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THE SOUND FIELD IN HOME LISTENING ROOMS

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SUMMARY Loudspeaker systems do not radiate uniformly at all angles because of cabinet diffraction, directivity effects, and driver interference near crossover frequencies. In order to assess the practical importance of these effects, and to determine the "frequency response" of typical room/loudspeaker combinations, measurements were made of the spectral balance at normal listener positions in 10 rooms used for music reproduction, using 1/3-octave pink noise. Results are compared with predicted and measured spectral balance in concert halls.

Even when the individual speakers in a high-fidelity speaker system radiate energy in a smooth and uniform manner at all forward angles, if each is measured by itself on a flat baffle, the system in which they are used does not do so. Interference between speakers in the crossover frequency regions causes reinforcement at some frequencies and cancellation at others. The frequencies at which these effects occur change with the angle from the speaker system axis at which the direct radiation is measured, because the speakers cannot occupy the same space on the mounting plate; therefore, as the observer moves around the cabinet, the difference in path lengths changes.

Another source of similar perturbations in the system's radiation pattern is diffraction, which is really a form of self-interference. Mounting surface discontinuities, the grille cloth molding, and the dimensions of the cabinet itself all produce diffraction that affects the direct-wave radiation in a complex manner dependent on the angle of the cabinet with respect to the observer.

To illustrate how substantial these effects can be, we took an AR-3a system from stock and made several kinds of measurements on it. Our main anechoic chamber has non-reflective wedges on only 5 of its interior surfaces. The sixth is smooth concrete, with an opening in its center; speakers to be tested are placed at this opening with suitable adapter baffles so that they are flush with the inside chamber wall. In this manner a 2π radiation angle is obtained with minimum discontinuity. Radiation into a hemisphere is typical of actual use conditions (whereas a $4\text{-}\pi$ solid angle is not), and is in conformance with existing Standards.*

Fig. 1 shows the response (above 200 Hz) of the AR-3a woofer at six angles: 0°, 15°, 30°, 45°, 60°, and 75° from the axis, all superimposed. The woofer is in its cabinet but the grille cloth molding has been removed. Major vertical scale divisions are in increments of 5 dB.

Next (Fig. 2) is the mid-range speaker of the same AR-3a tested at the same six angles, 0° through 75°. The speaker was removed from the cabinet and installed on a flat baffle board, flush with inside chamber wall. Its electrical input was supplied through the AR-3a crossover network. The level control is set at the maximum position. Note that the design crossover frequencies for the AR-3a are 575 Hz and 5 kHz.

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*RETMA SE-103 and ASA S1.5-1963

Fig. 3 is a family of response curves of this system's tweeter, at maximum level control setting, with test conditions the same as for the mid-range unit.

The speakers were put back in the AR-3a cabinet and the complete system on-axis curve, with level controls at maximum settings, is shown in Fig. 4. The grille cloth molding is still not in place. Note the interference effect between mid-range and tweeter units in the crossover region. The low-frequency response follows the chamber calibration curve (the superimposed dashed line) quite well to 45 Hz, and is 6 dB down at 30 Hz -- exactly what an AR-3a woofer is supposed to do.

Now we reinstall the grille cloth molding and make the front of the molding flush with the inside of the smooth chamber well. Fig. 5 shows the on-axis response obtained with the level controls still set at maximum. The mere presence of the molding produces increased level (on axis) in the range from 300 to 1,000 Hz, a 5- or 6-dB notch at 1,400 Hz, and miscellaneous perturbations on up in frequency.

Figs. 6 and 7 are 15° families of the complete system, taken in a horizontal arc first in one direction away from the system axis and then the other. The grille molding is in place and the level controls are at maximum. It is difficult to assess performance because the output level changes rapidly not only with frequency but with small angular increments as well. And keep in mind that you have seen the output variation only in one plane around the system!

The picture becomes far more complex when the same system is measured in 4π environment. We took this AR-3a to the large walk-in anechoic chamber at Harvard Acoustics Laboratory, and repeated the measurements there. Fig. 8 shows on-axis response of the individual speakers of the system, in the cabinet and with molding in place. Mid-range and tweeter curves are shown for both the normal and maximum level control settings.

The most obvious feature of Fig. 8 is the woofer response. There is a continuous down-hill slide from about 400 Hz, at which frequency the cabinet is a reasonably effective 2π baffle, to about 170 Hz, and then a flat response below that frequency. At 170 Hz and below the radiation angle is 4π steradians and the output, quite predictably, is lower than it was into a 2π angle.

Molding and cabinet-edge diffraction are clearly at work on the axial response curves of the mid-range unit. Fig. 9 is the on-axis system curve, with molding, level controls at maximum. Some representative curves at other angles appear in Figs. 10 through 16. Fig. 10: $+30^{\circ}$, horizontal. Fig. 11: -60°, horizontal. Fig. 12: -75°, vertical. Fig. 13: -45°, vertical. Fig. 14: $+15^{\circ}$, vertical. Fig. 15: $+75^{\circ}$, vertical. Fig. 16: -90°, horizontal.

It is commonly recognized that interference and diffraction do not change the total energy radiated by a speaker system; they merely redirect it, bunching it at favored angles for particular frequencies. The truth of this can be verified easily by diffuse-field measurements in a very reverberant environment. Fig. 17 is the response curve of this same AR-3a system taken in AR's reverberant chamber. Input to the system in this case is pink noise. The microphone (located behind the cabinet, so as to prevent any direct radiation from reaching it) is flat for random-incidence energy. Its output is fed to a General Radio swept 1/3-octave filter with coupled chart recorder. Superimposed on the response curve is the chamber calibration for flat energy input.

Clearly, the total energy output of this system is more easily predicted by the 2π anechoic measurements of the individual speakers than by the 4π measurements of the complete system cum cabinet. But what do listeners hear from the system?

Do they perceive the total energy output, or do they perceive as the "frequency response" of the system whatever the direct-radiation output may be at the angle of their location relative to the system? These are extremely significant questions. Very little research has been done to provide answers, except by indirect means.

We can provide intuitive answers for extreme cases. If listening is done in anechoic conditions (outdoors, for example), the only information reaching listeners is the direct wave. Its spectral balance is the only thing that can be perceived; therefore, the quality of the individual speakers in the system is of significance but does not alone determine the system performance. Interference and diffraction play major roles in what is heard.

In a perfectly reverberant environment, on the other hand, it would not matter in the least what the frequency response might be for the radiation at any particular angle from the speaker system. It would not matter what angle most of the energy were radiated at any particular frequency. So long as the total energy radiated from the system were constant at all frequencies of interest (and of course if there were no audible time differences in the radiation), the sound field in most of the room would have the same spectral balance as it would have if this energy were radiated in a perfectly omnidirectional manner by the speaker system.

But of course we all know that a typical listening room is not a perfect acoustic integrator. It is only necessary to walk around the room while some kinds of speakers are playing, and observe the constantly changing tonal balance, in order to realize that. Evidently, real rooms are neither completely anechoic nor completely reverberant, but fall at some semi-reverberant point between these extremes. It is important to know approximately where that point is if we are to understand why speaker systems that "measure" in a certain way sound as they do in use.

Leo Beranek in his book Acoustics has dealt with this question in a general theoretical way. As he points out, it is easier to understand what happens if we first consider the direct sound and the reverberant sound field separately.

The direct sound from the speaker decreases in sound pressure level in strict proportion to the distance from it, according to the so-called "square law". For each doubling of distance the direct field SPL decreases by 6dB. If the source is highly directive, then of course the direct field SPL at a given distance varies in accordance with the directivity; it will be considerably higher on the axis of the lobe than it is off the axis. Put another way, if the source is directive then a given direct-field SPL amplitude will extend farther into the room, on the axis of a lobe, than it would for a nondirective source. Off the axis of the lobe it would not extend as far into the room.

The reverberant field, on the other hand, is by definition uniform in amplitude throughout the room except for the effect of room modes (standing waves). In a typical living room standing waves have little effect on the reverberant field SPL at a particular location above 1 kHz, and steadily increasing effect below that frequency.

Aside from the effects of standing waves, the reverberant field SPL is (theoretically) determined only be two factors: the power level of the source, and the room constant R. R is a factor expressing the average energy absorption coefficient of the room surfaces and the total surface area. Thus the room can be thought of as an acoustic energy sink: the source of energy (the loudspeaker) pours energy into the sink at a given rate, and the steady-state amplitude of this energy is determined by the rate at which energy is absorbed by the room surfaces and furnishings. The steady-state energy, which is the reverberant field, is independent of the directivity of the source or the position it occupies in the room, at least above 1,000 Hz. Below 1,000 Hz the reverberant field in a living room is not dependent on the directivity of the source but it is dependent to some extent on the position of the source, because position affects room mode excitation.

The room absorption constant R clearly is related to room size; in general, the larger the room, the larger the room constant. That is why more acoustic power is needed to create a given sound pressure level in large rooms than in small ones. R is also related to the "liveness" or "deadness" of a room; it is larger for a dead room than for a live one of the same size, and for the same acoustic power input the reverberant field SPL will be lower in a dead room.

Fig. 18 brings together the direct and reverberant field SPL so that their relationship is apparent. The vertical scale on the left is total SPL of the direct and reverberant fields combined, relative to the power level of the source, at the distances from the source shown on the horizontal scale at the bottom. Five sets of curves are given, corresponding to directivity factors (Q) of 1, 2, 5, 10, and 20. Each of these curves is shown for representative room constant values (R) of 50, 500, and 10,000.

As expected, the reverberant field's relative SPL is entirely a function of R; the five Q curves converge to that value of SPL representing the reverberant field only. The direct field predominates at distances close to the source and is submerged in the reverberant field farther away. For higher values of Q the direct field predominates at greater distances than for lower values. (Note that the chart assumes the measurement to be made on axis of the directivity lobe; if the measurement were made off axis, then of course the direct field would become insignificant very close to the source).

What does the chart say about living rooms? Let us assume a living room of average size -- say, 2,500 cubic feet, which is a room 14 by 23 feet with average ceiling height. If this room is of "average" absorptivity, neither very live nor very dead, its room constant will be 200. Assuming that the loudspeaker is placed against one wall its directivity factor will be 2 at low frequencies. If it is a high-quality unit its directivity factor will be 2 also at middle frequencies. At high frequencies it will be at least 3 for even the highest-quality systems, and 4 or 5 for merely very good speakers.

Following the horizontal line extension of R = 200, we see that it intersects the Q = 2 direct-field line at a distance of a little less than 3 feet. At 2 3/4 feet, then, the direct field is equal in level to the reverberant field for a nondirectional source placed against a wall in this average room. At 5½ feet the direct field is 6 dB down from the reverberant field SPL; the reverberant field is certainly predominant. This would apply at middle frequencies also for the best speaker systems.

For a Q value of 3, the direct and reverberant fields are of equal amplitude at about 3½ feet from the speaker. At 7 feet the direct field is 6 dB below the reverberant field. And for a Q of 5, the two fields are equal at 4½ feet; the reverberant field would not predominate by 6 dB for a listener on the axis of the speaker until he were at least 9 feet away from it.

Most typical listening positions are at least 6 feet away from the speakers. Probably it would be accurate to say also that 90% of listeners are at least 9 feet away from the speakers when they are in their favorite chairs. If loudspeakers systems with very good high-frequency dispersion are used, therefore, Beranek's calculations would imply that listeners are almost always in the reverberant field of the room for all frequencies being reproduced. But it should be noted that not all speaker systems -- not even all quite costly ones -- have very good dispersion at all frequencies. Q values of 10 or more are common, particularly at high frequencies; that requires a distance of at least 12 feet to get well into the reverberant field.

Depressions or notches in the direct radiation at certain frequencies, due to interference, would not be heard by a listener because the SPL at those frequencies would be maintained by the reverberant field. But what about direct-radiation peaks due to diffraction effects? An increase of 3 dB in the direct field, caused by diffraction, is equivalent to a doubling of the directivity index for that frequency at that angle. Here the situation is not so self-evident. In a practical sense there are other questions that might be raised about the importance of the direct and reverberant fields, in addition to the simple one of whether or not the relative amplitudes agree with Beranek's chart. There are three questions of fundamental importance:

1. In widely varying home listening situations, is the field at any practical listener location primarily direct rather than reverberant?

2. Even if the field is primarily reverberant on a random-incidence basis, do head and outer-ear shielding weight the field at the ear canal entrance toward the direct sound?

3. Whether or not the field at the ear canal is mostly reverberant, is there something in the ear/brain system that judges spectral balance only on the basis of the spectrum of first-arrival (direct) sound, much as it judges the direction of the source on the basis of first-arrival information?

To address ourselves directly to these questions, we measured the fields produced by loudspeakers in ten actual listening rooms that vary widely in type of furnishing and size. These rooms are shown photographically and by scale drawings in Fig. 19 through 28, together with the AR-3a data. Eight of the rooms are the living rooms or home music listening rooms of AR-3a owners who reside in the Greater Boston area; two are office/listening rooms at the AR offices in Cambridge. None of the rooms was rearranged, nor the speaker systems moved, prior to the measurements. The speakers were not special in any way.

Most of the work involved the random-incidence field produced by AR-3a's in these rooms. We used pink noise, fed to one or both AR-3a's, as the main source, and analyzed the microphone output by means of a General Radio 1/3-octave swept filter with coupled chart recorder. In order to avoid the possibility of bias in deciding on microphone positions we did not perform the analyses on the spot; we recorded the field samples on a Magnecord 1028 machine, with Scotch #203 tape, for the later filter analysis. Our random-incidence measurements were made with a 1/2-inch B&K microphone flat to 20 kHz for random-incidence fields, always placed at seated ear-level height.

Figs. 19 through 28 show summaries of the AR-3a random-incidence field information for each of the 10 rooms. Each slide is allotted to one room only; the individual charts on each page are marked to identify the room, the microphone location (keyed in the scale drawing), and the fact that this is a random-incidence recording. There are basically two types of recordings here: those made with both speakers operating and facing as they normally do, and those made with a single speaker system facing directly at the microphone. For each single-speaker recording on the speaker axis, we made additional recordings with the speaker turned 30° and 60° away from the microphone. These additional recordings (not shown) are summarized as differences from the 0° recording. Since it is known that the spectral balance of direct radiation from any multiple-speaker system depends on the angle at which it is radiated, these differences give strong clues to the proportion of direct to reverberant sound at that microphone location. Turning the speaker, rather than moving the microphone, minimizes the influence of room modes on this aspect of the investigation. (In two of the rooms, H and M, it was not practical to make these angular measurements because the speakers were on narrow shelves close to the ceiling). Measurements were made in other rooms at various distances ranging from very close (3 ft.) to typical listening positions. Whenever possible we used the left-channel speaker for these angular measurements, simply for consistency.

These (and all other recordings in this series of tests) were made with both the mid-range and tweeter level controls turned all the way up. We did this, despite the fact that it produces unnatural balance on music recordings, because it is an adjustment easily made to achieve standard repeatable conditions, and because it shows the maximum output available from each of the three speakers in the system.

At typical listening positions the data indicate that the field is decidedly reverberant.

The curves show also that discernible room modes are almost nonexistent above 1 kHz. When modes are present at lower frequencies their effect is different at different locations. It is difficult to see any justification for elaborate multi-filter "room equalizers". If correction is needed, simple tone controls would do it better.

Figs. 29 and 30 are designed to answer fundamental question No. 2: does the physical shape of the head and pinnae change the ratio of direct to reverberant sound appreciably at the ear canal entrance from that which would exist at the same spot on a random-incidence basis? We placed a dummy head, with Altec type 21 microphones at the ear canal entrance, in the same locations as the random-incidence mike locations in rooms A and B, and repeated the angular measurements. The dummy head faced the speaker directly in each case, of course. The difference curves are quite similar to those for the random-incidence measurements. It is clear that the head does not affect the ratio of direct to reverberant energy significantly, although it does have a major effect on the spectral balance of the combined field at the ear canal entry.

We thought it advisable to obtain data on a quite different kind of speaker system -- the AR-4x -- to see how these same rooms treated relatively directional tweeter radiation. The AR-4x data were obtained in room A and in both AR listening rooms. Figs. 31 through 33 are the AR-4x counterparts of Figs. 19 through 28 for the AR-3a. As might be expected, the reverberant field is predominant at room locations closer to the AR-4x (as compared with the AR-3a) for middle frequencies, and not nearly as close at high frequencies.

There is still fundamental question 3 to be answered. In an attempt to do so, we made binaural music recordings with the dummy head facing the speaker at various distances in rooms A and B. We turned the speaker at 10-second intervals during the course of each 1-minute recording. In each case the speaker faced Sam directly (0°) for the first 10 seconds. Succeeding intervals were at speaker angles of 30°, 60°, 30°, 0°, and 30°. The spectral contribution of the direct component was thereby changed frequently. Voice announcements on the tape identify the room, the dummy head location, and the speaker (AR-4x or AR-3a). I will now play these two tapes over loudspeakers. That isn't the same as hearing them on headphones, as they were meant to be heard, but you may get some idea of the results anway. We can detect no changes in spectral balance beyond the 3-foot distance as the AR-3a is turned. We can detect slight changes in the AR-4x because of the high-frequency losses at wide angles, but only for the fairly close distances. Based on this evidence the answer to question 3 is also, "no". We believe that this is a subject warranting a more thorough investigation.

To summarize these results:

1. We are convinced that home music listeners perceive the spectral balance of the sum of the direct and reverberant fields, and that the very small time differences between them have no effect on this perception of balance. In other words, directional perception based on precedence is carried on by a different mechanism than operates for the judgment of spectral balance.

2. When using loudspeaker systems that have low directivity factors at all frequencies, listeners at typical listening positions in virtually all living rooms are well within the area in which the reverberant field predominates. Predominance of the reverberant field becomes progressively less probable at typical listener locations as the directivity factor increases.

3. The reverberant field spectral balance is determined primarily by the acoustic power frequency response of the loudspeaker system. Thus, the single most important factor in assessing the "frequency response" of a loudspeaker system is the integrated output at all angles. Moreover, because the output at low frequencies is influenced strongly by the solid angle into which the speaker radiates, either this measurement should be made with the speaker facing 2π steradians or the difference should be taken into account.

For a realistic assessment of loudspeaker spectral performance, it is clear, both types of response curves are needed: reverberant energy response, and anechoic curves to investigate directivity. Anechoic polar curves would do nicely for that.

I would like at this point to go into the matter of high-frequency balance relative to bass. Standing-wave modes in a single room make it virtually impossible to know with any assurance exactly what the speaker is doing apart from the influence of the room. On the plausible supposition that a more reliable indication of true speaker system output would be obtained by averaging the relevant curves in all rooms, we did that for Fig. 34. In preparing the composite we did the following:

A. Discarded data for the two AR listening rooms, because they are not home living rooms.

B. Discarded the very close (3 ft.) direct-field data, taken where nobody listens.

C. Used only the data taken with both speakers of each stereo pair operating. (The only exception was for location B, room A. We did not have a two-speaker record for that location and used, instead, the 30° single-speaker curve).

D. Plotted points for each of the remaining curves at the frequencies 30, 50, 70, 100, 150, 200, 250, 300, 400, 500, 600, 800, 1,000, 1,200, and 1,500 Hz; 2, 3, 5, 7, 10, 15, and 20 kHz.

E. Averaged these levels for all the curves in each room individually.

F. Averaged the composite data for the eight rooms.

G. Subtracted the tape machine response error and plotted the resultant.

There is one obvious contaminant left in the data: the effect of the average room absorption with frequency. Still, Fig. 34 does show the spectral distribution that will be obtained with the average of 16 AR-3a's at 22 locations in the average acoustical setting of 8 typical living rooms.

Examination of this composite reveals several interesting characteristics. Among them are:

1. The general trend in the range below 250 Hz demonstrates that real rooms do not give the low-frequency support that is commonly assumed. Since this falling response is not a property of the AR-3a when radiating into a hemisphere, and cannot be attributed to a large radiation angle (the average angle in these rooms is visually smaller -- not larger -- than 2π), it must clearly be the result of increasing energy absorption at low frequencies. Room furnishings don't absorb much at low frequencies (certainly not <u>more</u> than at middle frequencies). Evidently most of the loss is the result of inadequate boundary stiffness -- flapping walls, floors, ceilings, and windows.

2. This low-frequency rolloff is interrupted by a 4-dB V-shaped notch centered just above 200 Hz. In addition, there is a smaller rise in output centered just above 400 Hz. These frequencies coincide precisely with quarter-wave and half-wave distances from the front of the cabinet to the wall behind the speaker system, which would produce reflections that alternately cancel and reinforce the forward radiation. The effect is minimized but does not disappear entirely at angles well off the forward axis, indicating that these strong reflections significantly change the loading on the woofer -- not surprising, since they occur at frequencies below that of ultimate radiation resistance. Furthermore, the more gradual slope for the V's lower-frequency leg is explained by the fact that the fronts of the speaker cabinets in these rooms can be (and some are) farther than 1.4 feet from the wall, but they can't be much closer and most are approximately at that distance.

Note that this effect is a function of the way speaker systems in general are used in homes. Nearly all systems made today are of about the same size and general low-frequency design. All should exhibit the same effect. Except Allison spkrs.

3. In the range from 250 to 2,500 Hz, a decade of primary aural sensitivity, the response is within ±1 dB. Keep in mind that this curve shows what <u>loudspeakers</u> are delivering to listeners' ears. If loudspeakers are still the "weakest link", it isn't evident here.

Microphones for both live broadcasts and recording sessions are invariably set up in the near field of the sound source, while concert-goers are in the reverberant field. In concert halls the reverberant field has a far more drastic high-frequency rolloff (relative to the bass) than is true of living rooms. Thus what is put into the speaker system is a near-field spectrum, usually made even "hotter" because the instruments are aimed at the microphones. To produce the same spectral balance at the ears of listeners in both concert halls and living rooms, the reproducing system must compensate for the difference between high-frequency rolloffs in concert halls and living rooms.

Fig. 35 shows the octave-band spectral distribution, at seated ear-level height, for four concert halls* with the composite AR-3a/living room curve added. This is information that has only recently come to our attention; it simply supports the qualitative and subjective judgments that have had to be made in the past on what seemed to be the proper "normal" settings for speaker level controls.

There is no way to get a close match below 250 Hz. The wall-reflections phenomenon in the living room/AR-3a composite curve, and the concert hall seat-dip phenomenon, are so different in their effects on spectral distribution that a bass tone control could help only in a limited way. It is just as evident that the balance of bass to middle and high frequencies in these concert halls varies widely.

Fig. 36 is a comparison of the <u>average</u> empty concert hall frequency response with the composite AR-3a/living room curve. It should be examined with the following in mind.

1. With the audience in the hall, the level at middle and high frequencies relative to the bass range could be expected to decrease still further.

2. The broad sag in the concert-hall curve centered at 125 to 150 Hz is explained by BB&N as the result of a "reactive acoustic impedance caused by the vertically compartmented seating geometry, significantly disturbing the sound field.... Near frequencies where the microphone-to-floor spacing is a quarter of one wave length, the measured sound pressure is significantly lower than at a large distance from the floor."

With the audience in place, the seat-dip probably is somewhat lessened in severity by damping. If that is true, the entire AR-3a curve should be raised to provide a better match at low frequencies, thus raising the middle- and high-frequency ranges still further above the concert-hall curve.

In the light of these findings we believe that typical operating settings for loudspeaker high-frequency balance controls should be well below the settings which produce flat acoustic energy output, if the objective is a spectrum similar to that produced at a concert hall seat. In view of the variations found in both living-room and concert hall frequency balance, and the manner in which these variations occur, we think that home listeners should be encouraged to make more liberal use of amplifier tone controls.

Certainly, in view of current recording practice, flat electrical response is more likely to be wrong than right, particularly if the loudspeaker systems used for playback are able to deliver flat acoustical power output.

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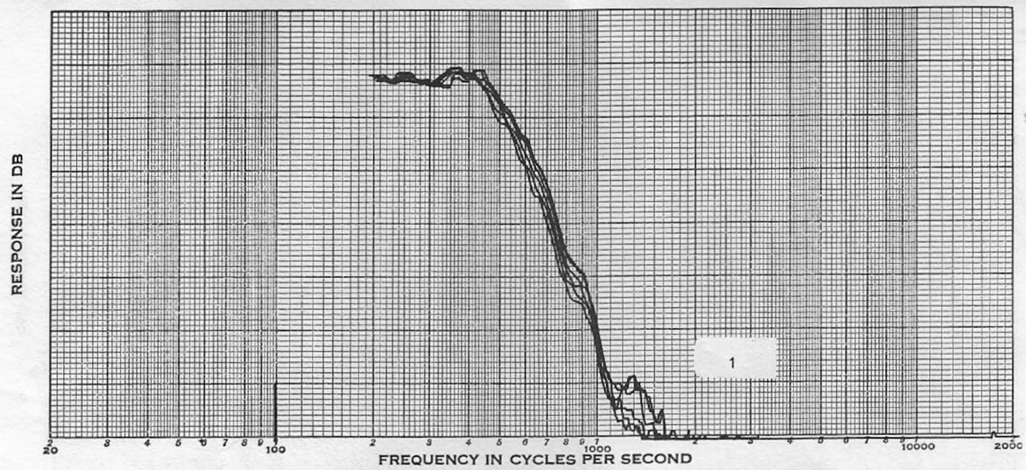
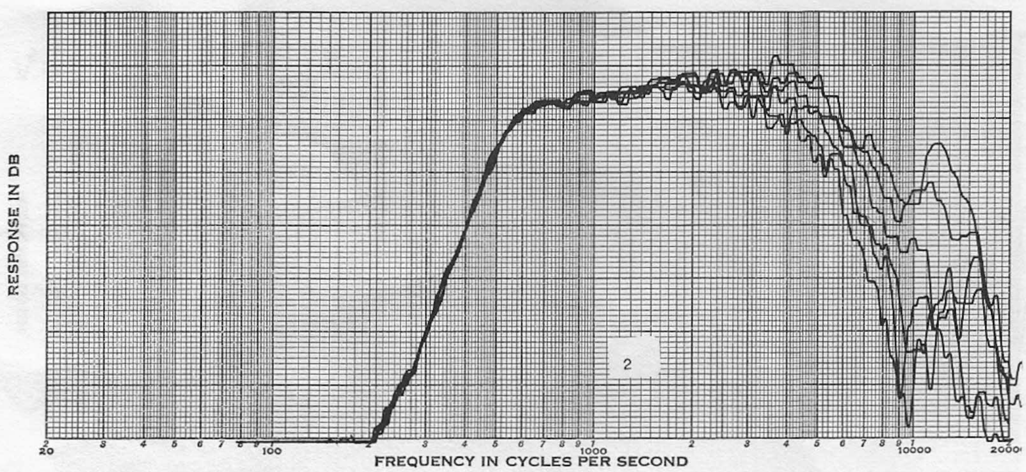
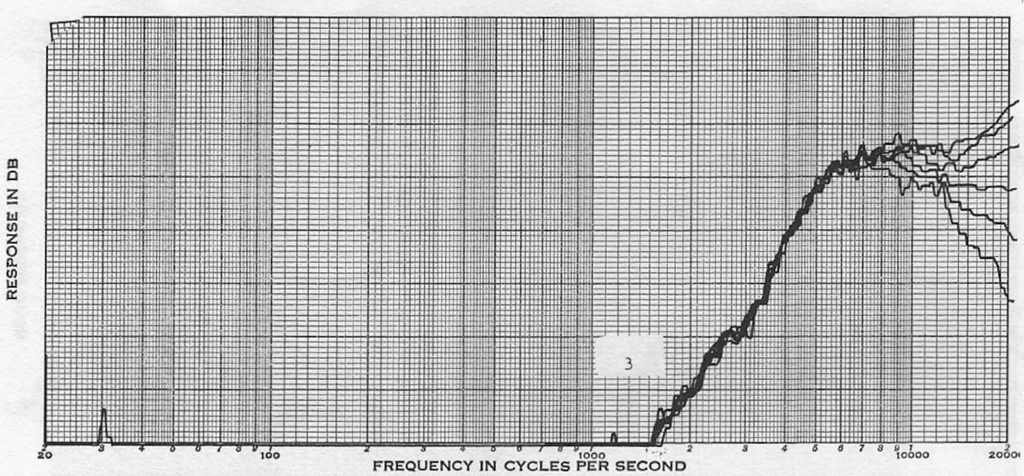
*The four halls for which information is shown here span the range from the brightest (Orchestra Hall, Chicago) to the deadest of nine halls measured, with the average falling very close to the middle. All were measured without an audience. These data are from unpublished files of Bolt, Beranek & Newman.



