inter•noise 2021

An overview of Leo Beranek's paper on "The Forty-fifth Thomas Hawksley Lecture: The transmission and radiation of acoustic waves by structures" and its influence on architectural acoustic research

Abstract ID#: 2201

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The Pennsylvania State University, USA

inter•noise 2021 1 - 4 AUGUST

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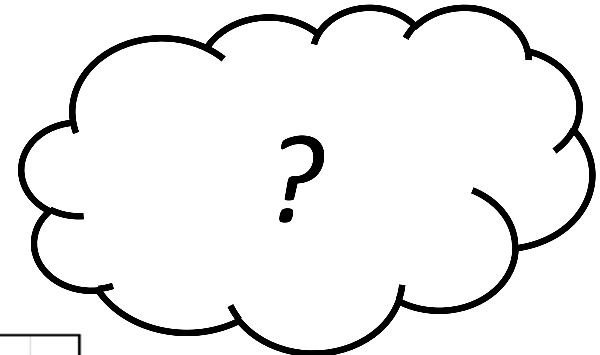
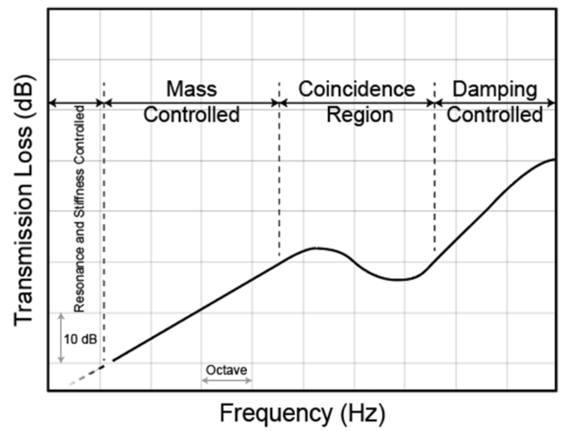
Biography
Of Leo L. Beranek

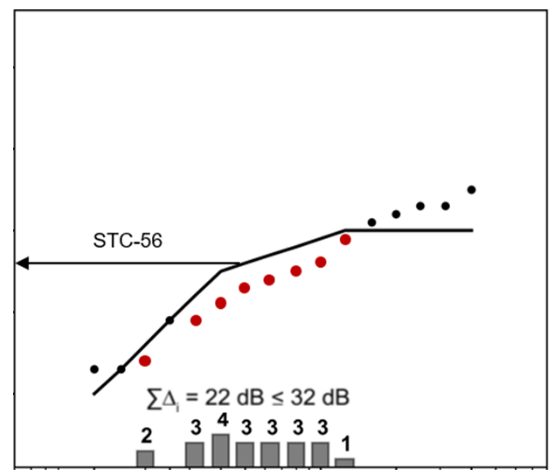
Knowledge Gap
Of acoustics in the mid-20th century



Contributions
Of “The transmission and radiation of acoustic waves by structures”



Influence
On architectural acoustics research and practice



Leo L. Beranek

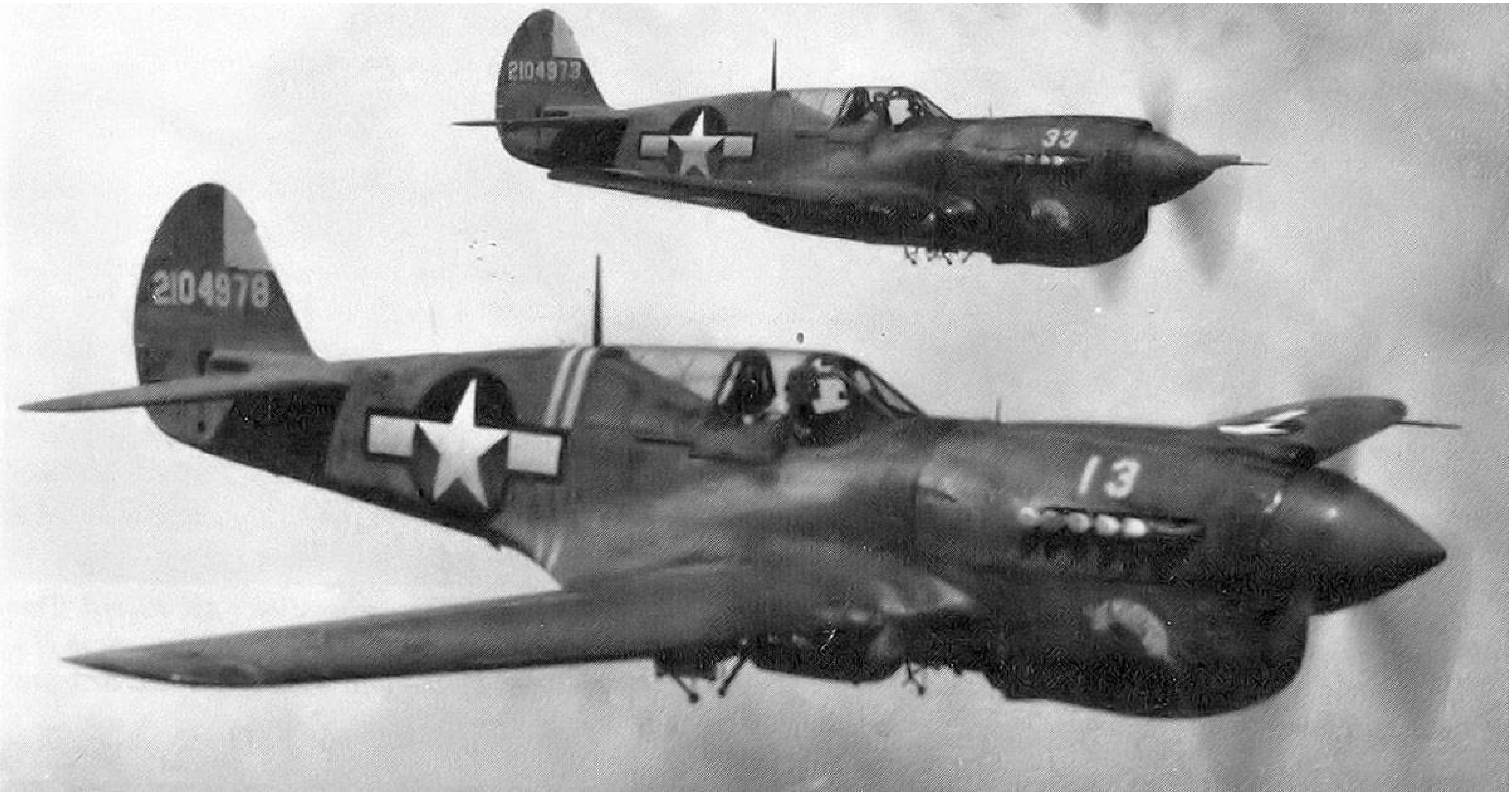
The New York Times, 2016

Leo L. Beranek

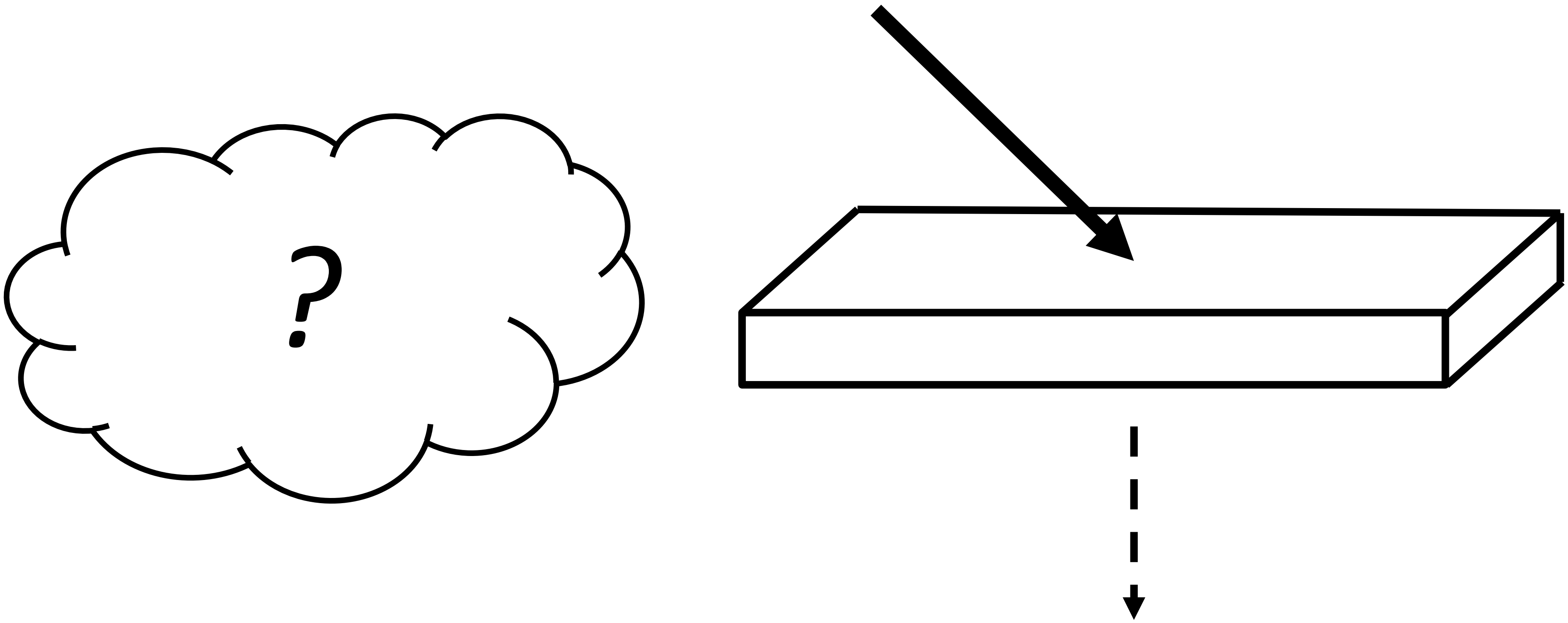
The Gazette, 2016

Loudspeaker
BBN
Radio
Research
Technology
MIT
Acoustics
Sound
Music
Design
Massachusetts
Concert Halls
Boston Symphony Hall

