Manual on the Code of the Book Entitled "Acoustic Waves Generated by Parametric Array Loudspeakers"

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Contents

1 Introduction

This document introduces the usage of the code package, which is a supplementary material for the book “Acoustic Waves Generated by Parametric Array Loudspeakers”. All demos and functions were tested by MATLAB R2022b installed on a personal computer with an AMD Ryzen Threadripper 3960X central processing unit (CPU) with 256 GB of random access memory (RAM).

1.1 Installation

Steps:

1. Download all codes from GitHub: JiaxinZhong/AWPAL
2. Run the script AWPAL.m at first to add subfolders to the path.

2 Demo Scripts and Core Functions

2.1 Direct Integration Method (DIM)

2.1.1 Ultrasound Field

2.1.1.1 General Solution

Function: DIM3D.m The calculation utilizes the Rayleigh integral reading that [1, Eq. (2.39)]

$$p_i(\mathbf{r}) = \frac{\rho_0 \omega_i}{2\pi \mathrm{i}} \iint_{-\infty}^{\infty} v_{i,z}(\mathbf{r}_\mathrm{s}) \frac{\mathrm{e}^{\mathrm{i}k_i|\mathbf{r}-\mathbf{r}_\mathrm{s}|}}{|\mathbf{r}-\mathbf{r}_\mathrm{s}|} \mathrm{d}^2\mathbf{r}_\mathrm{s}. \tag{1}$$

2.1.2 Audio Sound Field

2.1.2.1 General Solution

2.1.3 Function: PalDIM3D.m

$$p_{\mathrm{a}}(\mathbf{r}) = -\frac{\beta\omega_{\mathrm{a}}^2}{4\pi\rho_0 c_0^4}\iiint_{-\infty}^{\infty}\frac{p_1^*(\mathbf{r}_{\mathrm{v}})p_2(\mathbf{r}_{\mathrm{v}})}{|\mathbf{r}-\mathbf{r}_{\mathrm{v}}|}\mathrm{e}^{\mathrm{i}k_{\mathrm{a}}|\mathbf{r}-\mathbf{r}_{\mathrm{v}}|}\mathrm{d}^3\mathbf{r}_{\mathrm{v}}. \tag{2}$$

2.1.3.1 On-Axis

Demo: PalDIM3D_CircSrc_Axis_Demo.m Figure 1 is generated by this demo file. The data is stored in file PalDIM3D_CircSrc_Axis_Demo_Uniform.mat.

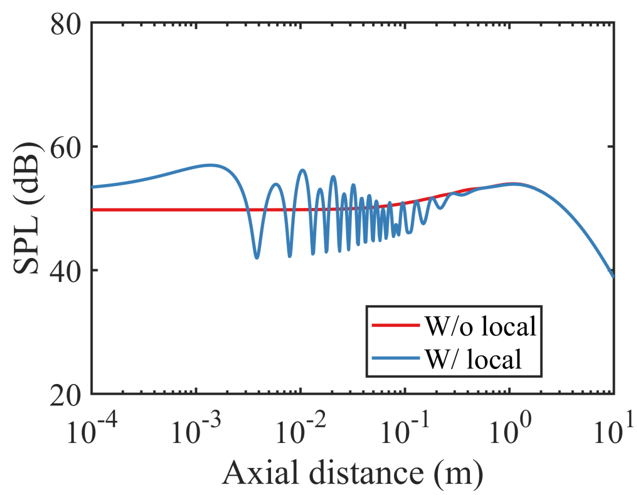

Figure 1: On-axial SPL (dB) as a function of the axial distance (z, m) [2, Fig. 2(d)]. The PAL has a circular uniform profile with a radius of $a = 0.1\,\mathrm{m}$.

Figure 2 is generated by this demo file. The data is stored in file PalDIM3D_CircSrc_Axis_Demo_Focus.