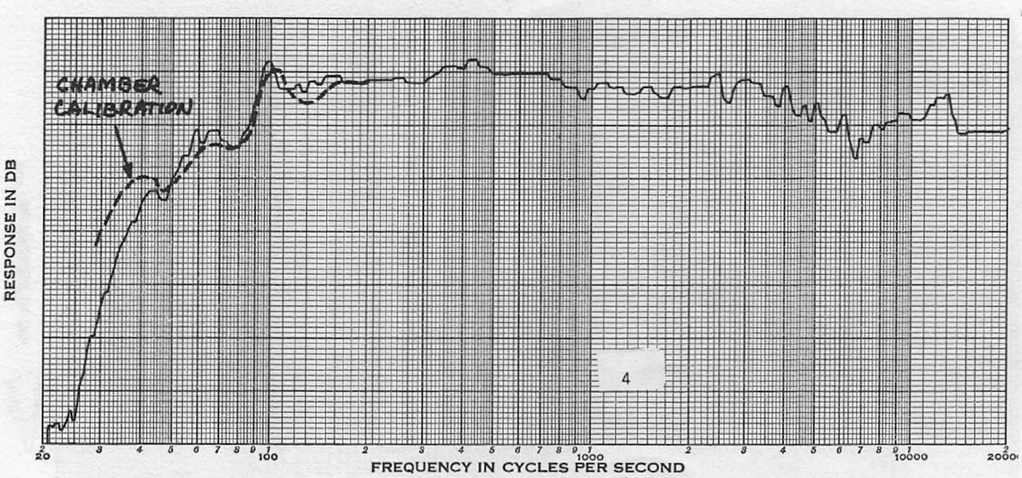
WOOFER



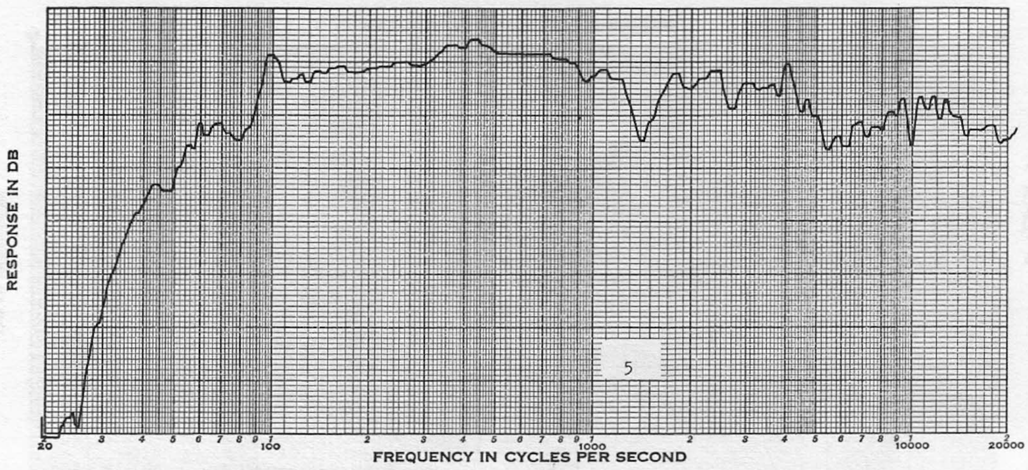
MID



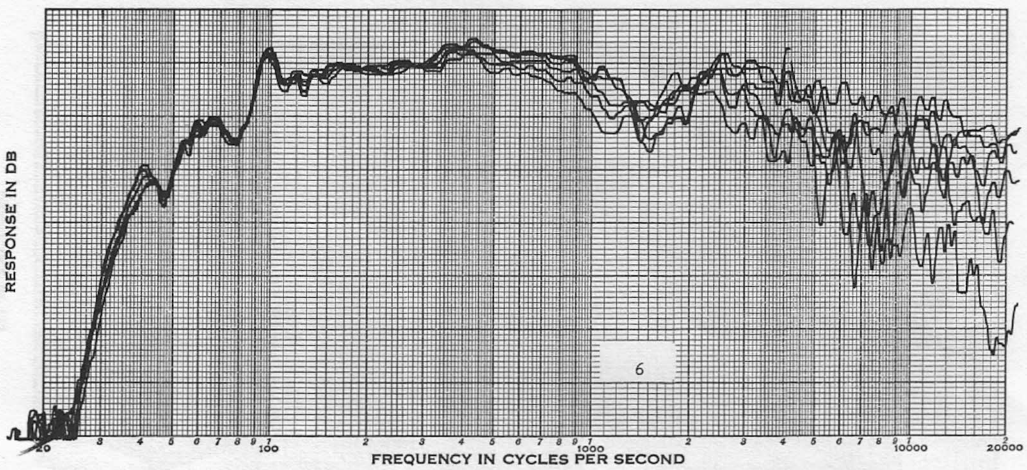
TWEETER



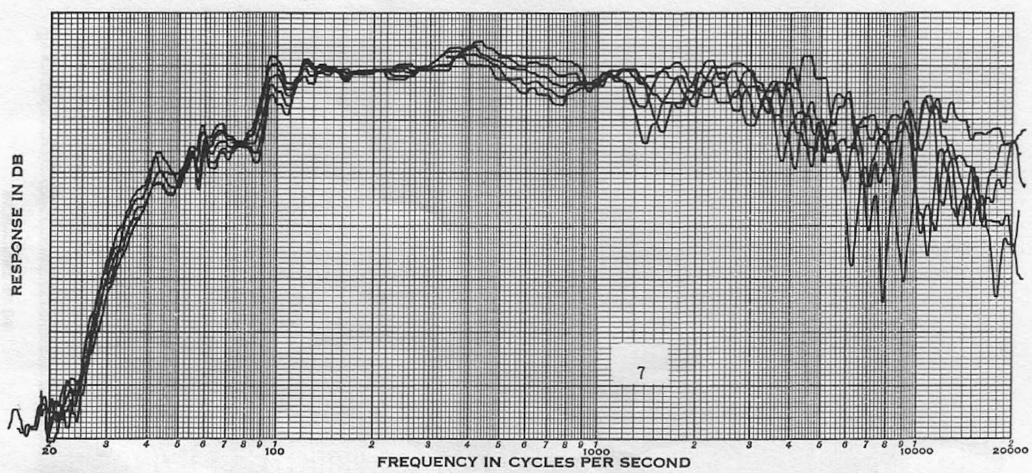
SYSTEM
ON-AXIS
(No molding)



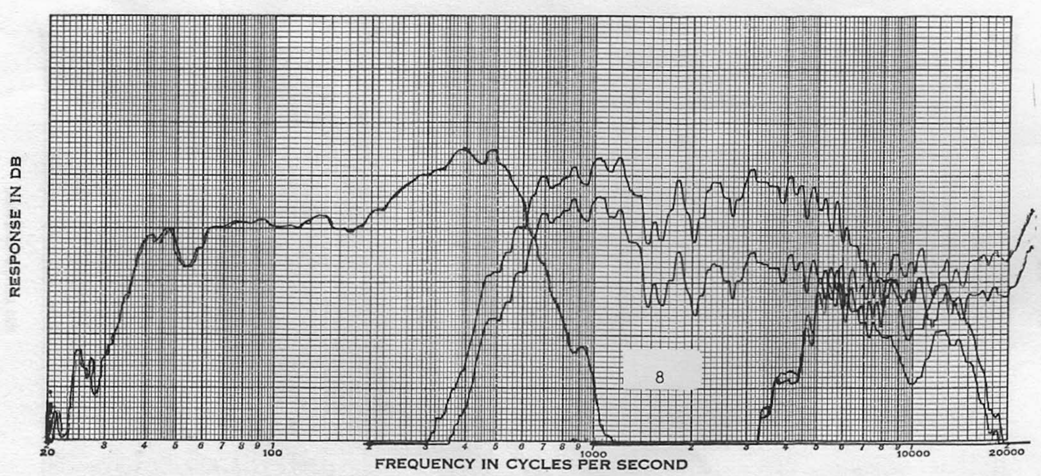
SYSTEM ON-AXIS (with molding)



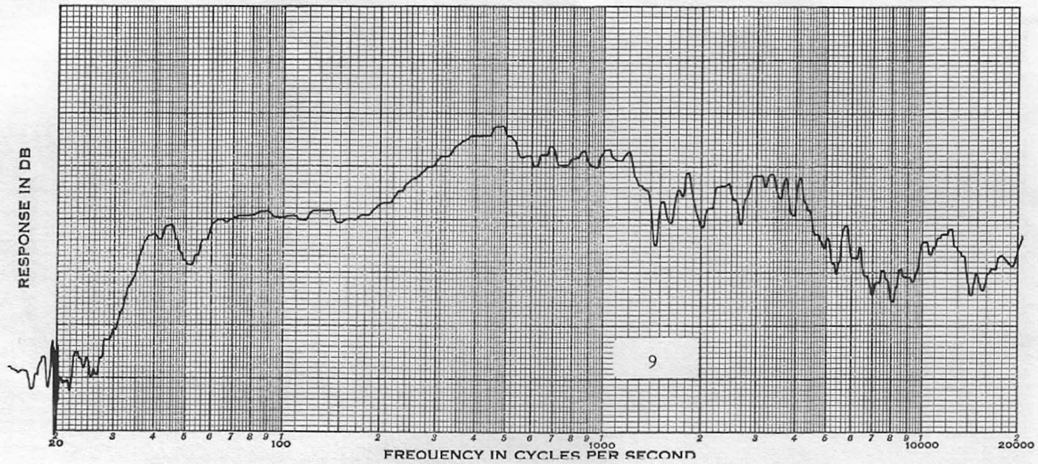
15° Increments (left)



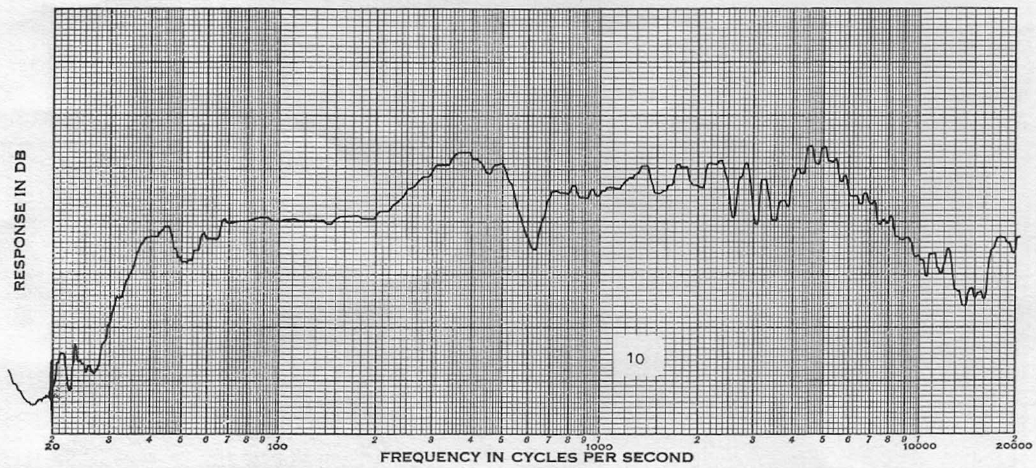
15° Increments (right)



