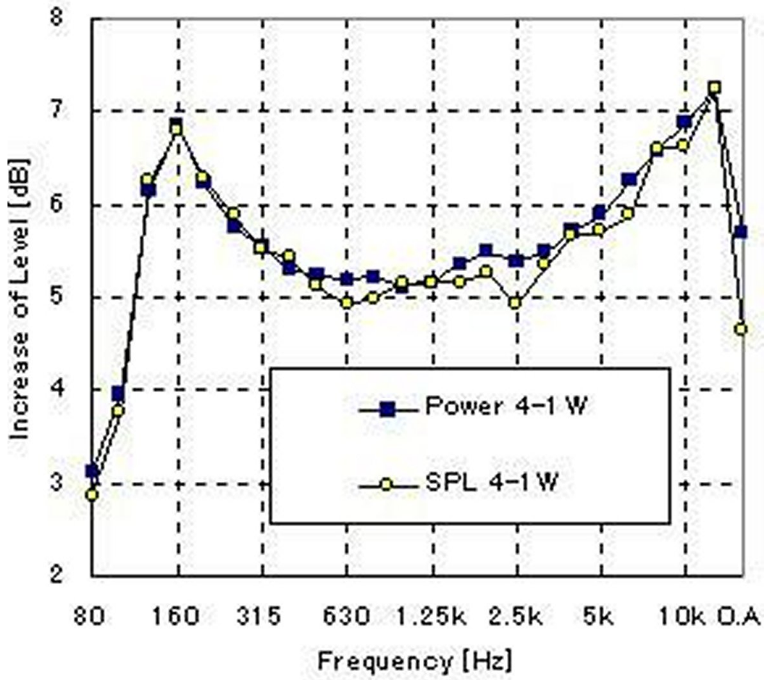


Figure 7: Comparison of increase in the sound power and internal sound pressure.