Sound Quality Issue:

Binaural Head vs. Measuring Mic.

A Systems Model View

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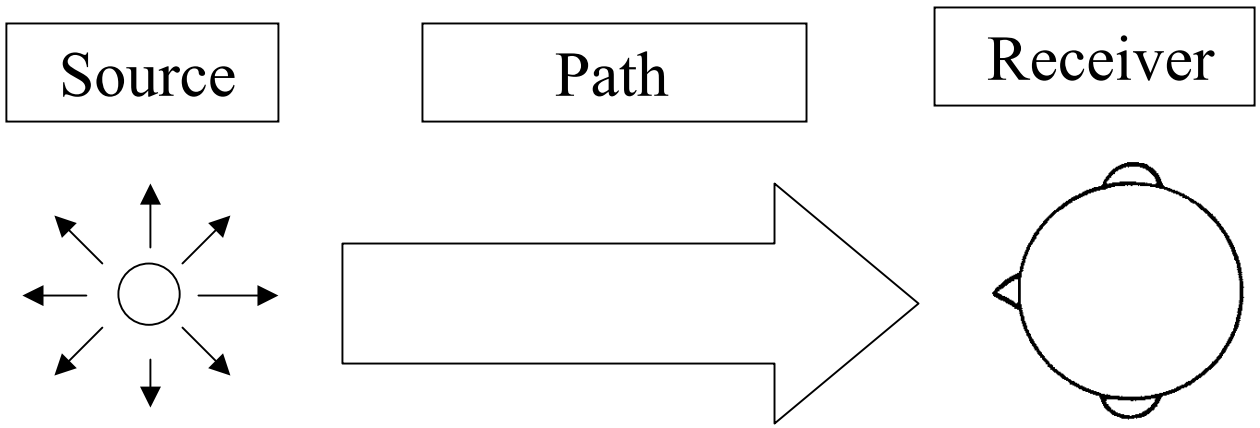
Sound Quality Systems Model

The systems model for N&V (including Sound Quality) consists of :



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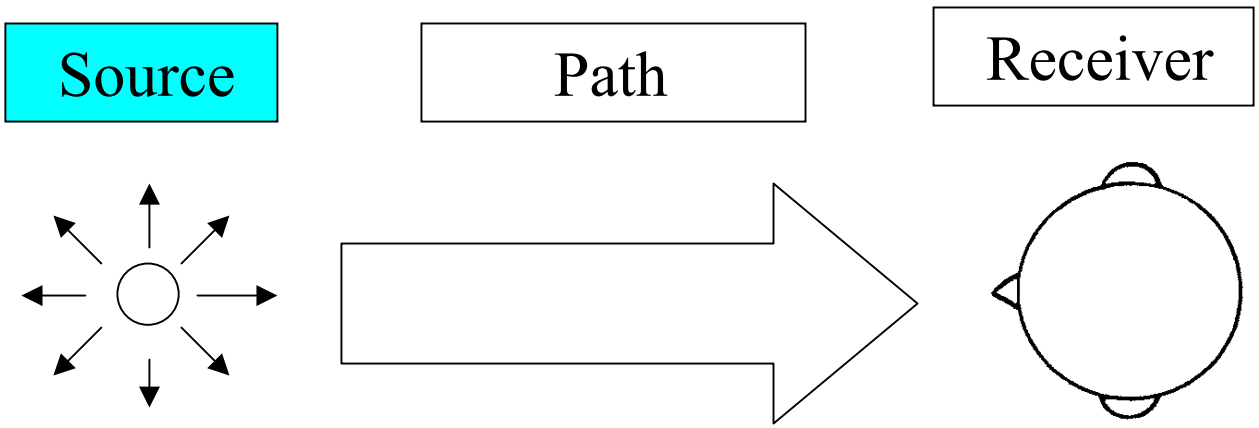

