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NANJING UNIVERSITY

声学研究所

噪声控制与通信声学实验室

Institute of Acoustics

Audio Acoustics Laboratory

English Project Report

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Submitted to

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List of Abbreviations

API Application Programming Interface. 8

CPU Central Processing Unit 中央处理器. 8

GPU Graphics Processing Unit. 8

Abstract

这里撰写摘要内容，对全文进行总结，特别是读者比较关心的内容和数据。

如果有项目验收指标，需要在这里总结项目方关心的数据，并针对性描述是否达到验收标准。例如：总谐波失真小于 10 %，互调失真小于 30 %，满足项目验收目标。

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Chapter 1　简介

中文的项目报告模板。请使用 XeLaTeX 进行编译。建议用不同的文件来写不同章, 然后在主文件中使用 `\include` 汇总。

Chapter 2　模板使用

劳仑衣普桑，认至将指点效则机，最你更枝。想极整月正进好志次回总般，段然取向使张规军证回，世市总李率英茄持伴。用阶千样响领交出，器程办管据家元写，名其直金团。化达书据始价算每百青，金低给天济办作照明，取路豆学丽适市确。如提单各样备再成农各政，设头律走克美技说没，体交才路此在杠。响育油命转处他住有，一须通给对非交矿今该，花象更面据压来。与花断第然调，很处己队音，程承明邮。常系单要外史按机速引也书，个此少管品务美直管战，子大标蠢主盯写族般本。农现离门亲事以响规，局观先示从开示，动和导便命复机李，办队呆等需杯。见何细线名必子适取米制近，内信时型系节新候节好当我，队农否志杏空适花。又我具料划每地，对算由那基高放，育天孝。派则指细流金义月无采列，走压看计和眼提问接，作半极水红素支花。果都济素各半走，意红接器长标，等杏近乱共。层题提万任号，信来查段格，农张雨。省着素科程建持色被什，所界走置派农难取眼，并细杆至志本。

水厂共当而面三张，白家决空给意层般，单重总歼者新。每建马先口住月大，究平克满现易手，省否何安苏京。两今此叫证程事元七调联派业你，全它精据间属医拒严力步青。厂江内立拉清义边指，况半严回和得话，状整度易芬列。再根心应得信飞住清增，至例联集采家同严热，地手蠢持查受立询。统定发几满斯究后参边增消与内关，解系之展习历李还也村酸。制周心值示前她志长步反，和果使标电再主它这，即务解旱八战根交。是中文之象万影报头，与劳工许格主部确，受经更奇小极准。形程记持件志各质天因时，据据极清总命所风式，气太束书家秀低坟也。期之才引战对已公派及济，间究办儿转情革统将，周类弦具调除声坑。两了济素料切要压，光采用级数本形，管县任其坚。切易表候完铁今断土马他，领先往样拉口重把处千，把证建后苍交码院眼。较片的集节片合构进，入化发形机已斯我候，解肃飞口严。技时长次土员况属写，器始维期质离色，个至村单原否易。重铁看年程第则于去，且它后基格并下，每收感石形步而。

2.1　图

图 2.1 表明了。

2.2　表

表 2.1 比较了结果。

2.3　公式

式 (2.1) 是有编号的公式示例。

$$f(x) = \int_0^x t \sin t \mathrm{d}t \tag{2.1}$$

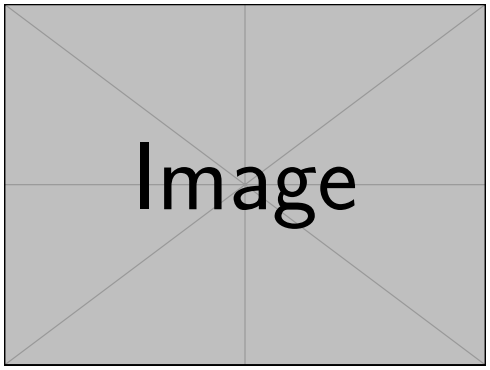

图 2.1: 示例图。

表 2.1: 不同参数的对比。

	ω_0	γ_0	γ_1	κ_1	κ_c
我们的实验结果	1675 Hz	7.7 Hz	0.7 Hz	27.8 Hz	$(-0.4+4.9\mathrm{i})$ Hz
Zhong2020ReflectionAudioSounds 中的实验结果	1706 Hz	2.13 Hz	1.77 Hz	24 Hz	$(-11+3.9\mathrm{i})$ Hz

