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VIBRATION CONTROL METHOD OF SPEAKER ENCLOSURE AND ITS EFFECT ON REPLAY SOUND QUALITY AND SUMMING LOCALIZATION

Kiminobu Nishimura [1] and Ryuhkei Ina [2]

[1]Department of Mechanical Engineering, School of Engineering, Kinki University
Higashi-Hiroshima, Hiroshima, 739-2116, Japan
[2] Kryna & Pluton Inc.
1156-1 Kanamori, Machida, Tokyo, 201, Japan
nisimura@hiro.kindai.ac.jp

Abstract

Vibrations occurred in stereophonic equipment seems not a minor cause for harmonic distortion. In the previous report, we proposed a new method to suppress higher harmonics contained in vibration and electric and/or acoustic signals by eliminating unnecessary vibration on stereophonic equipments. Its effect on sound quality and summing localization was remarkable one.

In this report, for further improvement, we propose a new method to eliminate directly the vibration on a baffle to vibration absorbing board set behind the enclosure through a transmission system. The effects on suppression of vibrations on the speaker baffle were measured as the changes in higher order harmonics of not only vibration but also radiated sound under sinusoidal input. Then, the suppression of the harmonics distortion on the baffle realizes following improvement of sound quality related with noise reduction, increase of clearness, distinct sound, increase of voluminosity at lower frequency, decrease of overlap of before and after notes, and etc. Furthermore, three dimensional representation ability of replay sound was also improved to illustrate well the location of instruments on a stage.

1. INTRODUCTION

Recently, according to progressive development of digital signal processing techniques, like multi-channel signal, multi-bit data, higher sampling rate etc., it leads to huge information of acoustic signal. These techniques realize the feeling of being at a live performance with moving phantoms of summing localization by linking up with pictures or movies. Furthermore, they promoted miniaturize, lightweight and low price of acoustic representation system, and as a result, these equipments are in common use. But, as most of the above phantoms are recognized under the influence of pictures, the realization of the sense of distance and/or direction is open to question without pictures.

Acoustic phantoms and sound quality of reproduced sound of stereophonic equipment suffer from effects of the equipments, signal and power transmission cables, a jitter of digital audio system and *etc*. [1],[2],[3]. Then, the high order acoustic and sensational information like the distribution of acoustic sources and circumstances of recording place may deteriorate due to the above distortion factors [4]. Generally, various methods are proposed to improve the sound quality from various viewpoints, but it seems prejudiced about individual favorite sound after repeating trial and error because of unknown detail relationship between physical feature of equipments and human recognition of acoustic phantom or sound quality. So, it seems too difficult to make sure which method is proper or not.

On the other hand, the human sense of hearing can recognize source locations and their kinds [5]. The ability to recognize acoustic phantom is advanced one, which seems difficult to realize easily by using signal processing technology. Because, the ability of human sense of hearing to recognize an acoustic source location and its kind seems due to minute difference of acoustic signal buried under electric noise. When one aims estimation of acoustic source location, the quality of acoustic signal should be pure and refined one.

The above spatial information at recording site is also recorded together with main acoustic signal through microphones in a very tiny level but enough to recognize them. When one aim to represent the high order acoustic information, the background noise and harmonic distortion generated in a stereophonic equipment and other originated noises cover the spatial information and make them blurred. For ideal stereophonic representation, scene of a stage should be represented and instruments on stage will be perceived as shown in Fig. 1. Then, the represented phantoms of instruments should be fixed regardless of the listening point. For example, the location of instruments b and d owing to phantoms should be recognised at different directions depends on the listening point A and B. To realize the above ideal representation, the stereophonic system is assigned three-dimensional representation ability. In previous study, we proposed a vibration eliminating system from stereophonic equipment to an absorbent base by double spikes. Then, we found out the vibration control of equipments is effective to suppress harmonic noise and it improves sound quality.