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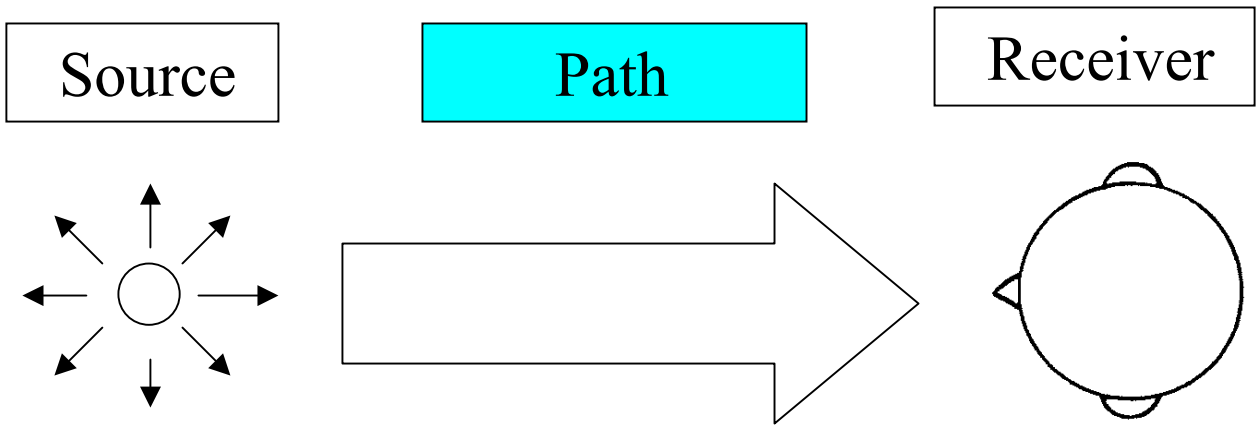

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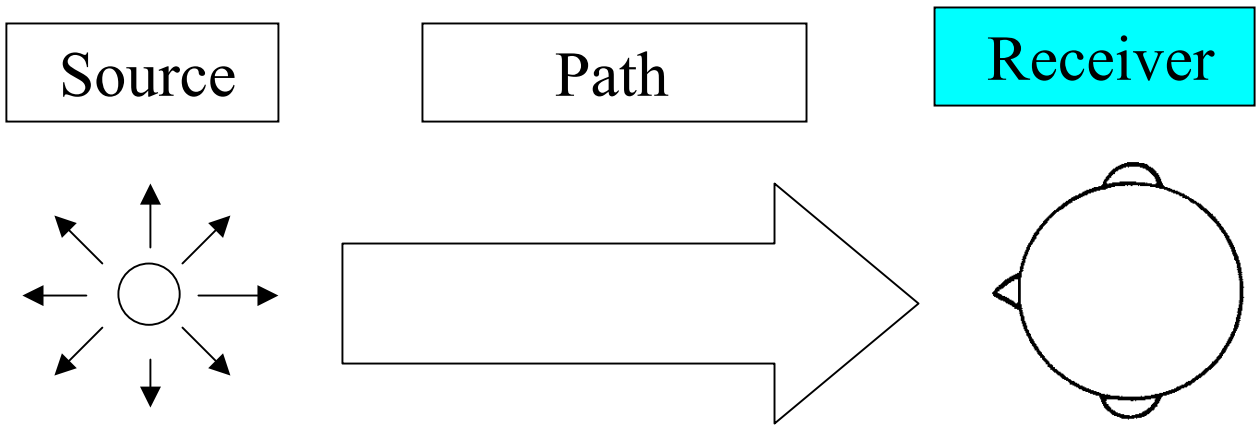
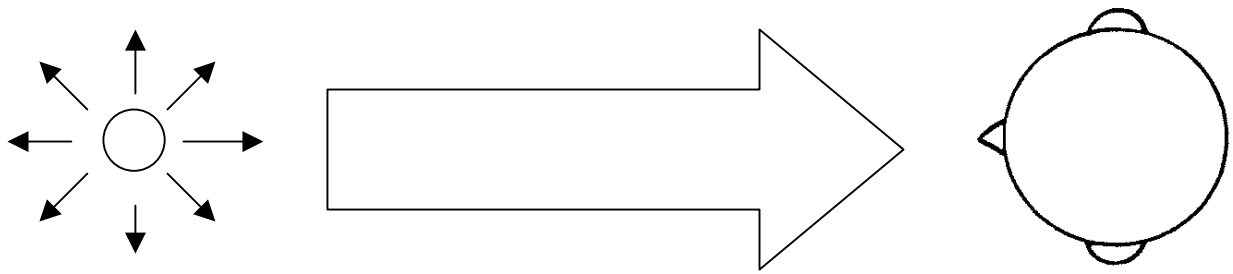