The Telegraph, 2015



History Collection, 2017



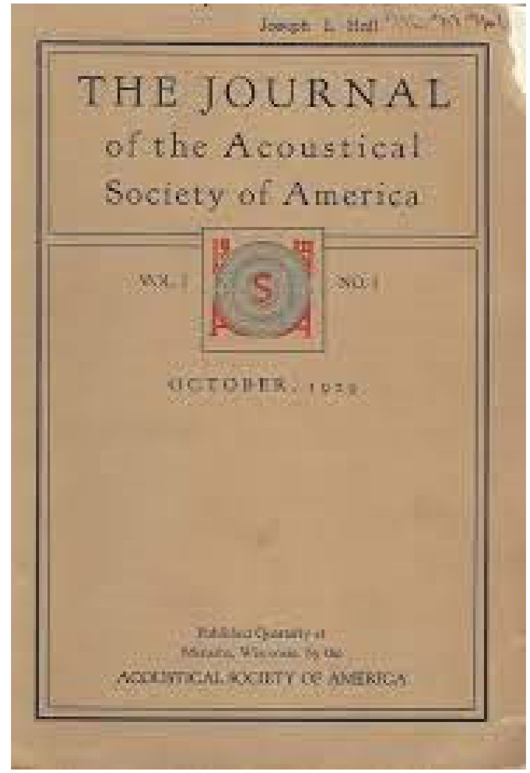
Acentech, 2021

Acta Acustica, 2019

AKUSTISCHE BEIHEFTE

ANWENDUNGSMÖGLICHKEITEN DER SCHALLSPEKTROGRAPHIE BEI AKUSTISCHEN UNTERSUCHUNGEN

Akustische Beihefte, 1956



JASA, 1929

The Thomas Hawksley Lecture

The Forty-fifth Thomas Hawksley Lecture

THE TRANSMISSION AND RADIATION OF ACOUSTIC WAVES BY STRUCTURES

By Leo L. Beranek, B.A., M.S., S.D., D.Sc.-Hon.*

Of major interest to architects, designers of vehicles, and acousticians is the control of structure-borne sound. Walls and panels are set into vibration by airborne waves or by vibrating mechanisms. The panel so excited will radiate sound and it may carry the vibrations to other panels or bodies.

In this lecture, the author will treat the problem of acoustic transmission through walls and panels in the audible frequency range. At low frequencies the panel vibrates as a plate or a stretched membrane. At higher frequencies the panel may behave as a quasi-infinite sheet. Above a particular 'critical' frequency, the wavelength of the bending waves in the panel will be longer than the compressional waves in air at the same frequency. The two wavelengths may be brought into coincidence provided the airborne wave impinges on the panel at an angle θ determined by

$$\cos \theta = c_a/c_B$$

where c_a and c_B are the speeds of sound in the air and panel, respectively. At the coincidence angle, an airborne wave striking one side of a panel will set it into a level of vibration such that the magnitude of the airborne wave radiated from the other side may be only a few decibels below that of the incident wave. This effect will be discussed both for airborne waves impinging at individual angles of incidence and for waves at many angles of incidence simultaneously.

Measurements on plates, concrete sheets, and masonry walls will be presented and analysed. Analysis of the different types of response to airborne wave excitation will be made. Rules for the selection of simple and complex structures for buildings and vehicles will be suggested.

Means for reducing the response of structures to airborne wave and mechanical excitation include the use of damping materials in or on the structure, the introduction of discontinuities and the use of sound-absorbing blankets in the structure. Recent data on damping materials and means for utilizing them to produce maximum reduction of flexural waves will be presented. It will be shown that by proper utilization of such materials a structure-borne wave may be attenuated in a given distance by a factor of 10 or more than when utilized in a conventional manner.

INTRODUCTION

SOUND IS DEFINED as a time-varying alteration in pressure, stress, particle displacement, or shear, occurring in an elastic medium. The medium in which the sound exists is indicated by an appropriate adjective before the word 'sound' such as airborne, water-borne, or structure-borne. Contrary to popular usage, not all sound waves evoke an auditory sensation. Sound is of importance to engineers because, if intense enough, it may affect human beings, may cause malfunction of electronic or mechanical equipments, and may produce structural failures.

Two kinds of sound waves are found in elastic media, namely, compressional and shear waves.

In gases, sound waves are compressional. Only in second order, because of viscosity, do shear waves exist. In perfect gases, the air particles would always move back and forth in a direction parallel to the direction in which a sound wave is travelling.

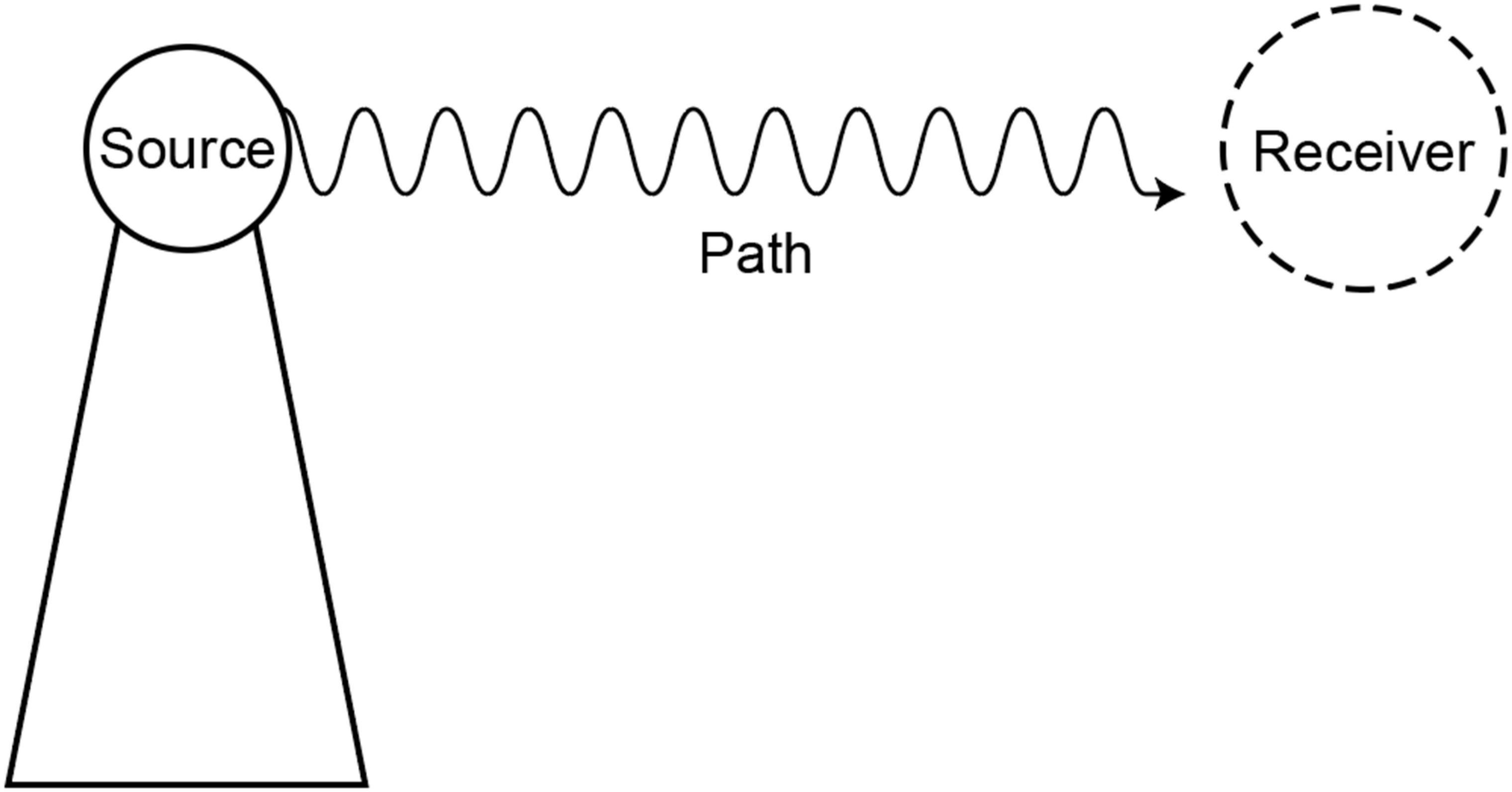
The MS. of this lecture was received at the Institution on 10th November 1958. For a report of the meeting, in London, at which this lecture was given, see p. 35.

* *Lecturer, Massachusetts Institute of Technology, and President, Bolt Beranek and Newman Inc., Cambridge, Massachusetts.*

Proc Instn Mech Engrs *Vol 173 1959*

Source-Path-Receiver

Source-Path-Receiver



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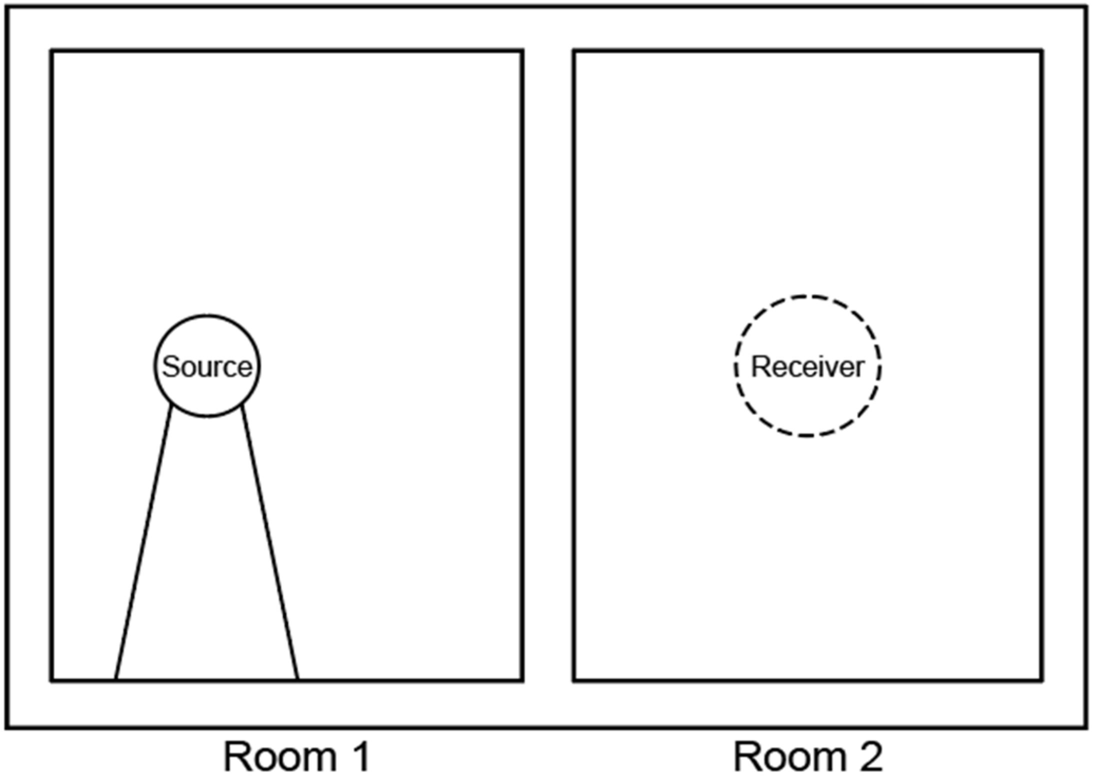