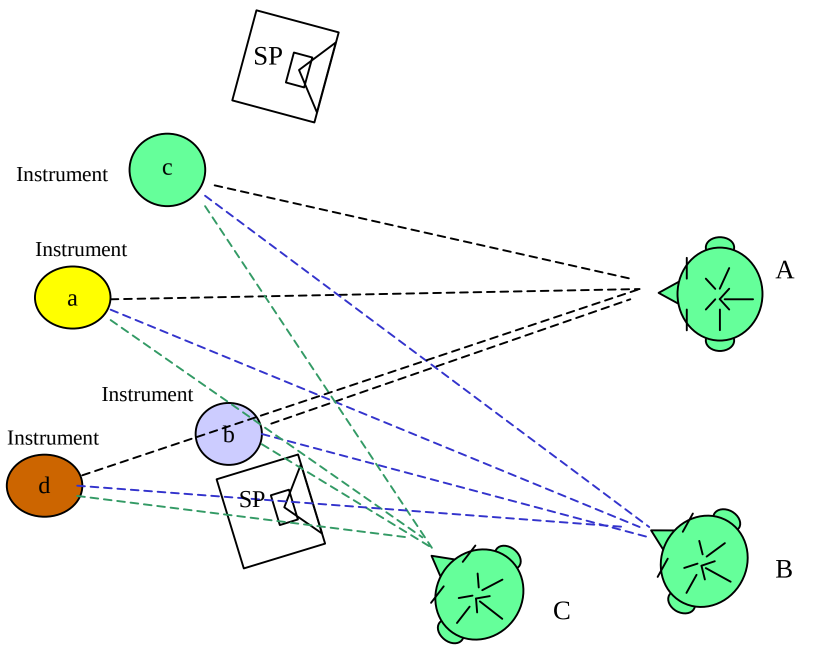


Figure 1. Ideal phantom distribution of represented stereophonic sound.

In this report, for further improvement, we propose a new method to eliminate directly the vibration on a speaker baffle to vibration absorbing board through transmission system. Its effects were measured through reduction in higher order harmonics of not only vibration on the baffle but also radiated sound under sinusoidal input. Then, the effects of suppressing the vibration or its harmonics distortion on baffle were confirmed by listening test for following improvement point on sound quality related with noise reduction, increase of clearness, distinct sound, increase of voluminosity at lower frequency, and etc. Furthermore, three-dimensional representation ability of replay sound was also improved to illustrate well the location of instruments on a stage.

2. EFFECT OF BAFFLE VIBRATION DISTURBANCE ON SPEAKER UNIT

2.1 Model of Speaker System

Speaker system is usually constructed with speaker units and enclosure. Its acoustical behavior can be illustrated by an equivalent circuit model with ideally rigid enclosure. The structure of speaker system can be illustrated as Fig. 2. The frame of speaker unit is mounted on a baffle. Actually, as the baffle is not rigid but stiff, it can be modeled by mass and stiffness. In the same way, the frame works as a spring for magnet. Furthermore, the diaphragm is suspended by two springs. Then, to illustrate the effect of baffle vibration on speaker diaphragm, we introduce a simple three-mass model of speaker system representing coupled motion of masses of diaphragm, magnet and baffle suspended by stiffness of frame, edges and baffle which is founded on rigid base as shown in Fig. 3.