Sound Quality Systems Model

Complete Problem Focus ⟷ Individual Element Focus

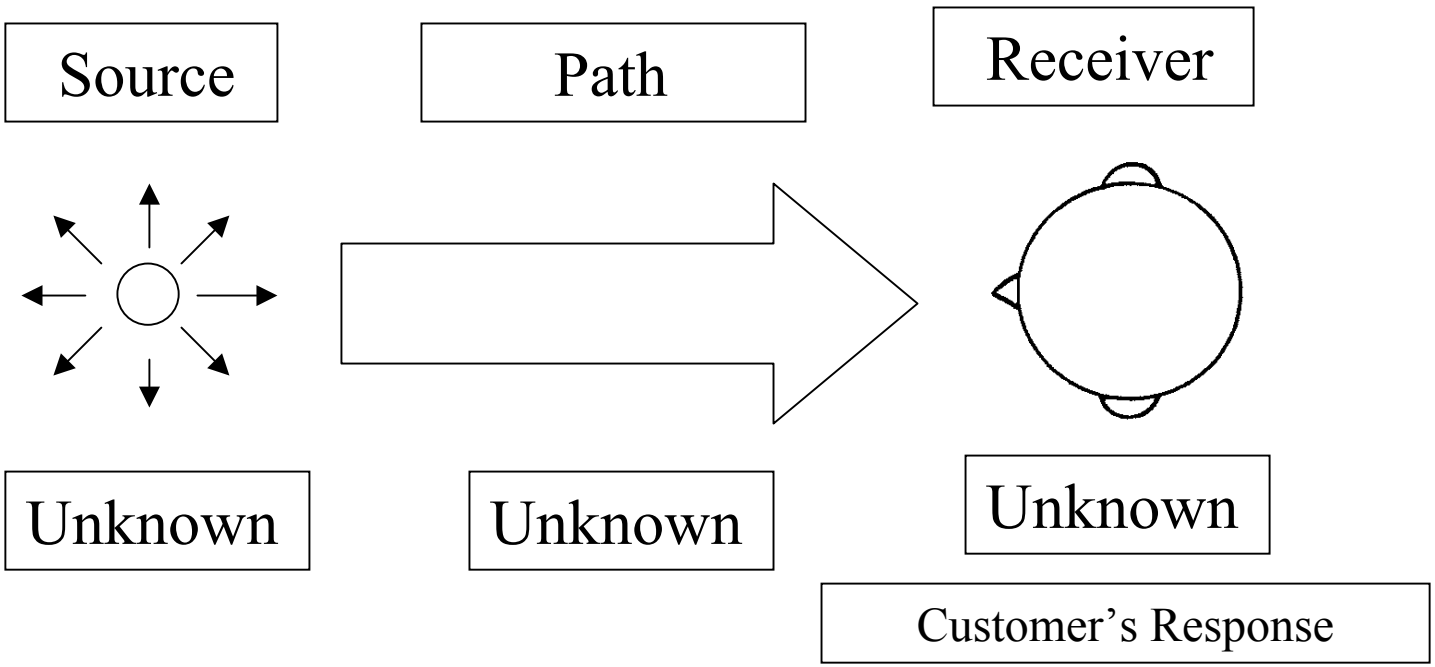
Source | Path | Receiver



Using this Model, work can be focused at different times on the complete system or on individual elements.

Sound Quality Systems Model

Complete Problem Focus



In this example, the focus is primarily on learning about the customer's response.