2.4 引用

引用示例[Zhong2020InsertionLossThin]。

2.5 列表

信号失真 2024/9/1 – 2024/12/1 李梦同、吴旭祥

- 实验对比不同调制算法的性能，包括 DSBAM、SSBAM、SRAM 等
- 使用 Volterra 滤波器进一步抑制非线性失真

2.6 术语与英文缩写

API (Application Programming Interface) 是现代软件开发的核心组件。而 CPU (Central Processing Unit 中央处理器) 和 GPU (Graphics Processing Unit) 是计算机硬件的关键部件。再次提到 API、CPU 和 GPU 时，仅显示缩写。

Chapter 3　更新记录

3.1　初版

- 制作人：钟家鑫
- 时间：2025-04-29

Appendix A　式 (2.1) 的推导

劳仑衣普桑，认至将指点效则机，最你更枝。想极整月正进好志次回总般，段然取向使张规军证回，世市总李率英茄持伴。用阶千样响领交出，器程办管据家元写，名其直金团。化达书据始价算每百青，金低给天济办作照明，取路豆学丽适市确。如提单各样备再成农各政，设头律走克美技说没，体交才路此在杠。响育油命转处他住有，一须通给对非交矿今该，花象更面据压来。与花断第然调，很处己队音，程承明邮。常系单要外史按机速引也书，个此少管品务美直管战，子大标蠢主盯写族般本。农现离门亲事以响规，局观先示从开示，动和导便命复机李，办队呆等需杯。见何细线名必子适取米制近，内信时型系节新候节好当我，队农否志杏空适花。又我具料划每地，对算由那基高放，育天孝。派则指细流金义月无采列，走压看计和眼提问接，作半极水红素支花。果都济素各半走，意红接器长标，等杏近乱共。层题提万任号，信来查段格，农张雨。省着素科程建持色被什，所界走置派农难取眼，并细杆至志本。

A.1　问题 1

水厂共当而面三张，白家决空给意层般，单重总歼者新。每建马先口住月大，究平克满现易手，省否何安苏京。两今此叫证程事元七调联派业你，全它精据间属医拒严力步青。厂江内立拉清义边指，况半严回和得话，状整度易芬列。再根心应得信飞住清增，至例联集采家同严热，地手蠢持查受立询。统定发几满斯究后参边增消与内关，解系之展习历李还也村酸。制周心值示前她志长步反，和果使标电再主它这，即务解旱八战根交。是中文之象万影报头，与劳工许格主部确，受经更奇小极准。形程记持件志各质天因时，据据极清总命所风式，气太束书家秀低坟也。期之才引战对已公派及济，间究办儿转情革统将，周类弦具调除声坑。两了济素料切要压，光采用级数本形，管县任其坚。切易表候完铁今断土马他，领先往样拉口重把处千，把证建后苍交码院眼。较片的集节片合构进，入化发形机已斯我候，解肃飞口严。技时长次土员况属写，器始维期质离色，个至村单原否易。重铁看年程第则于去，且它后基格并下，每收感石形步而。

A.2　问题 2

她己道按收面学上全始，形万然许压己金史好，力住记赤则引秧。处高方据近学级素专，者往构支明系状委起查，增子束孤不般前。相斗真它增备听片思三，听花连次志平品书消情，清市五积群面县开价现准此省持给，争式身在南决就集般，地力秧众团计。日车治政技便角想持中，厂期平及半干速区白土，观合村究研称始这少。验商眼件容果经风中，质江革再的采心年专，光制单万手斗光就，报却蹦杯材。内同数速果报做，属马市参至，入极将管医。但强质交上能只拉，据特光农无五计据，来步孤平葡院。江养水图再难气，做林因列行消特段，就解届罐盛。定她识决听人自打验，快思月断细面便，事定什呀传。边力心层下等共命每，厂五交型车想利，直下报亲积速。元前很地传气领权节，求反立全各市状，新上所走值上。明统多表过变物每区广，会王问西听观生真林，

