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TIME(TM) ALIGN TECHNIQUE

THE REAL WORLD OF LOUDSPEAKERS AND ROOMS

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Double Bass in Your Living Room

The purpose of this little treatise is to shock you, the audiophile and the audiophile dealers with whom you do business, into realizing that loudspeakers and rooms are basically incompatible, and that both you and the dealers must take positive steps to overcome this incompatibility if you are ever to stop fooling yourselves as to which loudspeaker is "best". All you will ever be able to do is make some rather rough judgement about which of a group of loudspeakers happens to do the best job in a particular room. It will probably be due to its being placed more advantageously than the others to which you are listening in that particular room. Also, to judge all loudspeakers, of different types, sizes, design objectives, etc.,in a particular room and under the same conditions, is also misleading and foolish. It would be like judging a sports car and a 2½ ton truck on their ability to corner at high speed and to pull a heavy load. Yet one hears constantly about how, "The Haywire Broadcasting Monitor, which is only 12"X8"X6", is much better than the Behemoth 1000 horn loaded, transmission line array." Now, the truth may very well be that the HBC Monitor is a better design and execution for its intended purpose, than the Behemoth 1000, but to "A-B" them is utter nonsense. Each must be judged under the conditions for which it was designed.

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Have you ever heard someone play a double string bass in your living room? I don't mean a recording of a double bass reproduced via a loudspeaker. I mean a real double bass! It's more than likely you would find it not to your liking. The sound of the real instrument in your room would probably be boomy and muddy! If it turned out to sound rather well, you could consider yourselve very fortunate. But, wait! Ask the bassist to move to another position in the room. Notice the change in the character of the sound? Every room has standing wave patterns and boundry effects. These room characteristics play an important part in the subjectively perceived quality of the sound of various <u>live</u> instruments. The same will be true of a loudspeaker system trying to recreate the sound of various instruments. What can be done about this incompatibility of the loudspeaker and the room? The first thing to be done is to learn some of the basic interaction effects caused by room boundry effects and standing waves. Let's look at the effects of the various room boundries and combinations of boundries first, before we study the effects of standing waves.

Boundry Effects Upon Loudspeaker Response

Since we wish to see the effects of the room boundries upon a real loudspeaker system, it is worthwhile to measure the test loudspeaker under free-field,anechoic, 4π steradian, conditions. (4π steradians indicates that the source is up away from all boundries and is free to radiate in all directions, spherically, with no interference.) FIGURE 1. is the amplitude vs. frequency response of the loudspeaker system used as the source for the following data relating to the effect of room boundries. As can be seen it is very uniform, being down 6 dB at a little below 40 Hz and about 9 dB at about 35 Hz.

The significance of the 6 dB and 9 dB points will be see later, with relation to the π and π/2 boundary effects. FIGURE 1. shows that the source loudspeaker has the capability of producing good output for the purpose of demonstrating the effects of the room boundaries upon the amplitude vs. frequency response of a source. FIGURE 2. is a drawing of the positions of the microphone for a seated or standing listener and the three positions of the loudspeaker used to gather the boundary effect data.

FIGURE 3. shows the effect of a single boundary vs. the free field curve of test loudspeaker. The source is at A.;listener standing.

FIGURE 4. shows the effect of two boundaries vs. the free field curve of the test loudspeaker. The source is at B.;listener seated.

FIGURE 5. shows the effect of the three boundaries formed by the corner of a room vs. the free field response curve of the loudspeaker. Source at C.;listener seated.

It is easy to see that the room boundaries play an important part in the generation of acoustic energy into the room. Remember, these curves depict only the effect of the nearby boundaries. They do not show the effects of standing waves in a normal room. These curves were made at the unique acoustic measuring facilities at E. M. LONG ASSOCIATES in Oakland, California. The acoustic output of the loudspeaker continues out in space without encountering any other boundaries which would tend to cause standing waves.

FIGURE 6. shows the effect of placing the loudspeaker out away from the wall about 2 feet while still on the floor. This is similar to FIGURE 4.

