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ACOUSTICAL LETTER

The new underwater sound system for synchronized swimming: An example of The 9th FINA Swimming Championships FUKUOKA 2001

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1. Introduction

There were concerns about the difference between the underwater sound fields in a temporary fiberglass reinforced plastic (FRP) pool and that in a conventional reinforced concrete (RC) pool, as the temporary FRP pool was to be used for competitions at the World Swimming Championships in Fukuoka. We considered three items as key factors for a swimming pool for synchronized swimming: 1) the sound source itself (output level, fluctuations in frequency characteristics); 2) the effect of the materials used in the pool upon installation conditions for sound sources; and 3) effect of the *m*-th mode low-frequency cutoff in "shallow water" [1–3]. To improve the basic problems related to the first factor, we developed a new actuator-driven underwater sound system (YALAS™), which can eliminate the effect of installation conditions for underwater speakers in the FRP pool. This new underwater system has now seen practical use in competitions. The following summarizes this new underwater sound system and compares the system with conventional systems in terms of acoustic characteristics. Note that the outline dimensions of the temporary pool and details of component parts are shown in Fig. 1. Floor panels (6,900 mm × 2,000 mm) are placed on the existing RC floor of the site. Panels of 6,000 mm W × 1,500 mm H, framed at the interval of 500 mm, are double-stacked to form sidewalls.

2. Overview of the new sound system

2.1. The sound system for synchronized swimming

Figure 2 shows a schematic diagram of the system used for the competitions. The basic new sound system is composed of three sub-systems: 1) for the audience; 2) for poolside fold-back; and 3) for underwater fold-back. Underwater speakers are placed in the center of the FRP pool to avoid any attenuation of sound pressure levels and interference in frequency characteristics caused by the FRP walls.

2.2. The new sound system for synchronized swimming

To provide both sufficient sound volume and uniform sound pressure distribution in the acting area for competition, and to avoid characteristic adverse wave reflections by the FRP walls, a number of actuators were evenly mounted on the back of the sidewall at the diving platform. We intended to apply a plane wave control method to the FRP pool to use the whole area of the sidewall as a single acoustic radiator. Figure 3 shows the system configuration, and Figs. 4 and 5 the locations and distribution of actuators, respectively. To improve radiation efficiency, actuators are mounted directly on a single FRP plate (4.4 mm in thickness) with the core layer removed from the panel. Figure 6 shows the vibration characteristics of a FRP wall in air.

3. Measurements

3.1. Basic characteristic of the new sound system

Figures 7 and 8 show the measured frequency characteristics. Flat responses are depicted in the frequency range above 1 kHz (3 dB deviation between 1 kHz and 10 kHz), showing a uniform response regardless of the distance from the sound source (less than 2 dB deviation). This new sound system achieved a higher sound pressure level than that of conventional underwater speakers by approximately 10 dB. We think that the cause of the lowered sound pressure level below 300 Hz is due to the effect of the *m*-th mode low-frequency cutoff in shallow water.

3.2. Sound field characteristics

Figures 9 and 10 show the measured sound field characteristics of both conventional systems and the new underwater sound system. Regarding reverberation time (T60), no significant difference is seen between the two systems. Measurement showed that the average sound absorption coefficient is smaller than 0.1, which, if compared with a sound field in a room, could be considered the one for a comparatively live sound space. The measured echo time patterns showed appropriate attenuation with time.

The average D50s along the frequency bands (Fig. 11) for both the conventional and the new sound system are more than 40%. This fact shows that there is no significant difference between the two systems and that the new system retains sufficient audibility.

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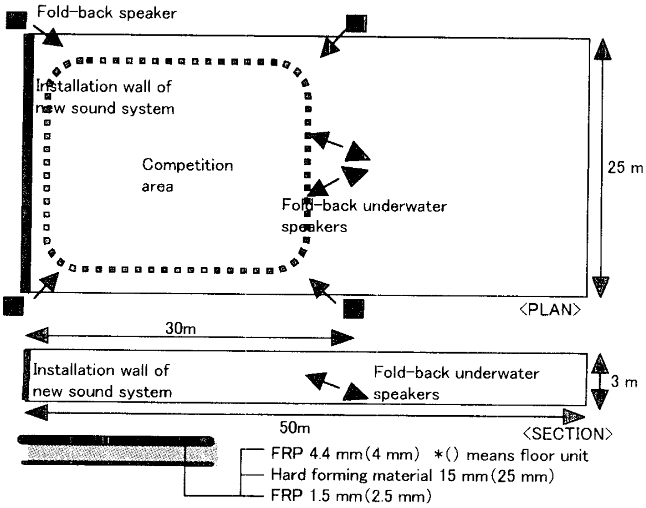

Fig. 1 Plan and section of the swimming pool.