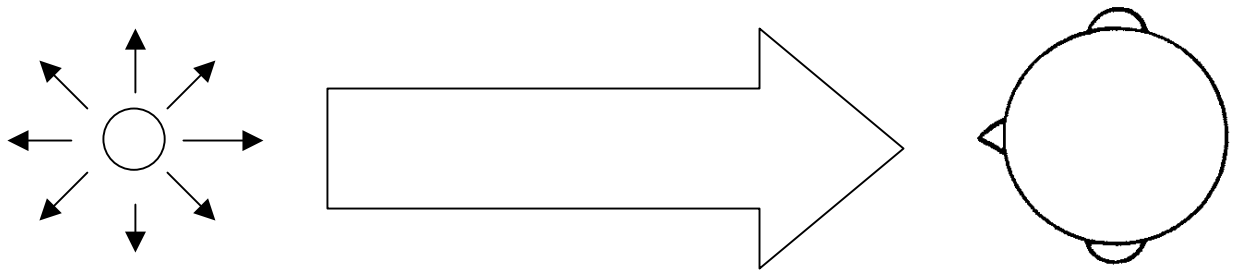
Sound Quality Systems Model

Individual Element Focus

Source

Path

Receiver



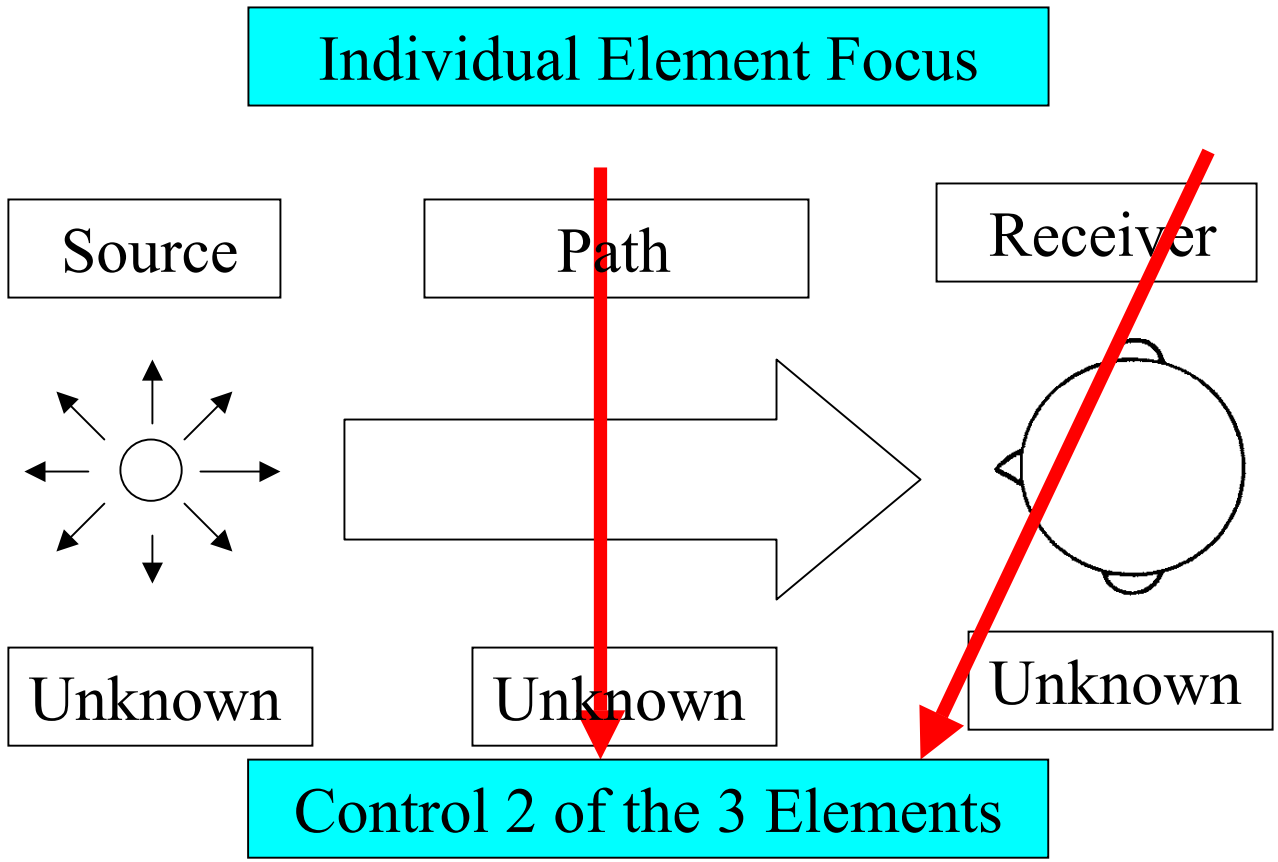
Unknown

Unknown

Unknown

