Analysis of Loudspeakers Directivity Diagram versus frequency and Impact to Sound Systems Effectiveness

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***Abstract**: The directivity diagram of loudspeakers is important parameter when acoustic engineer starts to design loudspeakers grid used in masking or public address systems. The key factor when we talking about closed premises is the placement of the loudspeakers and his directivity pattern. That is why during the early 1960s many researches were made by companies like JBL and TOA at loudspeaker directivity pattern. The aim was to create wide band loudspeakers to respond the sound masking systems wide spectrum that also has enough acoustic power to cover maximum floor area and to create homogeneously sound ambiance. This will alleviate the engineer design and the total quantity of the speakers which will make the entire system less complex and more effective. Now in this topic we will check and examine the directivity pattern of three types of loudspeakers according to the generated frequencies from sound masking systems. The most common methods to obtain the frequency response and directivity pattern are Swept Sine method, MLS method and RTA method. We are going to use the RTA (Real time analyzer) method which gives practical results in real acoustic ambiance.*

Keywords: ***loudspeaker directivity, real time analyzer, directivity pattern***

1. INTRODUCTION

Human ears are sensitive to sound radiated from loudspeakers, and loudspeakers are sensitive to frequencies which they must produce [1] and [2]. Here in this article are analysed the loudspeaker directivity diagram especially regarding to the sound masking systems. The directivity diagram of loudspeakers can be used for increasing the effectiveness of sound masking, choosing the loudspeakers with wider band and constant SPL at wider angles. Know this is possible to use the laws of physics [3] and [4] to put some requirements of "*long throw*" loudspeakers with high directive diagrams. Because here are investigated masking systems which generates white/pink noise the most important requirement is to have speaker with most wideband frequency response.

2. MODEL DESCRIPTION OF THE PROPOSED RTA METHOD

The proposed real time measurement method to test loudspeakers is based on a set of signal generator, turntable, Omni-directional microphone and RTA software. The coordinate system used for current measurements is presented in Fig.1, P_0 – microphone position, P_1 – speaker position and d = 1m are components of the horizontal plane.

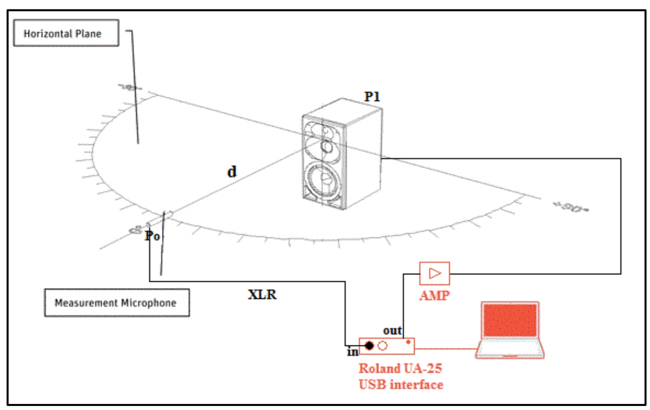

Fig. 1. Coordinate systems used in directivity pattern measurement

The directivity pattern is presented here with the following equations if *d* is keeping constant (*d* =const) [5]:

$$p(f, J);\ \ p(f, J) / p(f, J=0);\ \ p(f, J) / p_{max}(f), \qquad (1)$$

The equations (1) present the loudspeakers directivity dependence from frequency and angle *J* in polar or half polar coordinate system.

For loudspeakers directivity can be defined also the following three characteristics: *direction factor Q(f); direction index DI(f)* and *beam width angle*.

3. Algorithm of the Proposed RTA Method for Directivity pattern

In the proposed RTA algorithm for measurements and analysis of loudspeakers directivity pattern the radiated from loudspeaker sound waves are presented with the following equation and as model of a disk or short cylinder fitting in a tube and moving in time *t* up and down in a tube with radius *r*, in direction θ:

$$p(r,\theta,t) = j\rho c\frac{Qk}{2\pi r}e^{j(wt-kr)}\left[\frac{2J1(ka\sin\theta)}{ka\sin\theta}\right] \quad (2)$$

Using the equation (2) in the developed algorithm are calculated loudspeakers directivity patterns depending on radiated from loudspeaker sound waves separated on the frequency ranges: low (isotopically radiated); medium (direction of radiation increased) and high frequencies (narrower and side lobes appear in radiation), shown on Fig.2, Fig.3 and Fig.4, respectively.