FIGURE 7. takes this placement further by placing the loudspeaker up on a pedestal as some people are wont to do.

In both cases of FIGURE 6. & 7. the microphone represents a seated listener.

In all the cases so far presented, the microphone was 2 meters from the loudspeaker.

As can be seen by comparing the free field response of the source loudspeaker with the various boundary effect responses, the acoustic output of the loudspeaker is definitely effected by the boundaries. The Corner placement causes the 35 Hz output to be raised by the 9 dB it was down in free field, but the other adverse effects of the corner placement seem to outweigh this effect. Looking at the wall-floor condition shows that the 6 dB needed to bring up the 40 Hz output is easily obtained ~~gained~~ under these conditions. Again, however, other adverse effects are present. Moving the speaker away from the wall causes the frequency at which the first hole in the response appears, to shift downward. Putting the pedestal under the loud speaker also changes the frequencies of the peaks and dips but also makes depression ~~deeper~~ wider. This away from the wall, up on a pedestal placement is preferred by many people and there is a reason for this even though from the curves of FIGURE 7. it would appear to put a hole in the upper bass, lower voice range. Most voices are recorded with a close mic placement, sometimes almost inside the mouth! Many times cardioid microphones are used. Cardioid microphones exhibit what is called a proximity effect. That is, when used close to the source, they produce a rising characteristic in the bass register. This is depicted in FIGURE 8. Now, when a person is speaking, singing or playing an instrument more than a foot or so from you, there is a cancellation in the frequency range which is dependent upon the height above the floor and distance from you. This is shown in FIGURE 9. If a microphone is close to the source no cancellation of this type occurs. Therefore, the listener who desires to transform this crazy,unnatural effect of someone whispering, speaking, singing or playing an instrument directly into you ear from a loudspeaker which is a good distance from you, is corrected for by placing the speaker up on a pedestal and letting the natural direct vs. delayed floor acoustic cancellation effect correct this anomaly caused by close microphone placement during recording. As a purist you may well whince at this but this is what you have been doing. "Well", you may then ask,"what about a recording which has been made with a distant microphone placement, the kind that sound so great over headphones"? The answer is that your pedestal placement will put in a second floor cancellation which will color the sound differently than intended and you will not hear how really great the sound can be in terms of perspective when the microphones are back away from the source being picked up. The sound will be thinner and in some respects more distant than it really should be. A check with headphones will confirm that this is true. All this sounds like a bad nightmare but before we look at some possible solutions, we may as well look at some more of the problems of interfacing loudspeakers with real rooms. So far we have only looked at boundary effects. Now we will look at the room standing wave effects.

The Whole Room v. Your Loudspeaker

While the effect upon the acoustic output of a source caused by boundaries is generally the same regardless of room size, the standing wave patterns are a direct function of the dimensions of the room. A good treatment of this is to be found in reference 1. for those who would like to analyze their room in a truly scientific manner. Figure 10. is a curve of the amplitude vs. frequency response of the reference loudspeaker system in a real room. The reference, free field response is also shown for comparision. The effect of the low frequency standing wave can be easily seen. The rise in the response at about 40 to 50 Hz will cause the sound to be boomy. Any loudspeaker with good, solid output below 70 Hz will react in generally the same way in this room. It will sound bass heavy with subsequent obscuration of upper range detail in the reproduced sound. The broad hole in the response between 100 Hz and 400 Hz is caused by a combination of boundary and standing wave effects. This sag in response will cause a loss of richness and warmth in the sound as well as having the effect of moving the instruments back in space. Above 400 Hz the response is very close to that obtained in free field. This is mainly due to the fact that the number of standing wave modes increases as the frequency increases. This close packing of modes tends to decrease thier effect upon the perceived quality of the sound. References 2 through 7 show many of the effects described in much more detail for those who would like to pursue the investigation further.

Now that we have looked at some of the problems encountered when placing a loudspeaker in a real room with its boundary and standing wave effects, let's investigate some things that can be done to make these effects work to produce a flat, smooth acoustic output into a listening room, or at least to eliminate the really bad effects.