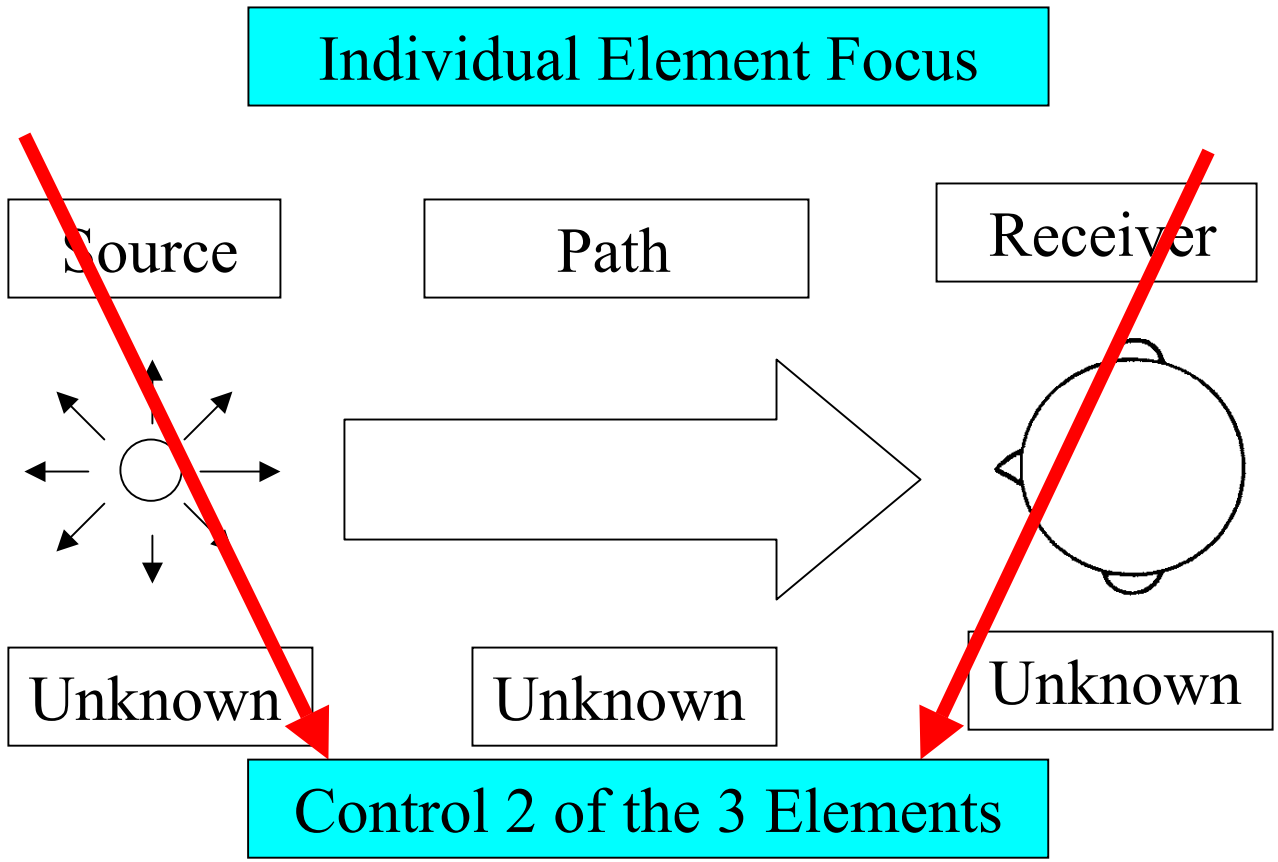
Control 2 of the 3 Elements

Sound Quality Systems Model



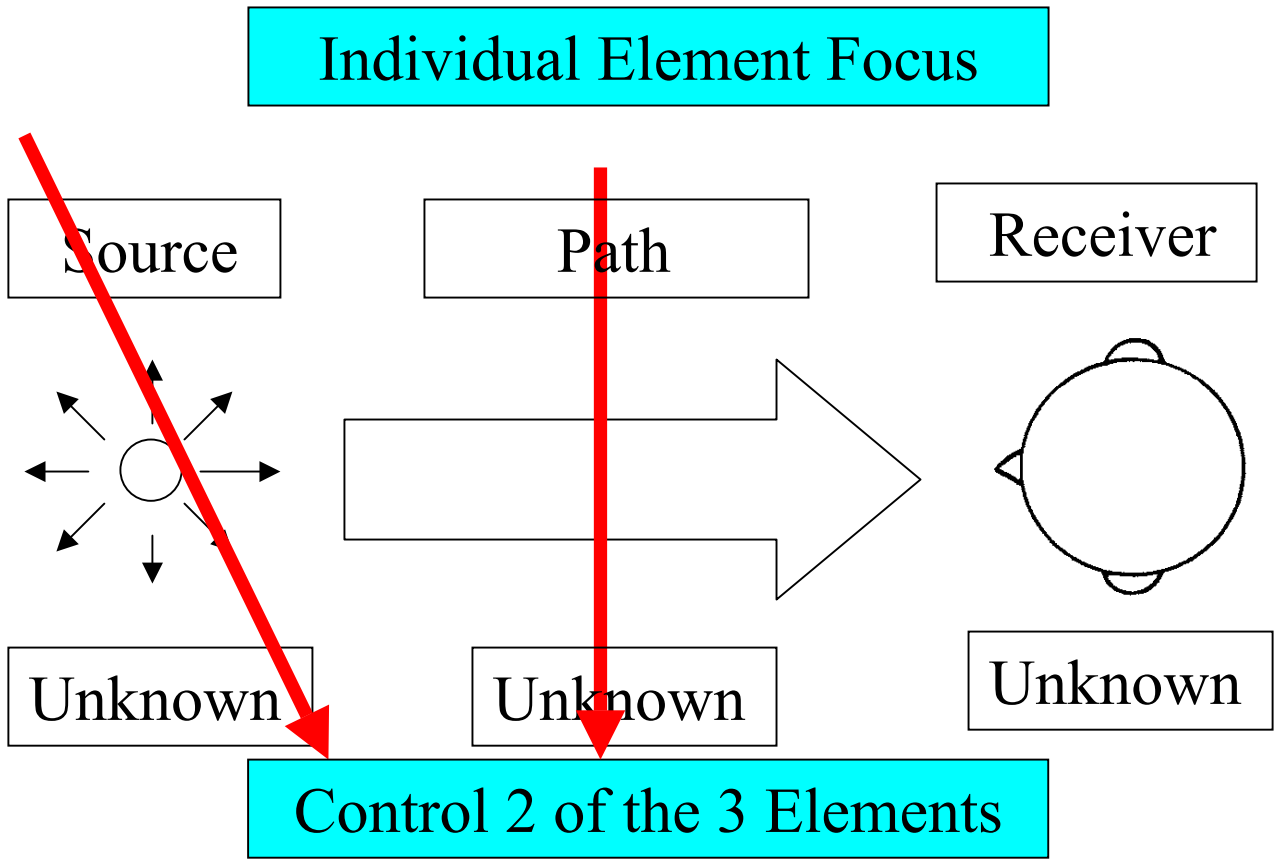
In this example, the focus is primarily on learning about the source.