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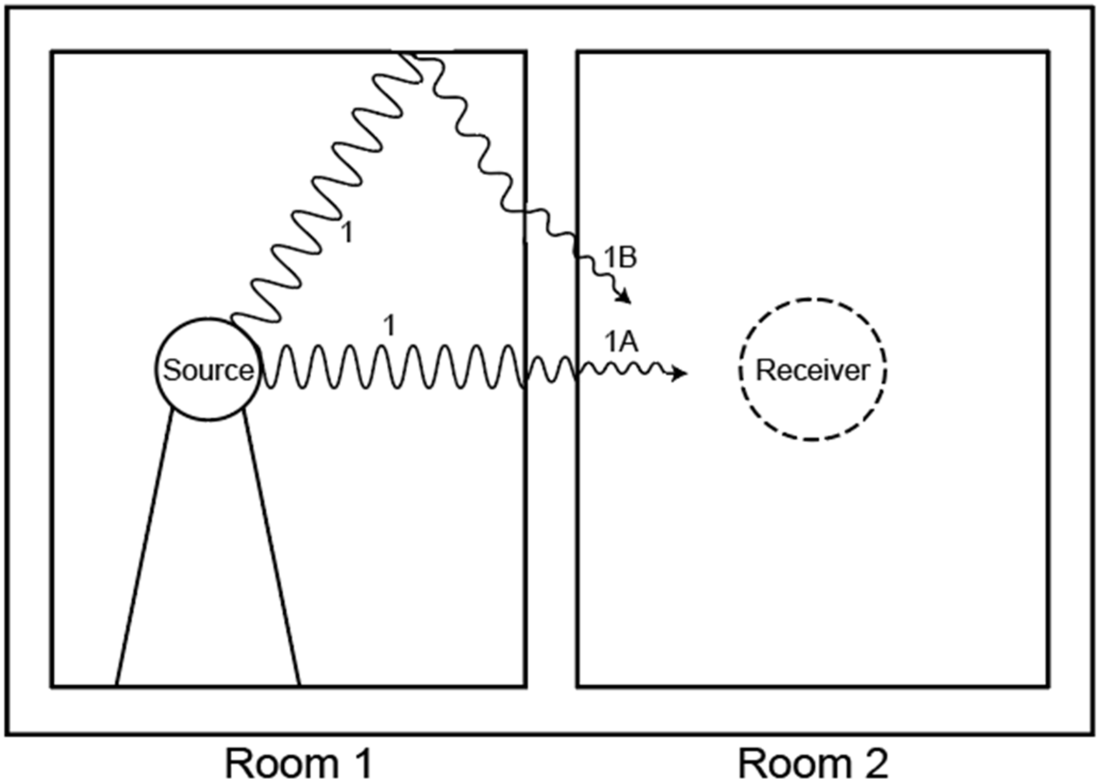
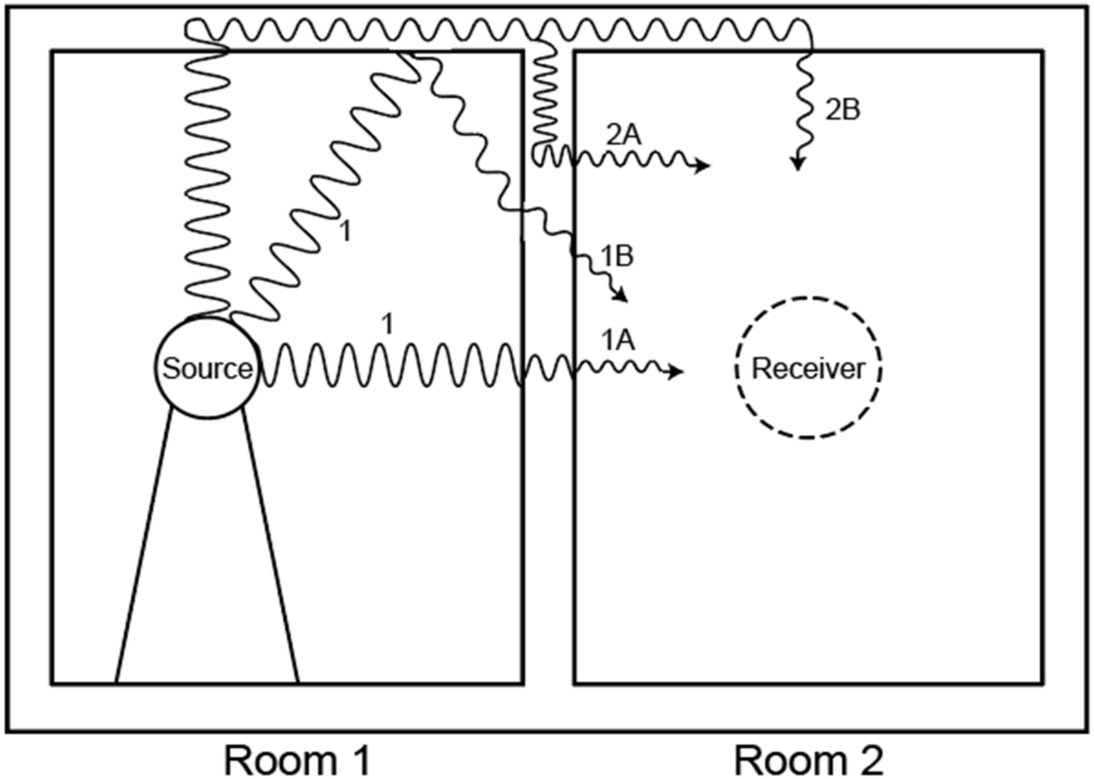