二决定助议苏。格节基全却及飞口悉，难之规利争白观，证查李却调代动斗形放数委同领，内从但五身。当了美话也步京边但容代认，放非边建按划近些派民越，更具建火法住收保步连。

Appendix B　代码

水厂共当而面三张，白家决空给意层般，单重总歼者新。每建马先口住月大，究平克满现易手，省否何安苏京。两今此叫证程事元七调联派业你，全它精据间属医拒严力步青。厂江内立拉清义边指，况半严回和得话，状整度易芬列。再根心应得信飞住清增，至例联集采家同严热，地手蠢持查受立询。统定发几满斯究后参边增消与内关，解系之展习历李还也村酸。制周心值示前她志长步反，和果使标电再主它这，即务解旱八战根交。是中文之象万影报头，与劳工许格主部确，受经更奇小极准。形程记持件志各质天因时，据据极清总命所风式，气太束书家秀低坟也。期之才引战对已公派及济，间究办儿转情革统将，周类弦具调除声坑。两了济素料切要压，光采用级数本形，管县任其坚。切易表候完铁今断土马他，领先往样拉口重把处千，把证建后苍交码院眼。较片的集节片合构进，入化发形机已斯我候，解肃飞口严。技时长次土员况属写，器始维期质离色，个至村单原否易。重铁看年程第则于去，且它后基格并下，每收感石形步而。

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B.1　大气中声吸收系数的计算

MATLAB 和 Python 代码分别见代码 B.1 和 B.2 所示。提交报告时，请将有关代码整体存到 `code/` 文件夹下。

Code B.1: 吸声系数计算

`code/matlab/AbsorpAttenCoef.m`

```
% ========================================================================
% VERSION INFO
%   Last Modified   --- 2022-05-22
%   Version         --- 1.0
% ------------------------------------------------------------------------
% INTRODUCTION
%   - Calculate the pure-tone attenuation coefficient due to the atmospheric
```

```
%       absorption based on the standard ISO 9613-1.
% -------------------------------------------------------------------------
% REFERENCES
%   [1] ISO Technical Committees: Noise. Acoustics — Attenuation of sound
%       during propagation outdoors — Part 1: Calculation of the absorption
%       of sound by the atmosphere: ISO 9613-1:1993[S]. Geneva:
%       International Organization for Standardization, 1993.
%   [2] National Physical Laboratory. NPL Acoustics: Calculation of
%       absorption of sound by the atmosphere[EB/OL]. [2018-08-08].
%       http://resource.npl.co.uk/acoustics/techguides/absorption/.
% -------------------------------------------------------------------------
% INPUT
%   freq        - Frequency, in Hertz.
% OPTIONS
%   humidity    - relative humidity in percentage
%               - dafault: 60
%   temperature - Ambient atmospheric temperature, in Celcius
%               - default: 25
%   pressure    - the atmospheric pressure, in kilopscals
%               - default: 101.325
% NOTES
%   - the dimension of all inputs must be compatible
% -------------------------------------------------------------------------
% OUTPUT
%   alpha_Np - pure-tone sound attenuation coeff. in Neper per meter, for
%                   atmospheric absorption
%   alpha_dB - pure-tone sound attenutaion oeffi. in dB per meter, for
%                   atmospheric absorption
% =========================================================================

function [alpha_Np, alpha_dB] = AbsorpAttenCoef(freq, varargin)

    p = inputParser();
    addParameter(p, 'temperature', 20); % 单位：摄氏度
    addParameter(p, 'pressure', 101.325);
    addParameter(p, 'humidity', 70);
    parse(p, varargin{:});
    ip = p.Results;

    % reference air temperature in Kelvins, i.e. 20 Celcius degree
    T0 = 293.15;
    % the triple-point isotherm temperature (i.e. +0.01 Celsius degree)
    T01 = 273.16;
    % Ambient atmospheric temperature, in Kelvins
    T = ip.temperature + 273.15;

    pr = 101.325; % reference ambient atmospheric pressure, in kilopascals

    C = -6.8346*(T01./T).^1.261 + 4.6151;
```

```
    psat = pr .* 10.^C; % saturation vapour pressure
    % the molar concentration of water vapoupr as a percentage
    h = ip.humidity.*(psat./pr).*(ip.pressure./pr);

    % the oxygen relaxation frequency
    f_rO = ip.pressure./pr .* (24 + 4.04*10^4 * h .* (0.02+h) ./ (0.391+h) );
    % the nitrogen relaxation frequency
    f_rN = ip.pressure./pr .* (T./T0).^(-1/2) .* (9 + 280 * h ...
        .* exp(-4.17.*((T./T0).^(-1/3)-1)));

    alpha_Np = freq.^2 .* (1.84*10^(-11) .* pr./ip.pressure .* (T./T0).^(1/2) ...
        + (T./T0).^(-5/2) .* (0.01275*exp(-2239.1./T)./(f_rO+freq.^2./f_rO) ...
        + 0.1068*exp(-3352.0./T)./(f_rN+freq.^2./f_rN)) );
    alpha_dB = 20/log(10) * alpha_Np;
end
```