Sound Quality Systems Model



In this example, the focus is primarily on learning about the path.

Sound Quality Systems Model



This case is typically a focus for academic research – NOT for applying existing techniques for automotive Sound Quality.

In this example, the focus is primarily on learning about the receiver.

Sound Quality Systems Model

Example of Academic Research

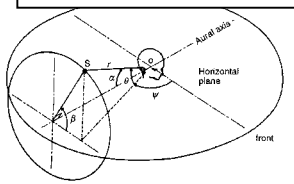


FIG. 1. Definition of an interaural-polar-axis coordinate system. S: sound source; O: center of the head; r: distance between a sound source and the center of head; θ: azimuth angle; θ: elevation angle; α: the angle between the aural axis and a straight line connecting the sound source with the center of a subject's head; β: the angle between the horizontal plane and the perpendicular from the sound source to the aural axis, that is, the vertical angle in a plane parallel to the median plane, called the sagittal plane.

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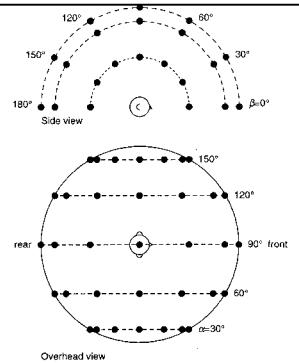

FIG. 2. Arrangement of loudspeakers used for the localization test. In the side view, loudspeakers in sagittal planes defined by angles $\alpha=120°$ and 150° are hidden by those in sagittal planes defined by angles $\alpha=60°$ and 30°, respectively.

Masayuki Morimoto: Upper hemisphere localization 1597

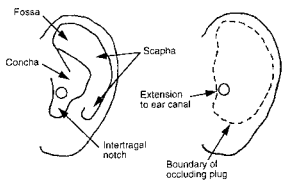

FIG. 3. The occluded part of a pinna.

C. Pinna conditions

The localization tests were done under four pinna conditions: (a) both ears open, i.e., the pinna cavities of both ears were not occluded; (b) right ear open, i.e., the pinna cavities of the right ear were entirely open while those of the left ear were occluded except for a passageway to the ear canal; (c) left ear open, i.e., the pinna cavities of the left ear were entirely open while those of the right ear were occluded except for a passageway to the ear canal; and (d) both ears occluded, as described above. The occluded part of cavities is shown in Fig. 3. In this experiment, the pinna cavities were occluded using a material normally used for dental impressions (Algix), and the passageway to the ear canal was made of a drinking straw. The surface of the occlusion was flattened to be level with the end of the straw and the helix. The length of the straw was almost equal to the distance from the surface to the entrance of the auditory canal.

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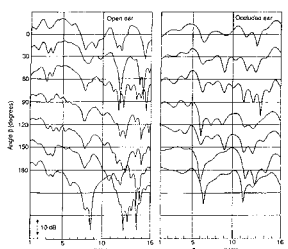


FIG. 4. Measured amplitudes of head related transfer functions of an open ear (left) and an occluded ear (right). Left ear of one of three subjects. Source angle α=30°.