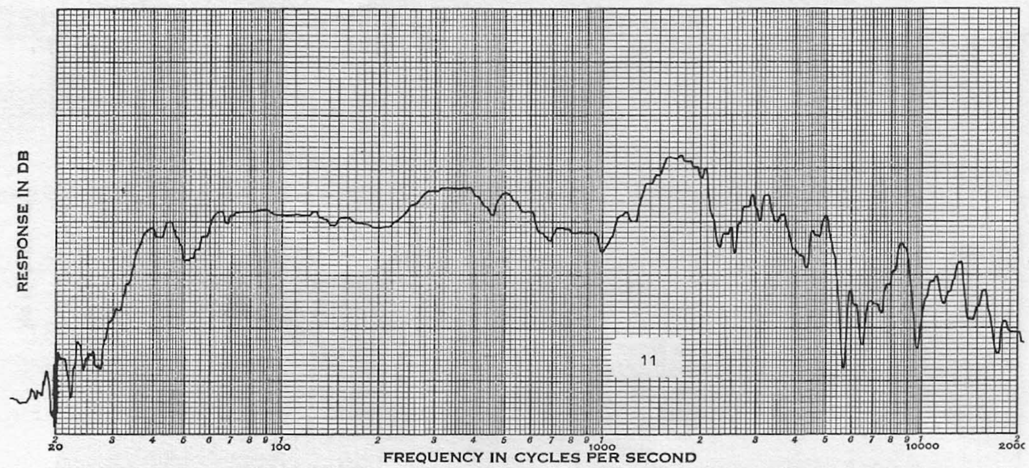
Drivers in cabinet



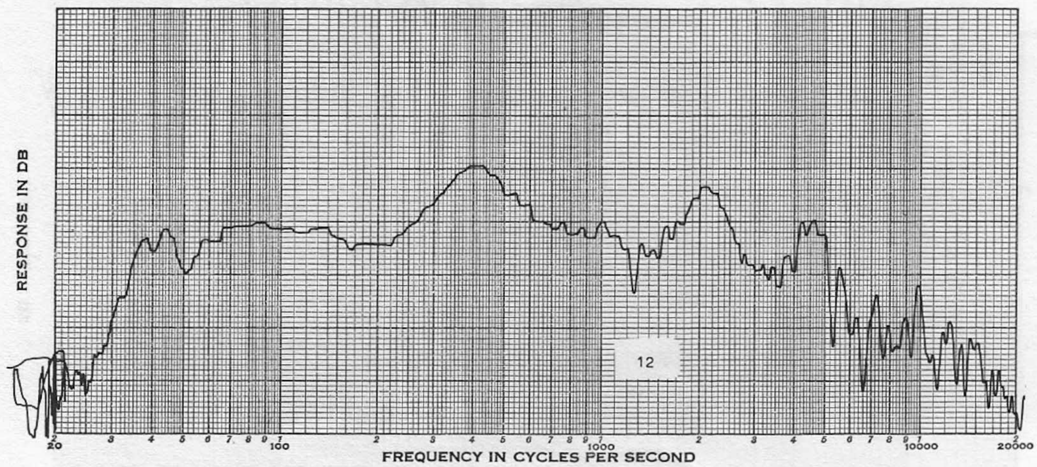
On Axis



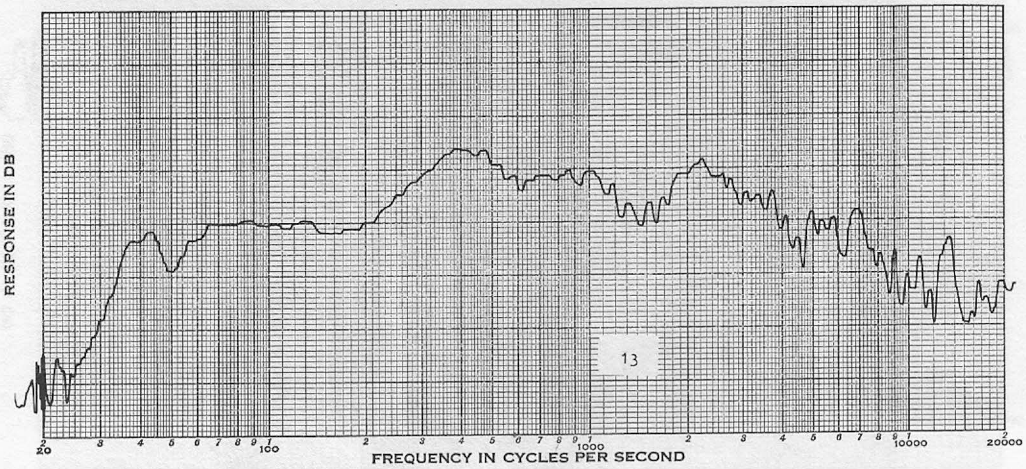
+30° Horizontal



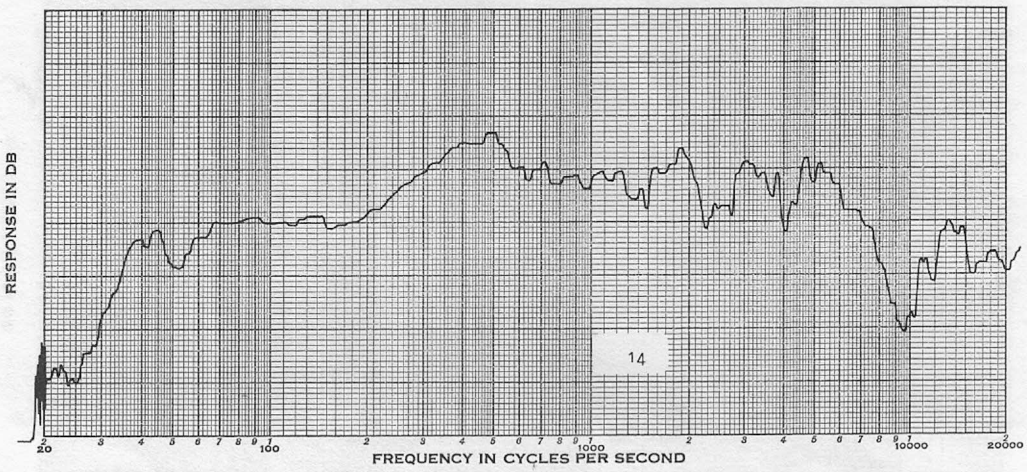
-60° Horizontal



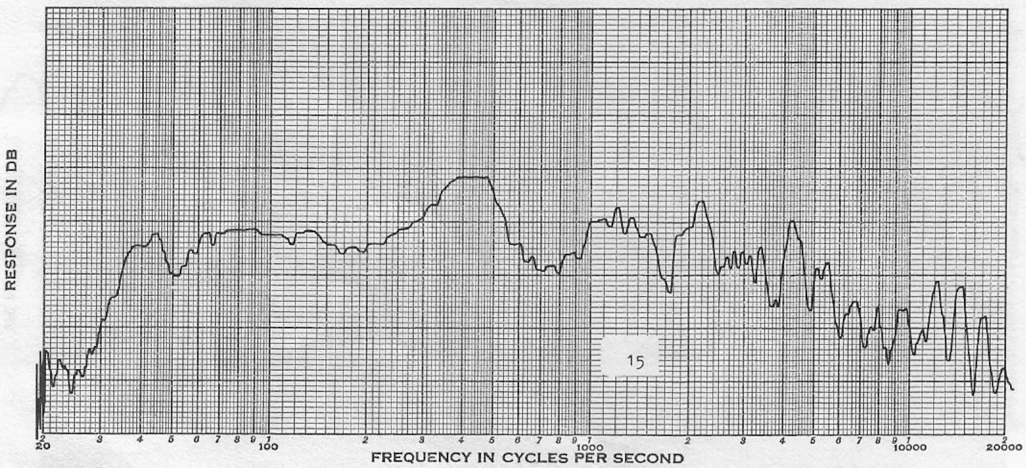
-75° Vertical



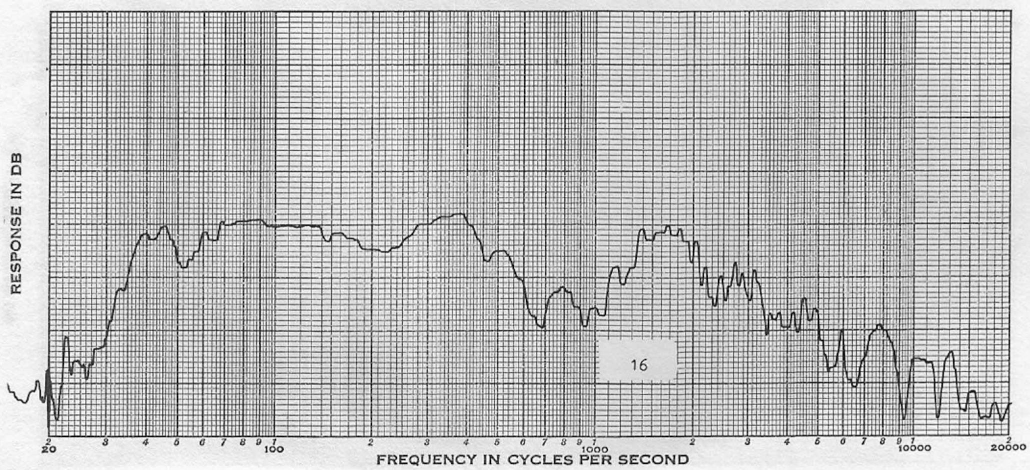
- 45° vertical



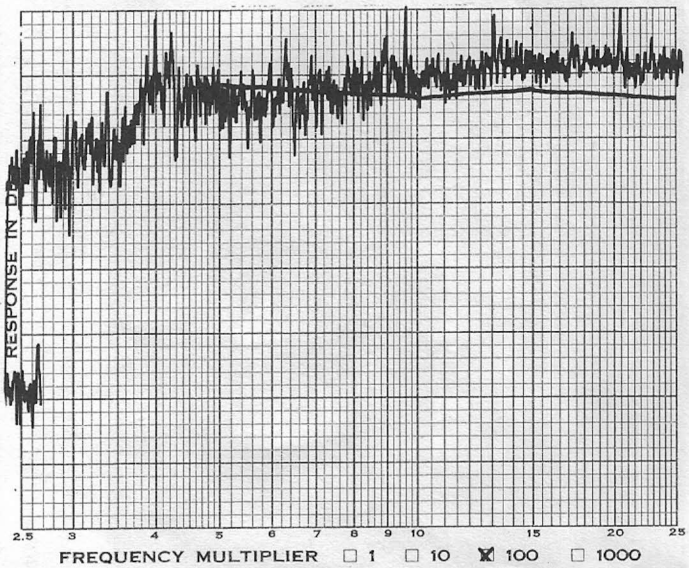
+ 15° vertical

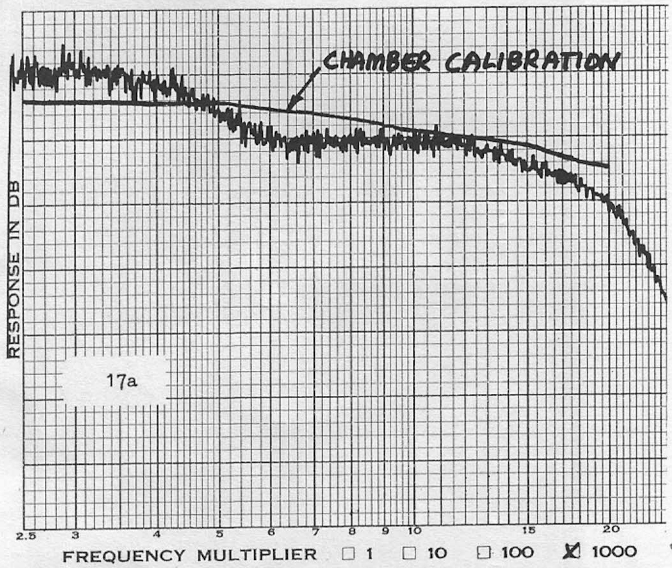


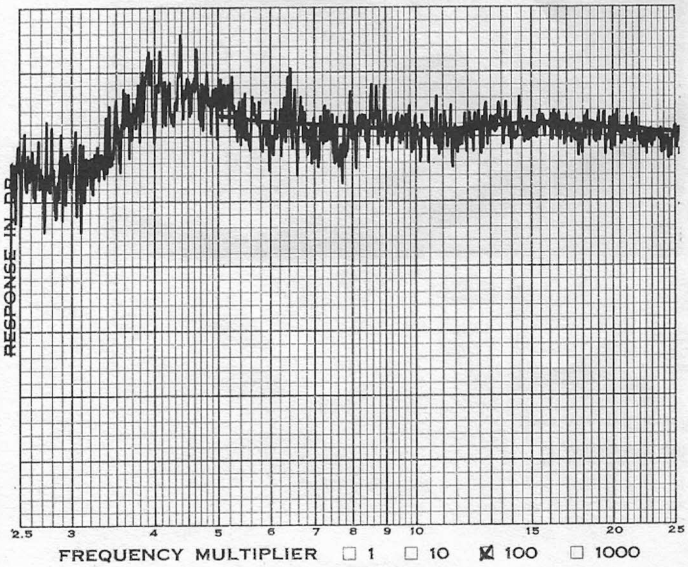
+ 75° vertical

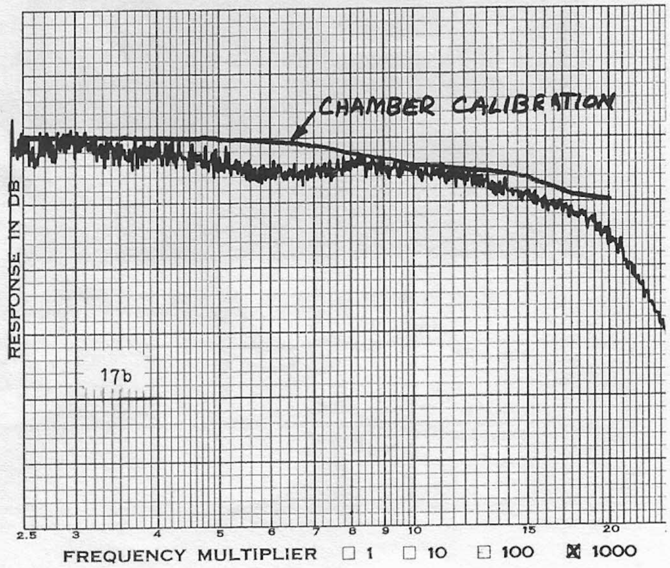


- 90° Horizontal



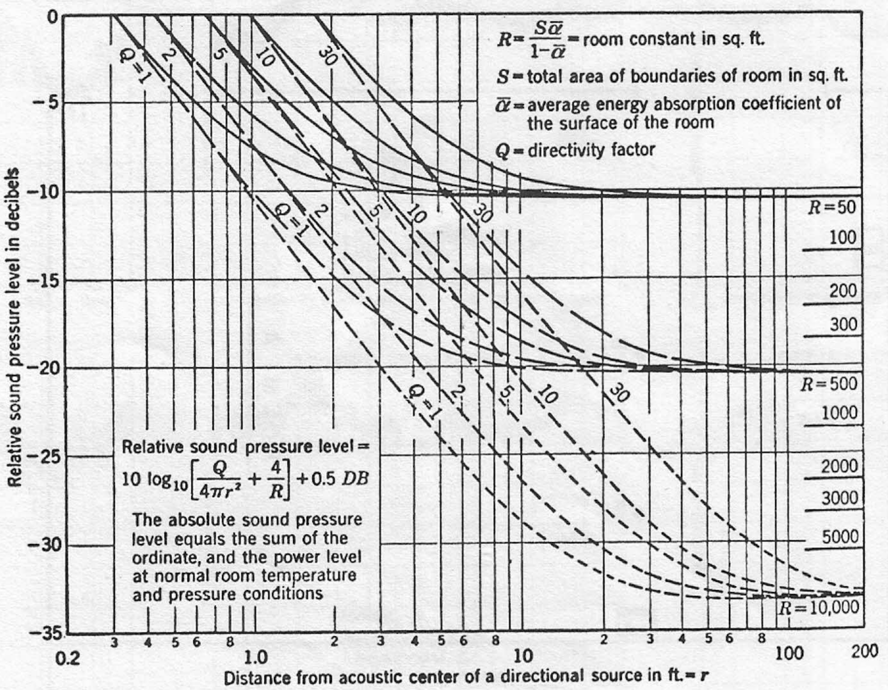


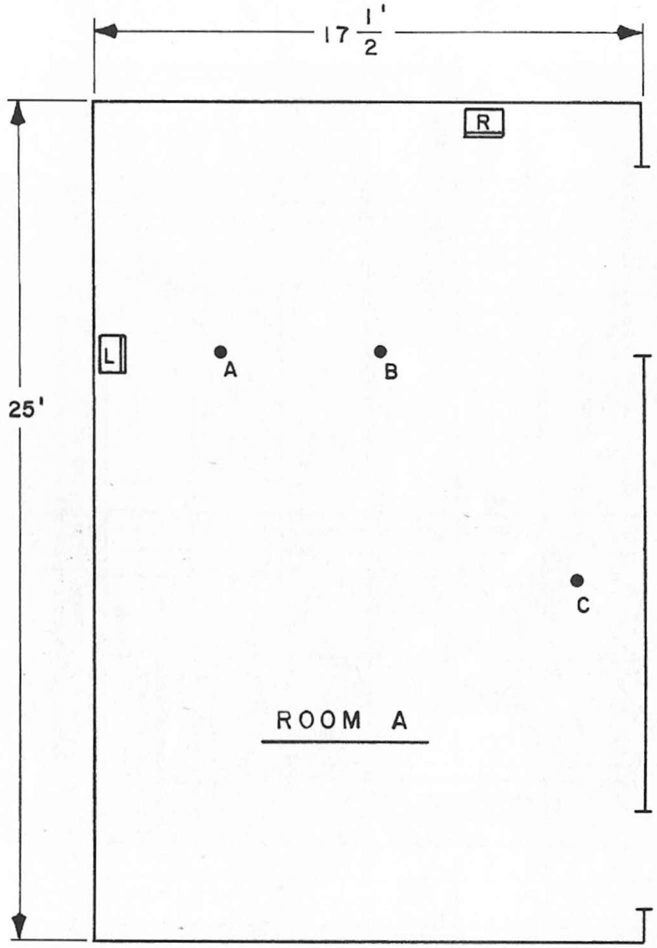




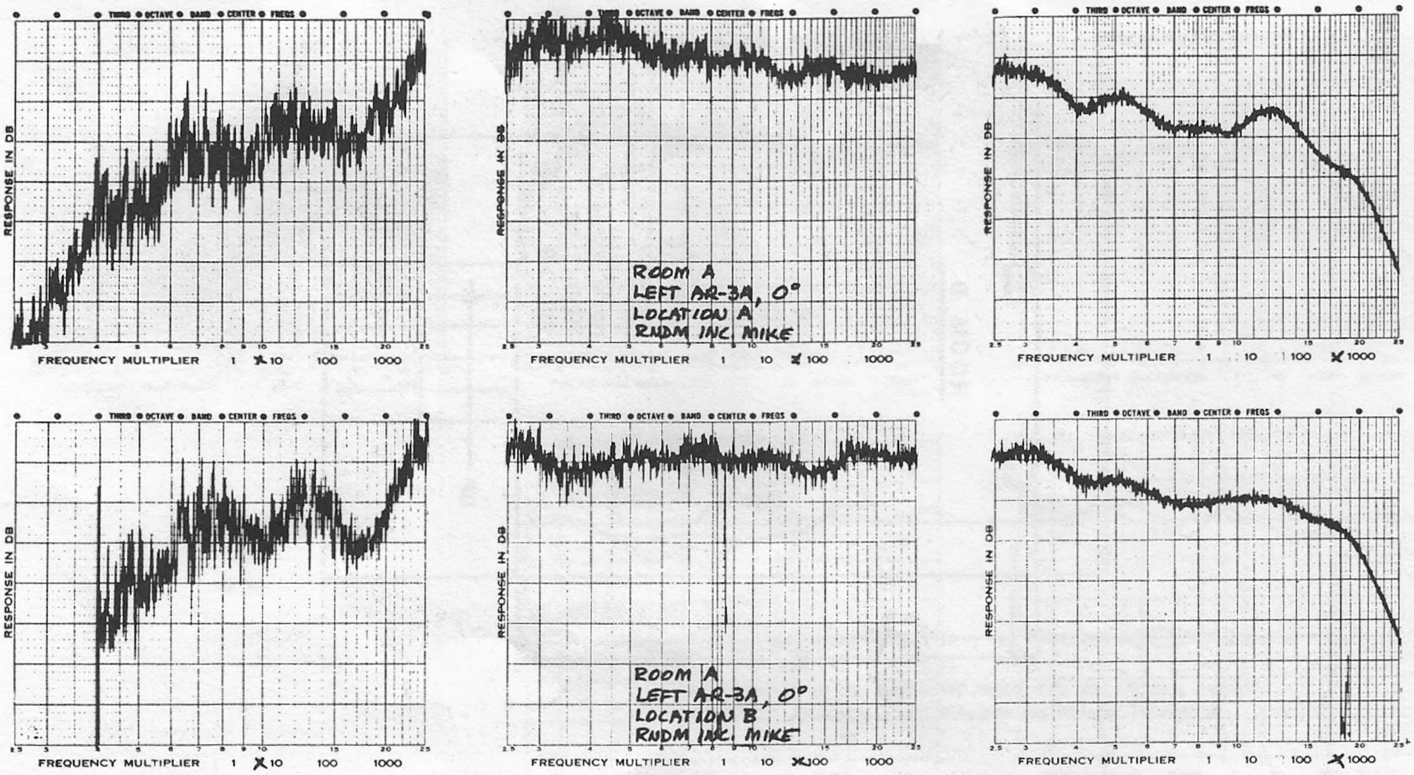
Reverberant-field response

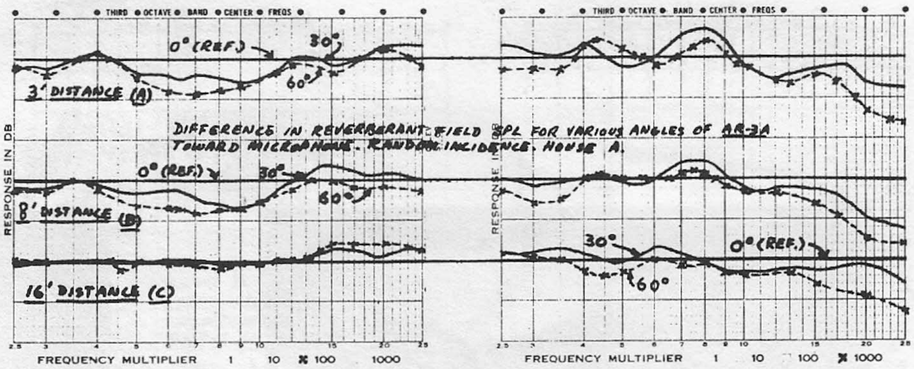
18



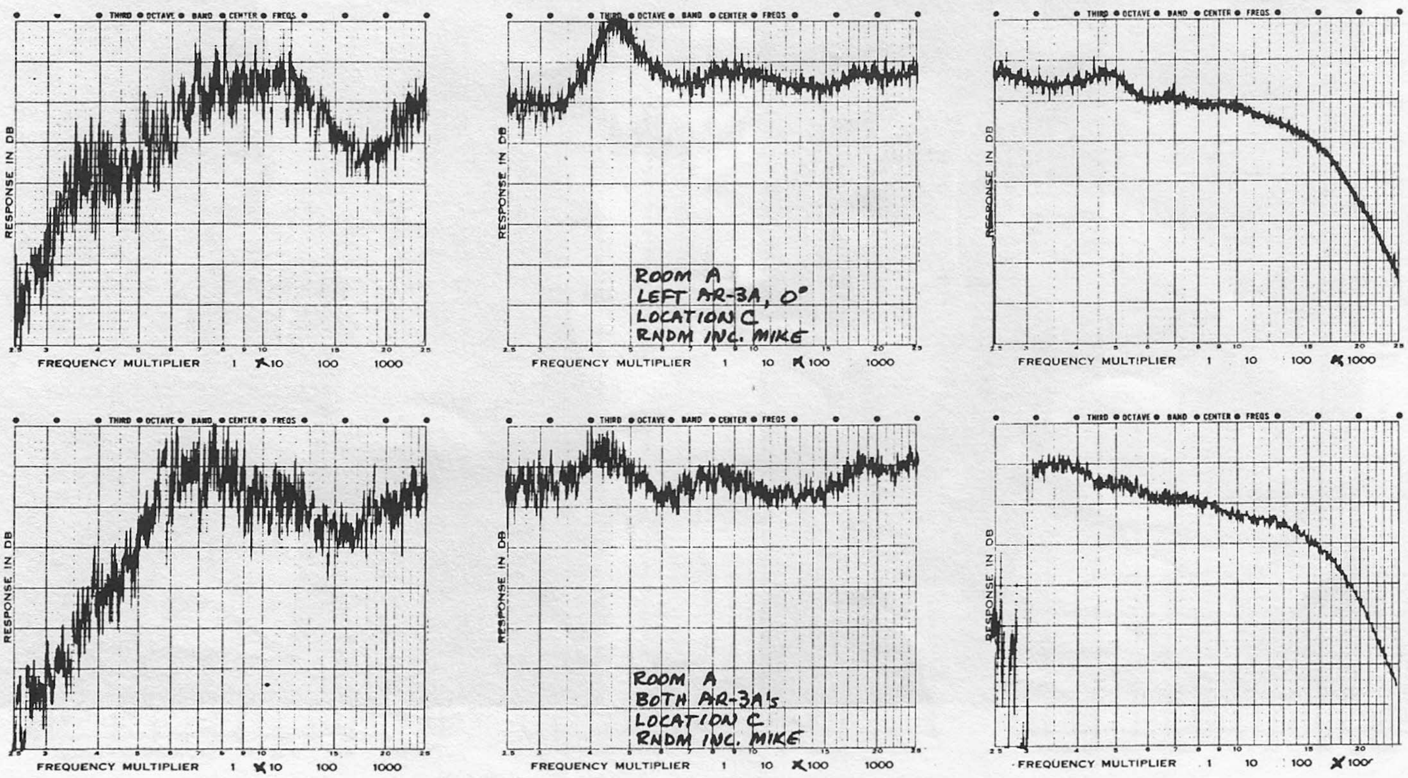


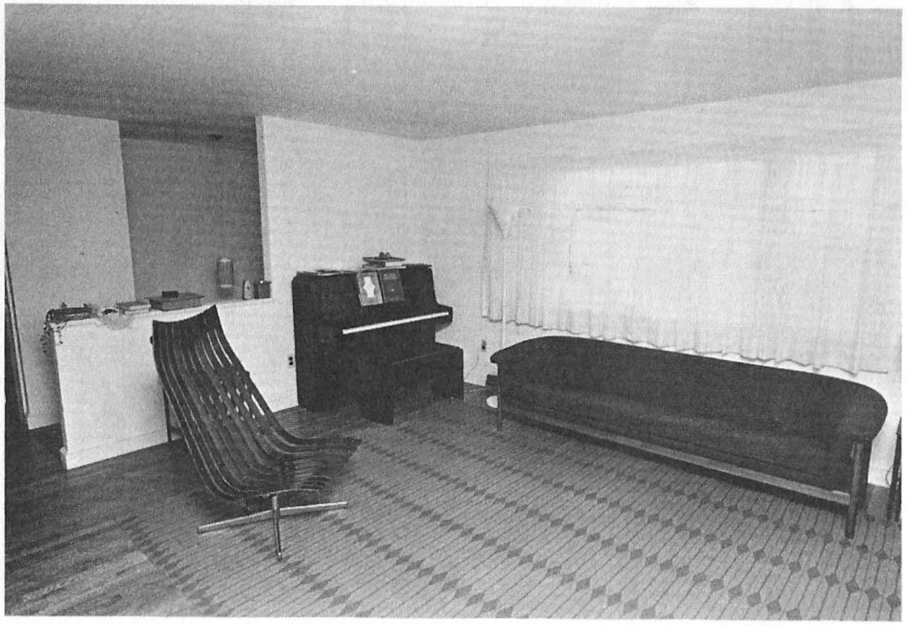
19a


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
ROOM A
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE
ROOM A
LEFT AR-3A, 0°
LOCATION B
RNDM INC. MIKE

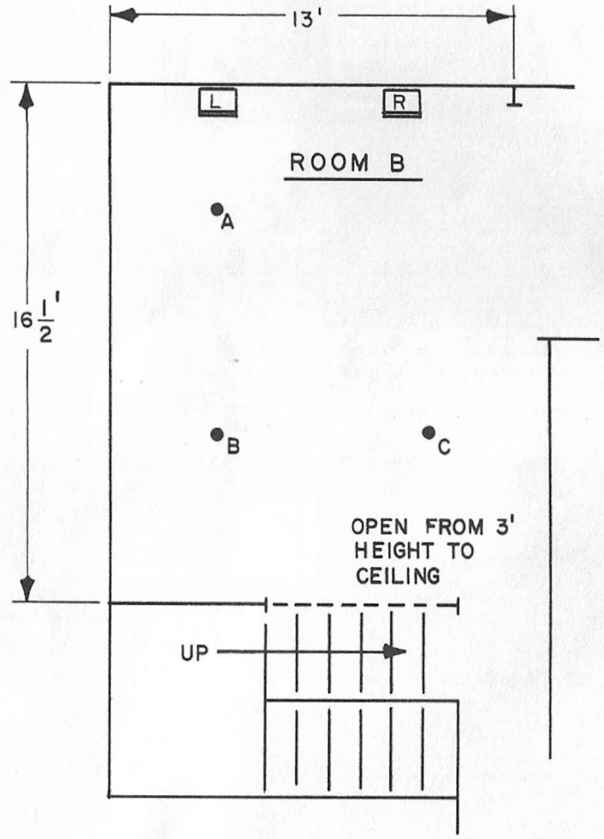

0° (REF.)
30°
60°
3' DISTANCE (A)
DIFFERENCE IN REVERBERANT FIELD SPL FOR VARIOUS ANGLES OF AR-3A
TOWARD MICROPHONE. RANDOM INCIDENCE. HOUSE A.
0° (REF.)
30°
60°
8' DISTANCE (B)
16' DISTANCE (C)
30°
60°
0° (REF.)
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

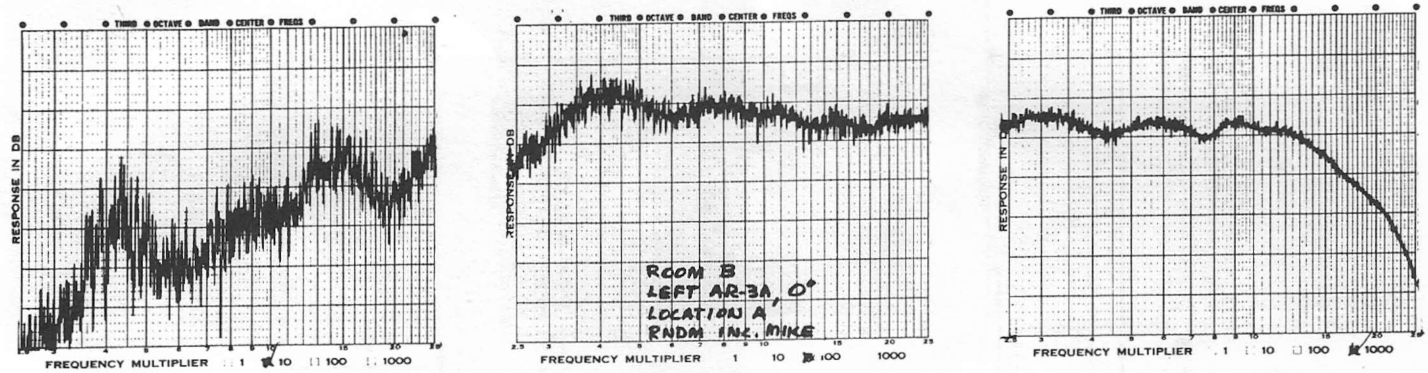
19b


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
ROOM A
LEFT AR-3A, 0°
LOCATION C
RNDM INC. MIKE
ROOM A
BOTH AR-3A's
LOCATION C
RNDM INC. MIKE

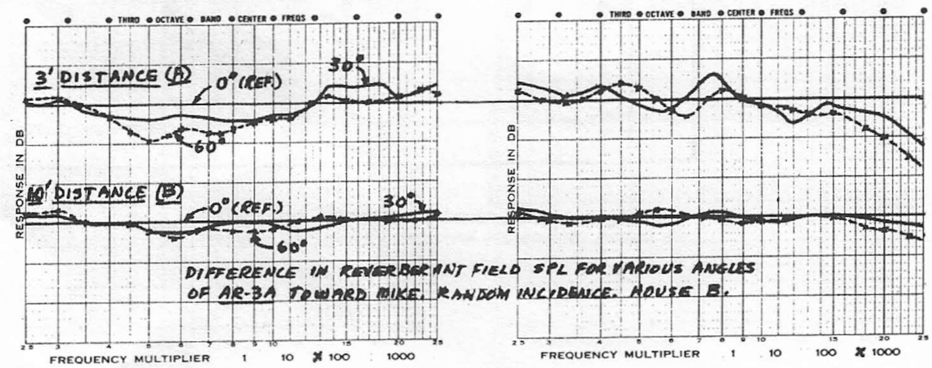


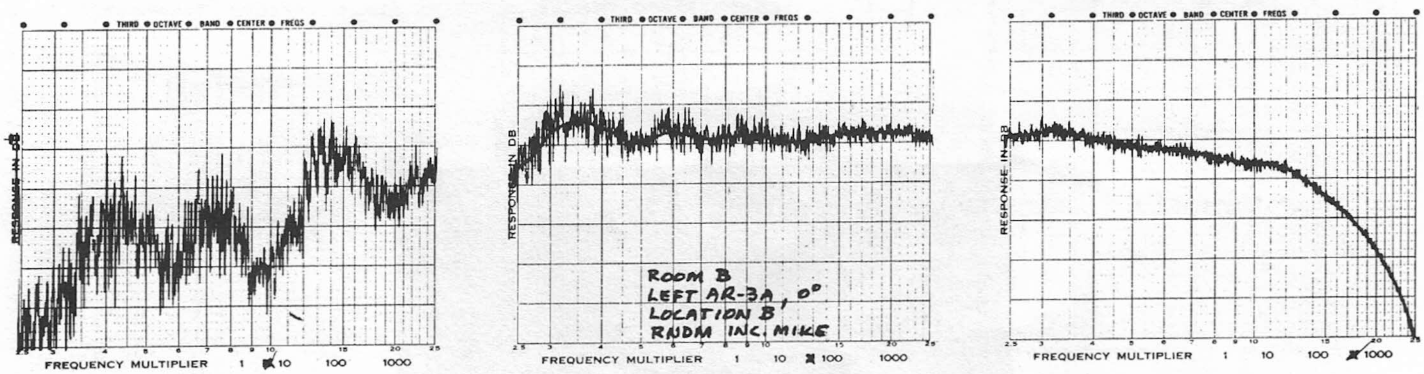
20a

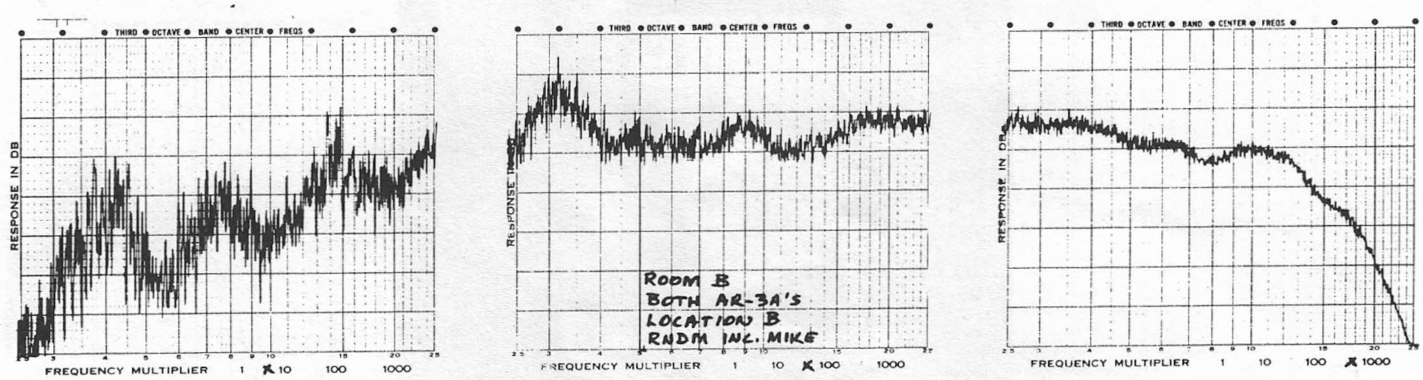


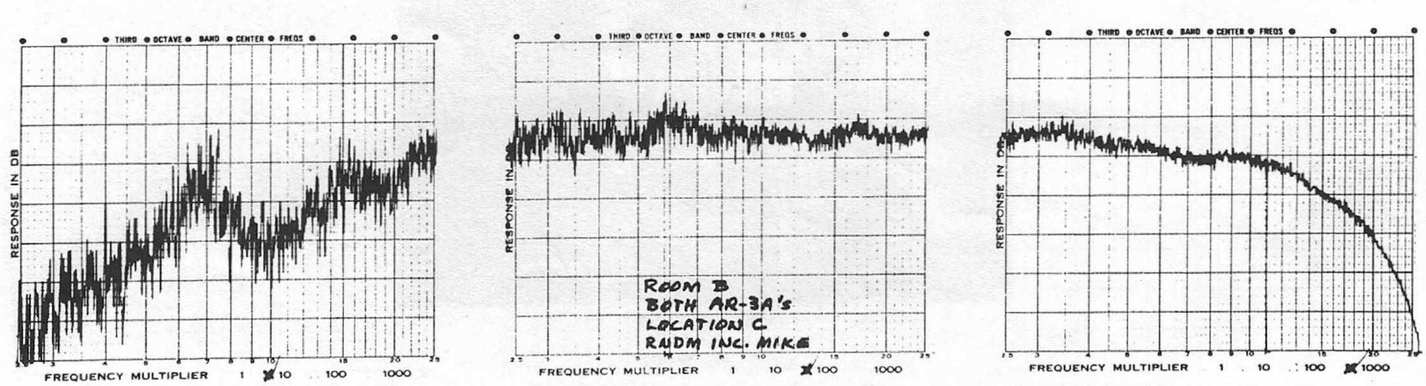

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
ROOM B
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE