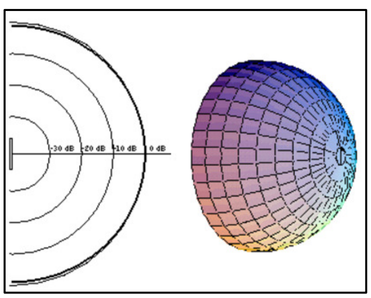

Fig.2. Directivity pattern at low frequencies

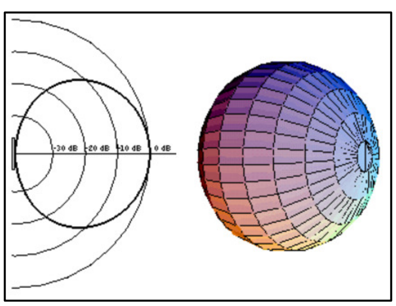

Fig.3. Directivity pattern at medium frequencies

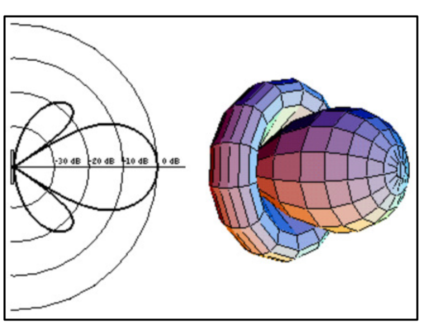

Fig.4. Directivity pattern at high frequencies

4. Experimental Results

4.1. Results from CV608-6.5" speaker

The proposed algorithm for determine the directivity pattern is tested with three different speakers. The first speaker – CV608 is low cost 6.5" driver used in mass public address systems; the second one ARX-08 is 4.5" midrange Hi-Fi speaker and last one ARN226-08 is 8" Hi-Fi bass driver.