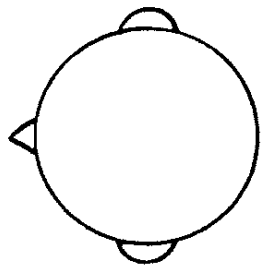
Masayuki Morimoto: Upper hemisphere localization 1598

Binaural Head – Frequency Response Functions for each ear are dependent on the angle of incidence in 3 dimensions. They cannot be equalized without knowing the angle of incidence.

Head-related Transfer Functions (HRTF)

Recording with Binaural Head

Receiver



Partially Known

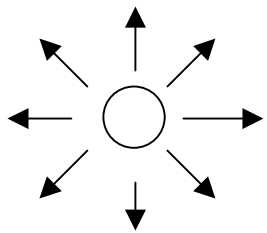
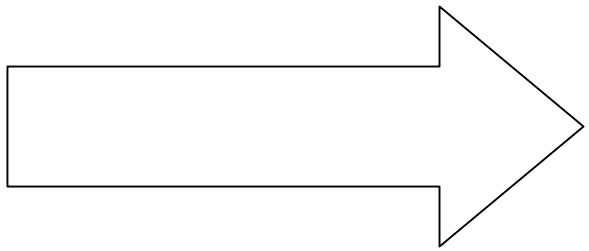
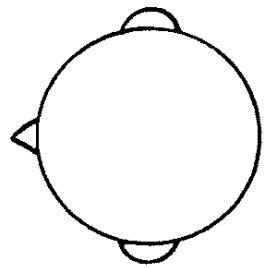
Binaural Head - Localization Cues Preserved for Subjective Evaluation

Sound Quality Systems Model

Complete Problem Focus

(Emphasis on Receiver)

Recording with Binaural Head

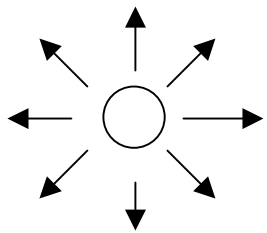
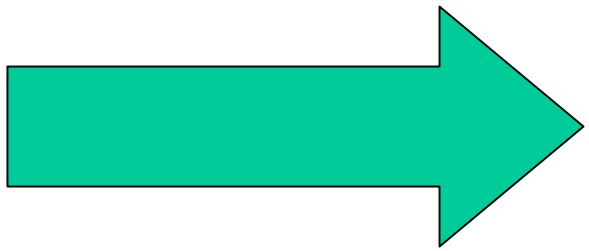
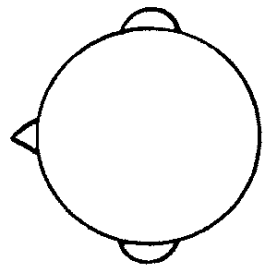
Source	Path	Receiver
		
Unknown	Unknown	Partially Known

Binaural Head - Localization Cues Preserved for Subjective Evaluation

The Binaural Head is a useful tool for this purpose.

Sound Quality Systems Model

Source Characterization Focus

Source	Path	Receiver
		
Unknown	Unknown	Partially Known

When the source is the focus, it is useful to eliminate the other unknowns.

Binaural Head

Sound Quality Systems Model

Source Characterization Focus

Step 1

Source

Path

Receiver

Unknown

Known

Partially Known

First, control the path...

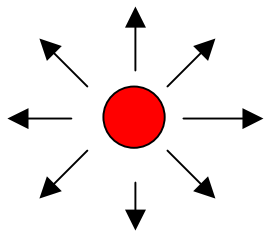
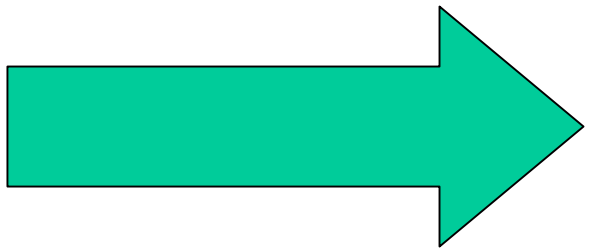
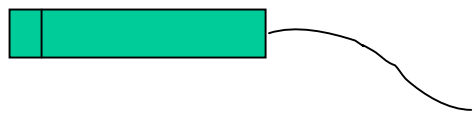
Anechoic room