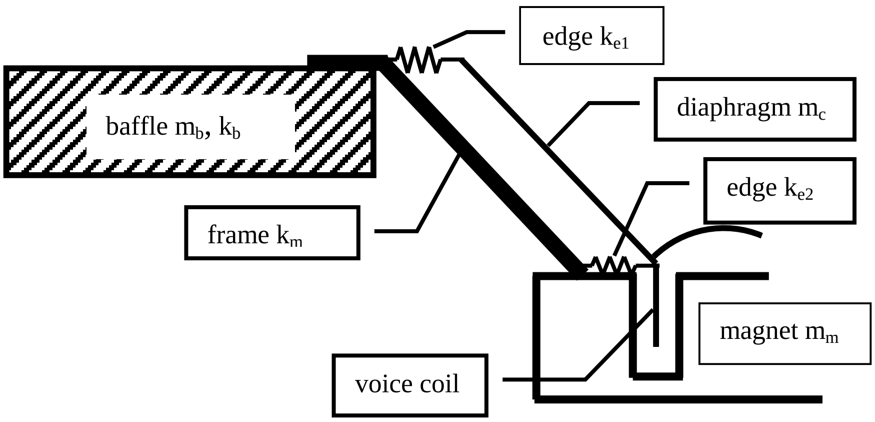


Figure 2. Model of a speaker system.

2.2 Simulation on Effect of Baffle Vibration to Speaker Diaphragm

By simplifying the above model to a two-mass model under fixed magnet, the change of the diaphragm vibration is calculated for fixed and unfixed baffle. In the calculation, Young's modulus E, density ρ, thickness h, width a and height b were set to 10^9N/m^2, 200kg/m^3, 0.02m, 0.2m and 0.3m respectively. The resonation (natural angular) frequency of speaker unit was set

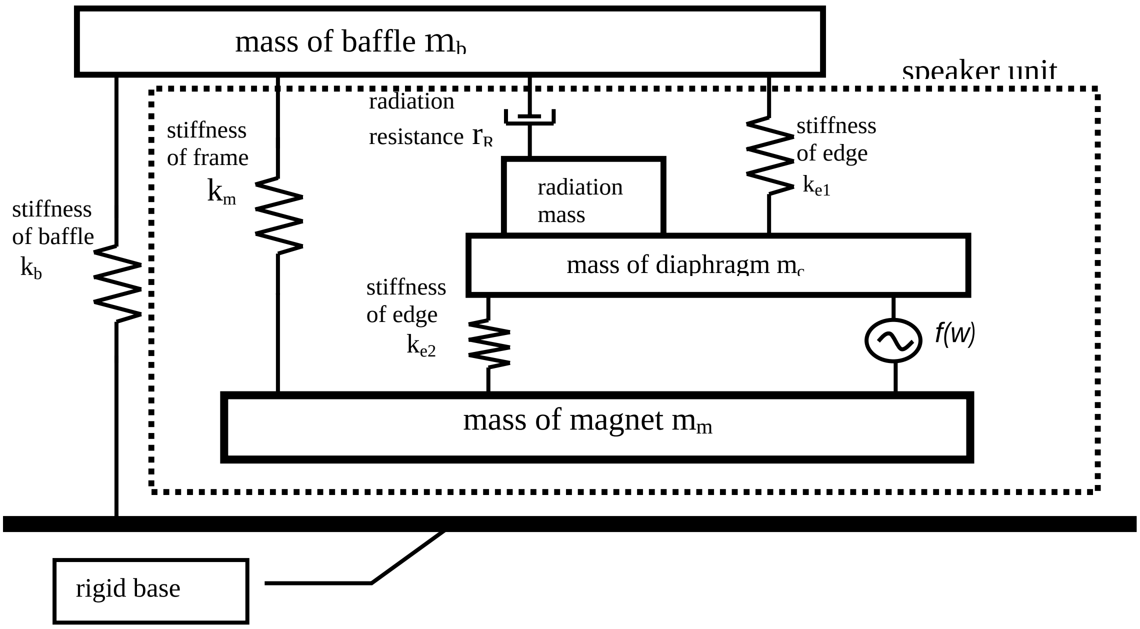
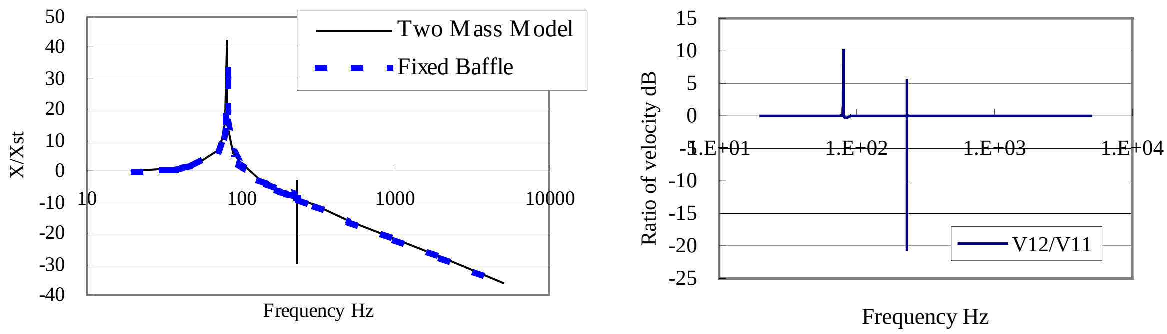