Function: PalDIM3D_CircSrc_Axis.m Calculate the audio sound field on the axis $\rho = 0$ using the DIM. The source profile is assumed to be axisymmetric in the azimuthal direction, i.e., $v_{i,z}(\mathbf{r}_{\mathrm{s}})$ is independent of φ_{s}. The formula used in this function is

$$p_{\mathrm{a}}(\rho = 0, \varphi, z) = -\frac{\beta\omega_{\mathrm{a}}^2}{2\rho_0 c_0^4}\int_{-\infty}^{\infty}\int_0^{\infty}\frac{p_1^*(\mathbf{r}_{\mathrm{v}})p_2(\mathbf{r}_{\mathrm{v}})}{\sqrt{\rho_{\mathrm{v}}^2+(z-z_{\mathrm{v}})^2}}\mathrm{e}^{\mathrm{i}k_{\mathrm{a}}\sqrt{\rho_{\mathrm{v}}^2+(z-z_{\mathrm{v}})^2}}\rho_{\mathrm{v}}\mathrm{d}\rho_{\mathrm{v}}\mathrm{d}z_{\mathrm{v}} \tag{3}$$

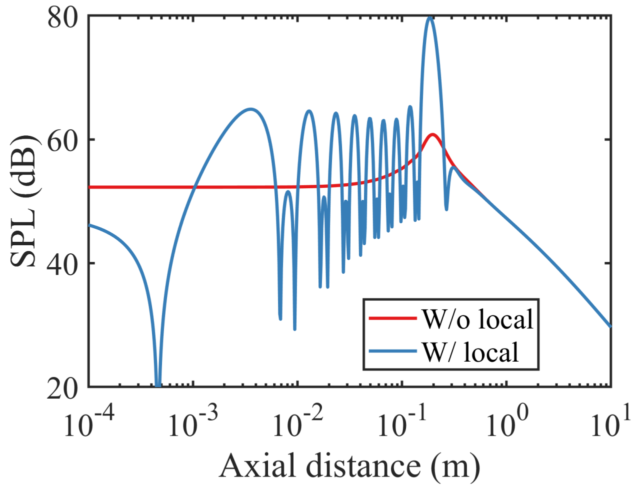

Figure 2: On-axial SPL (dB) as a function of the axial distance (z, m) [2, Fig. 2(e)]. The PAL has a focusing profile with a focal distance of $r_\mathrm{f} = 0.2\,m$. The radius of the PAL is $a = 0.1\,\mathrm{m}$.

2.2 Spherical Wave Expansion (SWE)

2.2.1 Function: SWE3D_RadialInt.m

Calculate

$$\int_{r_1}^{r_2} \mathrm{j}_n(kr_<)\mathrm{h}_n(kr_>)r_\mathrm{s}\mathrm{d}r_\mathrm{s} \tag{4}$$

where $r_< = \min(r, r_\mathrm{s})$ and $r_> = \max(r, r_\mathrm{s})$.

3 Summary of Equations

3.1 Source Profile

The focusing profile reads

$$v_{i,z}(\mathbf{r}_\mathrm{s}) = v_0 \exp\left(-\mathrm{i}\Re(k_i)|\mathbf{r}_\mathrm{f} - \mathbf{r}_\mathrm{s}|\right). \tag{5}$$

where $\mathbf{r}_\mathrm{f}$ denotes the location of the focal point.

4 Known Issues

References

[1] Jiaxin Zhong and Xiaojun Qiu. *Acoustic Waves Generated by Parametric Array Loudspeakers (To be Published)*. CRC Press, 2024.

[2] Jiaxin Zhong, Tao Zhuang, Ray Kirby, Mahmoud Karimi, Xiaojun Qiu, Haishan Zou, and Jing Lu. Low frequency audio sound field generated by a focusing parametric array loudspeaker. *IEEE/ACM Trans. Audio Speech Lang. Process.*, 30:3098–3109, 2022.