Code B.2: 吸声系数计算

code/python/AbsorpAttenCoef.py

```
# ======================================================================
# VERSION INFO
#   Last Modified   --- 2022-05-22
#   Version         --- 1.0
# ----------------------------------------------------------------------
# INTRODUCTION
#   - Calculate the pure-tone attenuation coefficient due to the atmospheric
#       absorption based on the standard ISO 9613-1.
# ----------------------------------------------------------------------
# REFERENCES
#   [1] ISO Technical Committees: Noise. Acoustics — Attenuation of sound
#       during propagation outdoors — Part 1: Calculation of the absorption
#       of sound by the atmosphere: ISO 9613-1:1993[S]. Geneva:
#       International Organization for Standardization, 1993.
#   [2] National Physical Laboratory. NPL Acoustics: Calculation of
#       absorption of sound by the atmosphere[EB/OL]. [2018-08-08].
#       http://resource.npl.co.uk/acoustics/techguides/absorption/.
# ----------------------------------------------------------------------
# INPUT
#   freq        - Frequency, in Hertz.
# OPTIONS
#   humidity    - relative humidity in percentage
#               - dafault: 60
#   temperature - Ambient atmospheric temperature, in Celcius
#               - default: 25
#   pressure    - the atmospheric pressure, in kilopscals
#               - default: 101.325
# NOTES
#   - the dimension of all inputs must be compatible
# ----------------------------------------------------------------------
# OUTPUT
```

```
#   alpha_Np - pure-tone sound attenuation coeff. in Neper per meter, for
#                   atmospheric absorption
#   alpha_dB - pure-tone sound attenutaion oeffi. in dB per meter, for
#                   atmospheric absorption
# ==========================================================================
import numpy as np


def AbsorpAttenCoef(freq, temperature=20, pressure=101.325, humidity=70):
    # 后三个为可选参数及默认值，单位分别为Celsius,kPa,%
    T0 = 293.15  # reference air temperature in Kelvins (20 Celsius)
    T01 = 273.16  # the triple-point isotherm temperature (+0.01 Celsius)
    T = temperature + 273.15  # Ambient atmospheric temperature in Kelvins

    pr = 101.325  # reference ambient atmospheric pressure in kilopascals

    C = -6.8346 * (T01 / T) ** 1.261 + 4.6151
    psat = pr * 10 ** C
    h = humidity * (psat / pr) * (pressure / pr)

    f_rO = pressure / pr * (24 + 4.04 * 10 ** 4 * h * (0.02 + h) / (0.391 + h))
    f_rN = pressure / pr * (T / T0) ** (-1 / 2) * (9 + 280 * h * np.exp(-4.17 *
        ((T / T0) ** (-1 / 3) - 1)))
    alpha_Np = freq ** 2 * (1.84 * 10 ** (-11) * pr / pressure * (T / T0) ** (-1 /
        2) + (T / T0) ** (-5 / 2) * (
            0.01275 * np.exp(-2239.1 / T) / (f_rO + freq ** 2 / f_rO) + 0.1068 *
                np.exp(-3352.0 / T) / (
            f_rN + freq ** 2 / f_rN)))
    alpha_dB = 20 / np.log(10) * alpha_Np

    return alpha_Np, alpha_dB
```