Figure 3. Three-mass model of a speaker system representing coupled motion of the diaphragm, frame, edges, magnet and baffle.

to 80Hz familiar f_0 value for 16 cm full range unit. For fixed baffle case, the model becomes one-degree-of-freedom system for fixed baffle and two-degree-of-freedom system for unfixed baffle. Comparisons of motion of diaphragm are illustrated in Fig. 4. In this figure, the magnet is assumed rigid and the baffle vibrates in principal mode (232Hz) without bending motion. In spite of considering only principal mode of baffle, it affects the motion of diaphragm as shown in Fig. 4. Higher mode will cause more harmonic distortion that disturbs acoustic signal.



(a) Vibration amplitude of diaphragm. (b) Difference of vibration velocity.

Figure 4. Comparison of difference in vibration of diaphragm under fixed and unfixed baffle.

3. VIBRATION CONTROL OF BAFFLE AND ITS EFFECT

3.1 Schematic Diagram of Clamp System

As mentioned in the previous section, it is obviously effective to suppress vibration on the baffle to preserve the quality of radiated sound. Though, there are many insulation systems and spikes to insulate the speaker system from external vibration excitation, they can't eliminate the disturbing vibration occurred in speaker system itself. The spike system set under a speaker system will eliminate inner vibration to its outside but only up-and-down direction which is right angle one against to that of speaker diaphragm motion. So, it is reasonable to eliminate the vibration along to the same direction of diaphragm motion. That is, it seems most effective to eliminate the vibration from baffle to absorbing board because of same direction to diaphragm motion. Figure 5 illustrates a new system to eliminate disturbing vibration on the baffle by using a vibration absorbing board, a clamp and spikes.