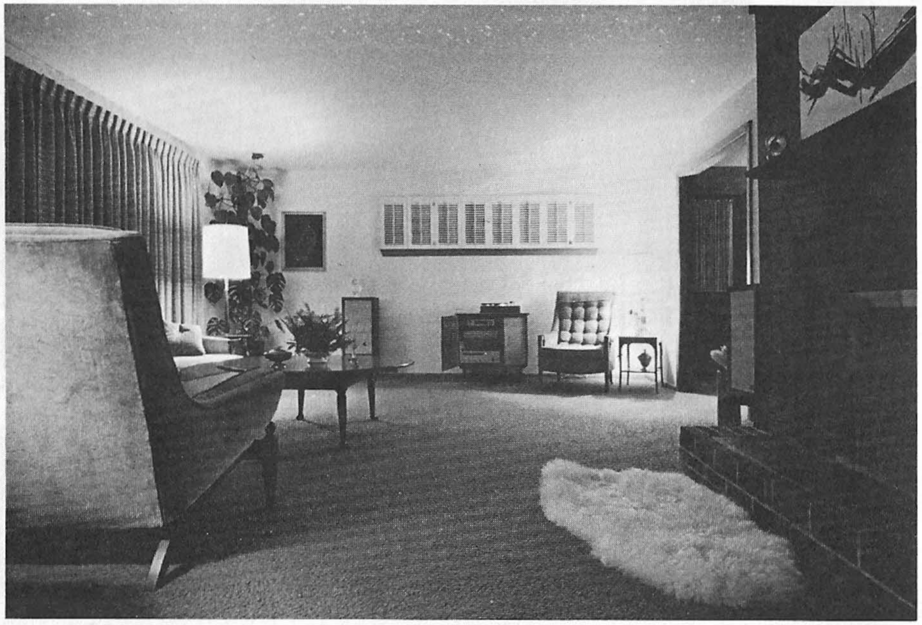
20b


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
3' DISTANCE (A)
0° (REF.)
30°
60°
10' DISTANCE (B)
0° (REF.)
30°
60°
DIFFERENCE IN REVERBERANT FIELD SPL FOR VARIOUS ANGLES
OF AR-3A TOWARD MIKE. RANDOM INCIDENCE. HOUSE B.
FREQUENCY MULTIPLIER 1 10 100 1000

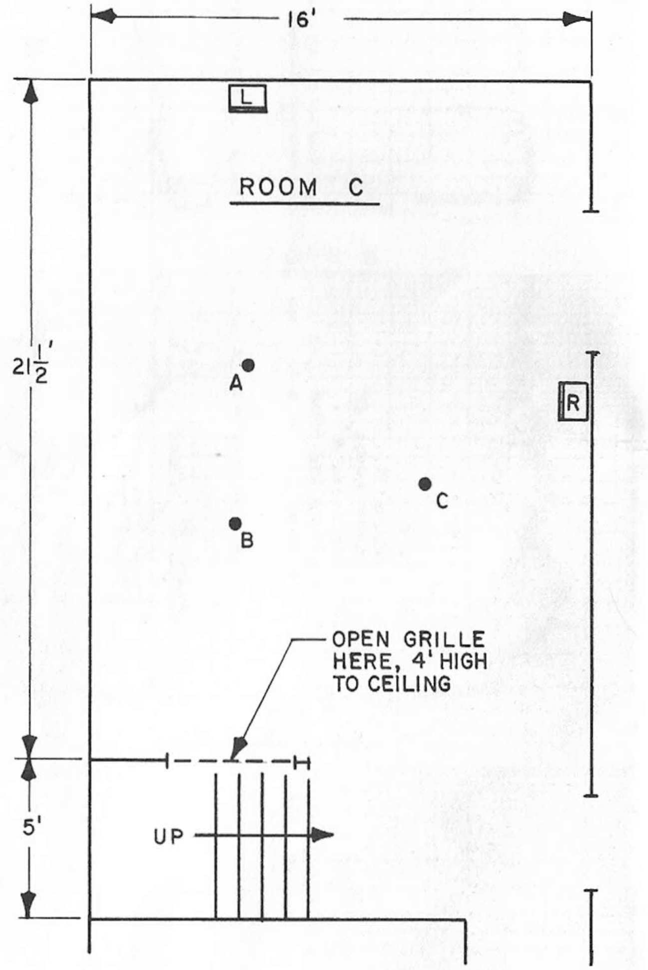

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM B
LEFT AR-3A, 0°
LOCATION B
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

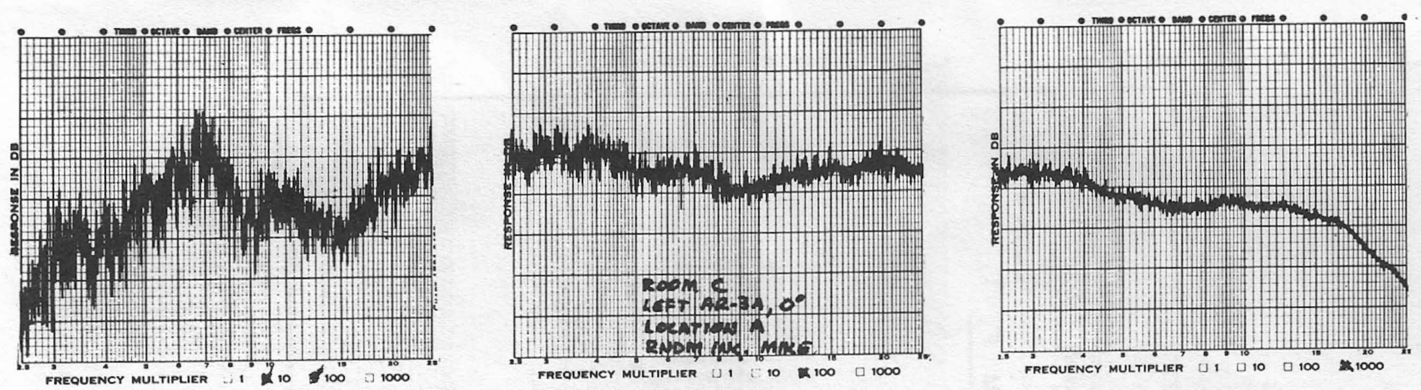

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM B
BOTH AR-3A'S
LOCATION B
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM B
BOTH AR-3A'S
LOCATION C
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

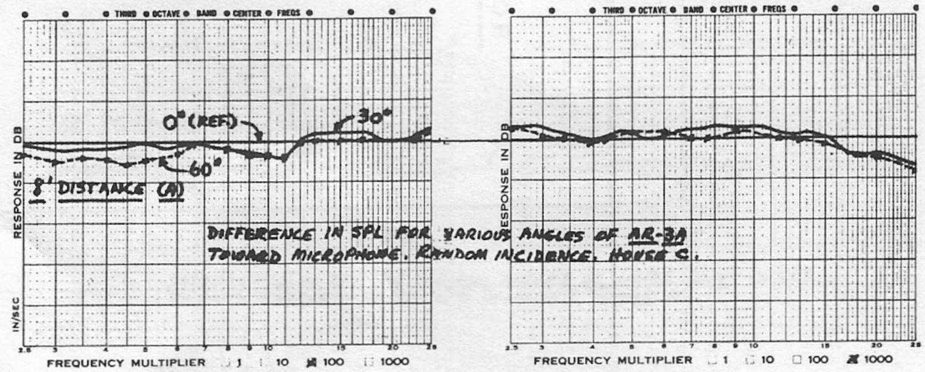


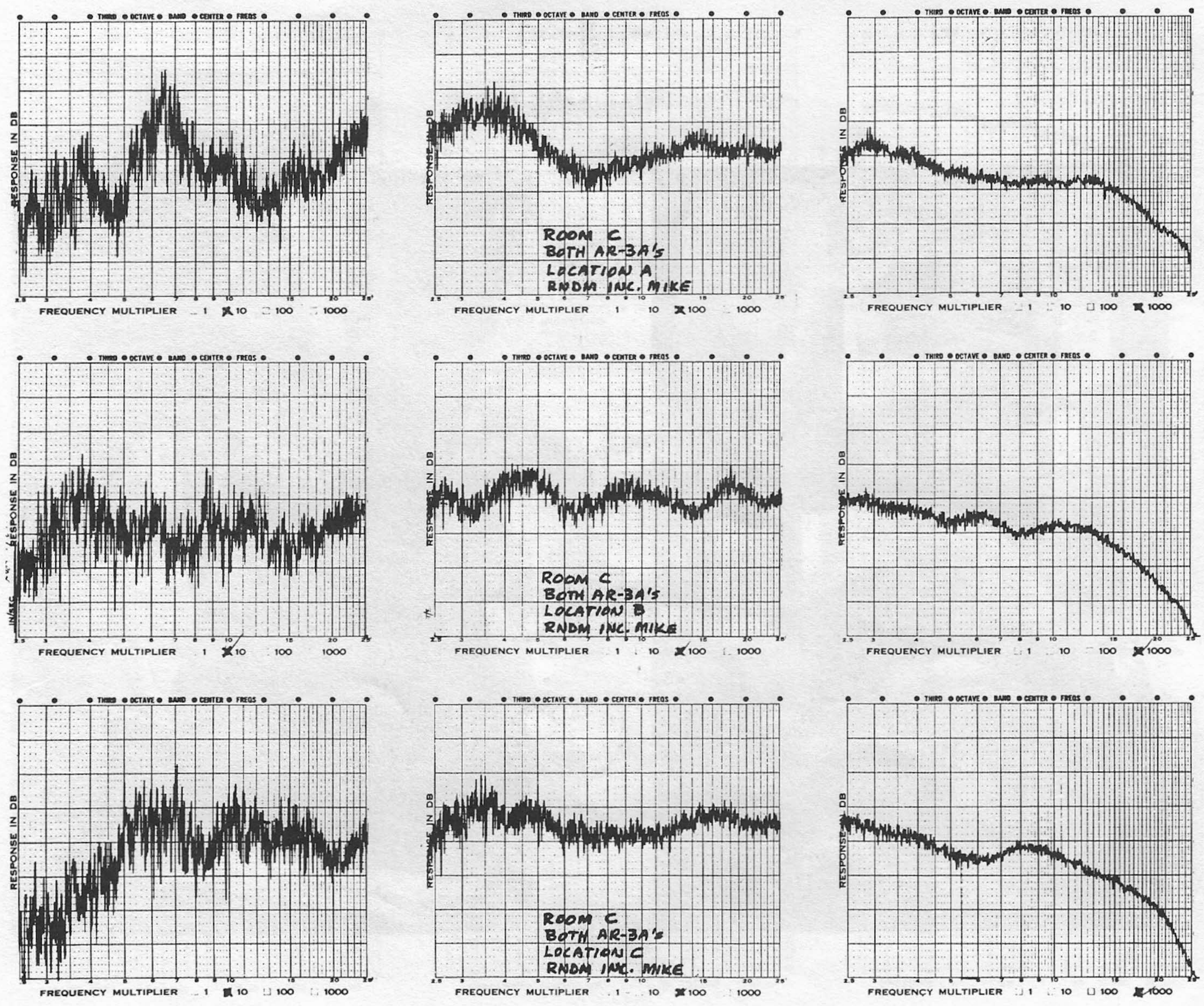
21a

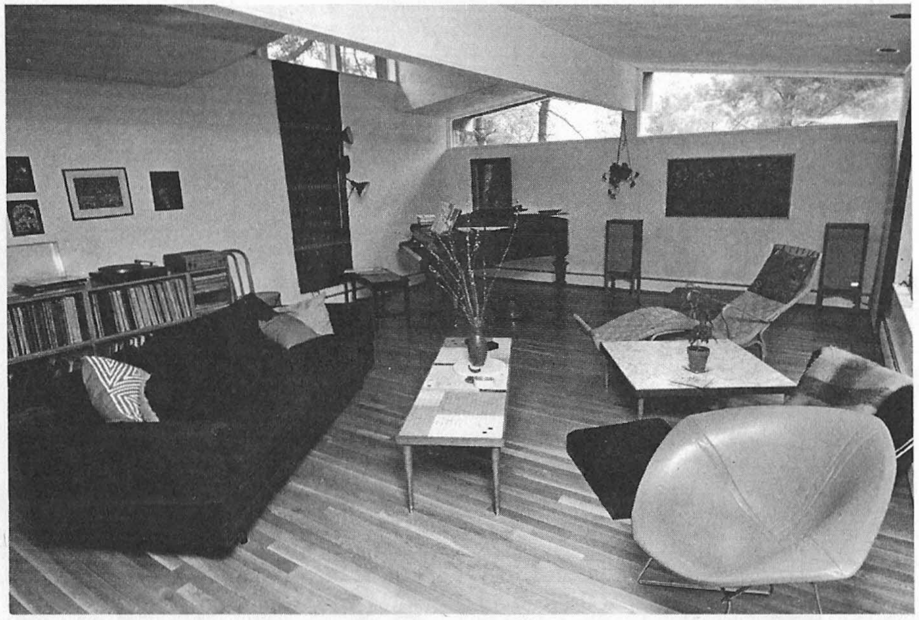

16'
L
ROOM C
$21\frac{1}{2}'$
A
B
C
R
OPEN GRILLE
HERE, 4' HIGH
TO CEILING
5'
UP

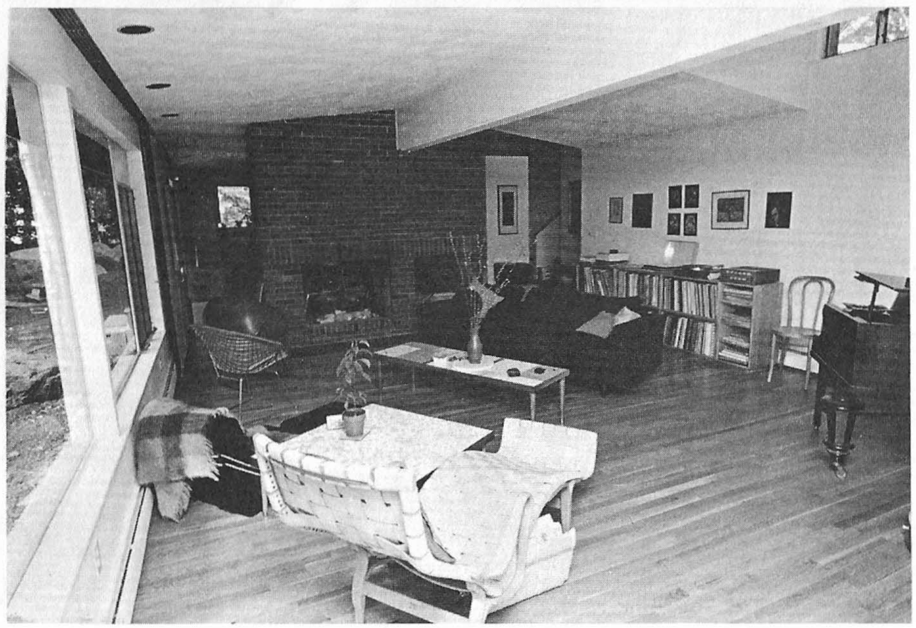

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
ROOM C
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE

21b

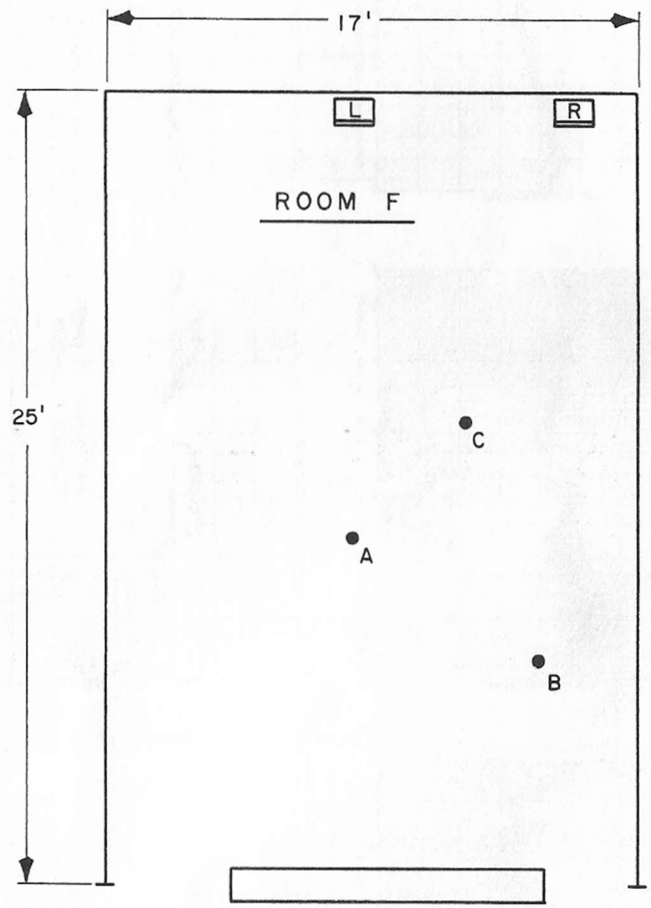

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
0° (REF)
30°
60°
8' DISTANCE (A)
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-3A
TOWARD MICROPHONE. RANDOM INCIDENCE. HOUSE C.
FREQUENCY MULTIPLIER 1 10 100 1000

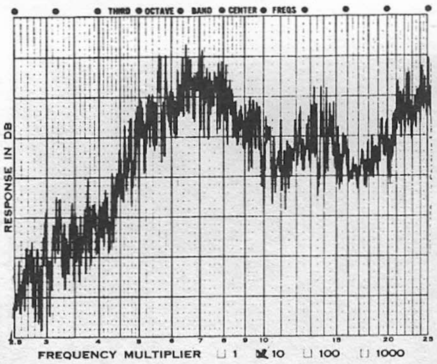

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
ROOM C
BOTH AR-3A'S
LOCATION A
RNDM INC. MIKE
ROOM C
BOTH AR-3A'S
LOCATION B
RNDM INC. MIKE
ROOM C
BOTH AR-3A'S
LOCATION C
RNDM INC. MIKE

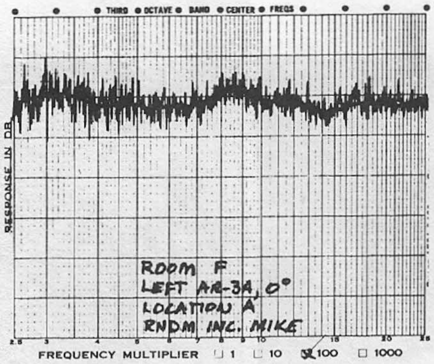


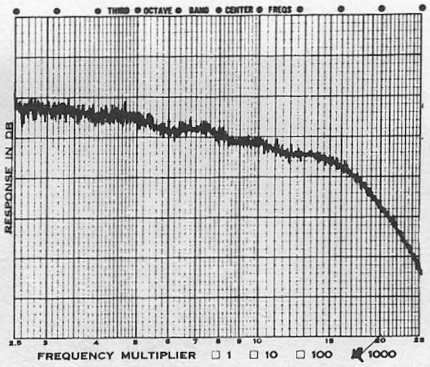


22a

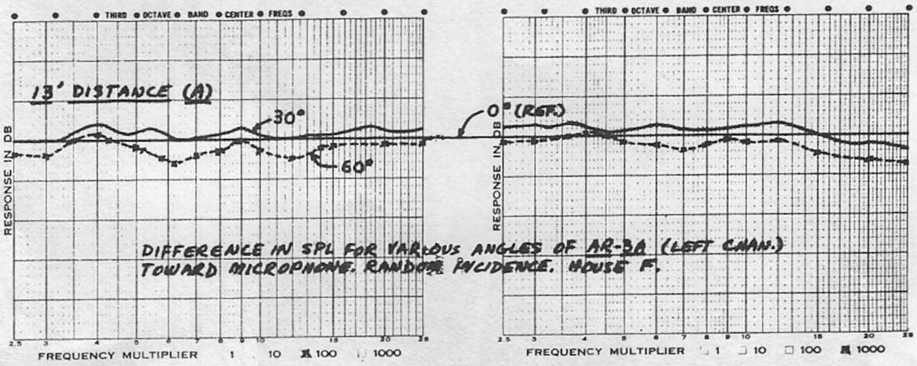


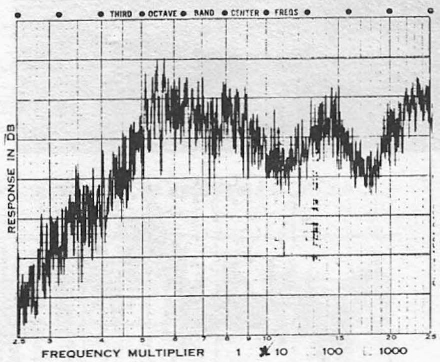

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

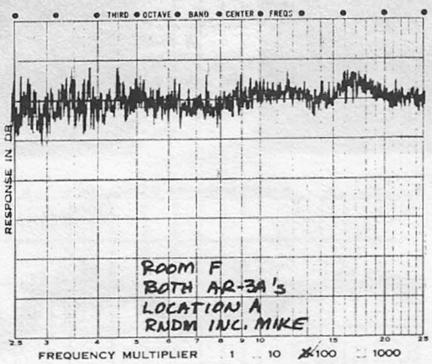

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM F
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

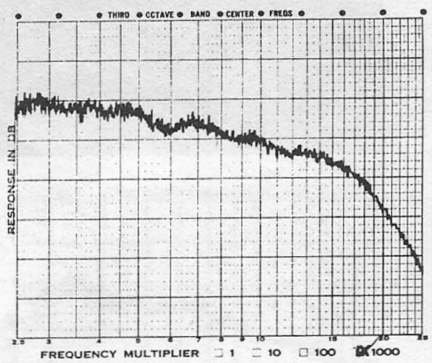

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

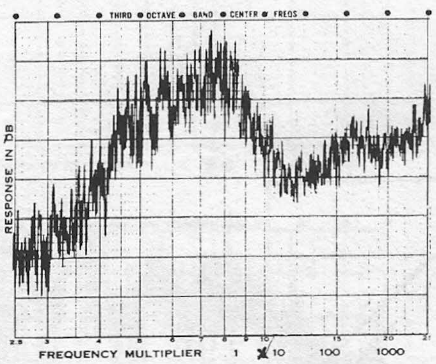
22b

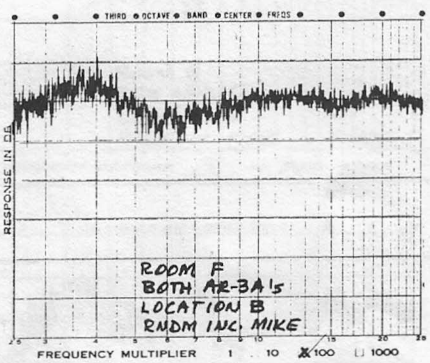

THIRD OCTAVE BAND CENTER FREQS
13' DISTANCE (A)
30°
0° (REF.)
60°
RESPONSE IN DB
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-3A (LEFT CHAN.)
TOWARD MICROPHONE. RANDOM INCIDENCE. HOUSE F.
FREQUENCY MULTIPLIER 1 10 100 1000

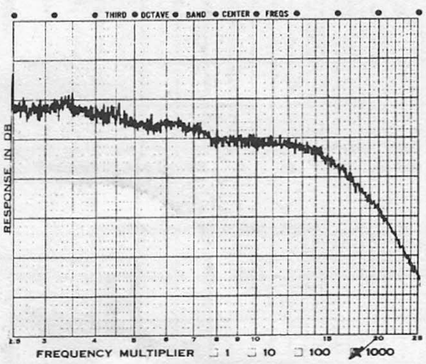

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

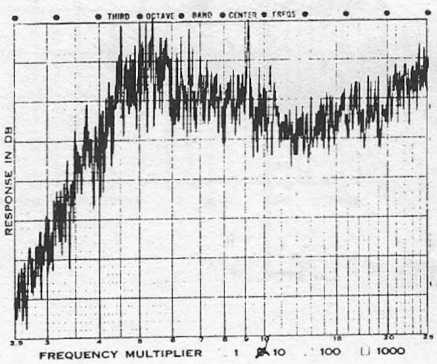

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM F
BOTH AR-3A's
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

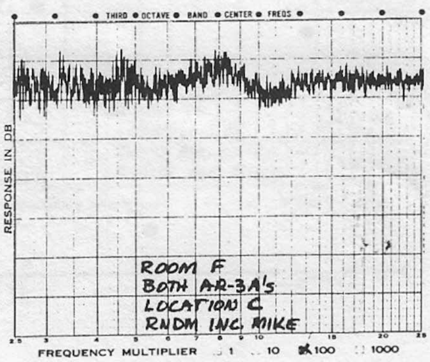

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

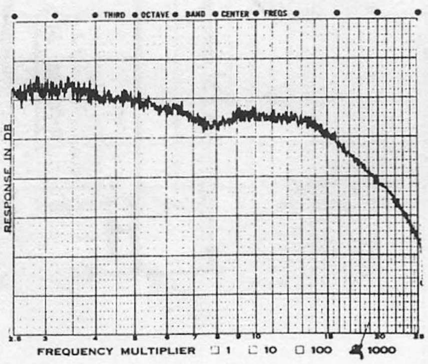

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

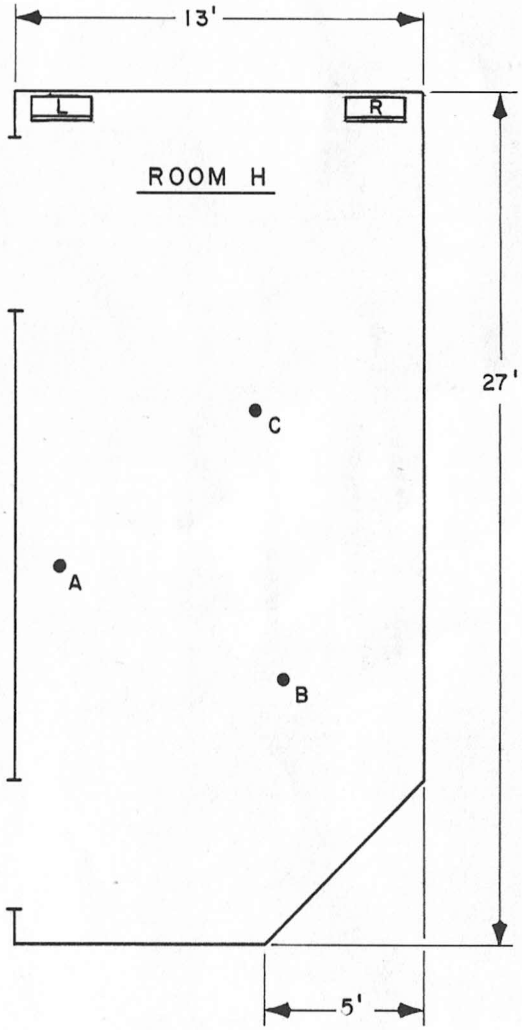

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM F
BOTH AR-3A's
LOCATION B
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