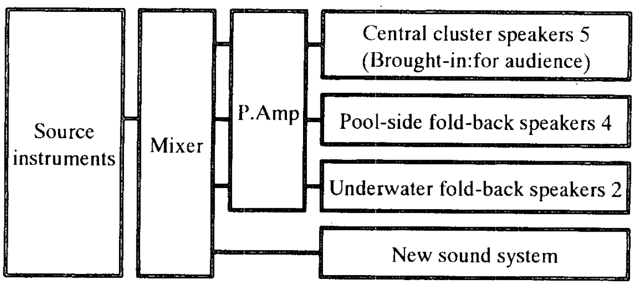

Fig. 2 Schematic diagram of the sound system.

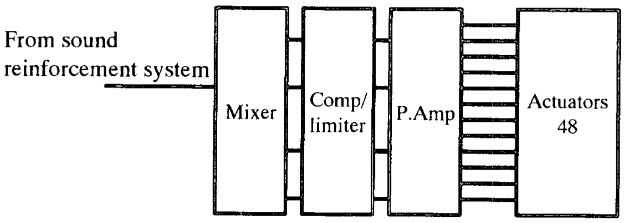

Fig. 3 Schematic diagram of the new sound system.

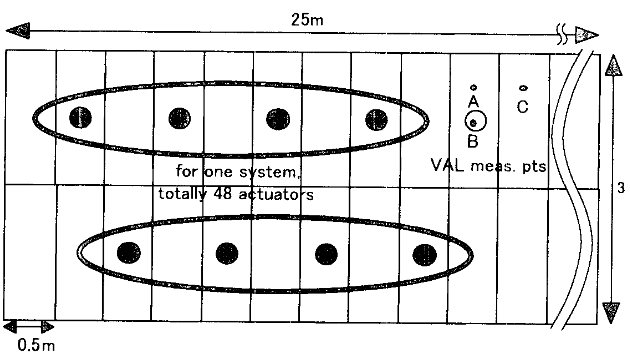

Fig. 4 Arrangement of the actuators.

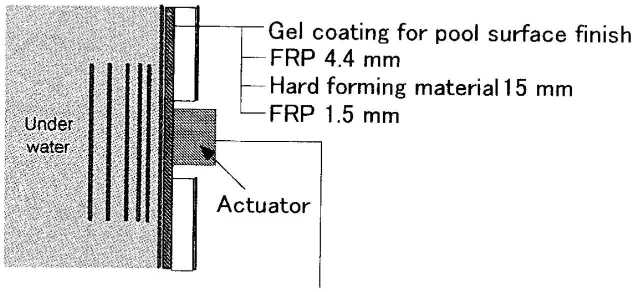

Fig. 5 Schematic arrangement of the actuators.

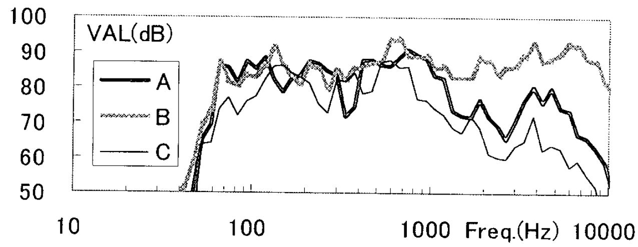

Fig. 6 Frequency characteristics of vibration of the panel.

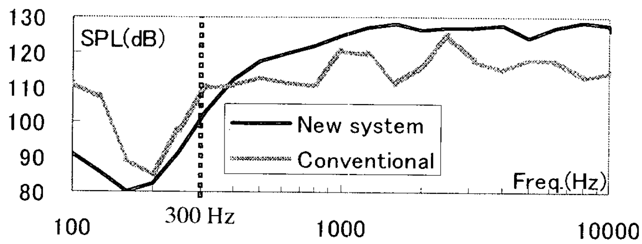

Fig. 7 Comparison of frequency characteristics of conventional and new system.