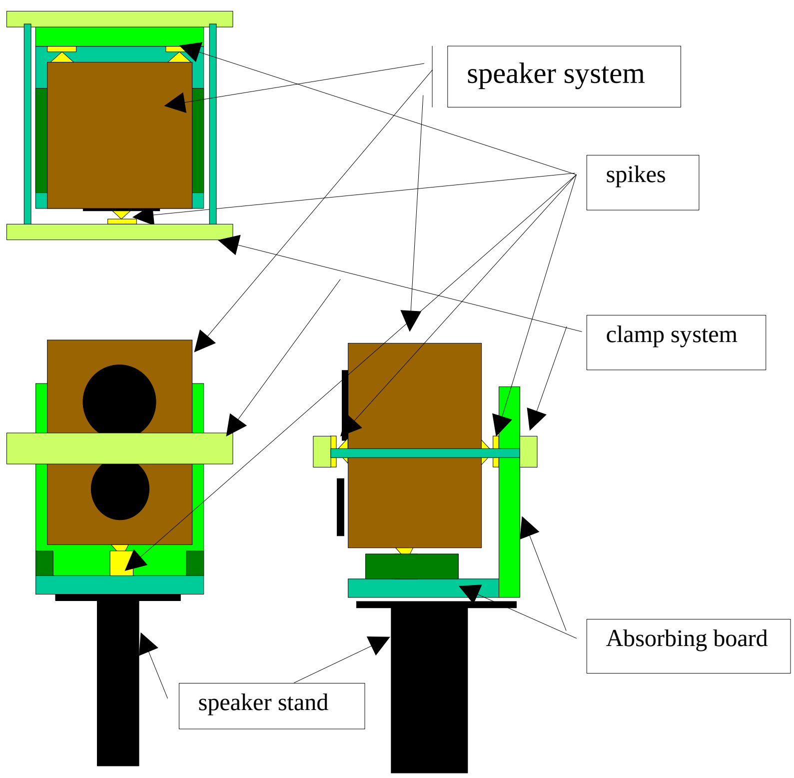


Figure 5. Clamp system.

3.2 Effects on Suppressing Baffle Vibration and Harmonics of Radiated Sound

3.2.1 Effect of Vibration Control on Speaker

Table 1 shows vibration level on baffle of speaker system comparing the difference in supporting methods with clamp system and double spikes under several sinusoidal inputs. Since suppressed vibration level on the baffle is better, the negative value of difference $\Delta\varepsilon$ illustrates improvement in vibration in this table. The clamp system is effective to suppress vibration of baffle. Table 2 shows comparisons of signal level and higher harmonics contained in radiated sound between clamp system and double spikes under sinusoidal input of 1 and 2 kHz. Though, the signal level should be higher level, the harmonic distortion should be suppressed lower as possible. In this table, “improvement” means amount of attenuation of harmonics relative to signal level between two methods. So, plus value of “improvement” illustrates the improvement by clamp system. According to this result, clamp system seems effective to radiate signal sound and to suppress higher harmonics. The frequency transfer function of speaker system was also measured under white noise input. Table 3 shows the average values and variances of those frequency transfer functions. In this table, the clamp system seems slightly effective and stable for transmitted signal but it is not so clear.

Table 1 Difference in vibration level on baffle with and without clamp system.

frequency of input signal [Hz]	with clamp system	double spikes	difference $\Delta\varepsilon$	notes
60	-84.84	-82.82	-1.96	no signal
100	-37.13	-34.61	-2.52	
1000	-74.08	-67.06	-7.02	
2000	-71.59	-73.46	1.87	
5000	-59.00	-62.72	3.72	
10000	-78.09	-63.10	-14.99	

[dB]

Table 2 Signal level and harmonic distortion of radiated sound and improvement index.

frequency [Hz]	clamp system	double spikes	improve-ment	frequency [Hz]	clamp system	double spikes	improve-ment
1000	-6.64	-9.86	3.22	2000	-6.17	-6.24	0.07
2nd	-31.78	-31.51	3.48	2nd	-25.48	-32.19	-6.64
3rd	-50.76	-54.39	-0.41	3rd	-63.97	-57.57	6.47
4th	-68.47	-67.55	4.13	4th	-76.18	-75.64	0.61
5th	-69.63	-70.76	2.08	5th	-86.34	-88.79	-2.38
6th	-87.26	-86.56	3.91	6th	-91.25	-90.62	0. 70
7th	-88.48	-88.15	3.55	7th	-92.69	-94.46	-1.70

[dB]

Table 3 Mean values and variances of frequency transfer function of radiated sound.

suspention method	mean value	variance
clamp system	-10.02	6.26
double spikes	-10.28	6.90

[dB]