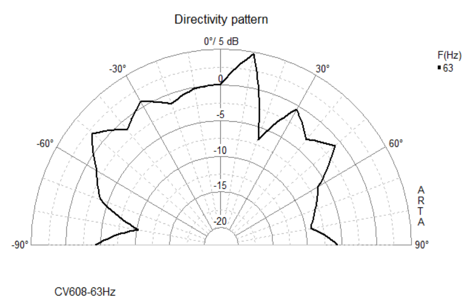

Fig. 5. CV608 directivity pattern in 1/3 – 63 Hz

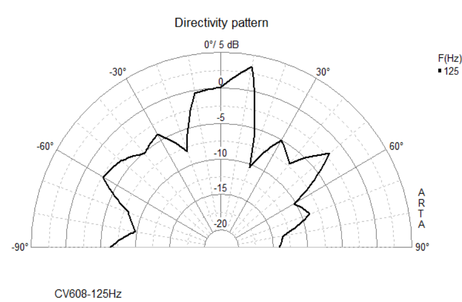

Fig. 6. CV608 directivity pattern in 1/3 – 125 Hz

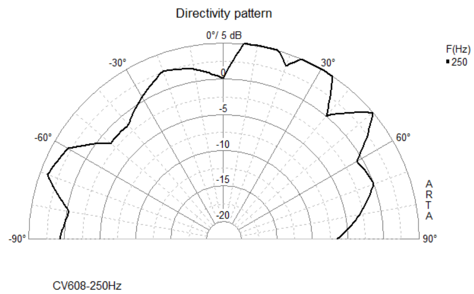

Fig. 7. CV608 directivity pattern in 1/3 – 250 Hz

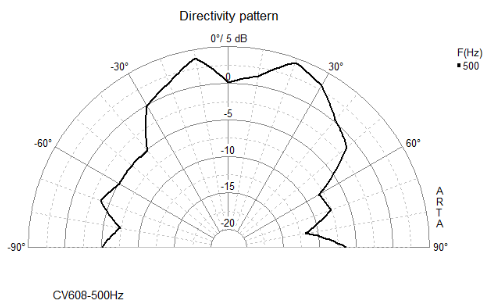

Fig. 8. CV608 directivity pattern in 1/3 – 500 Hz

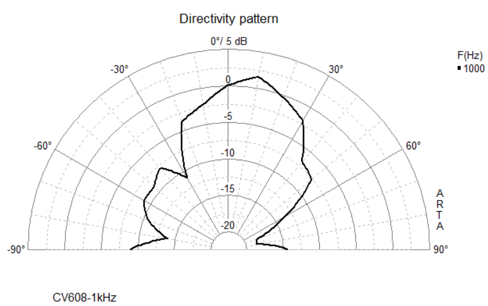

Fig. 9. CV608 directivity pattern in 1/3 – 1 kHz

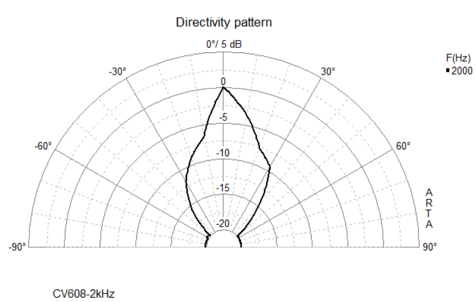

Fig. 10. CV608 directivity pattern in 1/3 – 2 kHz

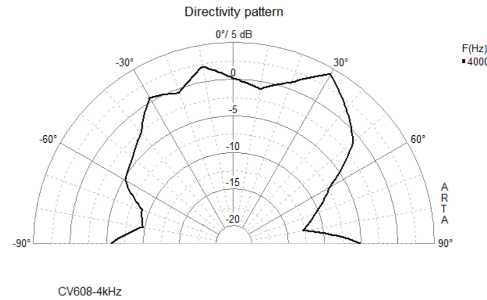

Fig. 11. CV608 directivity pattern in 1/3 – 4 kHz

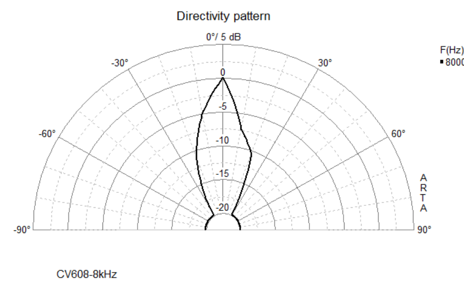

Fig. 12. CV608 directivity pattern in 1/3 – 8 kHz

4.2. Results from ARX-4.5" speaker

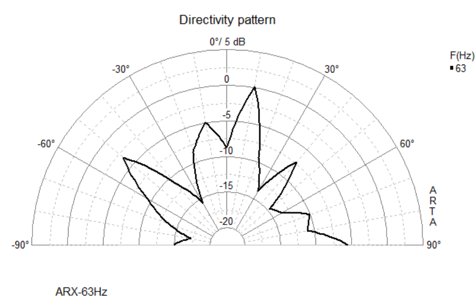

Fig. 13. ARX directivity pattern in 1/3 – 63 Hz

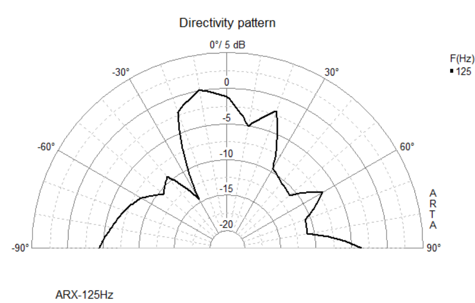

Fig. 14. ARX directivity pattern in 1/3 – 125 Hz

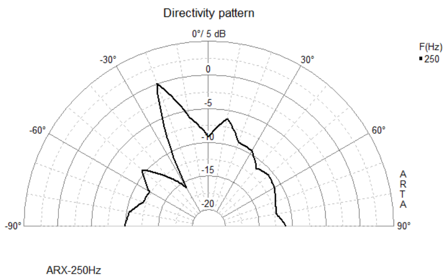

Fig. 15. ARX directivity pattern in 1/3 – 250 Hz

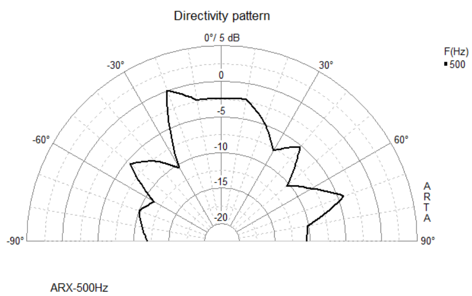

Fig. 16. ARX directivity pattern in 1/3 – 500 Hz

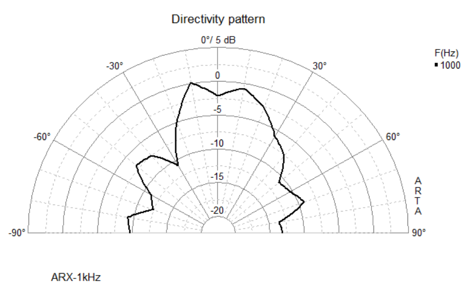

Fig. 17. ARX directivity pattern in 1/3 – 1 kHz

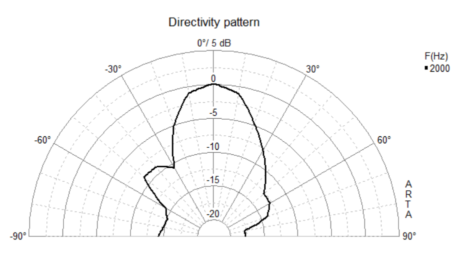

Fig. 18. ARX directivity pattern in 1/3 – 2 kHz

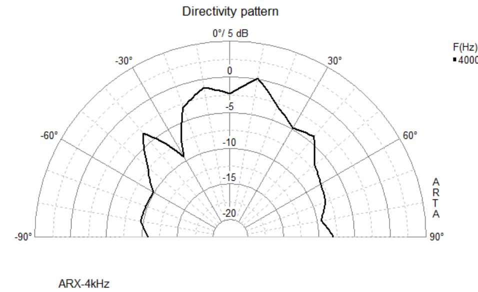

Fig. 19. ARX directivity pattern in 1/3 – 4 kHz

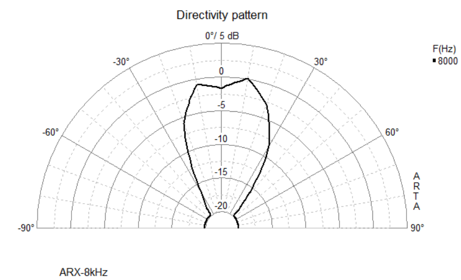

Fig. 20. ARX directivity pattern in 1/3 – 8 kHz

4.3. Results from ARN-226-8" speaker

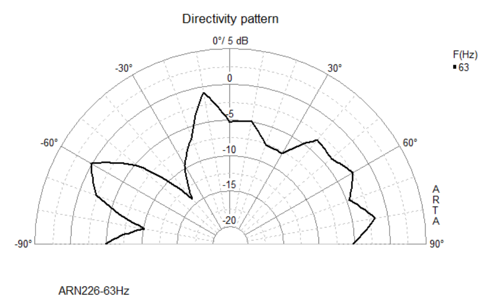

Fig. 21. ARN-226 directivity pattern in 1/3 – 63 Hz