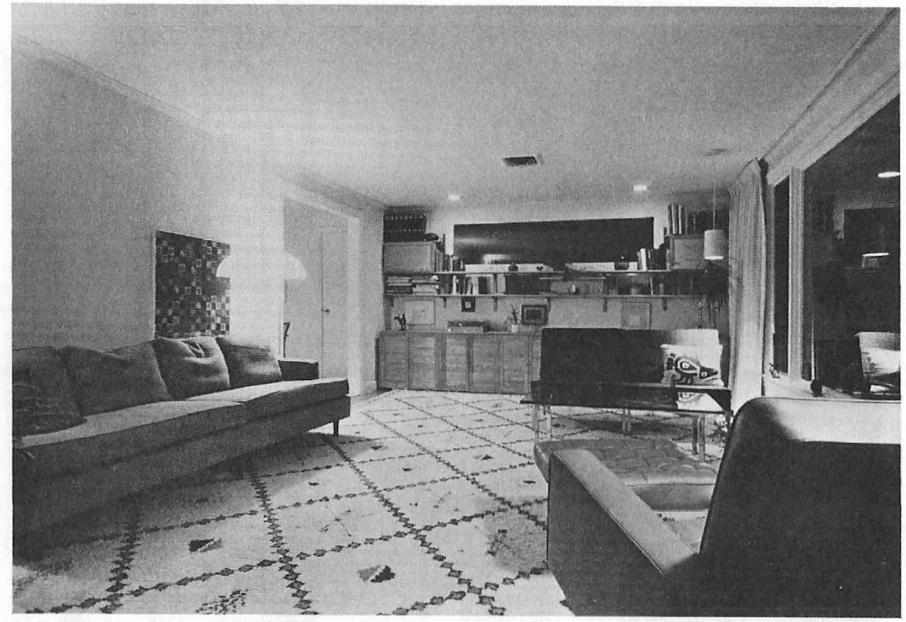

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

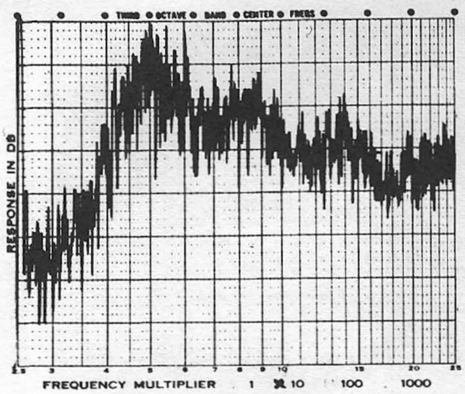

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM F
BOTH AR-3A's
LOCATION C
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

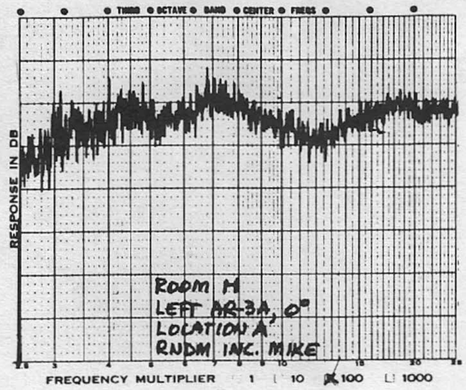

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

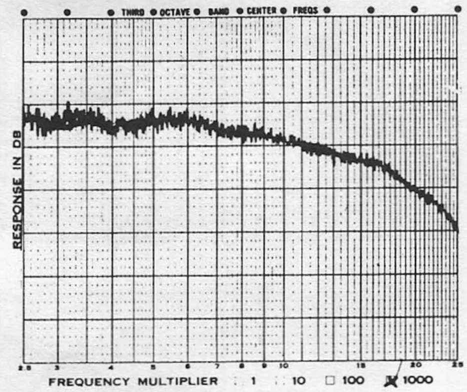


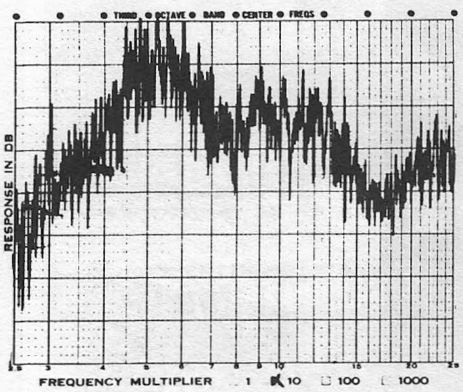
23a

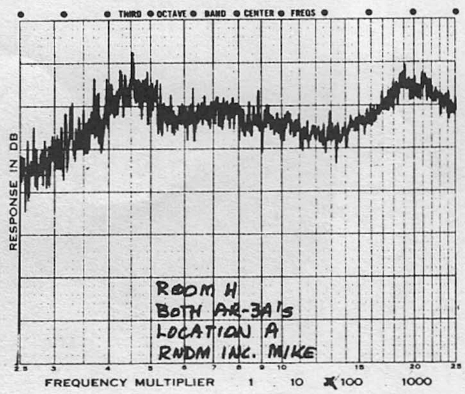


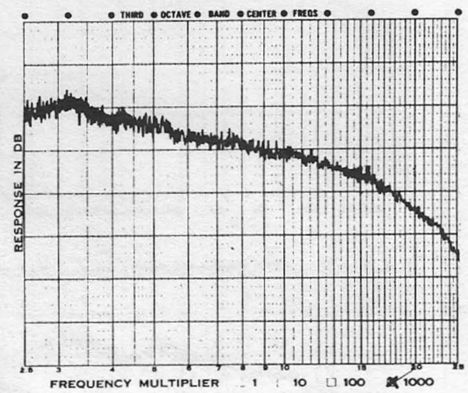

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

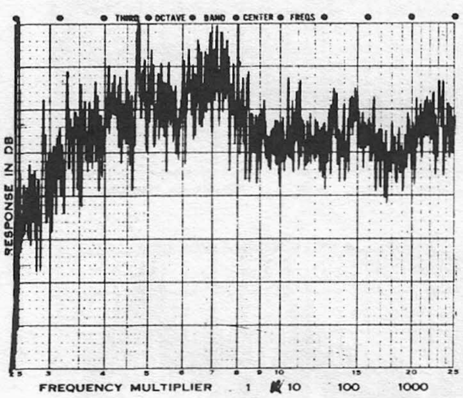

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM H
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

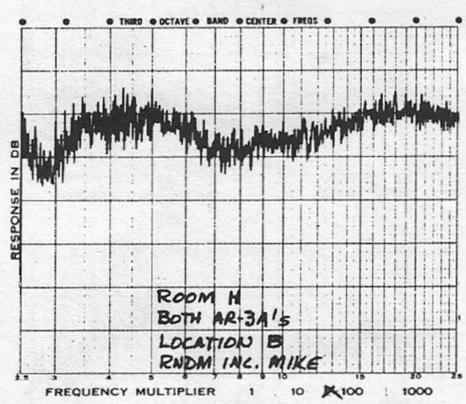

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

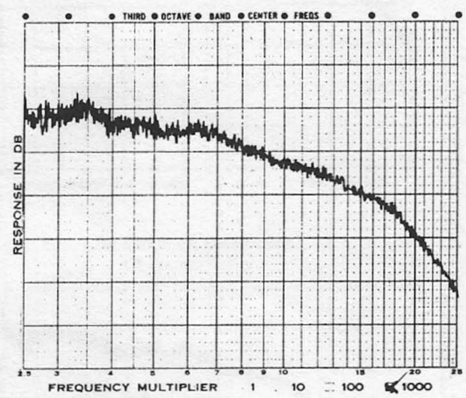

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

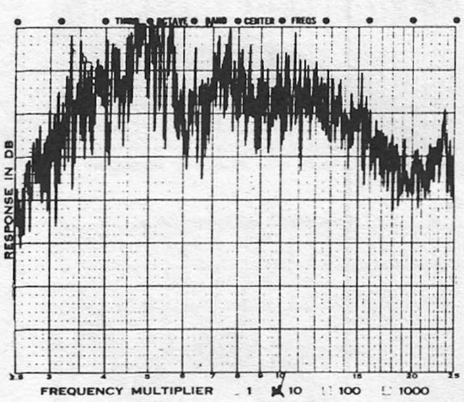

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM H
BOTH AR-3A's
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

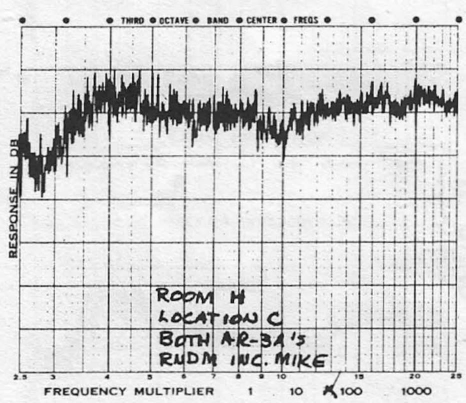

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

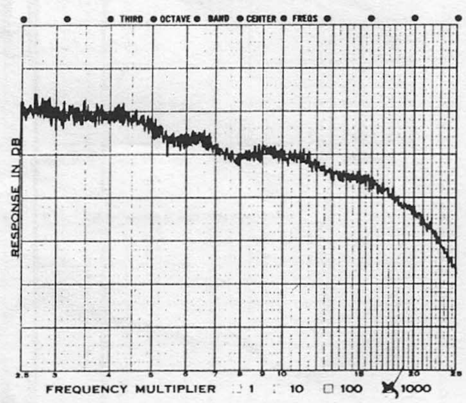

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

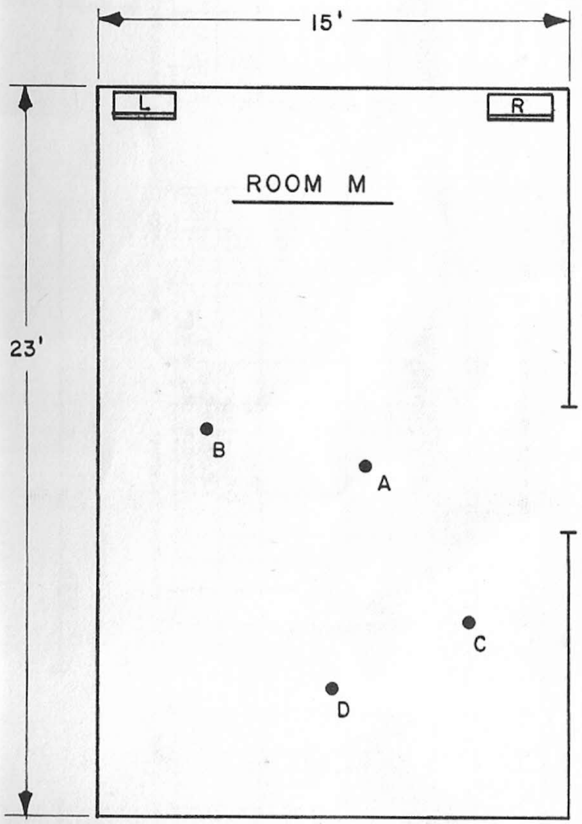

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM H
BOTH AR-3A's
LOCATION B
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

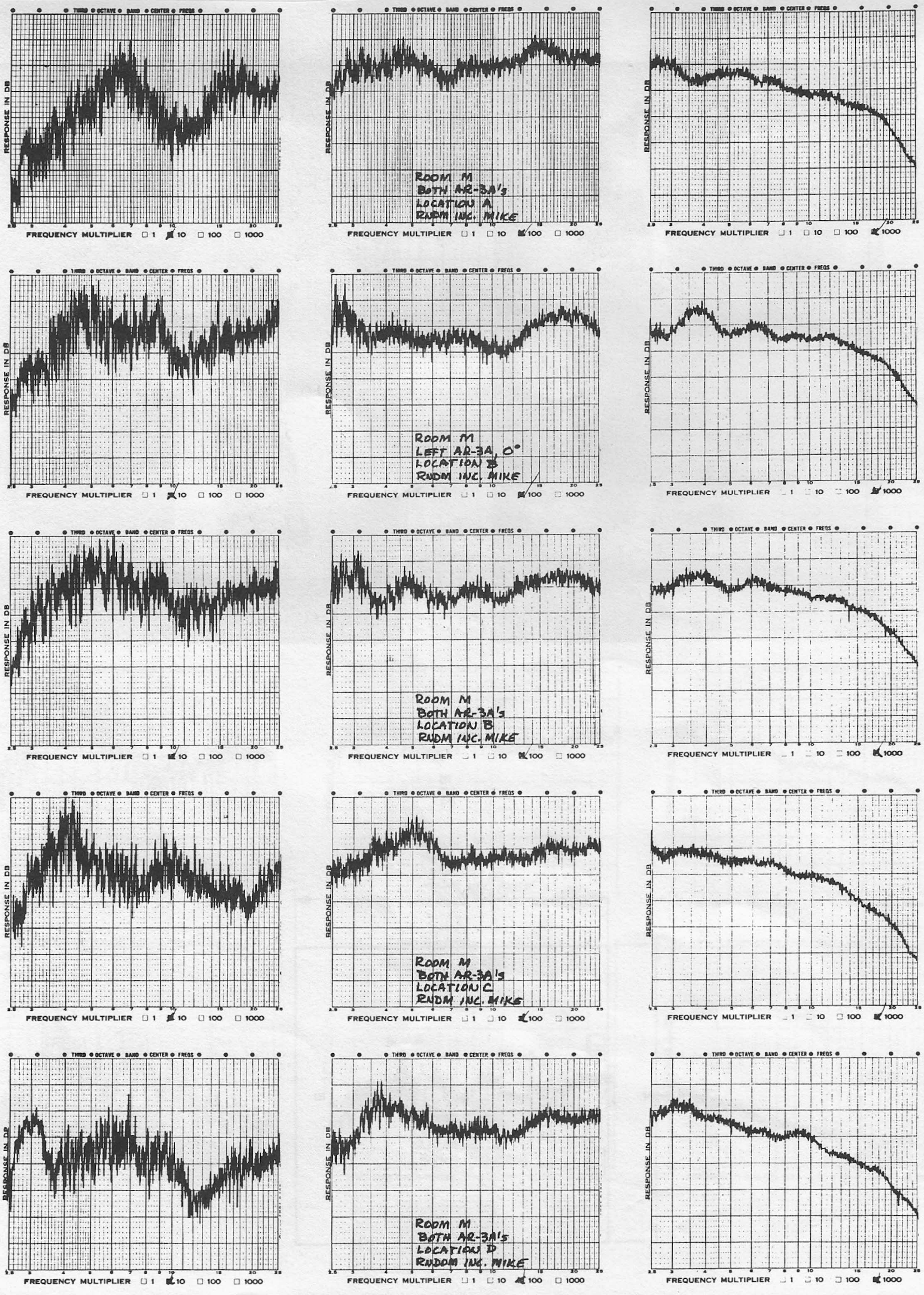

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM H
LOCATION C
BOTH AR-3A's
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

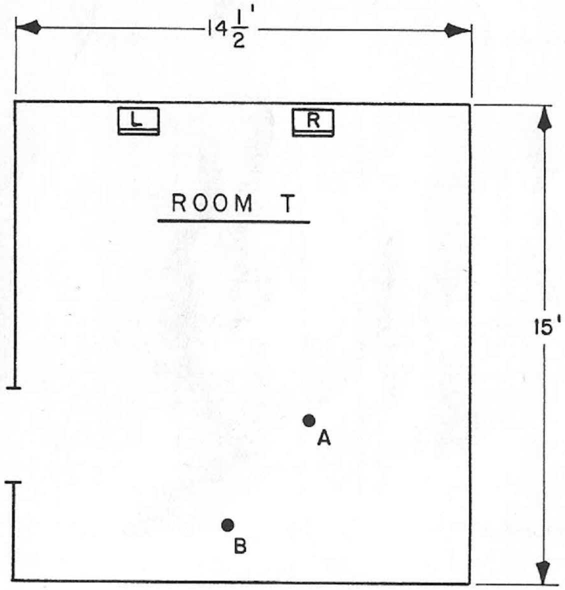

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000



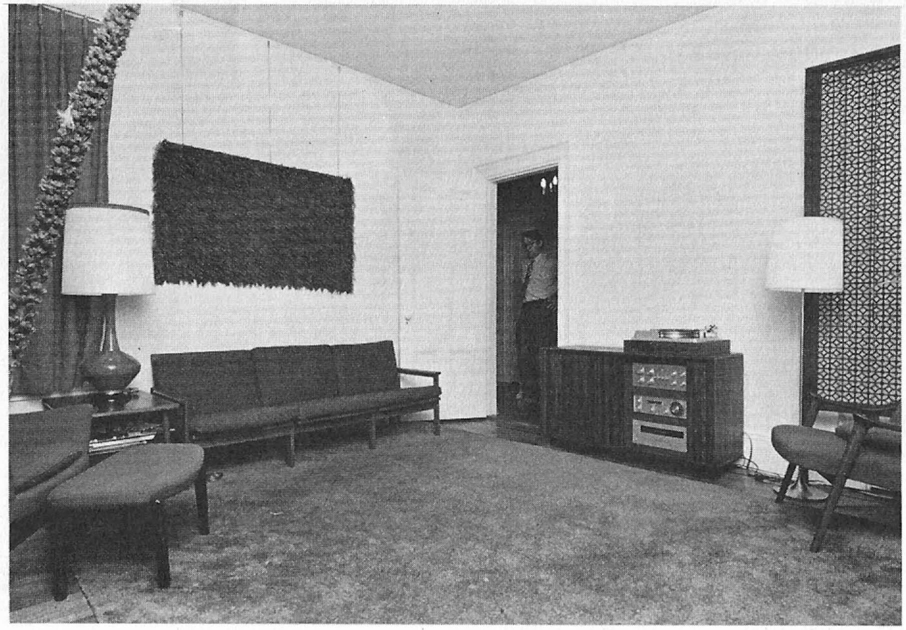
15'
23'
L
R
ROOM M
B
A
C
D

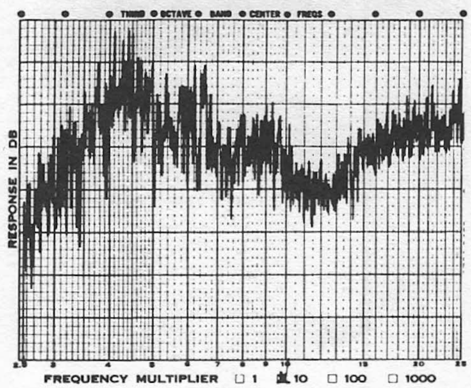
247

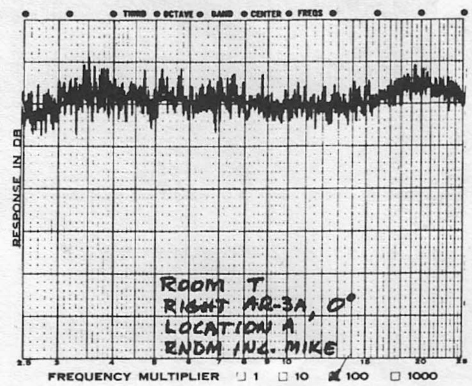

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
ROOM M
BOTH AR-3A's
LOCATION A
RNDM INC. MIKE
ROOM M
LEFT AR-3A, 0°
LOCATION B
RNDM INC. MIKE
ROOM M
BOTH AR-3A's
LOCATION B
RNDM INC. MIKE
ROOM M
BOTH AR-3A's
LOCATION C
RNDM INC. MIKE
ROOM M
BOTH AR-3A's
LOCATION D
RNDM INC. MIKE

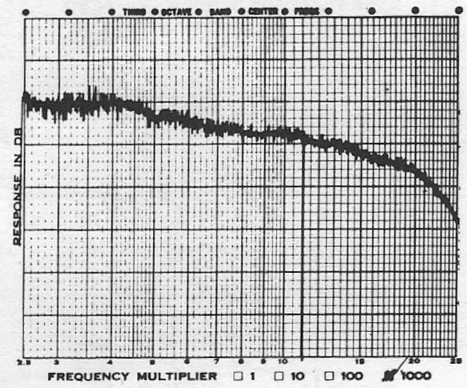


25a

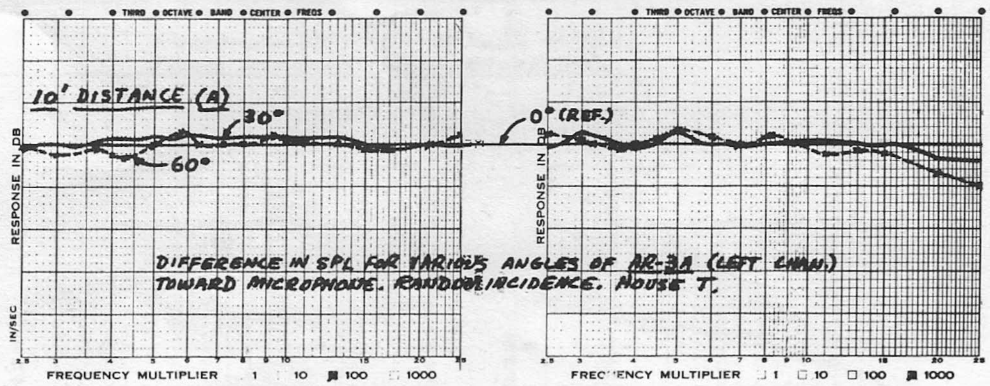


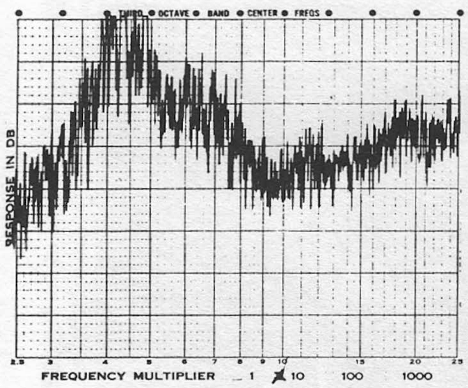


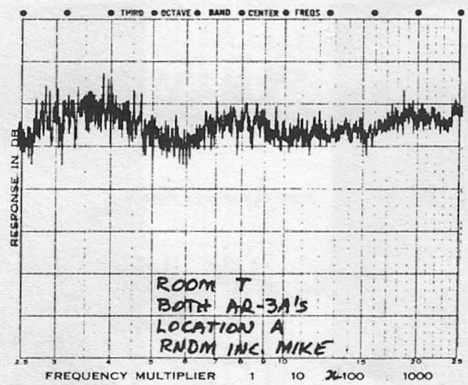

ROOM T
RIGHT AR-3A, 0°
LOCATION A
RNDM INC. MIKE

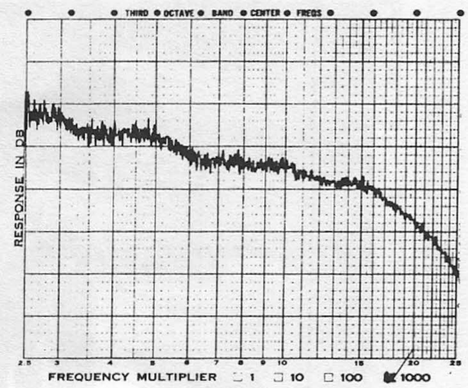


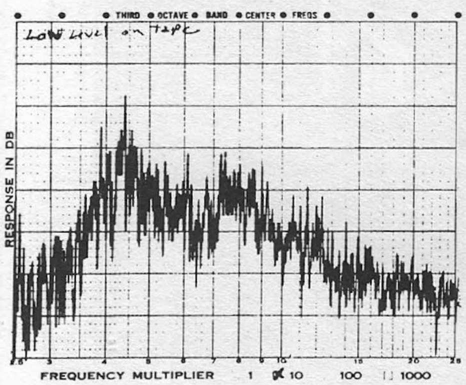
25b

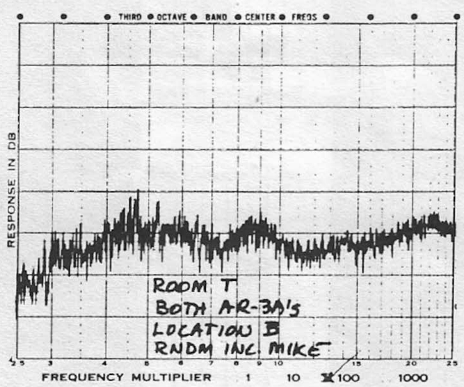

10' DISTANCE (A)
30°
60°
0° (REF.)
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-3A (LEFT CHAN.)
TOWARD MICROPHONE. RANDOM INCIDENCE. HOUSE T.