3.3 Listening Test on Sound Quality and Phantoms

As mentioned above, the vibration control seems effective to suppress higher harmonics and background noise. So, to evaluate the effect of physical changes on stereophonic equipments to the reproduced sound, we carried out listening test. From several types of music CD on the market, which can illustrate well the spatial distribution of sound sources, an orchestra performance with vocal (comp.: Manuel de Falla, title: El sombrero de tres picos, Ballet: Introduction, orchestra: Orchestre symphonique de Montreal, cond.: Charles Dutoit) was employed as test signals. Two loudspeakers (Audience42, DYNAUDIO) were arranged in the standard stereophonic arrangement with base angle about 60 degrees and stereo base distance 2.0m. The listening tests were carried out in an ordinary listening room with good quality of sound absorption behind the speakers. Five healthy adults working in audio shop were employed as subjects. The subject illustrates the distribution and stretch of phantoms to specified instruments appeared in the test music on the front view and plane view sheets. Samples of illustrations by fifth subject are shown in Fig. 5. And each subject also answers a questionnaire on words of sound quality. The words were selected from literature [6],[7] and newly added appropriately.

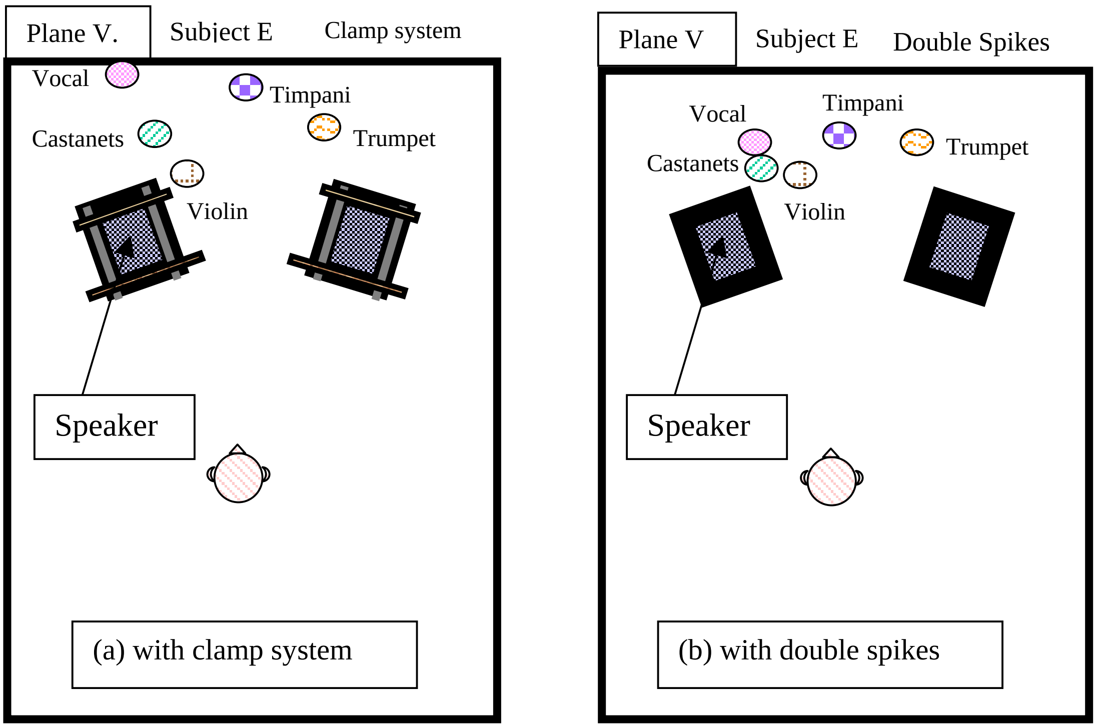


Figure 6. Difference in reproduced acoustic phantom recognition with clamp system and double spikes to support speaker systems.

3.3.1 Effect of Vibration Control on Distribution of Phantoms

Figure 6 shows an example of plane view illustrating the distribution of images on reproduced acoustic phantoms for two cases of speaker supporting systems. This figure illustrates the difference in location and stretch of phantoms on violin, castanets, trumpet, timpani, and vocal in an orchestra performance for clamp system and double spikes vibration control of speaker system. The clamp system could illustrate well the spatial distribution of each instrument on the stage, than those of double spikes. That is, in Fig. 6(a), the subject can recognize the distribution of instruments on the stage well, but it becomes difficult one in (b). There were clearer distinctions about the acoustic phantoms reproduced by summing localization in case (a) than (b). By vibration control, the phantoms come to sharp and clear one. And the difference between their locations was more emphasized.