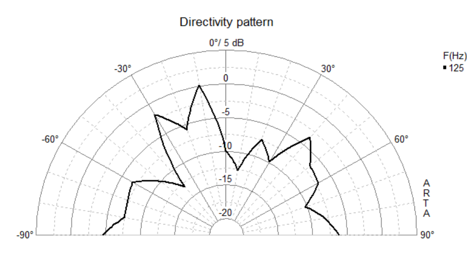

Fig. 22. ARN-226 directivity pattern in 1/3 – 125 Hz

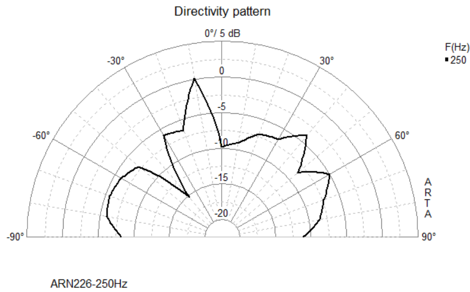

Fig. 23. ARN-226 directivity pattern in 1/3 – 250 Hz

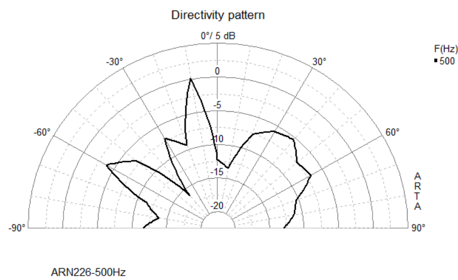

Fig. 24. ARN-226 directivity pattern in 1/3 – 500 Hz

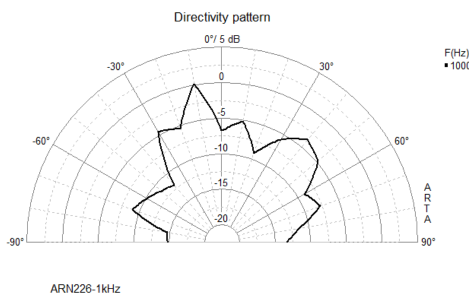

Fig. 25. ARN-226 directivity pattern in 1/3 – 1 kHz

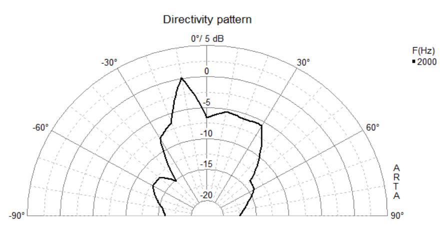

Fig. 26. ARN-226 directivity pattern in 1/3 – 2 kHz

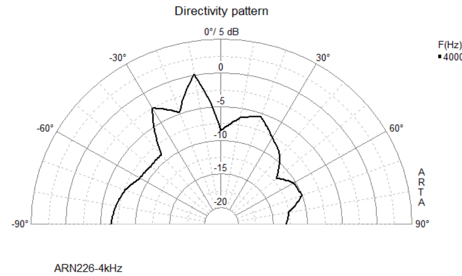

Fig. 27. ARN-226 directivity pattern in 1/3 – 4 kHz

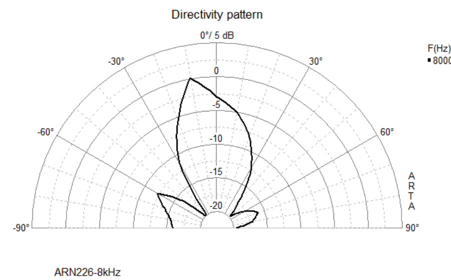

Fig. 28. ARN-226 directivity pattern in 1/3 – 8 kHz

4.4. Results explanation

Table1. Results of direction factor – *Q* and direction index – *DI* extracted from the three measurements

	CV608-6.5”		ARX-4.5”		ARN226-8”	
Fr 1/3, Hz	**Q**	**DI,dB**	**Q**	**DI,dB**	**Q**	**DI,dB**
63	0.96	-0.2	0.45	-3.4	0.62	-2.1
125	1.47	1.7	1.82	2.6	0.26	-5.9
250	0.39	-4.1	0.42	-3.8	0.29	-5.4
500	0.92	-0.4	1.52	1.8	0.19	-7.3
1000	2.08	3.2	1.65	2.2	0.64	-1.9
2000	3.99	6	3.19	4.9	0.77	-1.1
4000	1.03	0.1	1.44	1.6	0.39	-4.1
8000	4.34	6.4	2.27	3.6	1.85	2.7

In table 1 are shown results from the directivity pattern measurements of the selected speakers. It is obvious that the *DI* is received by *Q* which is the reason to pay more attention at him.

After comparing the *Q* of the three speakers we can expose that ARX has the best *Q* and probably must be the logical choice. But this will be a mistake because if we lower the frequency the beam effect will be less and vice versa if we higher the frequency the beaming effect will be stronger. Logically the small diameter of a full range loudspeaker like the ARX shows less beaming with high frequencies occurs - higher Q. But the smaller diameter of the diaphragm is less powerful and need larger coil movement to put out the appropriate energy. This means that ARX it is not the best choice when we start designing sound masking system in office building with huge open space inside.

That is why we must choose our driver between ARN226 and the low cost CV608. Again after comparing the Q we can conclude that ARN226 is the better one at low frequency which makes him good option if we designing a 2-way loudspeaker box. But we don't design Hi-Fi box and if we look at the Q of the CV608 we can see that this speaker has the optimal direction factor from 500 – 8000 Hz. Now if you remember our requirement that we state in the beginning of the topic that the loudspeaker must have most wideband frequency response it seems that the CV608 is the most right choice. This match the mandatory rule in Professional Audio/Masking systems for speakers to have good Q and to provide enough SPL because of the emergency cases.

5. CONCLUSION

The proposed in this topic RTA method with low cost test bench provides good results for selecting proper loudspeaker for sound masking systems or public address systems. The used method based on conducted measurement is helping to take a closer look to directivity pattern and can be useful for checking the manufacturer specifications. For achieving more precise results an anechoic chamber can be used to eliminate all negative reflections committed during measurements.

ACKNOWLEDGEMENT

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