1A & 1B: **Air-borne** Sound Waves
Radiated from Room 1 to Room 2

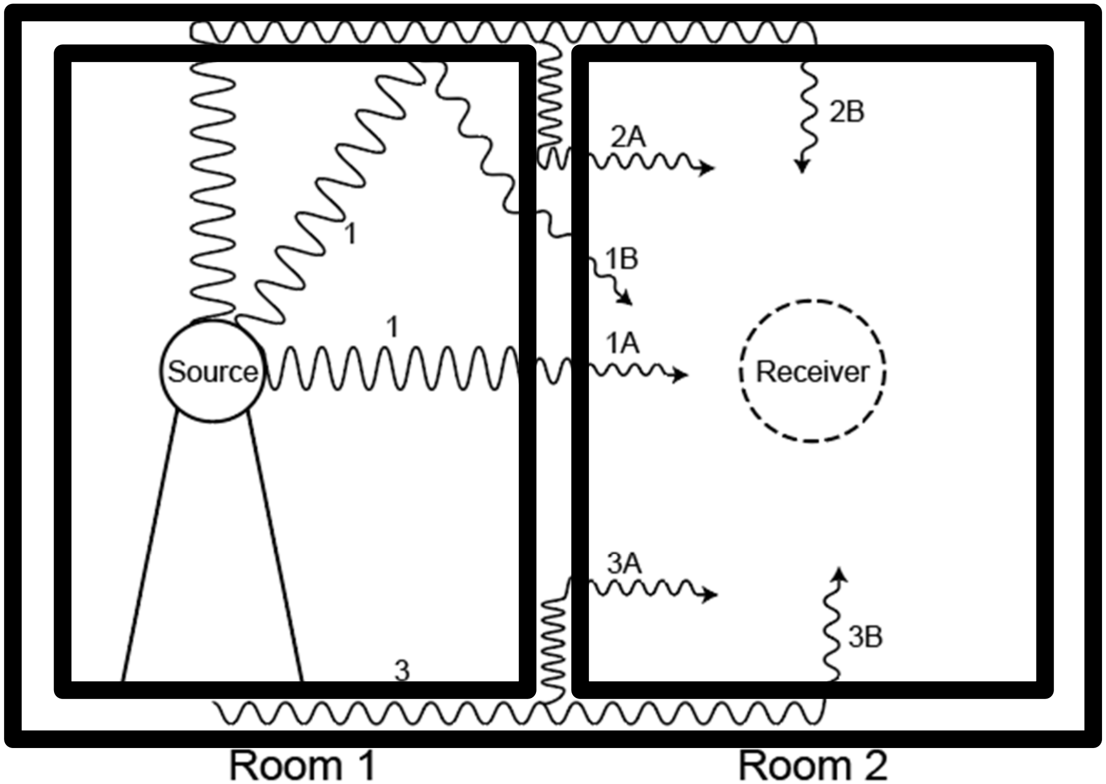
Source-Path-Receiver



1A & 1B: **Air-borne** Sound Waves
Radiated from Room 1 to Room 2

2A & 2B: **Air-borne** Sound Waves
Radiated from Wall and Ceiling Structure

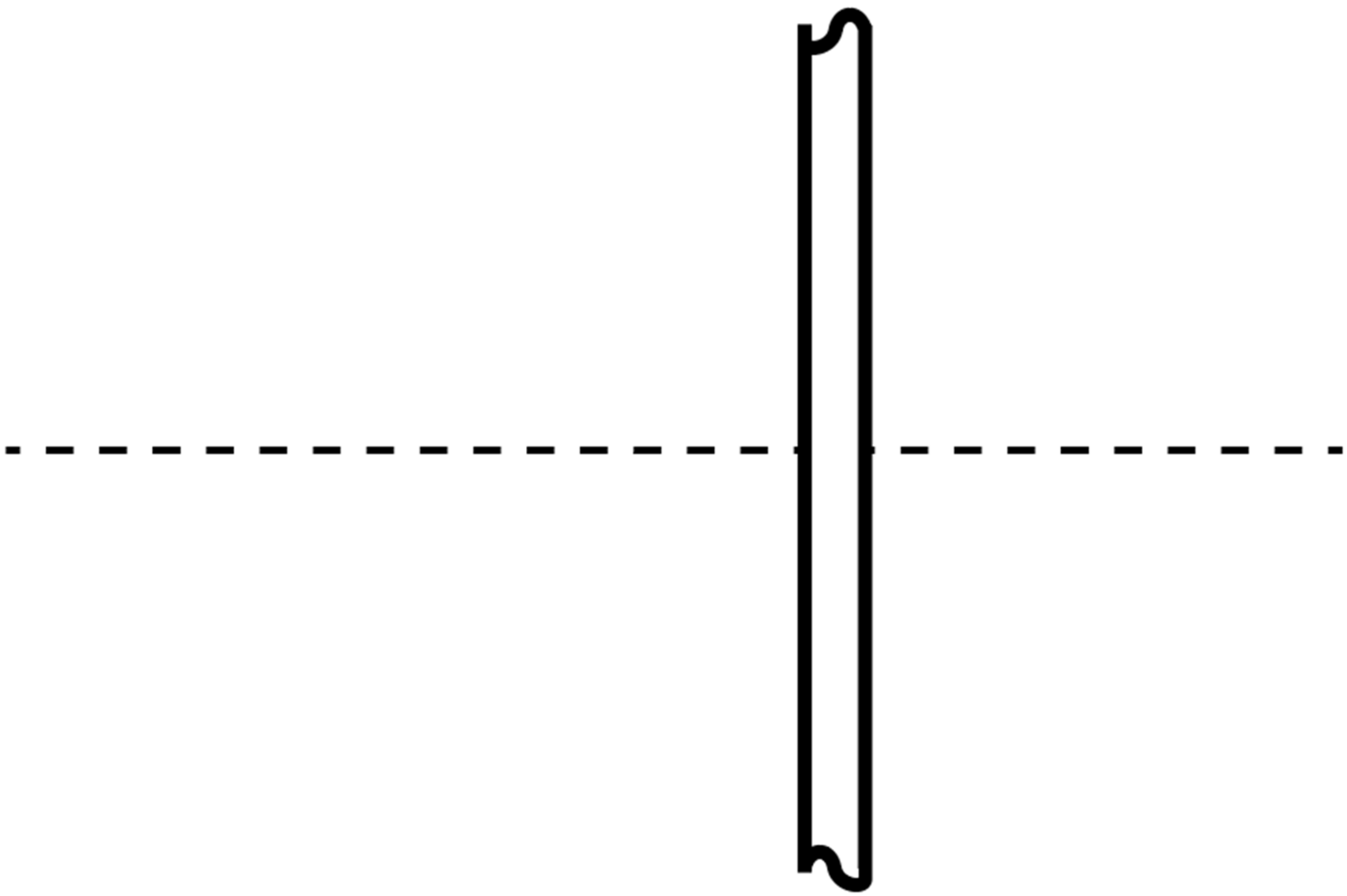
Source-Path-Receiver



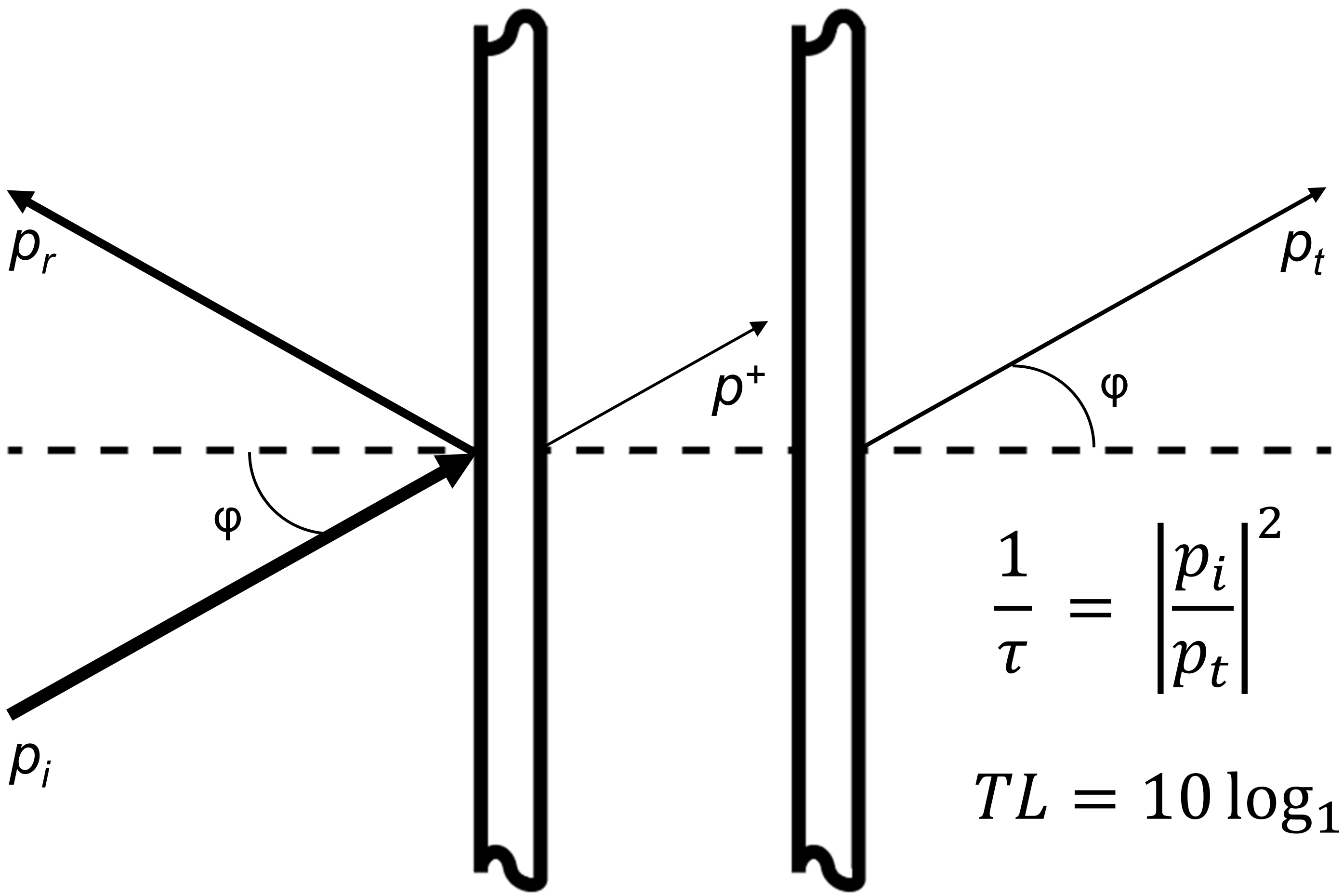
1A & 1B: **Air-borne** Sound Waves
Radiated from Room 1 to Room 2

2A & 2B: **Air-borne** Sound Waves
Radiated from Wall and Ceiling Structure

3A & 3B: **Structure-borne** Sound Waves
Radiated from Wall and Floor Structures



Sound Transmission



$$\frac{1}{\tau} = \left|\frac{p_i}{p_t}\right|^2$$

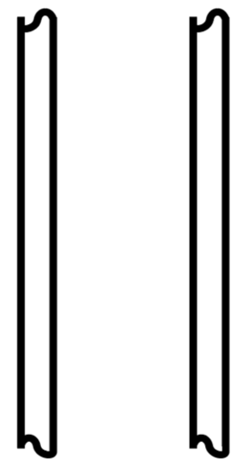
$$TL = 10\log_{10}\left(\frac{1}{\tau}\right)\ dB$$