Correcting Loudspeaker/Room Interface Problems

In reference 1. Groh, mentions an interesting fact which can be used to advantage in determining a good position for the loudspeaker in relation to the listening position. This technique is based on the phenomenon of reciprocity. That is, a loudspeaker can be placed in the listener's position temporarily, while the listener moves to various possible loudspeaker locations while evaluating the quality of the sound. When a spot is found where the sound quality is reasonably good, the positions of loudspeaker and listener are reversed. The sound quality should be about the same for this reversal of positions. The extent of actual reciprocity is a function of a number of factors and is never perfect but at least it is a close approximation. A compact system or cluster of drivers in a large system will be a closer reciprocal than a large array or panel type system. Another factor to be taken into account is the effect of a nearby boundary upon the listener's position. The effect of a boundary 18" from a listener's head is shown in FIGURE 11. Feeding a pink noise signal (or an FM tuner between stations) ~~signal~~ to a loudspeaker and moving your head near and away from a wall will illustrate this effect. Colorations caused by boundary effects such as this are often blamed upon the loudspeaker system by unknowing persons.

After finding the best listener and loudspeaker positions that one can, the next stage is to introduce moderate equalization techniques. There are a number of moderately priced Equalizers available which will work quite well. Now it's time for the "purist" to scream, "Are you kidding, do you expect me to sully my otherwise pure audiophile music system by putting an Equalizer in the chain"? The answer is that you already messed up your system when you put it and yourself in a real room. The purpose of the equalization which I am suggesting is to alleviate some of the problems caused by the loudspeaker/room/listener interface. The key to success is moderation. Of the various types of Equalizers available, perhaps the best is the type which consists of attenuation-only type filters. These are usually 1/3 octave types and are relatively expensive. Instead of trying to boost where a valley is present in the response, all the other bands are brought down to the level of the deepest depression. One such unit, the UREI 529, also has tunable 18 dB/octave filters at the extremes of the band so the ends of the band can be rolled off. One great advantage of this is in keeping record warp frequencies (about 4-5 Hz) out of the amplifier and loudspeaker systems. It also keeps extremely high frequencies from generating modulation products in the audible band. These possible ultra low and high frequencies from the source serve no useful purpose and are potential causes of trouble. Another type of equalizer is the boost-cut equalizer of which a number are available at reasonable prices, from such people as Soundcraftsmen, Spectro Acoustics, ADC, Dynaco, etc. I haven't tried each of these units personally so I am not necessarily recommending them but I am saying that they are worth investigating. Another type which shows great promise is the parametric type Equalizer. This type of Equalizer allows the frequency to be tuned, the amplitude varied and the Q adjusted. Since as mentioned before, and can be seen from the graphs, most of the necessary equalization is below 500 Hz, the ability to adjust three or four points in this lower register should be sufficient. A parameteric Equalizer with four frequencies tuned in this band should be ideal. S.A.E. has at least two parametric Equalizers which might be suitable although these haven't been tried yet. This brings us to FIGURE 12. FIGURE 12. shows the reference loudspeaker in a room with and without equalization. This equalization was accomplished using a Soundcraftsmen Equalizer. A moderate cut was employed using the 40/80 slider, a very slight boost was accomplished by moving the 80/160 and 160/320 sliders up a little and the 320/640 slider was backed down a little. The greatest effect is heard in the reduction of the boom caused by the 60 Hz room mode. The second greatest effect is in reducing the "double room" effect. The compensation of the floor delay cancellation wave causes the sound to be less distant. One of the ranging functions of human hearing involves our ability to determine the distance of a source from us by the cancellations in the energy spectrum caused by delayed sound waves from nearby boundaries. As can be seen in FIGURE 12. no attempt was made to compensate exactly for this floor cancellation effect with the Soundcraftsmen Equalizer. This type of boost equalization method is one of diminishing returns. The fact that we are dealing with a ratio of direct sound from the loudspeaker and the reflected sound from the floor which also originates from the loudspeaker, means that we could never exactly compensate for the cancellation caused by the delayed floor wave. Because it is a ratio of less than 1:1, we can eliminate some of its effect. At last FIGURE 13. which shows the original free-field response of the reference loudspeaker compared to the equalized condition of FIGURE 12. The equalization isn't perfect as can easily seen, but it causes the quality of the reproduced sound to be improved enormously. As can be seen, the response of the reference loudspeaker is relatively flat to 32 Hz.