Table 4 Evaluation words of questionnaire and results of sound quality test.

Evaluation words	Mean Value		Variances	
	Clamp	W Spikes	Clamp	W Spikes
Resolution	3.4	2.8	0.24	0.26
Depth	3.5	2.5	0.1	0.2
Expanse	3.5	2.6	0.2	0.24
Elevation	3.6	2.7	0.04	0.06
Band width	3.6	3.1	0.14	0.24
Lightness	3	3	0.1	0.4
Smoothness	2.8	2.9	0.16	0.14
Silentness	2.7	3	0.46	0.4
Quality	3.6	2.2	0.24	0.96

3.3.2 Effect of Vibration Control on Judgement of Sound Quality

Listening test was carried out by filling a questionnaire on words of sound quality with use of the same system as mentioned in previous section. Each evaluation word was scored 5 step points from 1 to 5. In this test, the criterion of judgement was set up on other higher quality speaker system and its evaluation were set to highest value 5. Table 4 shows the words of questionnaire and numeric results of judgement. In this table, larger values mean improvement of sound quality. Figure 7 shows its radar graph of sound quality test.

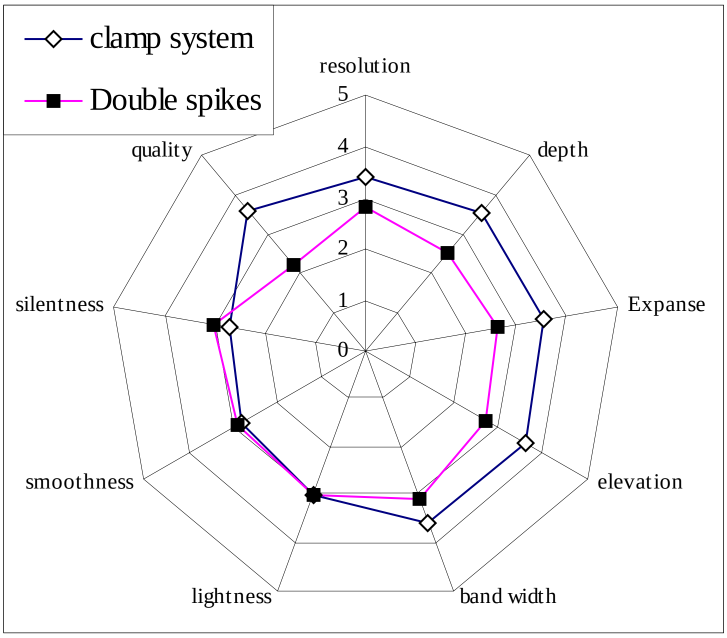


Figure 7. Results on sound quality test of clamp system comparing with double spikes.

Comparing the result from Tables 1 to 4, the suppression of vibration on baffle provides higher quality of reproduced sound. Then, the vibration control seems effect-tive to improve the sound quality and 3-dimentional representations by stereophonic equipments.

4. CONCLUSIONS

In this study, human listening ability to recognize phantoms as summing localization for stereophonic sound transmission process will change owing to the distortion originate in higher harmonics and S/N. By comparing the results on change in physical feature and reproduced sound quality and acoustic phantoms under clamp system and double spikes system vibration control, following results are obtained:

1) The clamp supporting system for speaker emphasizes signal but suppresses the obstacle vibration like higher harmonics on the baffle.
2) The clamp supporting system improves the S/N, sound quality and summing localization of reproduced stereophonic sound than those of double spikes.
3) The frequency transfer function dose not illustrate the difference between two supporting system.

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