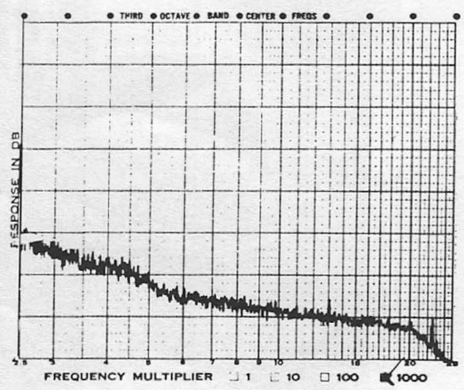


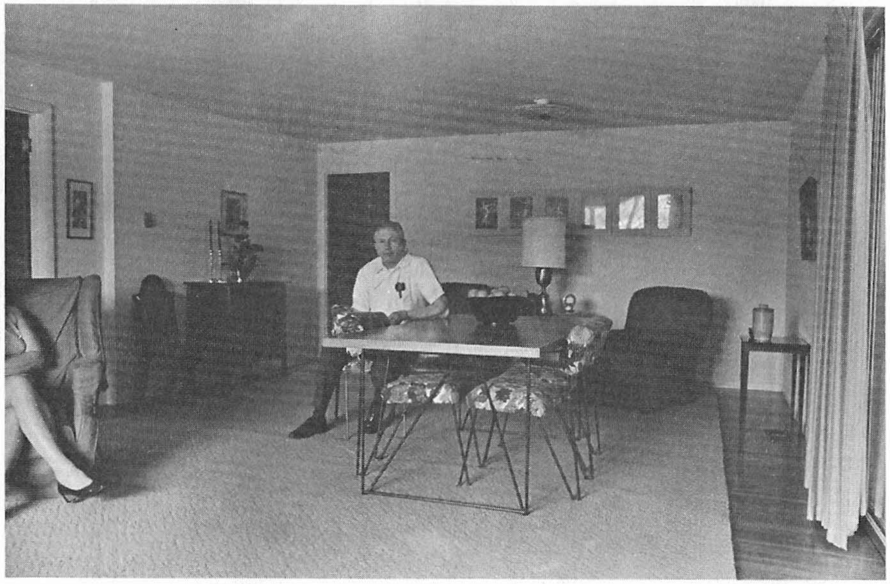

ROOM T
BOTH AR-3A's
LOCATION A
RNDM INC. MIKE



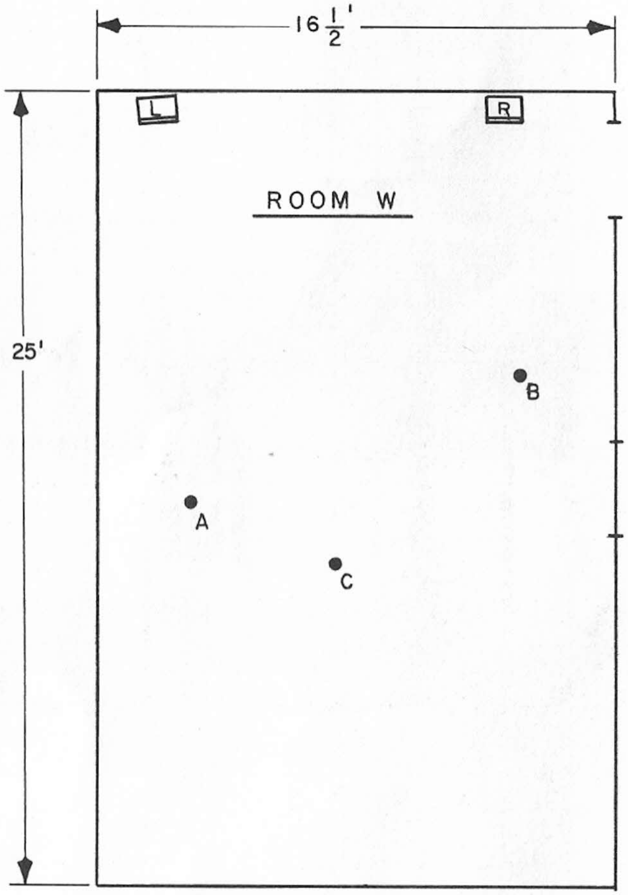

Low Level on tape

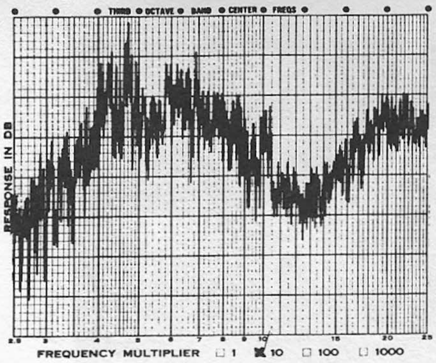

ROOM T
BOTH AR-3A's
LOCATION B
RNDM INC. MIKE

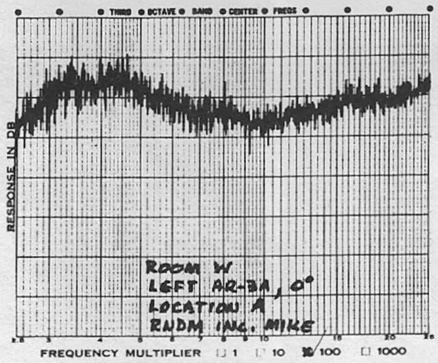




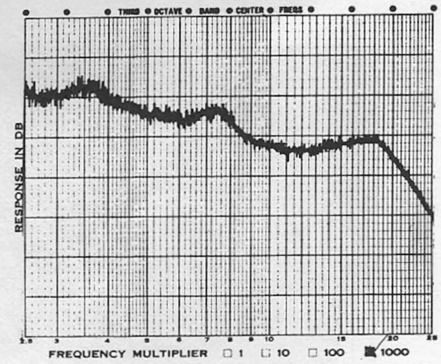
26a



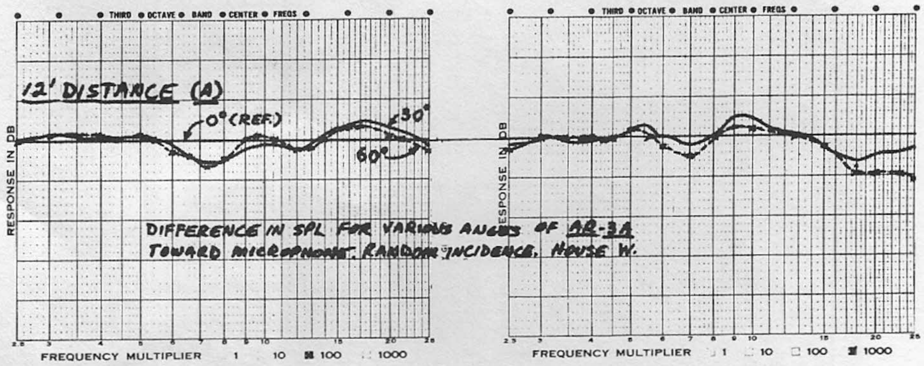




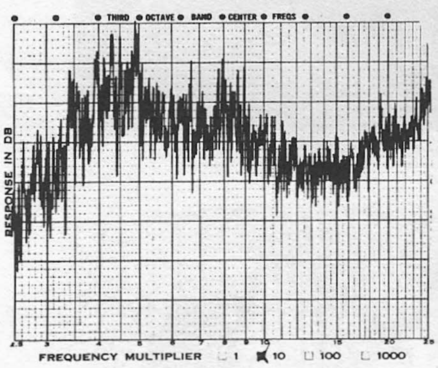
ROOM W
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE

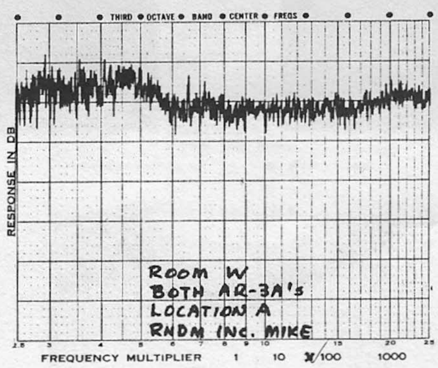


26b

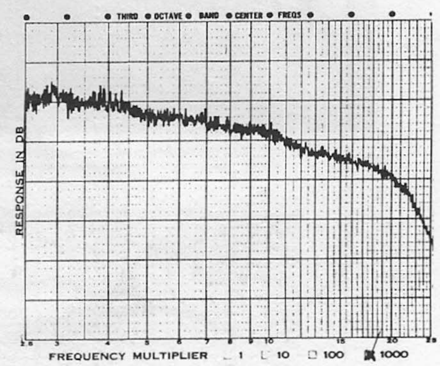


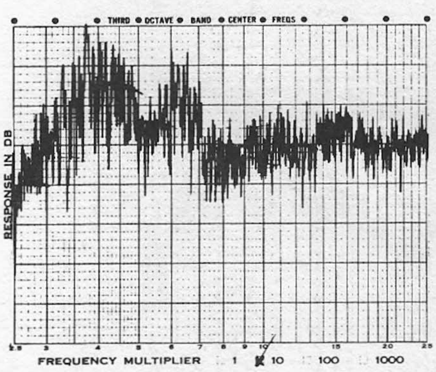
12' DISTANCE (A)
0° (REF.)
30°
60°
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-3A
TOWARD MICROPHONE. RANDOM INCIDENCE. HOUSE W.

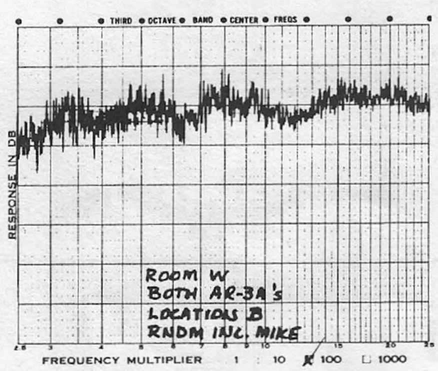




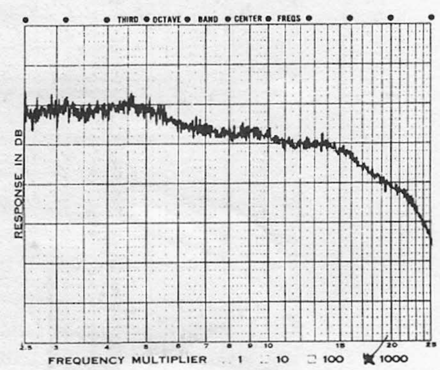
ROOM W
BOTH AR-3A's
LOCATION A
RNDM INC. MIKE

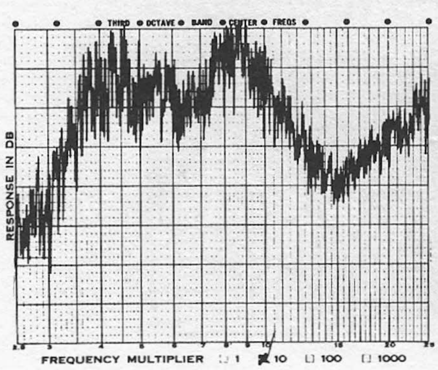


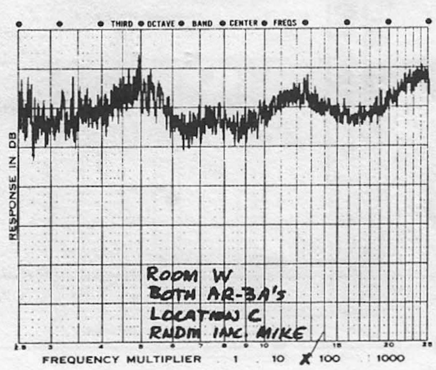




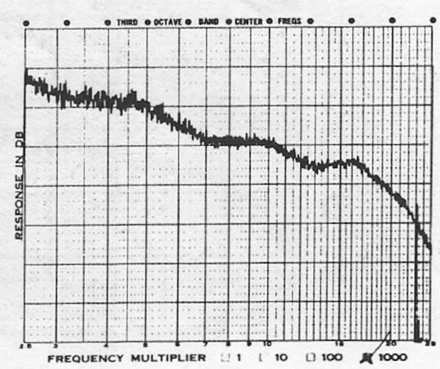
ROOM W
BOTH AR-3A's
LOCATION B
RNDM INC. MIKE

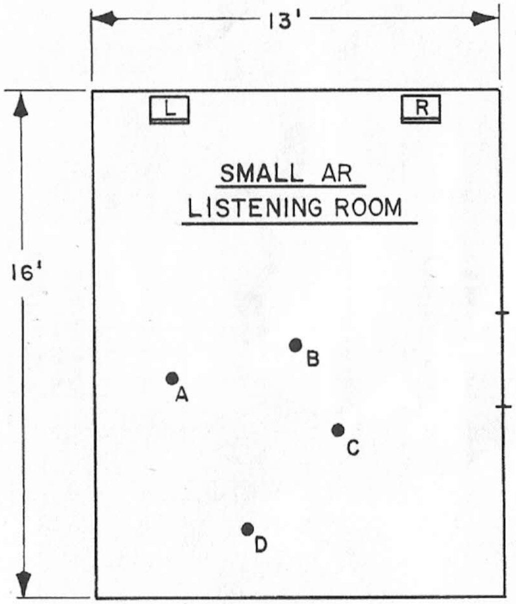


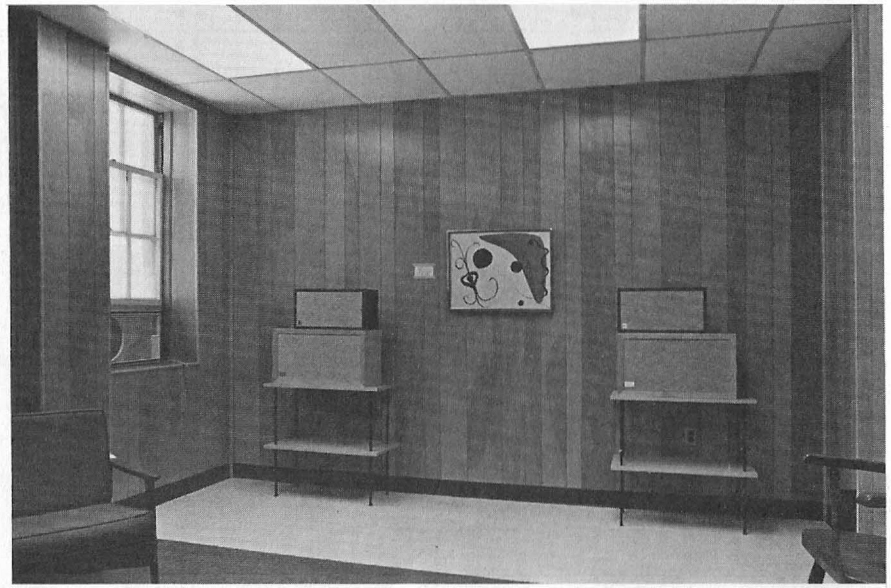


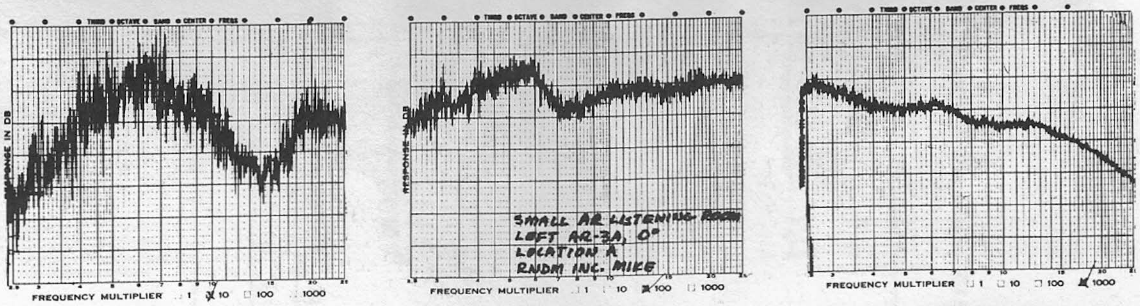


ROOM W
BOTH AR-3A's
LOCATION C
RNDM INC. MIKE

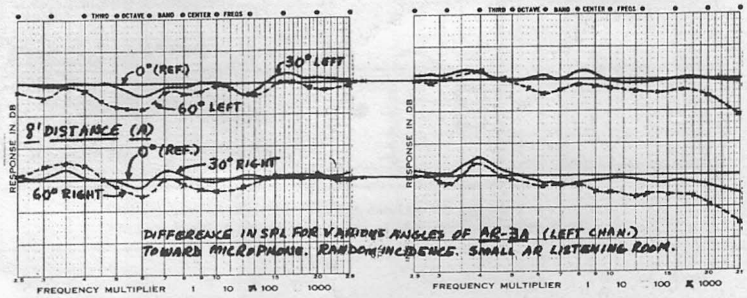


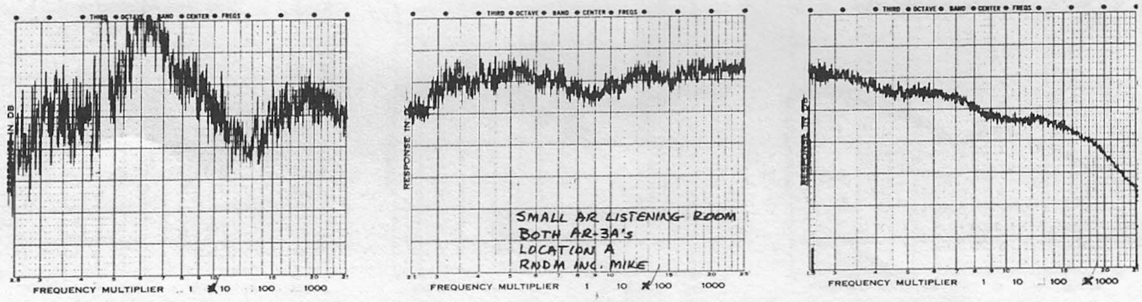

13'
16'
L
R
SMALL AR
LISTENING ROOM
A
B
C
D

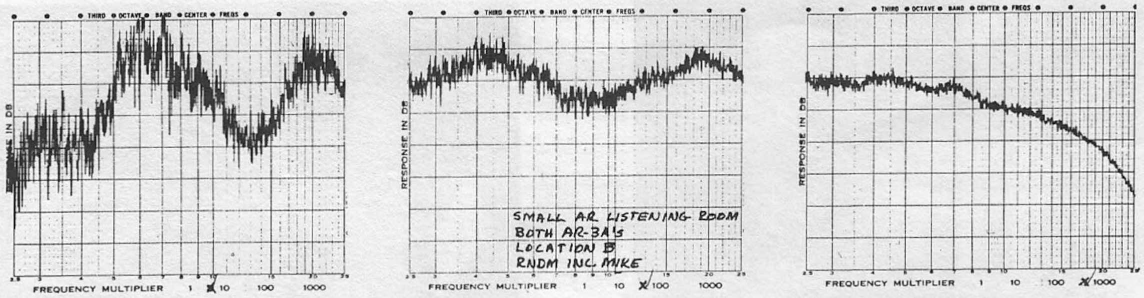


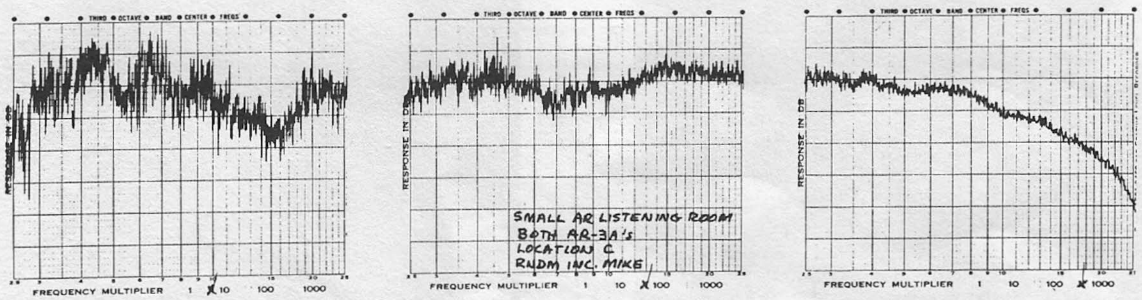

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
SMALL AR LISTENING ROOM
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

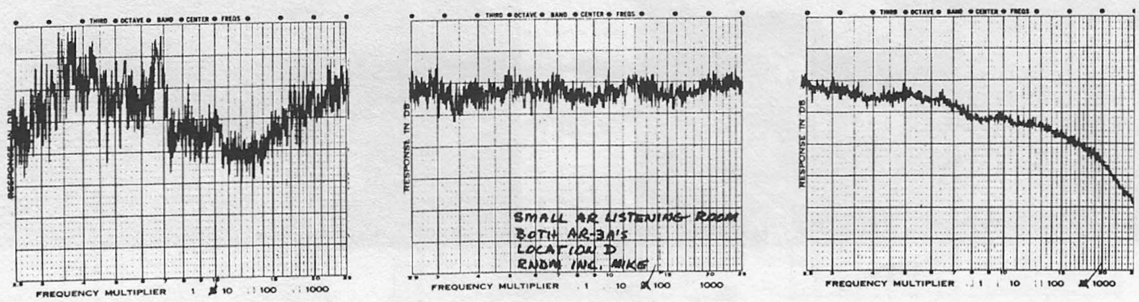
27b

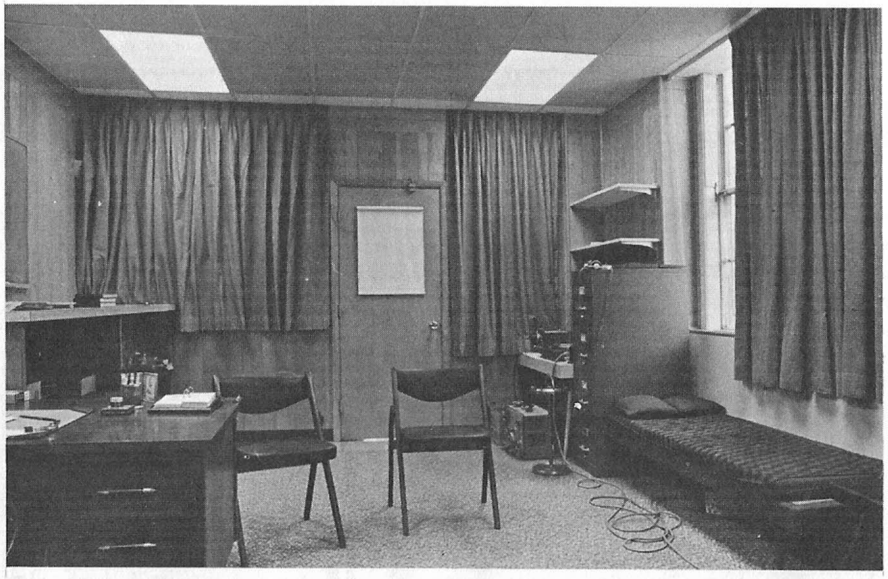

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
0° (REF.)
30° LEFT
60° LEFT
8' DISTANCE (A)
0° (REF.)
30° RIGHT
60° RIGHT
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-3A (LEFT CHAN.)
TOWARD MICROPHONE. RANDOM INCIDENCE. SMALL AR LISTENING ROOM.
FREQUENCY MULTIPLIER 1 10 100 1000

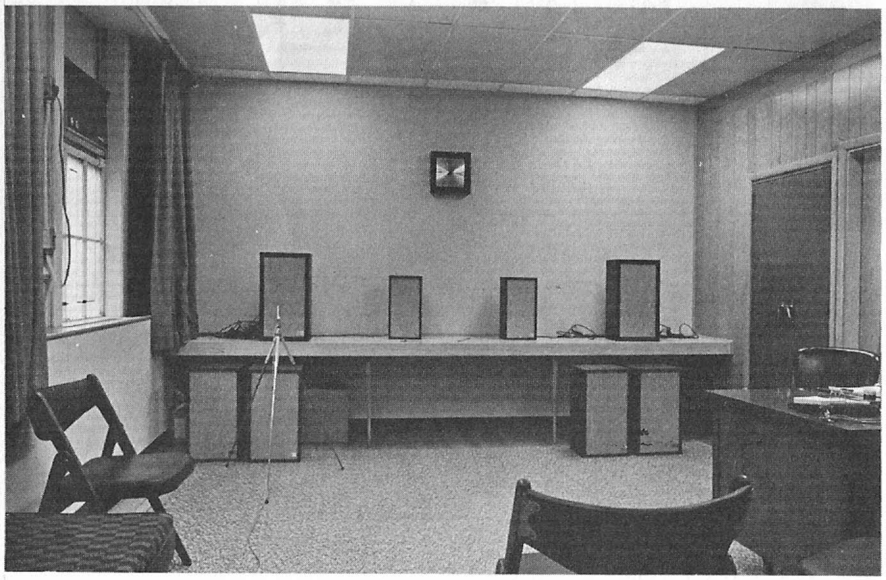

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
SMALL AR LISTENING ROOM
BOTH AR-3A'S
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

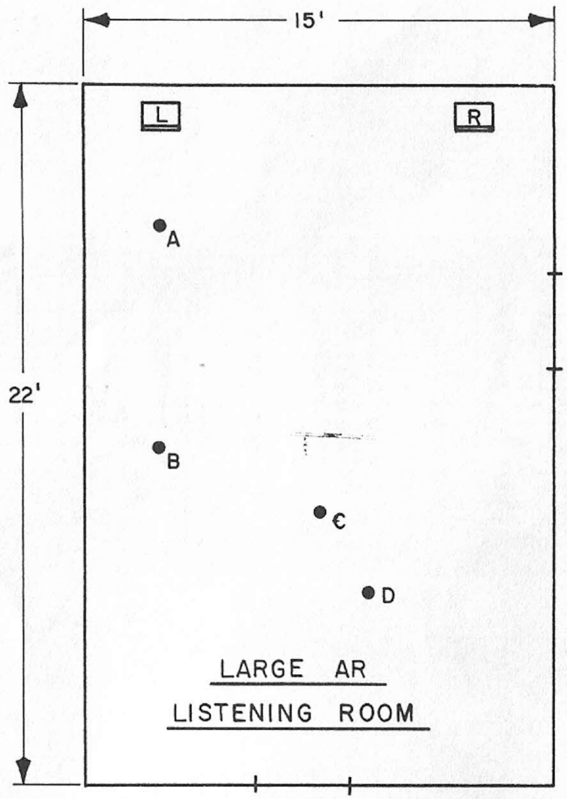

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
SMALL AR LISTENING ROOM
BOTH AR-3A'S
LOCATION B
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

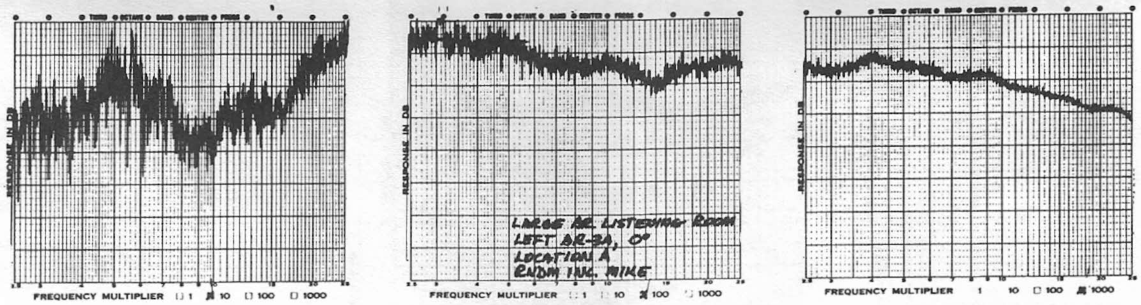

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
SMALL AR LISTENING ROOM
BOTH AR-3A's
LOCATION C
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
SMALL AR LISTENING ROOM
BOTH AR-3A'S
LOCATION D
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 100 1000