Binaural Head

Sound Quality Systems Model

Source Characterization Focus

Step 2

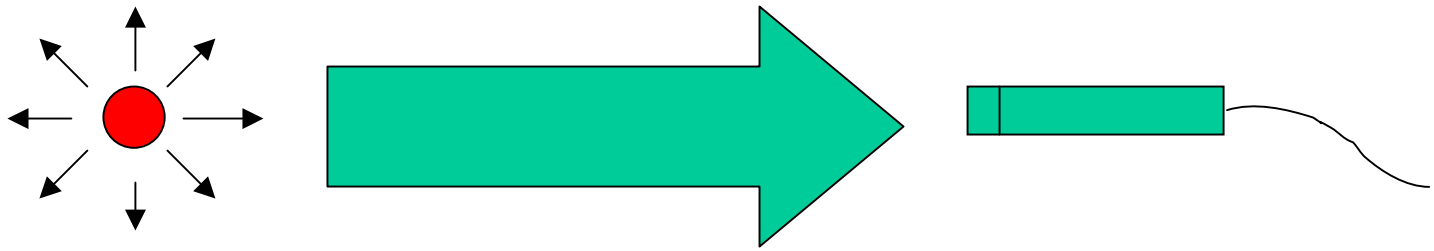
Source	Path	Receiver
		
Unknown	Known	Known
Next, control the receiver...	Anechoic room	Measuring Mic

(Omnidirectional with flat frequency response)

Sound Quality Systems Model

Source Characterization Focus

Step 3



Now, measure and analyze...

Known	Known	Known
Characterized (Completely or at least Partially)	Anechoic room	Measuring Mic

(Example: Airborne Focus)

Sound Quality Systems Model

Consider again this focus...

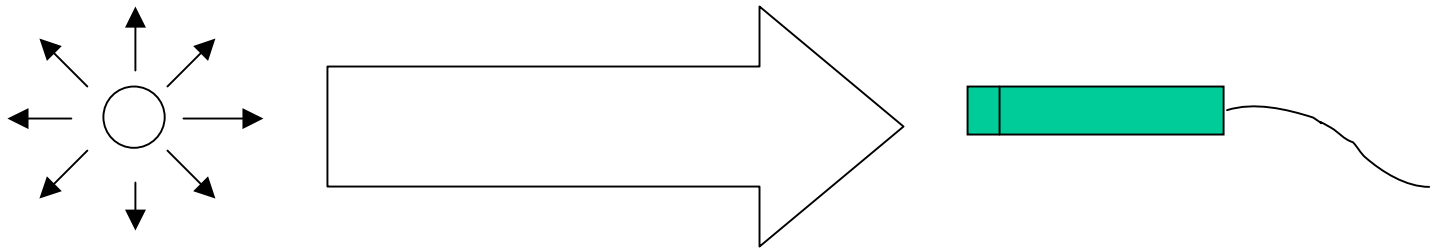
Complete Problem Focus

Analysis with Measuring Mic

Source

Path

Receiver



Unknown

Unknown

Known

Localization Cues Not Preserved for Subjective Evaluation

A Measuring Mic can also be useful in this situation, but note the change in emphasis.

Sound Quality Systems Model

Complete Problem Focus

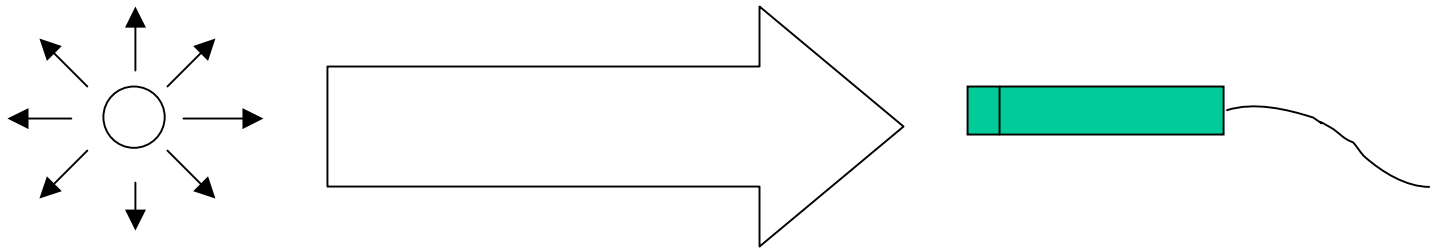
(Emphasis on Source)

Analysis with Measuring Mic

Source

Path

Receiver



Unknown

Unknown

Known

Compare Results from Complete Focus with Source Characterization Focus for Source Requirement Validation

A partial understanding of the path contribution can be learned from the differences in the two results.

Sound Quality Systems Model

Comparing results (using measuring microphones) from the

Complete Focus

with the

Source Characterization Focus

can help determine the relative importance of airborne and structure-borne contributions to sound quality.