Schoch, 1937

Sound Transmission for Walls

$$TL = 10\log_{10}\left(\frac{1}{\tau}\right)\ dB$$

$$\frac{1}{\tau} = \left|\frac{p_i}{p_t}\right|^2$$



Single Panel Wall

$$\left|\frac{p_i}{p_t}\right| = 1 + \frac{Z_s cos\varphi}{2\rho c}$$

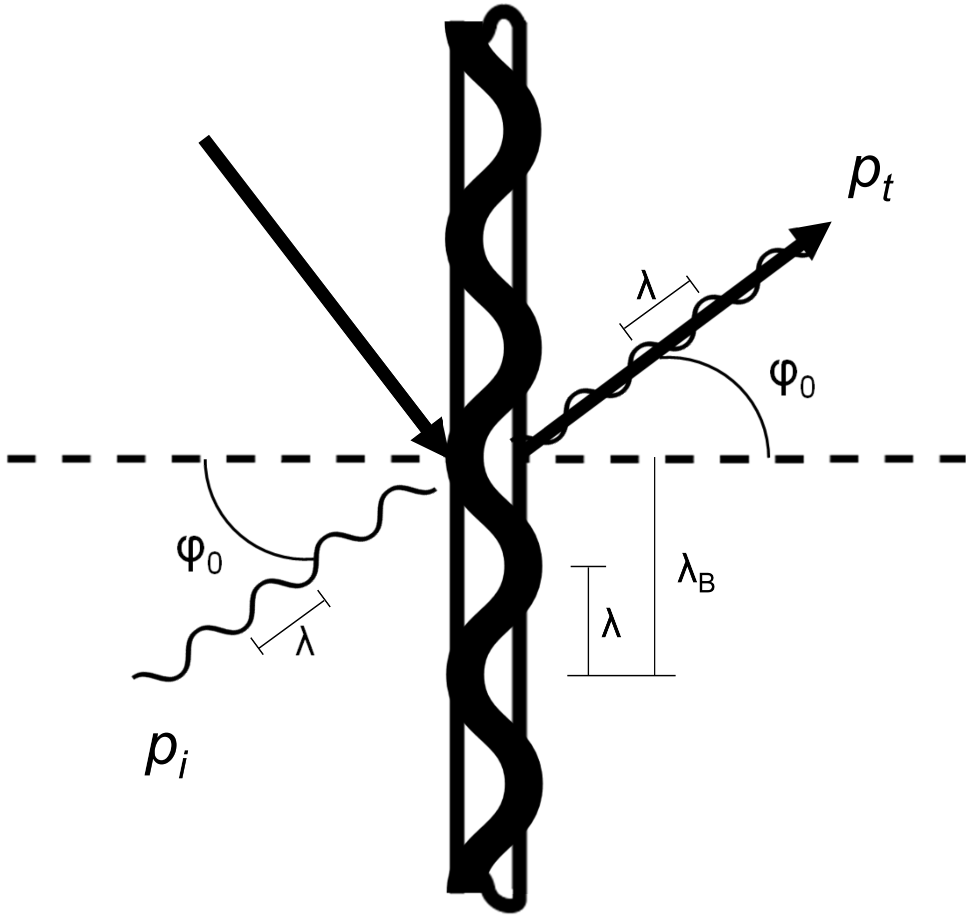
Beranek, 1959

Double Panel Wall

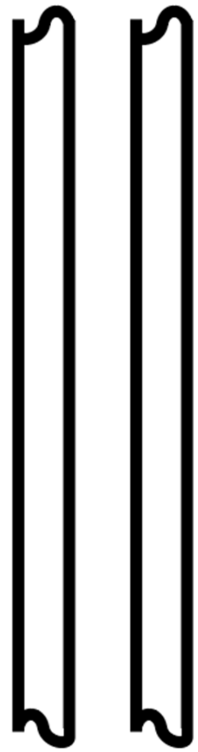
$$\left|\frac{p_i}{p_t}\right| = 1 + \frac{Z_s cos\varphi}{\rho c} + \left(\frac{Z_s cos\varphi}{2\rho c}\right)^2 \left(1 - e^{-2j\beta}\right)$$

