Standing Wave Problems In Acoustic Behavioral Testing Of Animals

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Experimental procedures designed to test auditory thresholds of animals require a room relatively free of extraneous noise to minimize masking effects. Specially designed rooms have accomplished this objective satisfactorily. However, pure tone stimuli generated within the room result in a spatial distribution of sound pressures which may affect test results. These sound pressure patterns are determined by the acoustic properties of the walls of the test room, in other words, by sound reflection from the walls and by the location of the sound source, to mention only two factors. The sound pressure patterns can be interpreted as a super position of traveling sound waves; some waves arriving directly from the source, others after single or multiple reflections at the walls. In certain points the waves tend to cancel whereas in other points they reinforce each other.

In one particular experiment, cats are behaviorally conditioned to jump a hurdle in a testing cage in response to changes in the frequency of an auditory stimulus. The objective is to determine the frequency discrimination for the cat under normal conditions and with various induced pathologies. When varying the frequency of the sound source the sound pressure pattern will shift and change; this leads to variation of sound pressure level at ear entrance (of stationary animal) which accompanies the change in frequency, whereas a change in frequency only is desired. The possibility of the animal responding to a change in sound pressure level should be eliminated.

The sound pressure patterns in a commercial sound treated room, with walls of perforated acoustic tile, were studied in an attempt to assess the magnitude of this problem in our experiments on frequency discrimination in cats.

METHOD

A sound source with driving force of constant frequency and amplitude will create a sound pressure field. At certain points sound pressures are less than at all adjacent points, such minima are termed partial pressure "nodes". At certain other points sound pressures are higher than at all adjacent points, such maxima are termed pressure "anti-nodes". The number of nodes and anti-nodes are related to frequency and their locations changes as frequency is altered. Sound pressures were created by feeding the amplified output of an audio oscillator into appropriate speakers, and measured with a calibrated 640 AA Western Electric condenser microphone in combination with a microphone amplifier and a sound pressure level recorder. (See Fig. 1). A band pass filter was inserted as shown so as to record only the sound pressure at the frequency of interest. The sound pressure was recorded for a series of discrete frequencies while the microphone was moved in a predetermined course in space. The microphone was moved by a gravity operated device controlled with an appropriate governor, which permitted the microphone to travel from near the

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ceiling to the floor, a distance of about five feet, at a speed of about one foot per minute. (See Fig 2).

Figure 1
Arrangement of measuring equipment.

Figure 2
Microphone positioning device.
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Figure 3
A key of positions in the soundproof room.

RESULTS

Recordings were made at the commonly used test frequencies, 250 cps. (Fig. 4a), 1000 cps. (Fig. 4b), 4000 cps. (Fig. 4c and d), 16,000 cps. (Fig. 5a, c and d), and 32,000 cps. (Fig. 5b), with the gravity operated device placed in several locations in the room, and with the microphone directed towards or away from a sound source. (See Fig. 3).

While the microphone traveled from the ceiling to the floor, the pen traversed the paper from left to right and simultaneously moved up as the sound pressure increased, or down when it decreased. A scale to indicate the height has been omitted, however, from the extreme left to the extreme right of the curve corresponds to approximately 5 feet; whereas the total height of the room was 6½ feet.

An examination of representative recordings reveals the following:

a. The number of nodes and anti-nodes increased with the test frequency. The microphone by-passed only one node at 250 cps; traveled through two nodes (sharp peaks downwards) and by-passed another node at 1000 cps. There are two recordings at 4000 cps., one taken in position 15 (right rear corner) where the microphone traveled through three nodes and the other taken in position 11 (left rear corner) which shows a more irregular pattern.

The patterns of Fig. 5a and b are representative for frequencies of 16,000 and 32,000 cps. with the microphone directed away from the speaker.
Figure 4
Sound pressure patterns.
Vertically: s.p.l.—sound pressure level in db
reference level is 0.0002 micro bar
Horizontally: height (See Text).
  a. Frequency 250 cps. Position 42.
  b. Frequency 1000 cps. Position 55.
  d. Frequency 4000 cps. Position 11.
Erratum: Figure 4, d. For 40 read 45.
Figure 5

Sound pressure patterns.
Vertically: s.p.l.—sound pressure level in db
reference level is 0.0002 micro bar
Horizontally: height (See Text).

a. Frequency 16,000 cps. Position 55.
b. Frequency 32,000 cps. Position 22.
c. Frequency 16,000 cps. Position 33.
d. Frequency 16,000 cps. Position 33.

b. The pressure may differ considerably from one point to another and the following table demonstrates some extremes.
The patterns present the pressure along the line of travel. If sufficient runs at a particular frequency are obtained they may provide a picture of the sound pressure in three dimensions; for low frequencies this could be useful for the interpretation of behavioral testing data. Another acoustical phenomenon important in this respect is demonstrated in Fig. 5c (microphone facing the sound source) and Fig. 5d (microphone facing the wall opposite the sound source), both recordings being taken in the center of the room. These two patterns differ widely because of the directive properties which the microphone exhibits at high frequencies. The pressure as recorded in Fig. 5c (radiation pattern of the speaker) was due to waves coming directly from the sound source, whereas in Fig. 5d, it was due to waves reflected from the wall opposite the sound source. The average pressure of reflected waves was about 30 db below the maximum of the direct pressure. The actual pressure with the microphone removed would be roughly the summation of those two components.

As mentioned before, the patterns shift and change when frequency is varied. Particularly for high frequencies, small changes in frequency may lead to large changes in sound pressure at a given point.

**DISCUSSION**

In the test situation, the cat is trained to move across a hurdle in the cage when a series of pure tone pulses, all of the same frequency, is suddenly changed so that alternating pulses are different in frequency. So long as signals of constant frequency and intensity are delivered to the sound source, no pressure alterations occur in this ear. However, sound pressure variations occur when either the frequency of the signal is altered or the animal moves his ear in space. Fortunately the animal often remains stationary during the unconditioned stimulus (tone pulses of equal frequency) and moves only on the presentation of the conditioned stimulus (alternating pulses of different frequency). The pressure variations at the ear resulting from frequency changes may provide an additional cue for those animals which maintain the stationary position of the head during testing. On the other hand, animals which moved about spontaneously were subjected constantly to intensity variations which may have interfered with the detection of small frequency differences.

It is obvious, therefore, that when motor response methods are used in testing frequency or intensity difference thresholds in animals, great care must be used to reduce sound reflection from the walls of the test room so as to minimize pressure alterations resulting from standing waves.
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LIST OF INSTRUMENTS USED

*Audio Frequency Oscillator*—B & K Type 1013*

*Speakers*—For 250, 1000 and 4000 cps, Ampex 620 Amplifier-Speaker
   - For 16,000 and 32,000 cps, Model T-3500 Ionovac Electro-Voice Super High Frequency Driver.

*Microphone Cartridge*—Western Electric Type 640 AA Ser. 1159 (calibrated)

*Cathode Follower*—B & B Type 2612. Used in conjunction with the Western Electric 640 AA cartridge.

*Microphone Amplifier*—B & K Type 2603

*Band Pass Filter*—Allison Model 2A and 2C

*Sound Level Recorder*—B & K Type 2304

*Audiometric Testing Room*—I. A. C. Model 1200 SP.

REFERENCES


*B & K*—B & K Instruments, Inc.