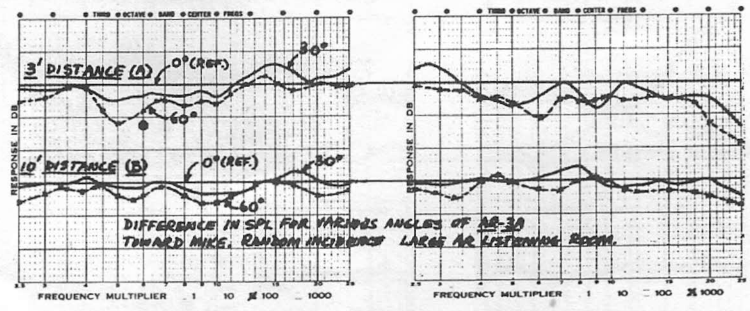


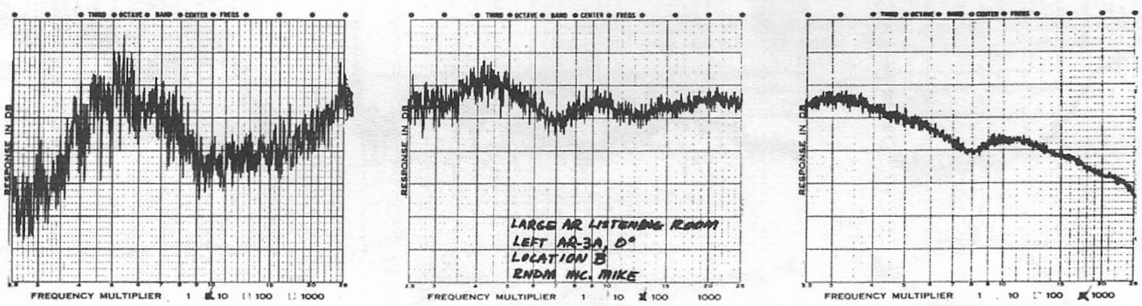


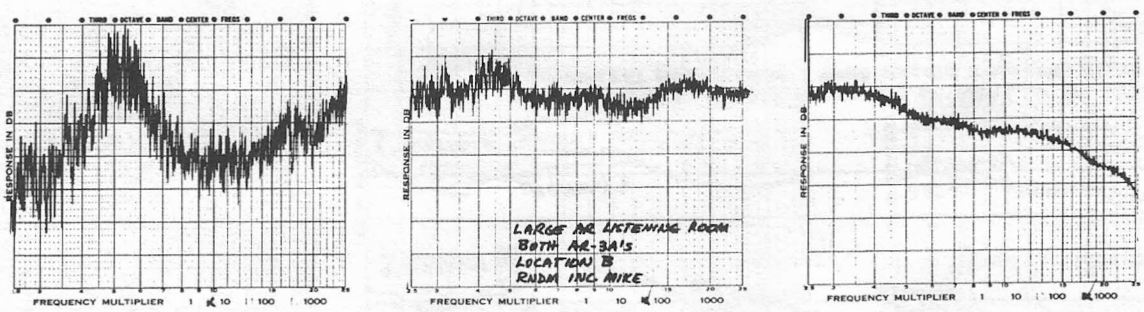

15'
22'
L
R
A
B
C
D
LARGE AR
LISTENING ROOM

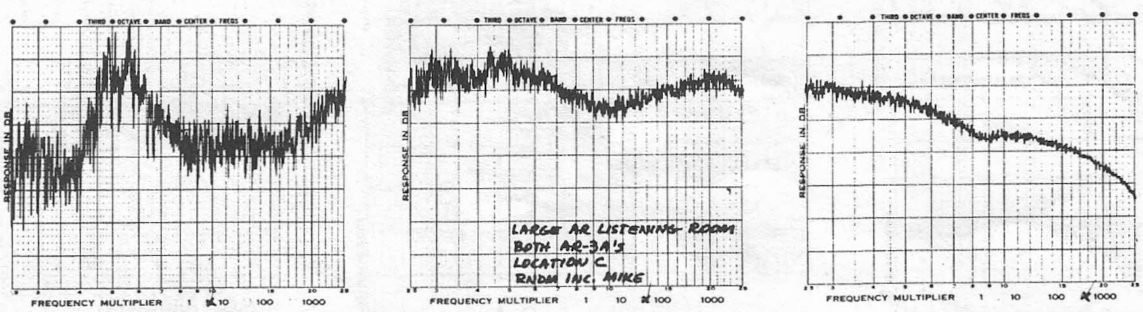

LARGE AR LISTENING ROOM
LEFT AR-3A, 0°
LOCATION A
RNDM INC. MIKE
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

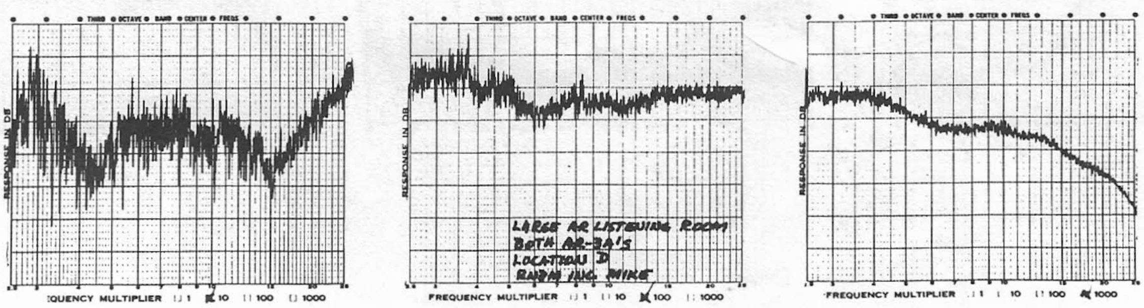
28b

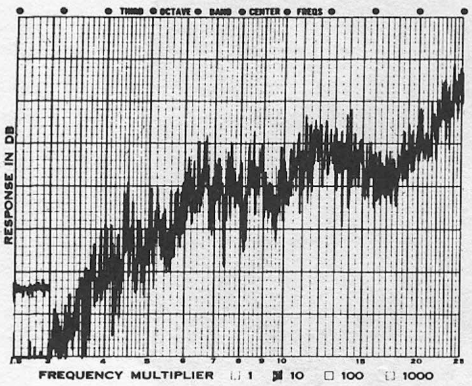

3' DISTANCE (A)
0°(REF.)
30°
60°
10' DISTANCE (B)
0°(REF.)
30°
60°
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-3A
TOWARD MIKE. RANDOM INCIDENCE LARGE AR LISTENING ROOM.
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

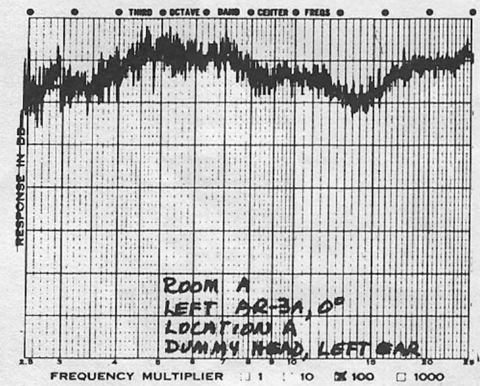

LARGE AR LISTENING ROOM
LEFT AR-3A, 0°
LOCATION B
RNDM INC. MIKE
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

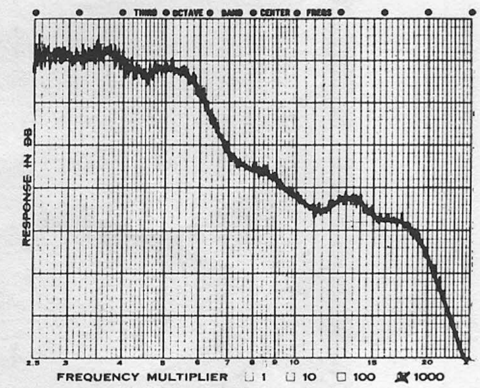

LARGE AR LISTENING ROOM
BOTH AR-3A'S
LOCATION B
RNDM INC. MIKE
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000


LARGE AR LISTENING ROOM
BOTH AR-3A'S
LOCATION C
RNDM INC. MIKE
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

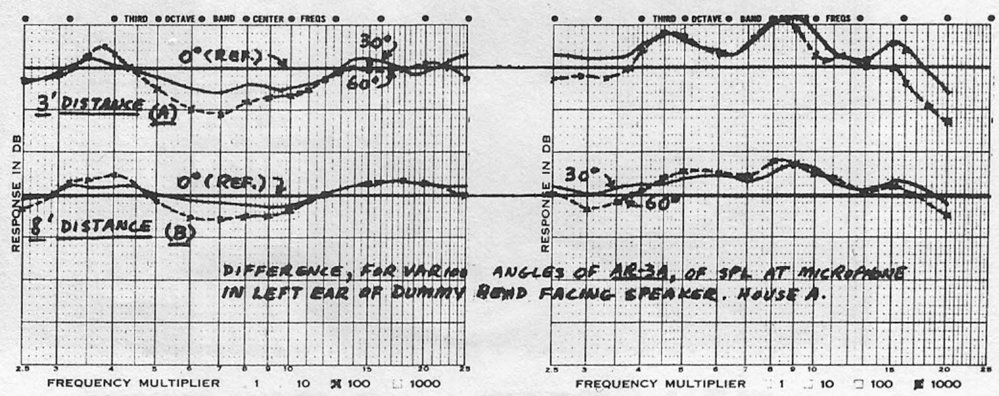

LARGE AR LISTENING ROOM
BOTH AR-3A'S
LOCATION D
RNDM INC. MIKE
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

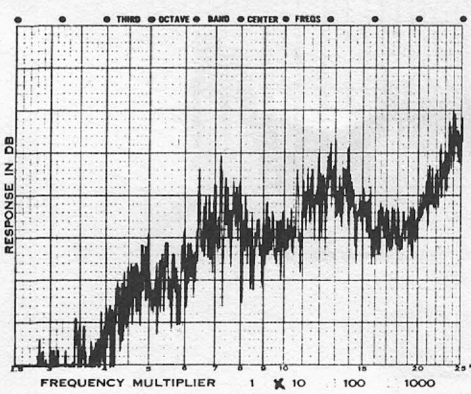

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

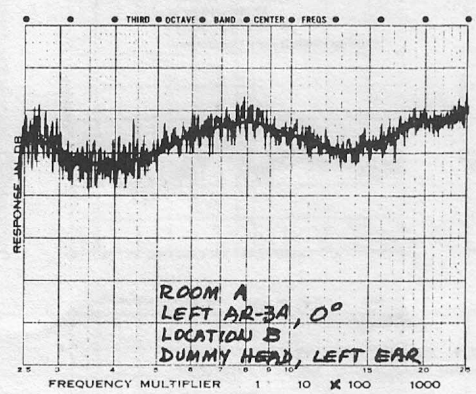

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM A
LEFT AR-3A, 0°
LOCATION A
DUMMY HEAD, LEFT EAR
FREQUENCY MULTIPLIER 1 10 100 1000

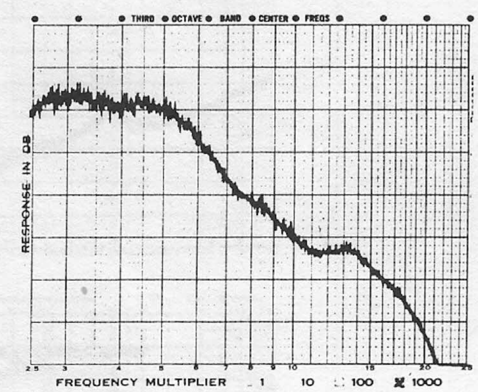

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

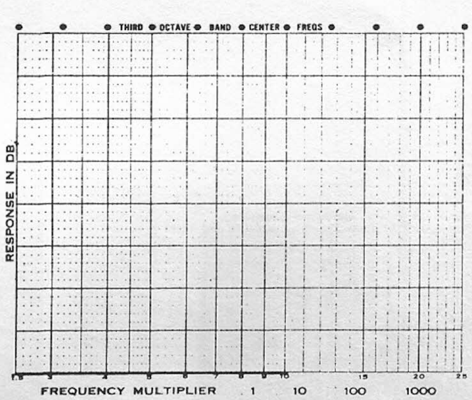
29

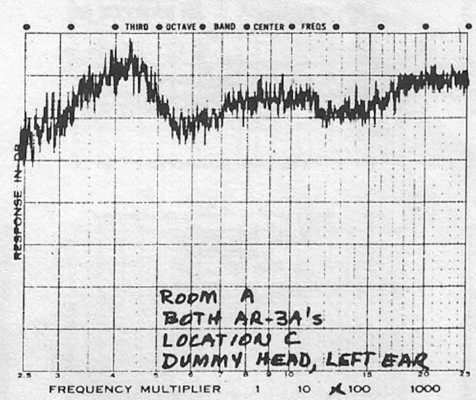

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
0° (REF.)
30°
60°
3' DISTANCE (A)
0° (REF.)
8' DISTANCE (B)
30°
60°
DIFFERENCE, FOR VARIOUS ANGLES OF AR-3A, OF SPL AT MICROPHONE
IN LEFT EAR OF DUMMY HEAD FACING SPEAKER. HOUSE A.
FREQUENCY MULTIPLIER 1 10 100 1000

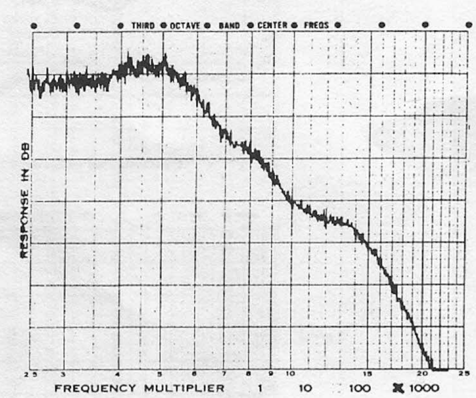

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

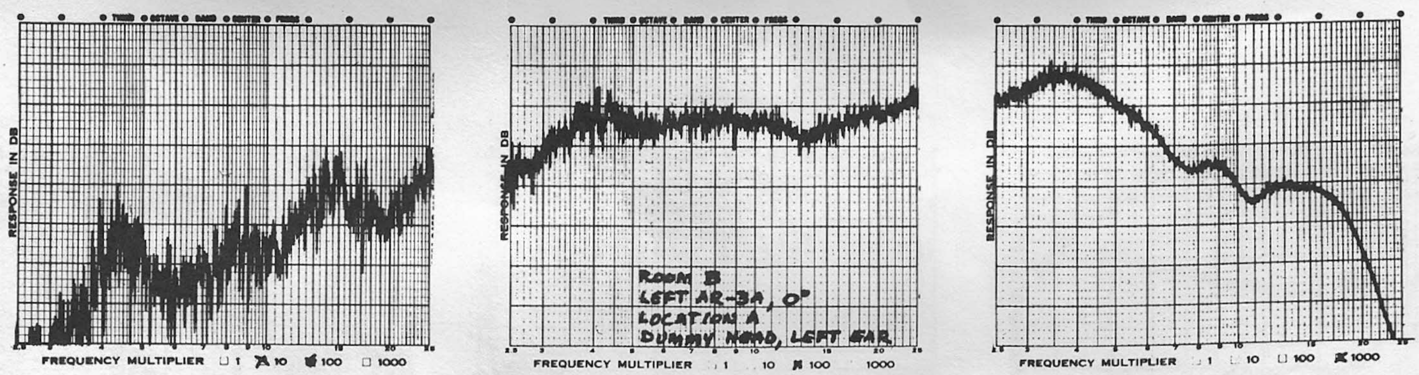

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM A
LEFT AR-3A, 0°
LOCATION B
DUMMY HEAD, LEFT EAR
FREQUENCY MULTIPLIER 1 10 100 1000

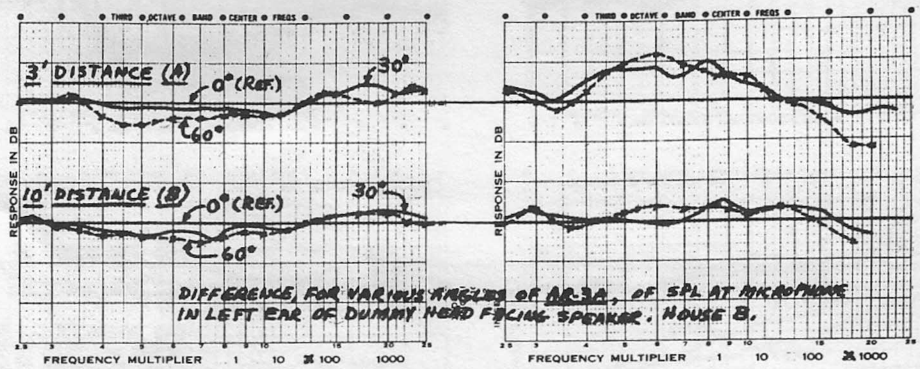

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

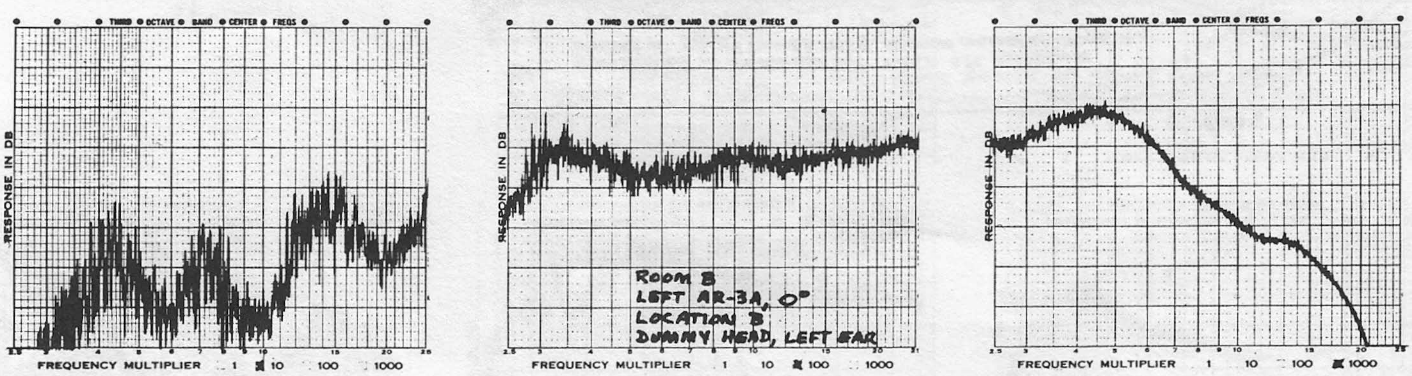

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM A
BOTH AR-3A's
LOCATION C
DUMMY HEAD, LEFT EAR
FREQUENCY MULTIPLIER 1 10 100 1000

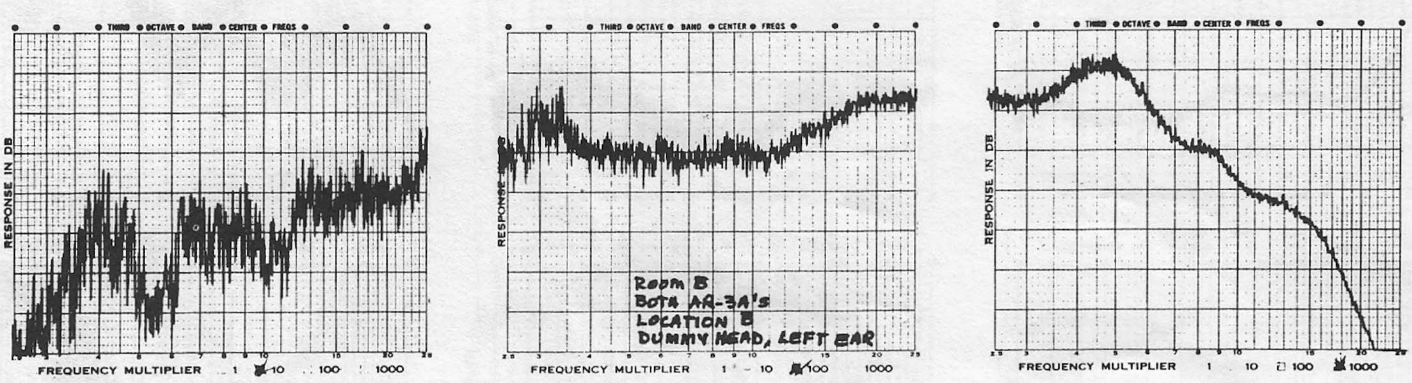

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000

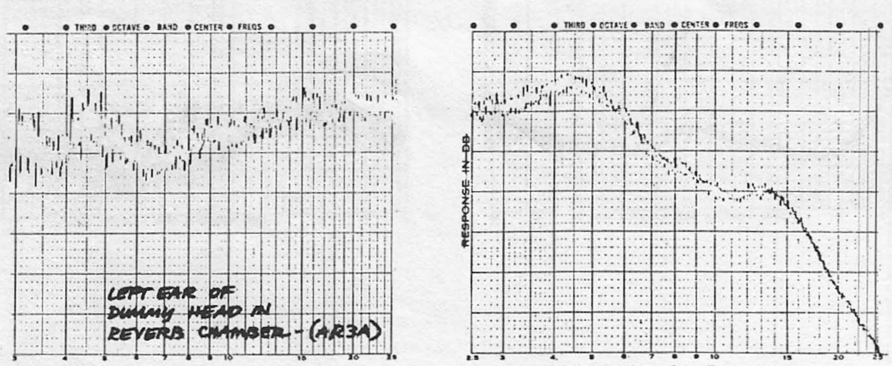

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
Room B
LEFT AR-3A, 0°
LOCATION A
DUMMY HEAD, LEFT EAR

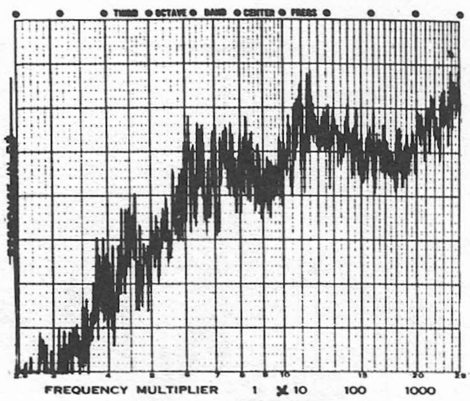

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
3' DISTANCE (A)
0° (REF.)
30°
60°
10' DISTANCE (B)
0° (REF.)
30°
60°
DIFFERENCE, FOR VARIOUS ANGLES OF AR-3A, OF SPL AT MICROPHONE
IN LEFT EAR OF DUMMY HEAD FACING SPEAKER. HOUSE B.
FREQUENCY MULTIPLIER 1 10 100 1000

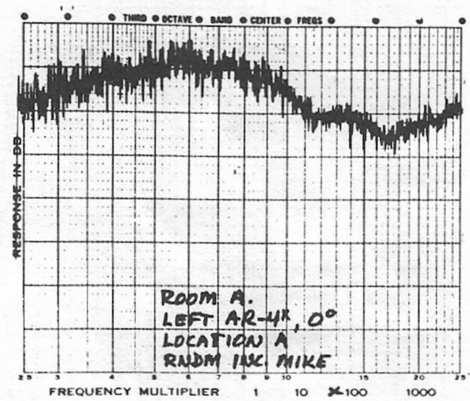
30

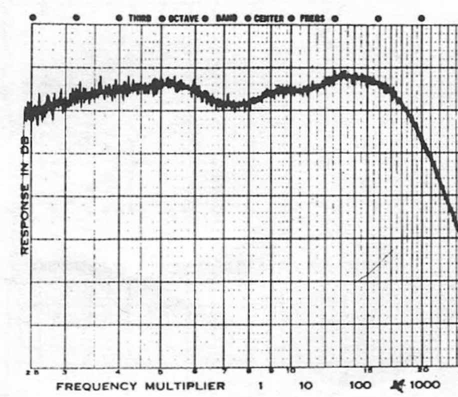

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
Room B
LEFT AR-3A, 0°
LOCATION B
DUMMY HEAD, LEFT EAR

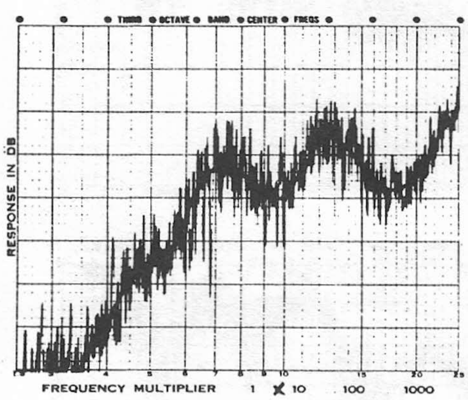

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
Room B
BOTH AR-3A'S
LOCATION B
DUMMY HEAD, LEFT EAR

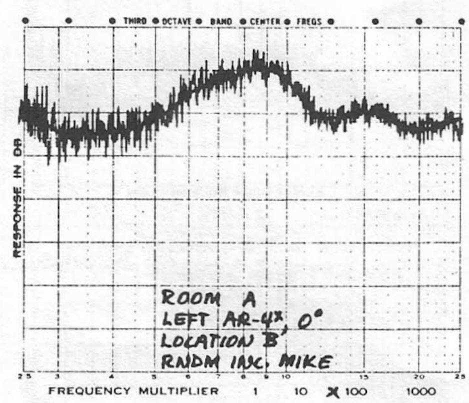

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
LEFT EAR OF
DUMMY HEAD IN
REVERB CHAMBER - (AR3A)
FREQUENCY MULTIPLIER 1 10 100 1000