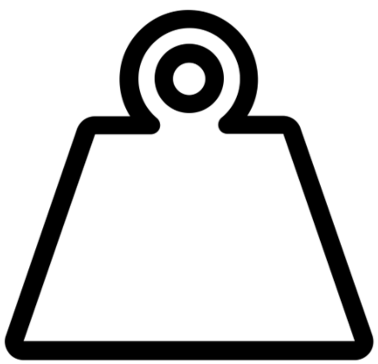
London, 1950

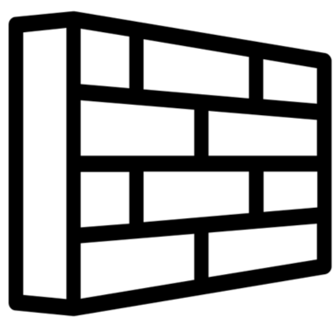
Wave Coincidence

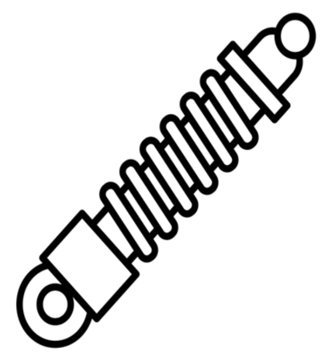


$$sin\varphi_0 = \lambda/\lambda_B$$



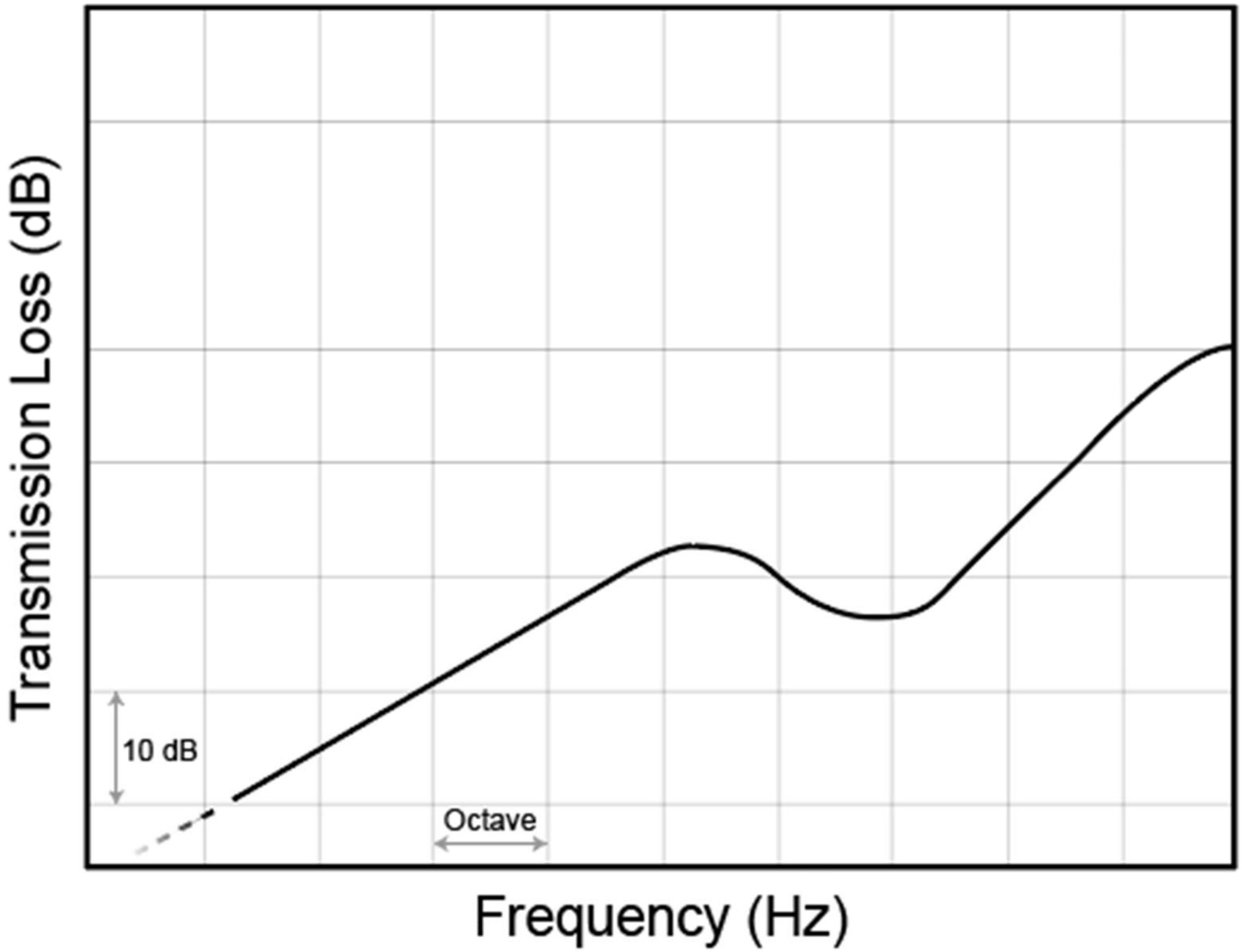




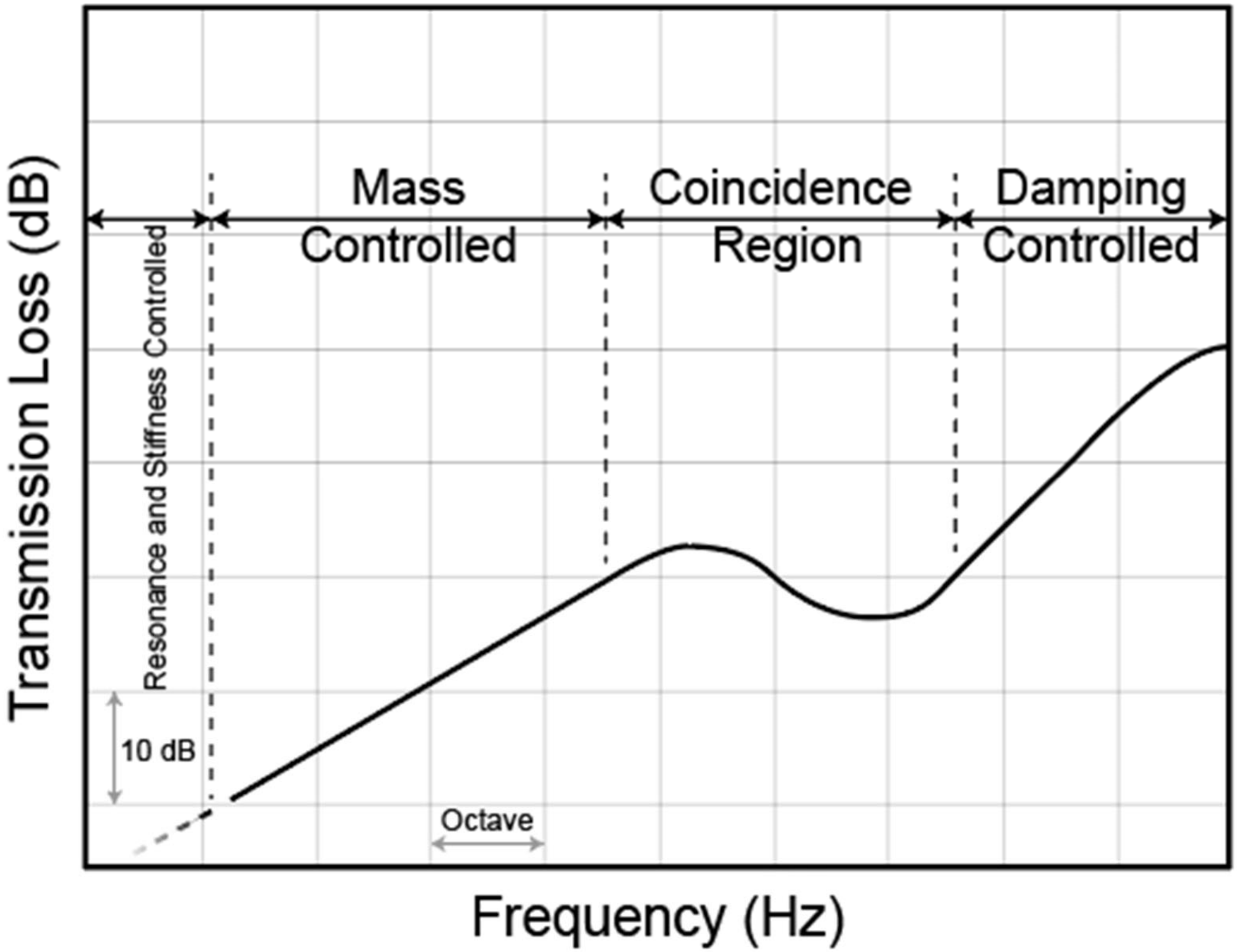


Design Aids

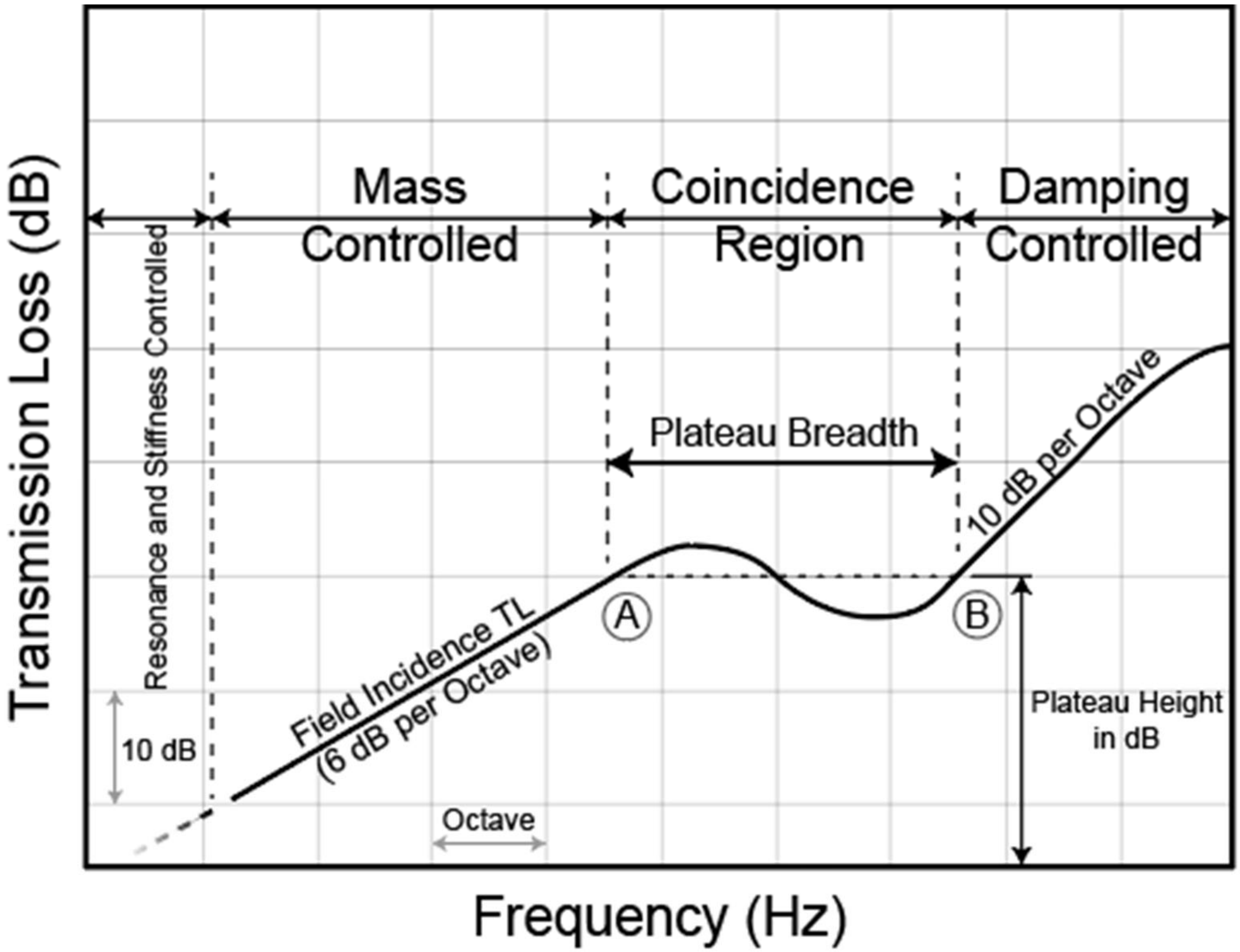
Design Aids



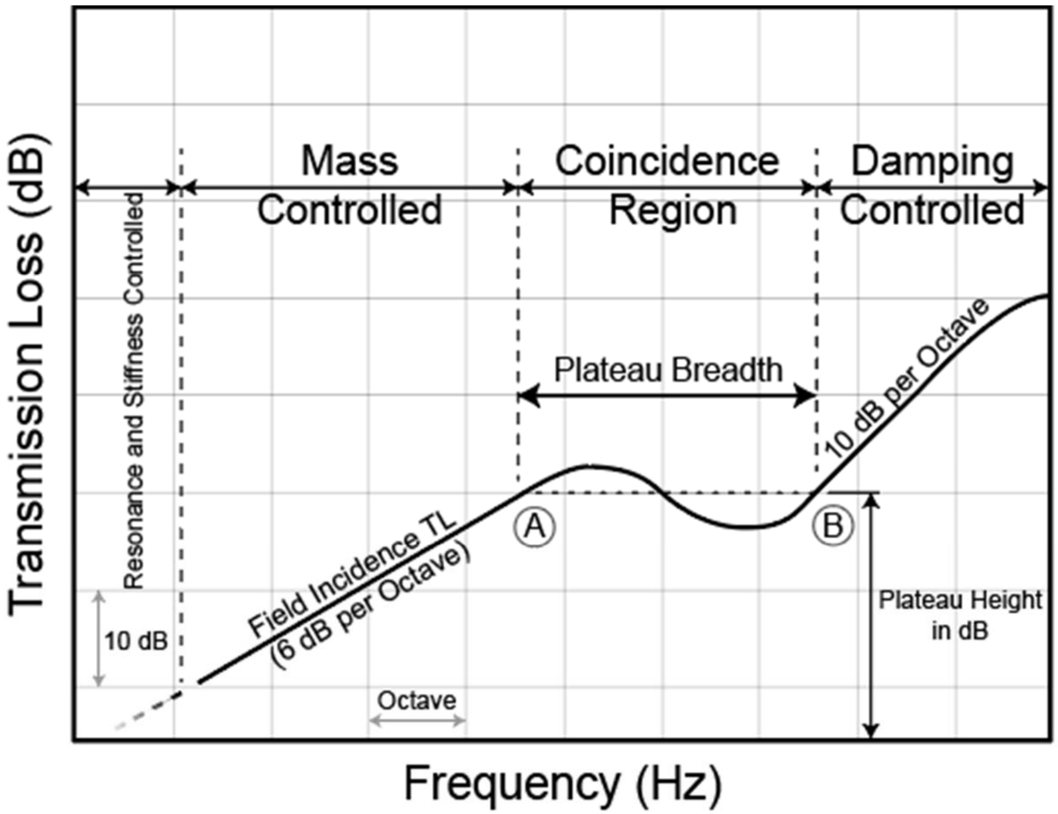
Design Aids


Transmission Loss (dB)
Resonance and Stiffness Controlled
Mass Controlled
Coincidence Region
Damping Controlled
10 dB
Octave
Frequency (Hz)

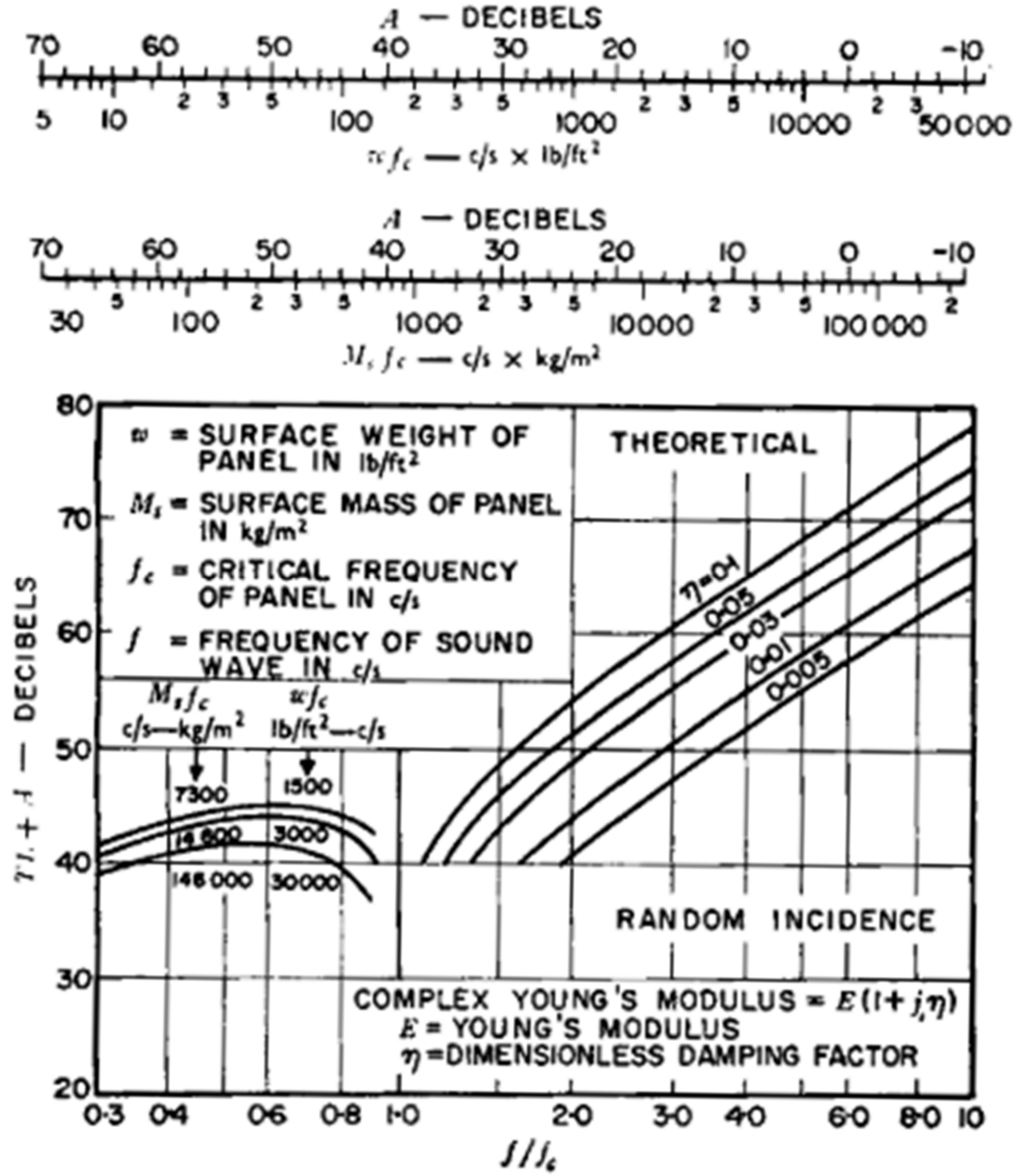
Design Aids


Transmission Loss (dB)
Resonance and Stiffness Controlled
Mass
Controlled
Coincidence
Region
Damping
Controlled
Plateau Breadth
10 dB per Octave
Field Incidence TL
(6 dB per Octave)
A
B
Plateau Height
in dB
10 dB
Octave
Frequency (Hz)