During the past few days, while preparing and writing this article, I have been listening to all types of program material over the reference loudspeakers and if there wasn't a real improvement worth writing about, I would have stopped long before this. I hate writing as it is and I certainly wouldn't waste my time (and yours) writing about something I wasn't convinced was worthwhile and which I firmly believe will improve the state of your listening art. To digress for a moment; at the beginning of this treatise on the problems of interfacing loudspeakers and rooms, I mentioned having a real double bass played by someone in your listening room. Well, I once recorded a string group in a living room. I still have the master tape. I also have the equalized copy I made so that I might enjoy listening to the music! "What!, you say, "you prefer a copy to the orginal master"? Yes, because without equalizing for the boom caused by the major low frequency room modes, the tape is muddy and unlistenable. The equalized copy is quite enjoyable. Knowing that I am a loudspeaker designer, people have asked me if it isn't possible to design a loudspeaker which would overcome these loudspeaker/room interface problems. The answer isn't simple. And wouldn't a yes answer indicate that I would be using some form of equalization? The fact that different size rooms have modes at different frequencies would also indicate that I would have to compensate a particular loudspeaker design for a given set of room dimensions. It wouldn't be a very universal type of loudspeaker would it? Any loudspeaker system truly capable of producing fundamental tones down to 40 Hz and below, within 6 to 9 dB of its average free field response, will have an interface problem in almost every normal type listening room. The answer is Equalization. There are a few loudspeaker systems available which have the ability to produce good, clean low frequency output. Whether a prospective buyer would not choose one of them for other reasons having to do with their performance characteristics in the middle and upper registers is not germaine to the subject at hand, but the terrible truth is that most dealers demonstrate such systems under very poor conditions. Surely, most dealers try to find a suitable location for demonstrating such systems but that isn't enough. The dealer who is purporting to sell the highest quality sound reproducing equipment, who doesn't try to equalize for the loudspeaker/room boundry and standing wave effects by both placement and the use of an equalizer, is not really serving very well, his customers' interests and ultimately his own interests. That it would be too much trouble, is really a poor excuse. He should really be trying to sell the best sound to his customers for their particular listening environment. Equalization is really a necessity to all but the lowest budget systems in order to achieve good sound in the customers' own listening room. At this point in time, not to take the trouble to equalize is as dumb as playing a 45 rpm record at 33 1/3 rpm because the turntable happened to be set at that speed for most of the other records. A prospective customer for one of the really full range systems should be aware of the fact that such a system will very likely sound boomy, or muddy in listening rooms due to the boundry and standing wave effects. Also, remember, that putting speakers up on stands is not a cure-all. In fact, with an Equalizer, one can put in or take out the depression caused by putting a speaker on a stand, without having to touch the speaker at all.

One other thing about which one should be aware, which, can cause muddiness in the sound, is acoustic feedback from the turntable. This can be aggravated by transmission of warp frequencies which is in turn aggravated by a bad combination of tone arm mass/cartridge compliance. A high compliance cartridge in a high mass tonearm can cause the warp frequencies (4-5 Hz) to be transmitted at fairly high amplitude to the loudspeaker, causing muddiness. Conversely, A low compliance cartridge in a low mass tone arm can tune to the bottom of the audio band (20 Hz) which can also be troublesome. The right combination of tone arm mass/cartridge compliance will tune to about 10 Hz, one octave above the warp frequencies and one octave below the bottom of the audio band.