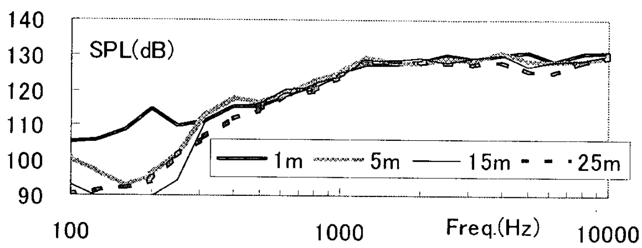

Fig. 8 Results of frequency characteristics.

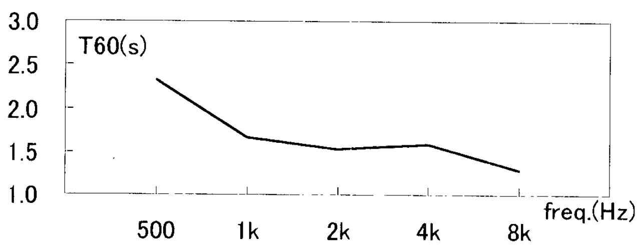

Fig. 9 Result of T60 measurement.

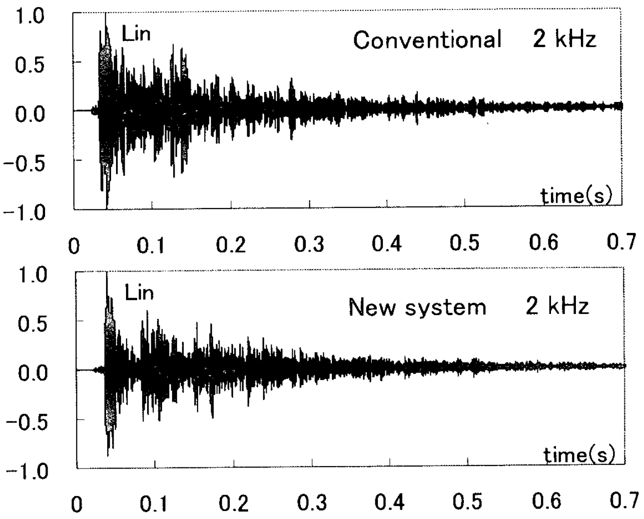

Fig. 10 Comparison of the measured echo pattern of conventional and new system.

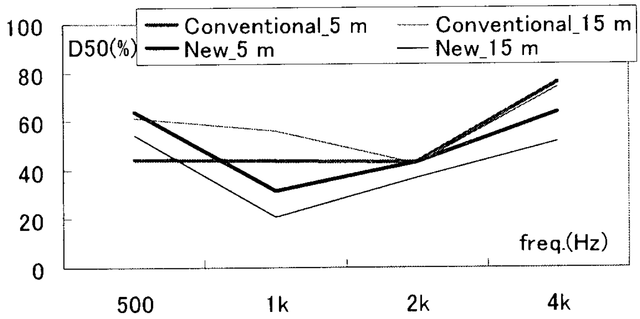

Fig. 11 Result of D50 measurement.

Table 1 Outline of The 9th FINA World Swimming Championships FUKUOKA 2001.

Venue	Marine Messe Fukuoka etc.
Auspice	Federation Internationale de Natation
Design and construction of FRP pool	YAMAHA Motor Marine Operations
Sound system operator	COL
Design of new sound system	YAMAHA Ad. Sys. Dev. Center
A period of competition	July 16–29, 2001
A period of construction	Installation 5 days, Removal 1 day

4. Conclusion

We have developed a new underwater sound system for a FRP pool, which can offer music with sufficient audibility in water when used for synchronized swimming competitions. We gained a good reputation from competitors because the new system showed superior performance to conventional systems in sound volume and sound quality, and in uniformity of sound distribution. We think there are two targets remaining for the future: 1) how to get over the constraints of the *m*-th mode low-frequency cutoff; and 2) development of a future underwater sound system that is suitable for RC pools, because this new system is not suitable for RC pools when used as it is.

References

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