Design Aids

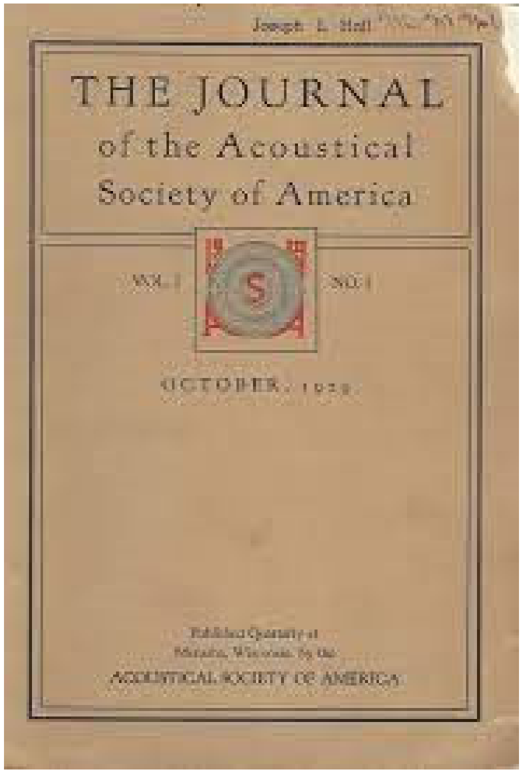


Material	Specific Surface Density		Plateau Height dB	Plateau Breadth	
	lb/ft² per in	kg/m² per cm		Octaves	Freq. Ratio
Aluminum	14	26.6	29	3.7	13
Concrete	12	22.8	36	3.3	9.8
Glass	13	24.7	27	3.3	9.8
Lead	59	112	56	2.3	4.9
Plaster, Sand	9	17.1	30	3.0	8
Plywood, Fir	3	5.7	19	2.7	6.5
Steel	40	76	40	3.7	13
Brick	11	21	33	2.5	5.5

