AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
MECHATRONICS ENGINEERING DEPARTMENT

Modeling of Duct Acoustics in the High Frequency Range Using Power Method

A Thesis submitted in partial fulfillment of the requirements of the

M.Sc. in Mechanical Engineering

By

Mina Wagih Ayad Nashed

B.Sc., Mechanical Engineering, Mechatronics Section
Ain Shams University, 2009

Supervised by

Associate Prof. Dr. Tamer Elnady

Associate Prof. Dr. Wael Akl

Cairo – (2014)

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

Modeling of Duct Acoustics in the High Frequency Range Using Power Method

By

Mina Wagih Ayad Nashed

B.Sc., Mechanical Engineering, Mechatronics Section
Ain Shams University, 2009

EXAMINERS COMMITTEE

Name	Signature
Professor Mats Åbom	…….
Associate Professor Ahmed Elassy	…….
Associate Professor Tamer Elnady	…….

Date: …. /……/…….

STATEMENT

This thesis is submitted as a partial fulfillment of M.Sc. degree in Mechanical engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis and no part of it has been submitted for a degree or qualification at any other scientific entity.

Signature

Mina Wagih Ayad Nashed

Researcher Data

Name	: Mina Wagih Ayad Nashed
Date of birth	: 28/11/1985
Place of birth	: Cairo
Academic Degree	: B.Sc., Mechanical Engineering
Field of specialization	: Mechatronics
University issued the degree	: Ain Shams University
Date of issued degree	: 2009
Current Job	: Research Assistant, Group for Advanced Research in Dynamic System (ASU-GARDS) Faculty of Engineering Ain Shams University

Abstract

Duct Networks (e.g. HVAC) should be carefully designed to maintain certain flow rate, acceptable noise levels and minimum pressure drop. To accurately analyze the acoustics in a duct network in the high frequency range, the following mechanisms need to be modeled: The sound power injected into the network by sound sources (e.g. Fans), the flow noise generated in different parts in the network (e.g. junctions), and the noise reduction across different parts of the network. Traditionally, only transmission of sound power with no reflection is considered in standards, e.g., ASHRAE or VDI, for analyzing noise in HVAC systems. A more general approach is considered based on dividing the duct network into two-port elements where each element can be described by a 2x2 scattering matrix. The state variables are taken as the acoustic power flow in the up/downstream directions. Junctions are described by multi-ports depending on the number of elements connected to the junction. A source term is added to each element and junction to handle sound power injection by fans or other aeroacoustic sources. The advantage of this approach is that the same formalism (based on two-port network theory) can be used to analyze low frequency range, flow distribution and pressure drop as well as the high frequency range. The two-port power based formulation was validated against a detailed HVAC example in VDI 2081: Part 2 and a real HVAC system.

Acknowledgment

I would never have been able to finish this work without guidance from my committee, help from my friends and support from my family and my wife.

First of all, this thesis would not have been possible without the guidance, help, support and patience of my principal supervisor, Dr. Tamer Elnady. The good advice and support of my second supervisor, Dr. Wael Akl, has been invaluable on both an academic and a personal level, for which I am extremely grateful.

Secondly, I would like to thank Dr. Ahmed Elassy and Eng. Tamer Tamemy for their helpful information and guidance in HVAC system measurements.

Also, I would like to thank Prof. Mat Abom for his guidance and academic advices.

Also, I would like to thank my friend Amir for his support and help in measurements during weekend; also I like to thank Mustafa Ali for being such a helpful guy in the measurements.

I would like to thank my friend Mina Ramsis for his help in elements drawings.

I would like to acknowledge the financial, academic and technical support of ASU-GARDS and its staff.

Finally and above all I would like to thank my wife, Marseal, she was always there cheering me up and stood by me through the good and bad times.

Mina W. Nashed

July 2014, Cairo-Egypt

Contents

Chapter 1: Introduction

Sound generation and propagation inside ducts have been researched for last decades for different applications. The nature of sound propagation inside ducts depends on the acoustic wavelength of the propagated wave with respect to the cross dimensions of the duct. Therefore the frequency range of interest can be divided into three different regions, where each region has its own character and consequently different techniques in modeling and characterization, see Figure 1-1.

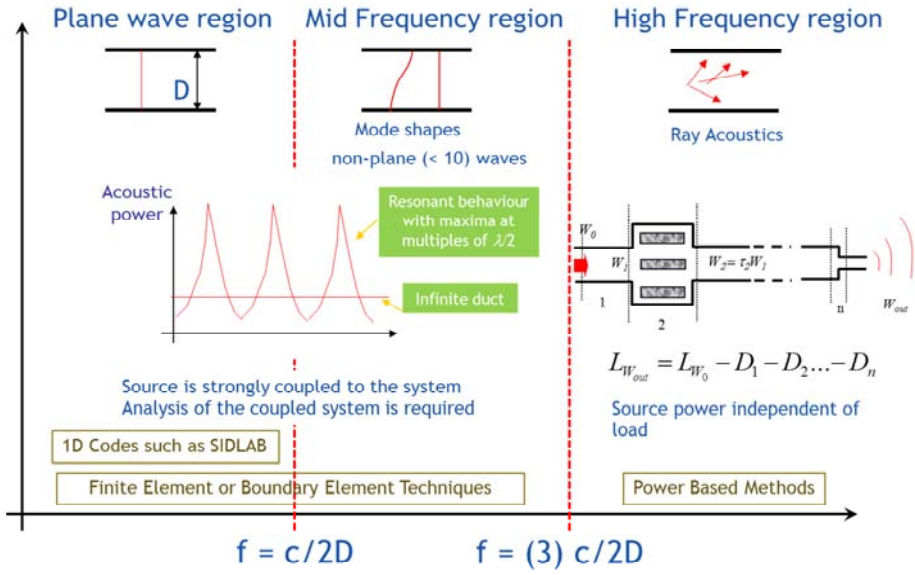

Figure 1-1. Analysis methods used in each frequency range

Low frequency range (plane wave) where frequency below cut-off frequency of plan wave, in this range a source is strongly coupled to a system and the acoustic output power varying strongly to system changes. In this range full modal description of the sound field is needed to capture the response, however because of plan wave exists only in this range 1D model can describe accurately the behavior of the acoustic wave.