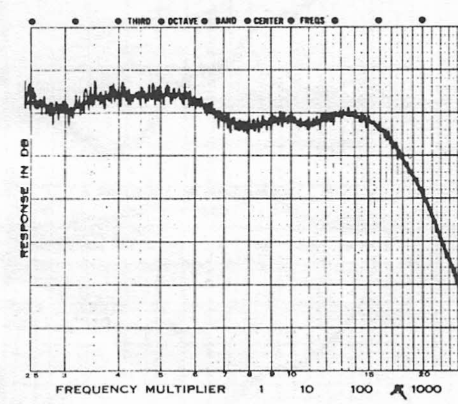

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 X 10 100 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM A.
LEFT AR-4X, 0°
LOCATION A
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 X 100 1000

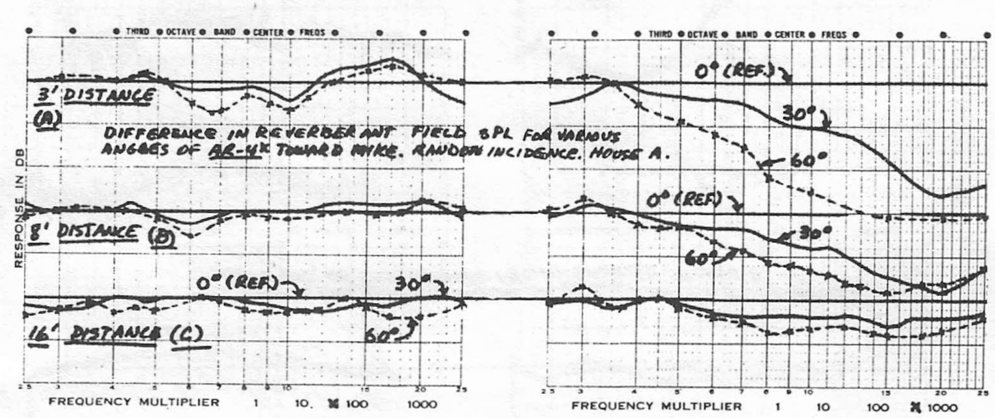

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 X 1000

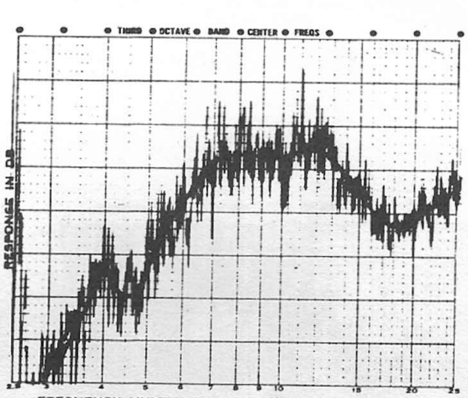

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 X 10 100 1000

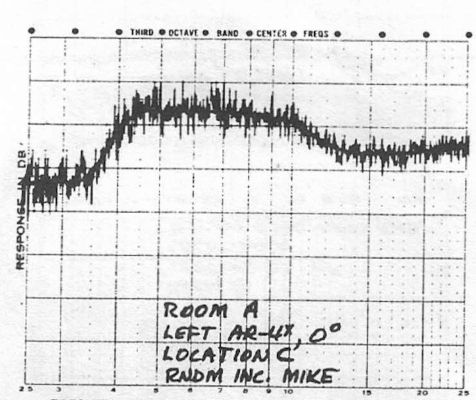

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM A
LEFT AR-4X, 0°
LOCATION B
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 X 100 1000

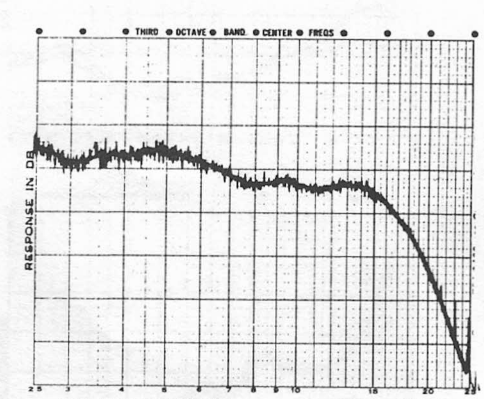

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 X 1000

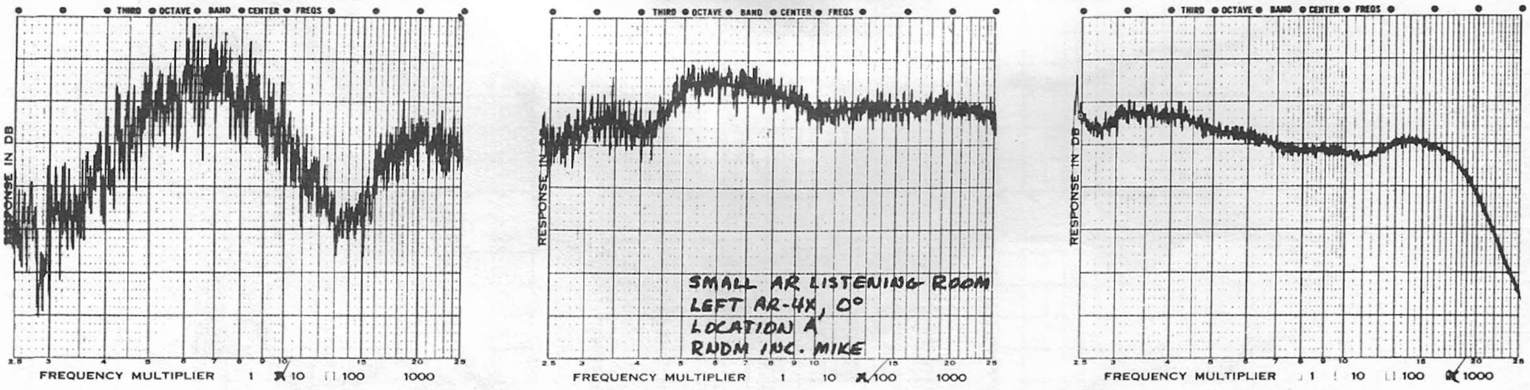
31

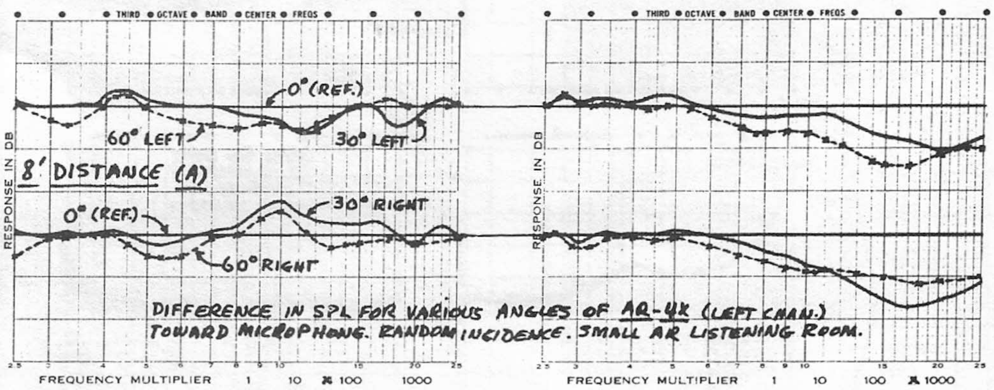

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
3' DISTANCE (A)
DIFFERENCE IN REVERBERANT FIELD SPL FOR VARIOUS ANGLES OF AR-4X TOWARD MIKE. RANDOM INCIDENCE. HOUSE A.
0° (REF.)
30°
60°
8' DISTANCE (B)
0° (REF)
30°
60°
16' DISTANCE (C)
0° (REF.)
30°
60°
FREQUENCY MULTIPLIER 1 10 X 100 1000
FREQUENCY MULTIPLIER 1 10 100 X 1000


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 X 10 100 1000

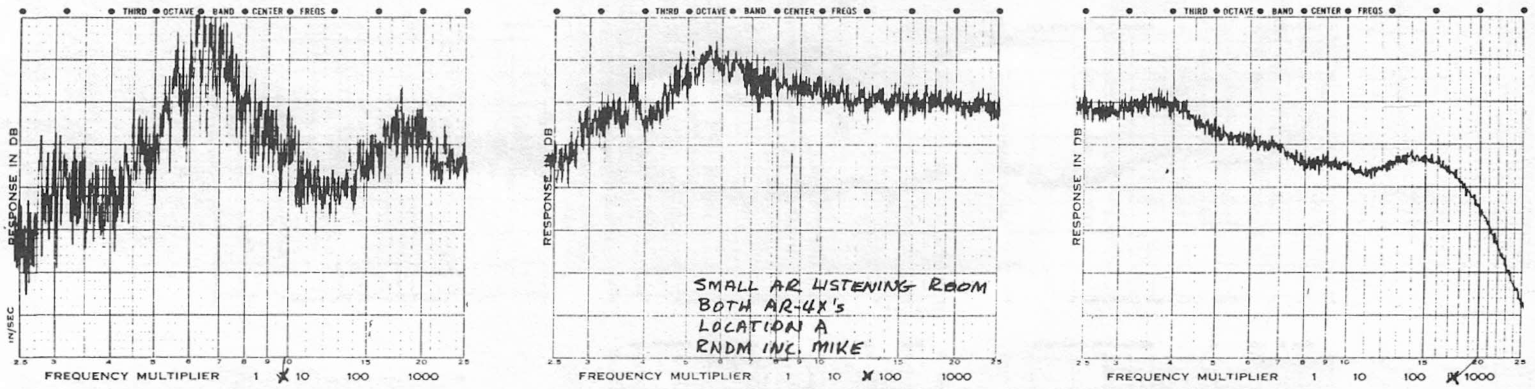

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
ROOM A
LEFT AR-4X, 0°
LOCATION C
RNDM INC. MIKE
FREQUENCY MULTIPLIER 1 10 X 100 1000

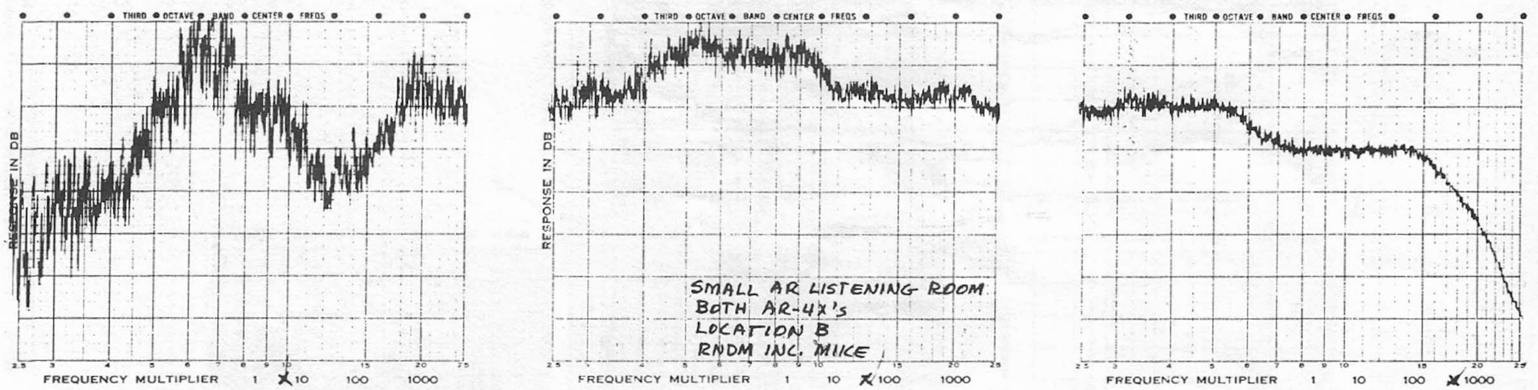

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 X 1000

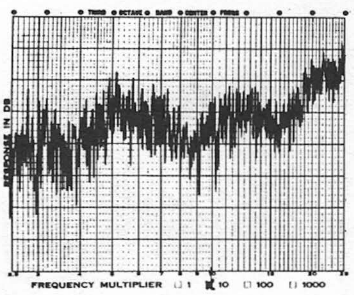

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
SMALL AR LISTENING ROOM
LEFT AR-4X, 0°
LOCATION A
RNDM INC. MIKE

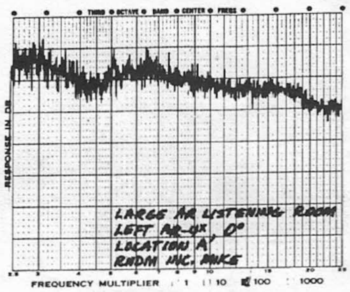

THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
0° (REF.)
60° LEFT
30° LEFT
8' DISTANCE (A)
0° (REF.)
30° RIGHT
60° RIGHT
DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-4X (LEFT CHAN.)
TOWARD MICROPHONE. RANDOM INCIDENCE. SMALL AR LISTENING ROOM.
FREQUENCY MULTIPLIER 1 10 100 1000

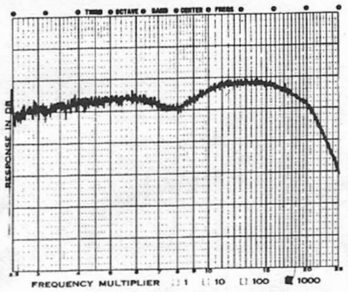
32


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
IN/SEC
FREQUENCY MULTIPLIER 1 10 100 1000
SMALL AR LISTENING ROOM
BOTH AR-4X's
LOCATION A
RNDM INC. MIKE


THIRD OCTAVE BAND CENTER FREQS
RESPONSE IN DB
FREQUENCY MULTIPLIER 1 10 100 1000
SMALL AR LISTENING ROOM
BOTH AR-4X's
LOCATION B
RNDM INC. MIKE




LARGE AR LISTENING ROOM
LEFT AR-4X, 0°
LOCATION A
RNDM INC. MIKE



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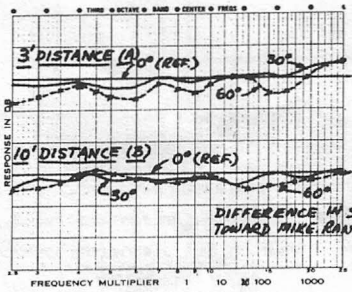
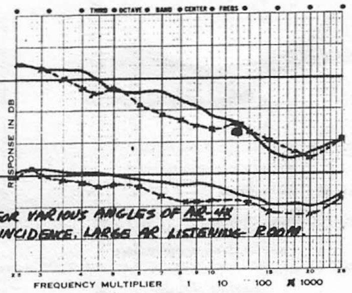
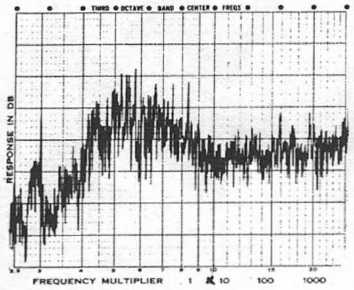
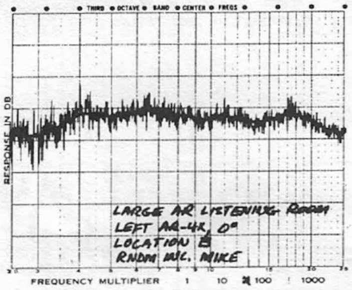
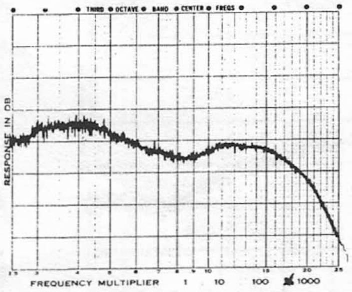
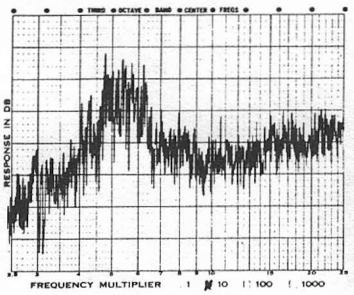

3' DISTANCE (A)
0° (REF.)
30°
60°
10' DISTANCE (B)
0° (REF.)
30°
60°

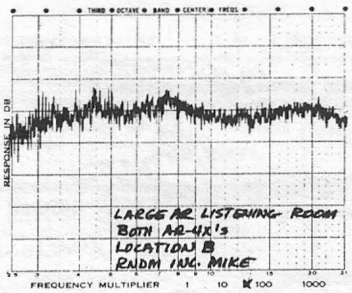

DIFFERENCE IN SPL FOR VARIOUS ANGLES OF AR-4X
TOWARD MIKE. RANDOM INCIDENCE. LARGE AR LISTENING ROOM.

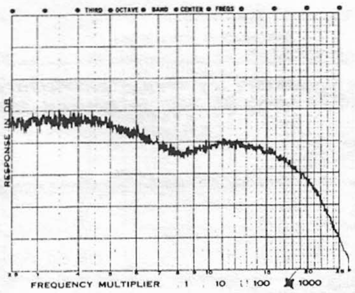


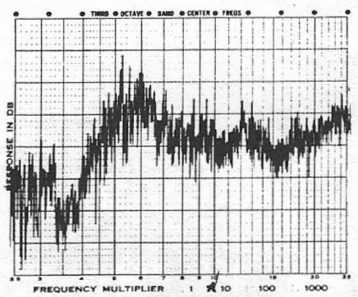

LARGE AR LISTENING ROOM
LEFT AR-4X, 0°
LOCATION B
RNDM INC. MIKE

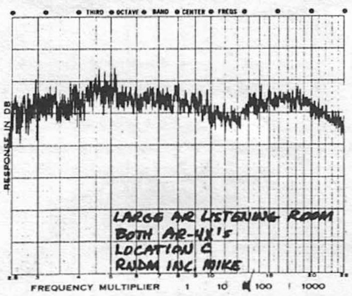


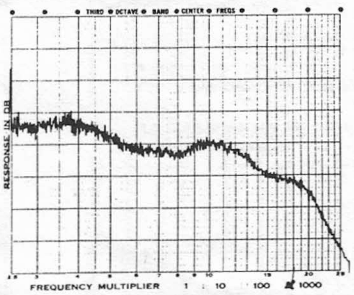


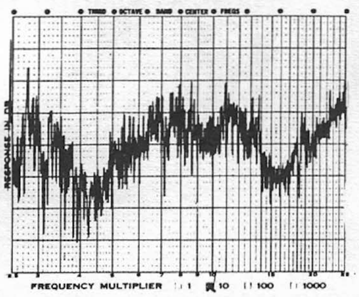

LARGE AR LISTENING ROOM
BOTH AR-4X's
LOCATION B
RNDM INC. MIKE

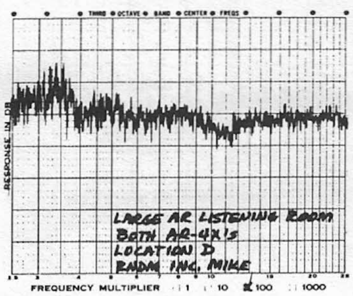


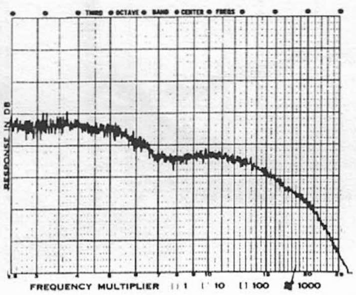



LARGE AR LISTENING ROOM
BOTH AR-4X's
LOCATION C
RNDM INC. MIKE

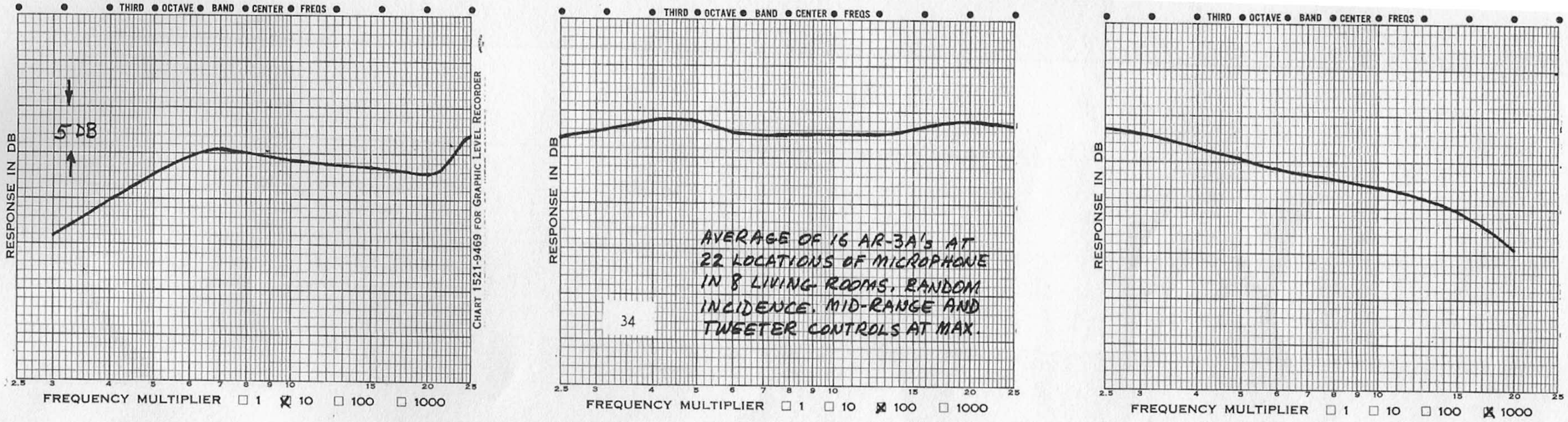


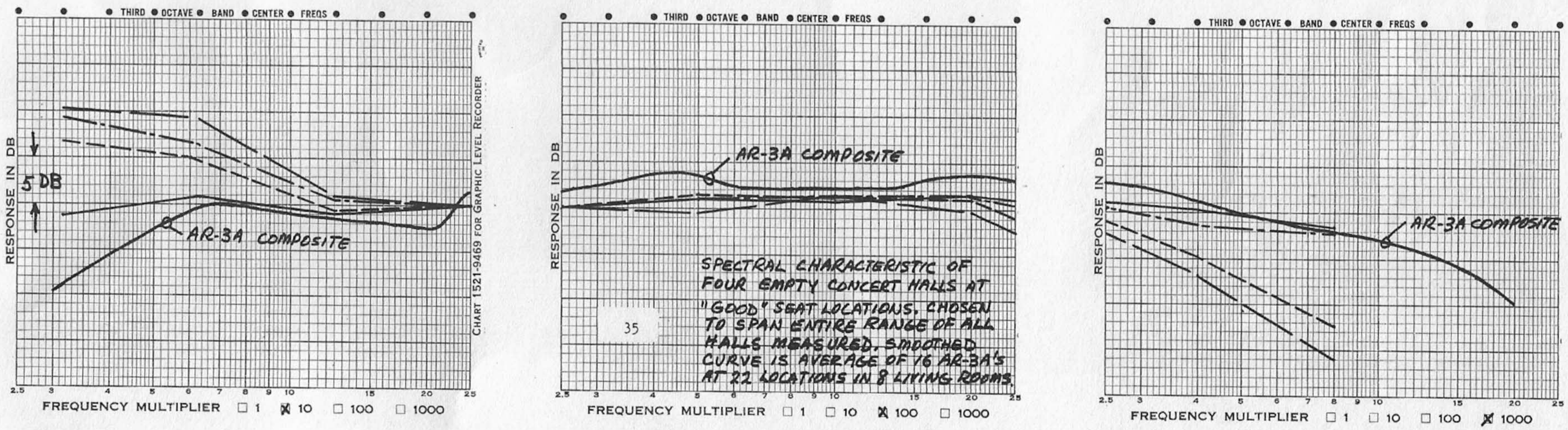


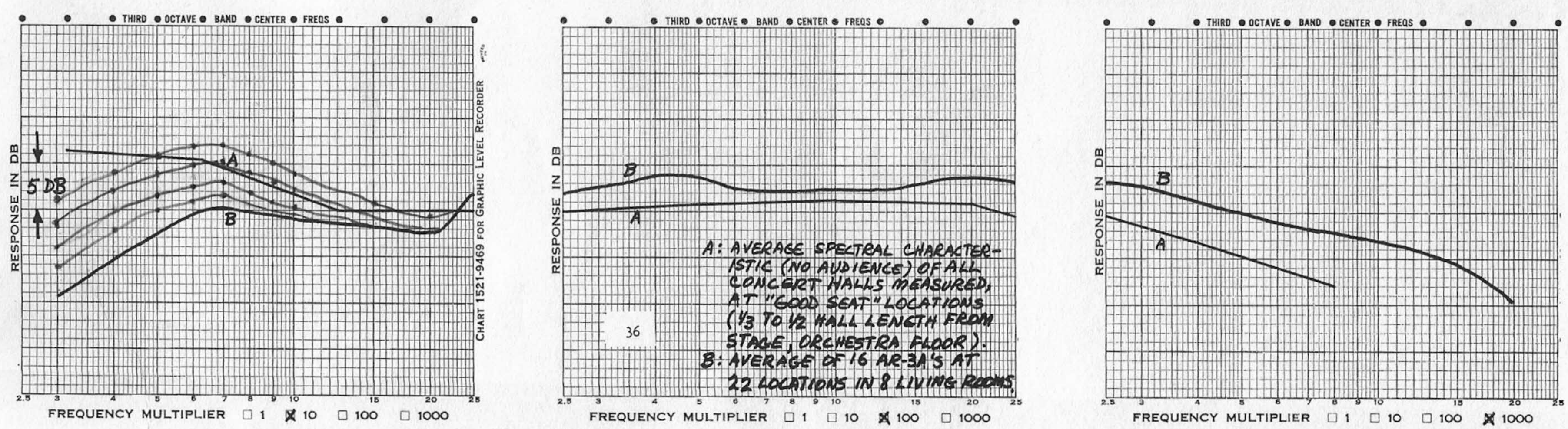

LARGE AR LISTENING ROOM
BOTH AR-4X's
LOCATION D
RNDM INC. MIKE



AR AMP
+ ADJUSTS
4/- 3/- 2/- 3/2







Illustrations to Accompany

THE SOUND FIELD IN HOME LISTENING ROOMS

by

Roy F. Allison
Robert Berkovitz

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AUDIO ENGINEERING SOCIETY