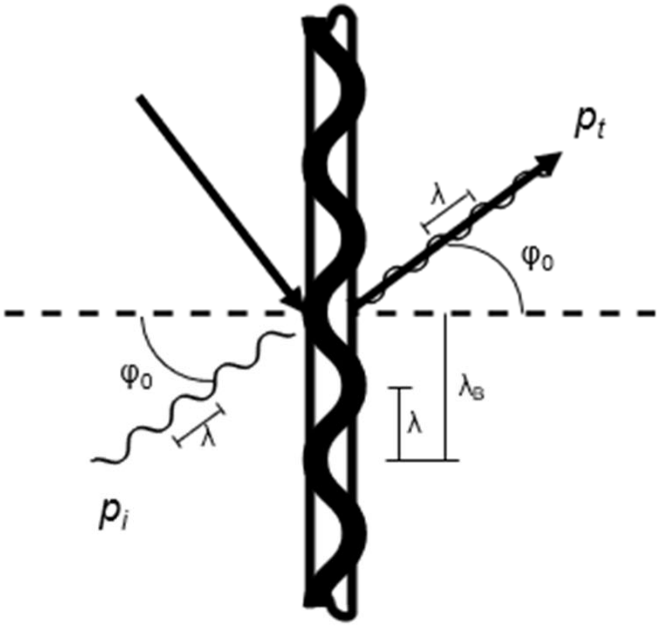


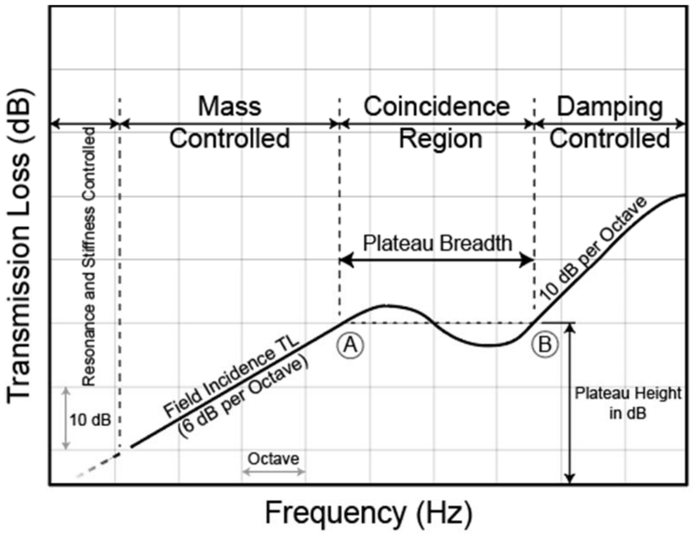
Feshbach, 1953

Beranek's Contributions

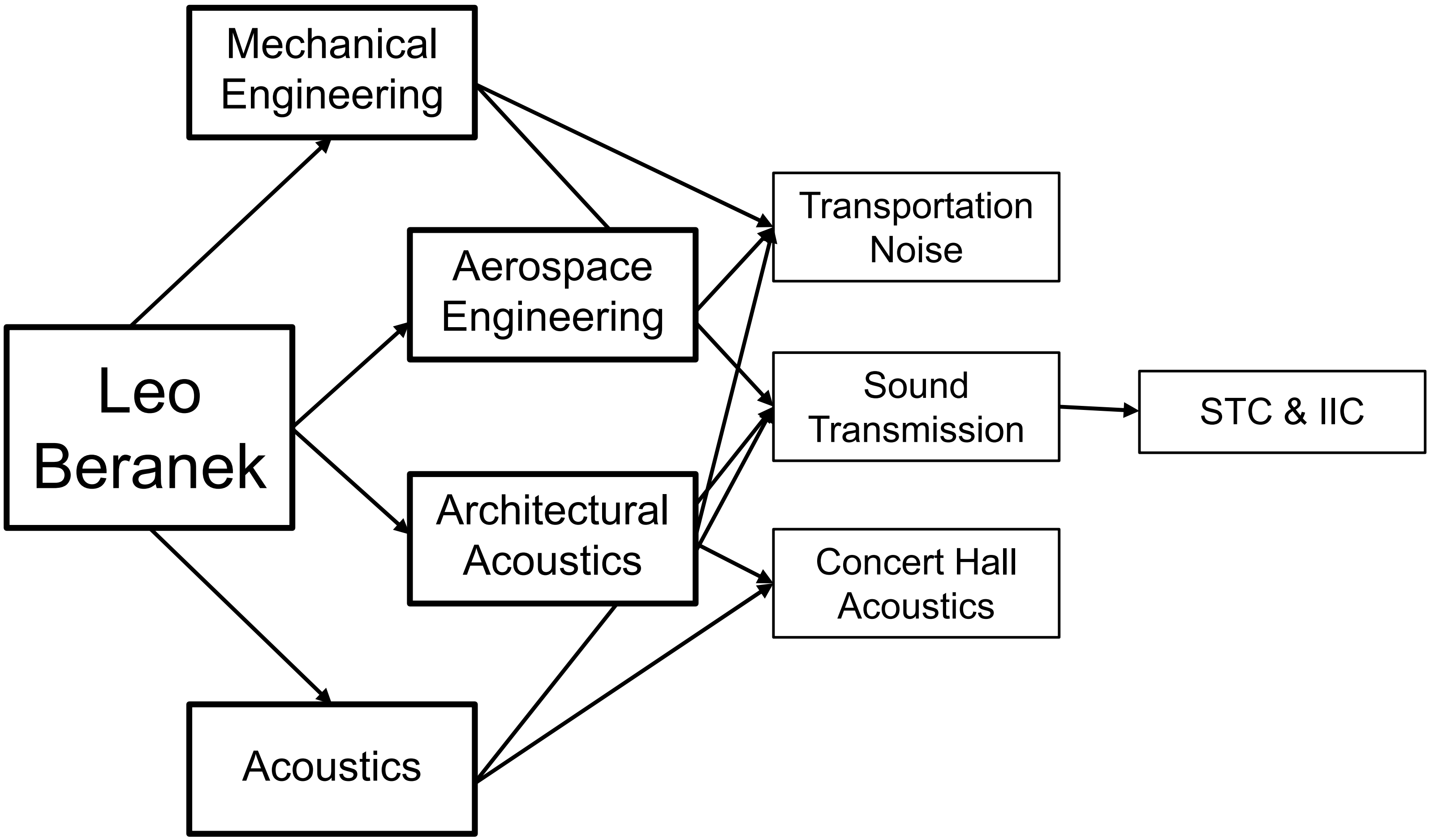


JASA, 1929



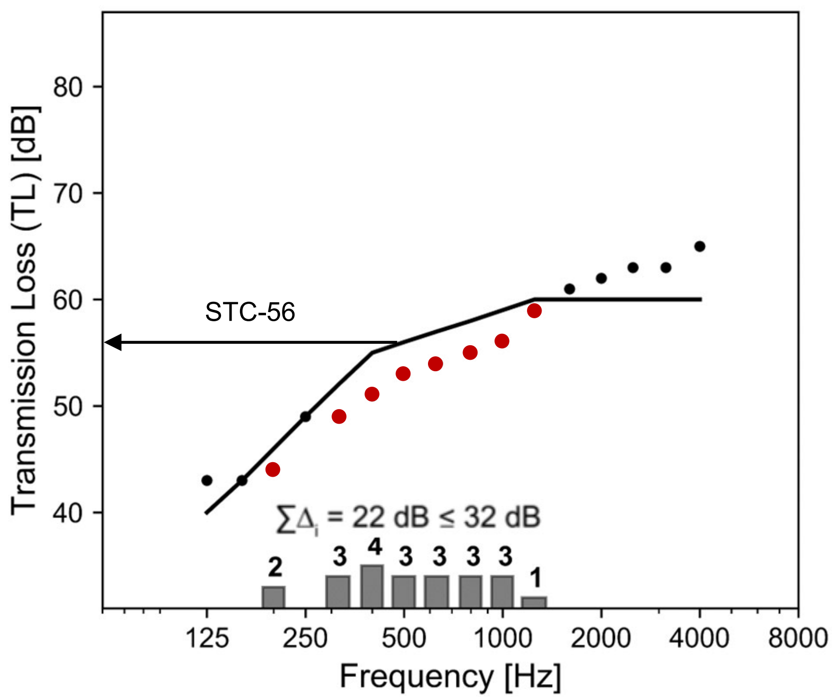


Legacy and Influence

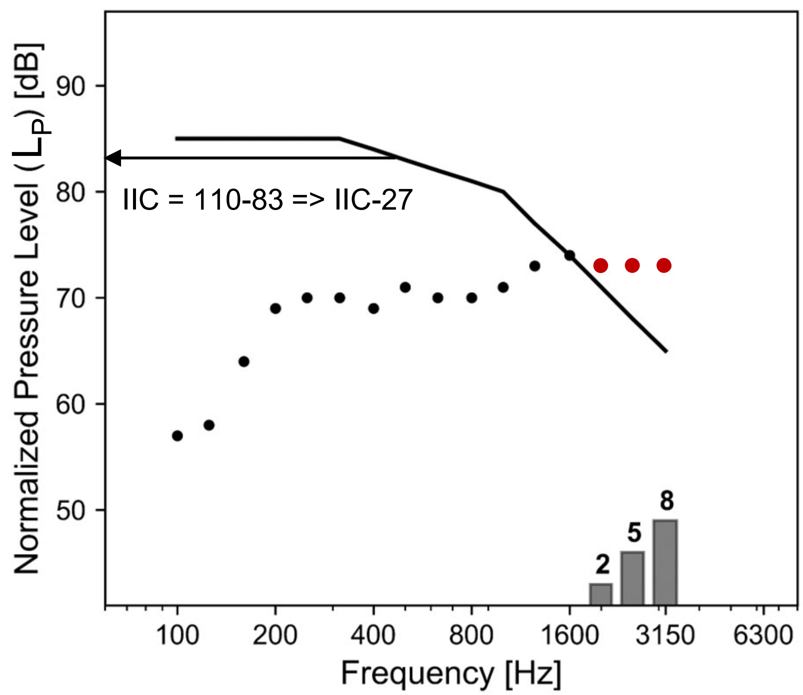


Standards and Metrics

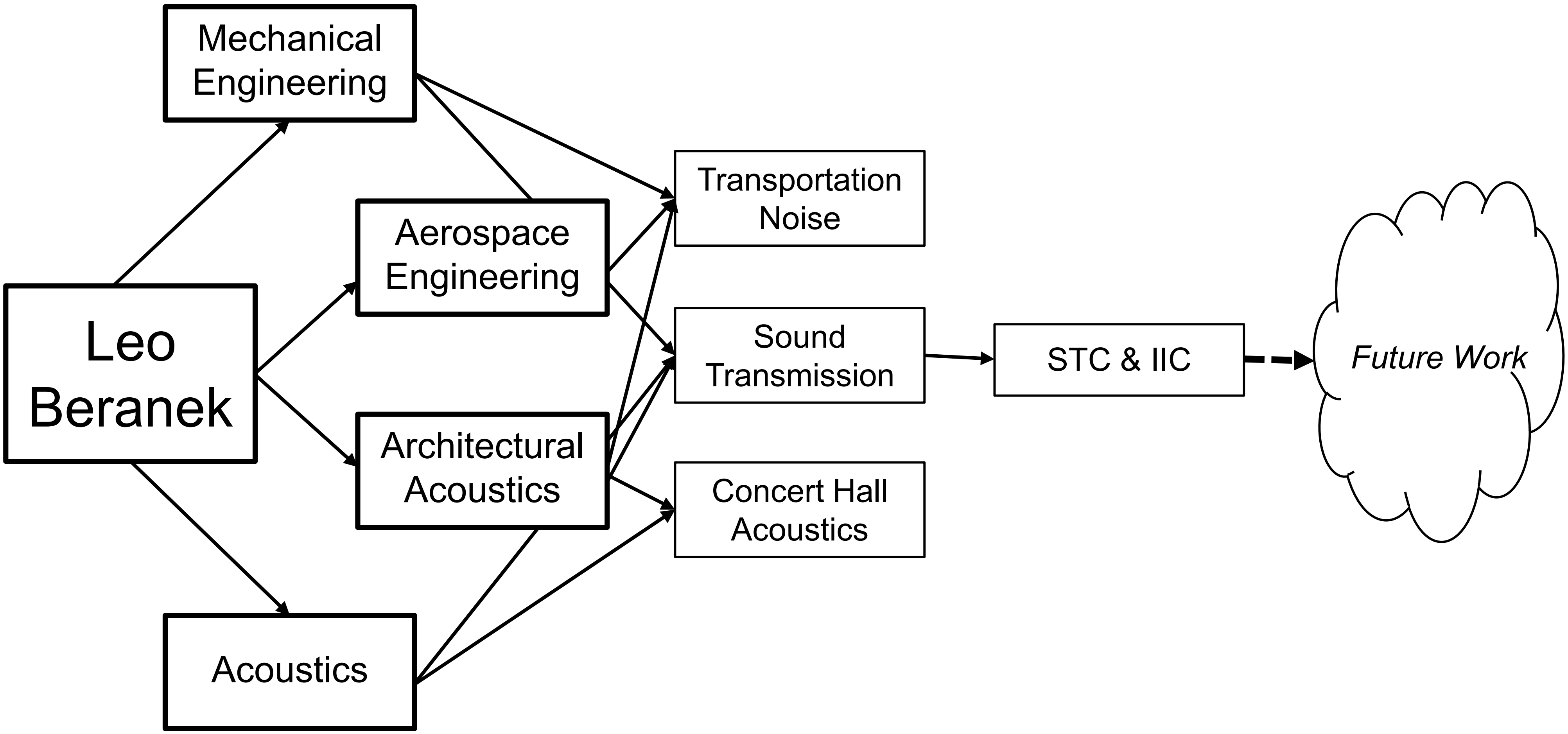
STC



IIC



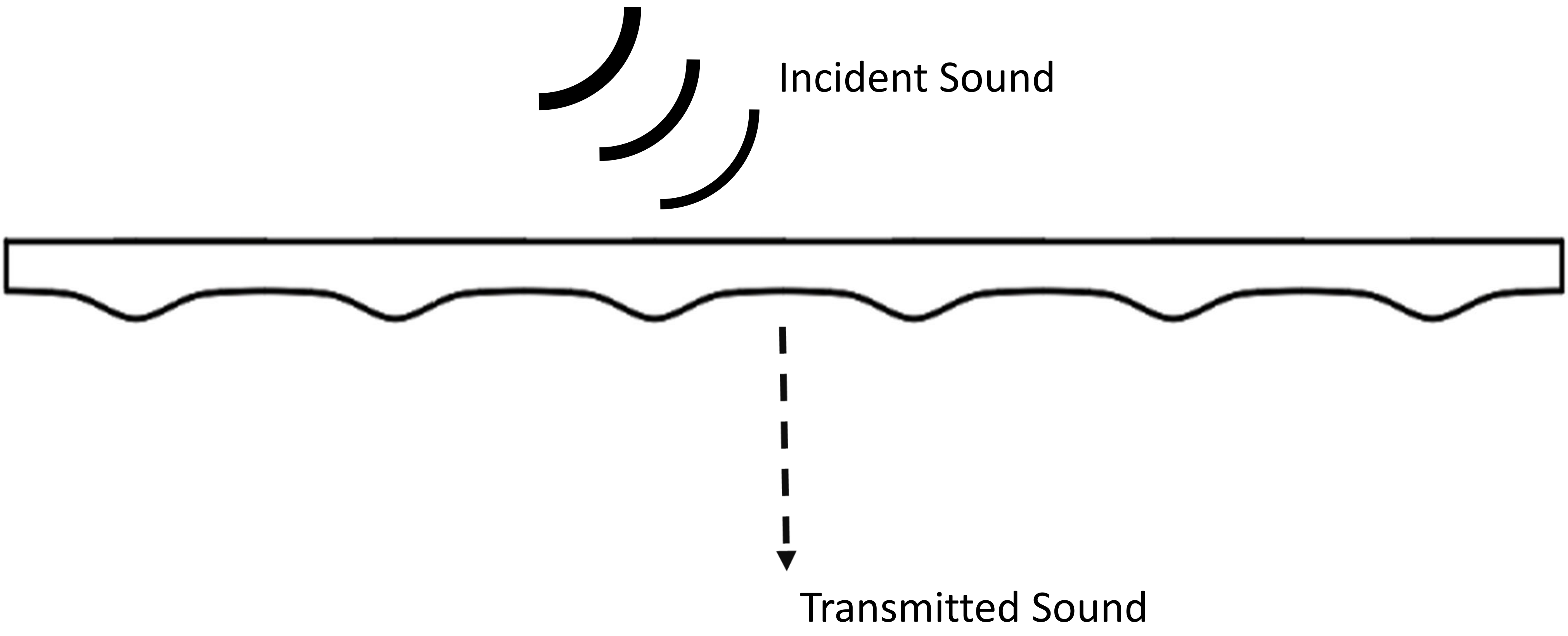
Legacy and Influence



Optimized Building Structures

Meibodi et al., 2018

Transmission Performance of Optimized Structures



Thank You