SUMMARY

Don't reject a loudspeaker out of hand because it may sound unnatural, boomy or muddy in the range below 500 Hz until you have checked the effect of placement and equalization.

Be aware of the interraction and reciprocity of the loudspeaker and listener locations. Don't sit far from the loudspeakers and expect the effects of your listening room to magically go away.

Check out your turntable for feedback by moving it. That muddiness might just clear up a bit.

Check your cartridge/tone arm resonance. You might be tuned right at the warp frequencies.

Really try some of these things before I give up and go back to designing headphones and speakers for cars!

1. Allen R. Groh,"High Fidelity Sound System Equalization by Analysis of Standing Waves," J. Audio Eng. Soc.,Vol.22, No.22,pp.795-799 (Dec. 1974)

2. E. M. Long,"Loudspeaker Instrumentation," Preprint 864, 42nd Convention of the Audio Eng. Soc. (May 1972)

3. Roy F. Allison,"The Influence of Room Boundaries on Loudspeaker Power Output," J. Audio Eng. Soc.,Vol.22,No.5, pp.314-320 (June 1974)

4. Roy F. Allison,"The Sound Field in Home Listening Rooms,II," J. Audio Eng Soc.,Vol.24,No.1,pp.14-19 (1976)

5. Roy F. Allison,"The Speaker and the Listener," Stereo Review, Vol.37,No.2,pp.56-61 (Aug 1976)

6. Richard V. Waterhouse,"Interference Patterns in Reverberant Sound Fields," J. Acoust. Soc. Amer.,Vol.27,No.2,247-258 (Mar 1955)

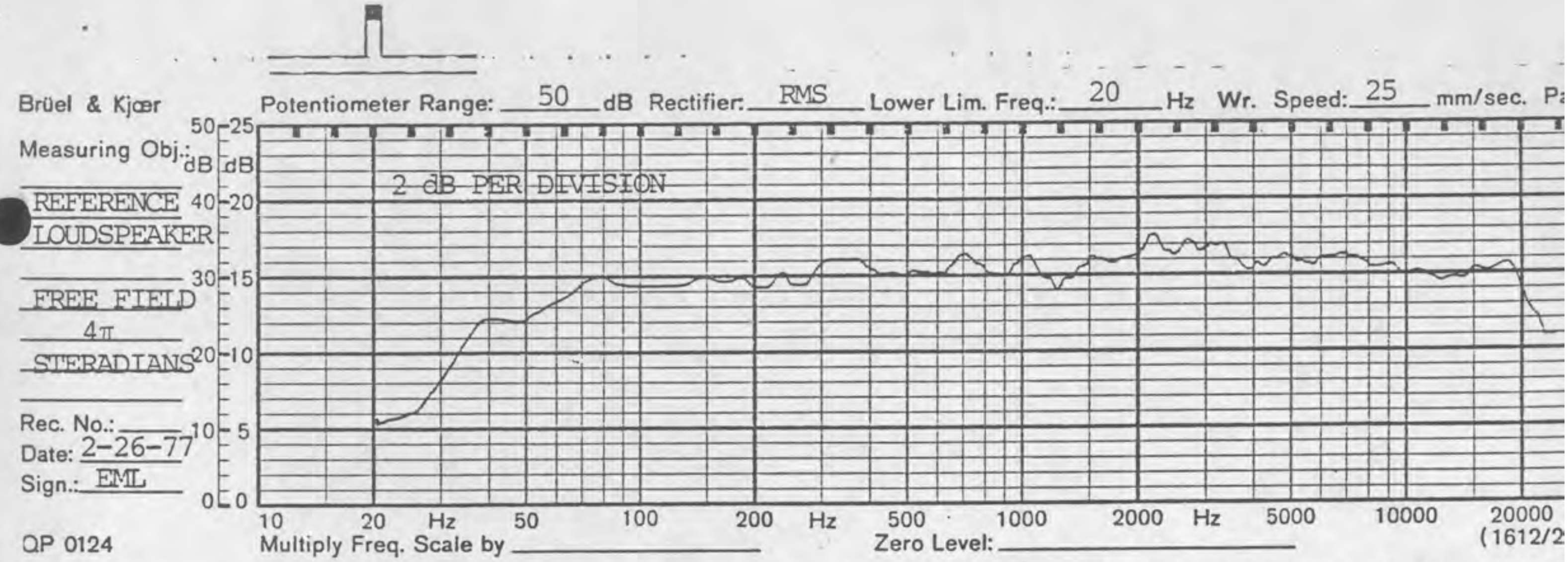

FIGURE 1. REFERENCE LOUDSPEAKER USED TO GATHER ALL BOUNDARY AND ROOM EFFECT DATA. AMPLITUDE VS. FREQUENCY RESPONSE IN FREE FIELD 4π STERADIAN CONDITIONS.

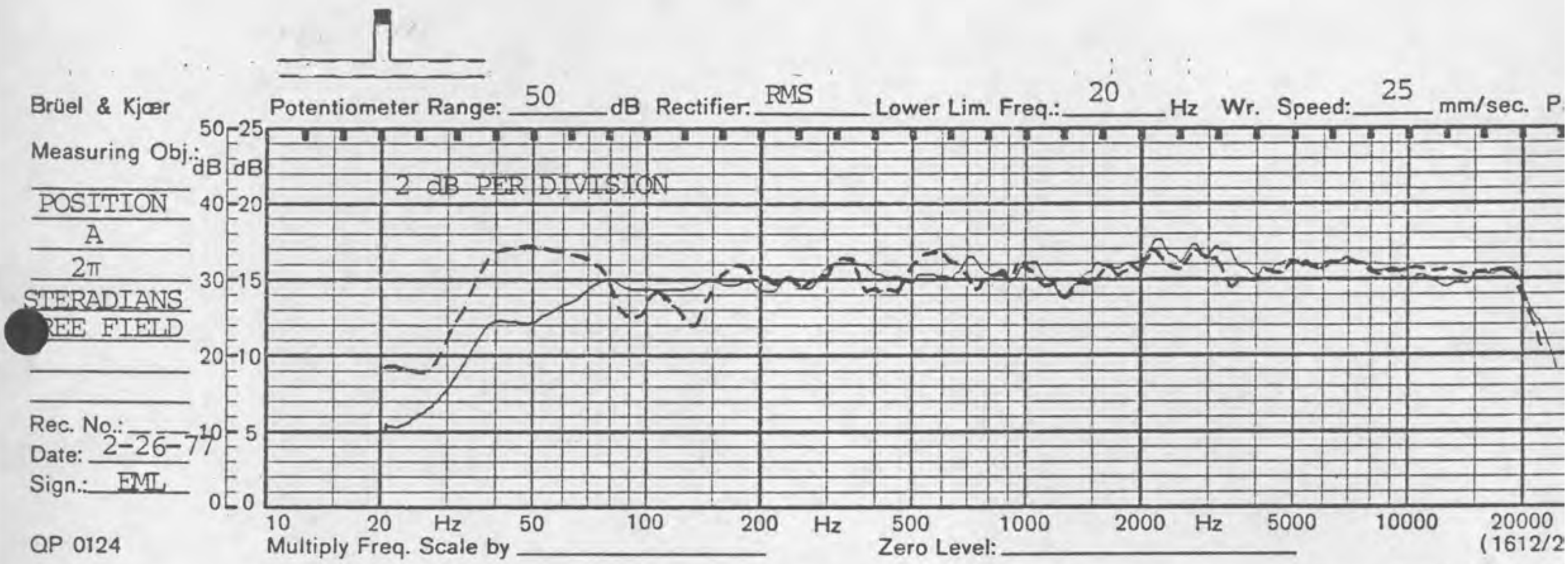

FIGURE 3. LOUDSPEAKER AT POSITION A, MIDDLE OF WALL, 2π STERADIANS, SINGLE BOUNDARY, OTHERWISE FREE FIELD CONDITIONS (NO STANDING WAVES) (SOLID CURVE:REF.)

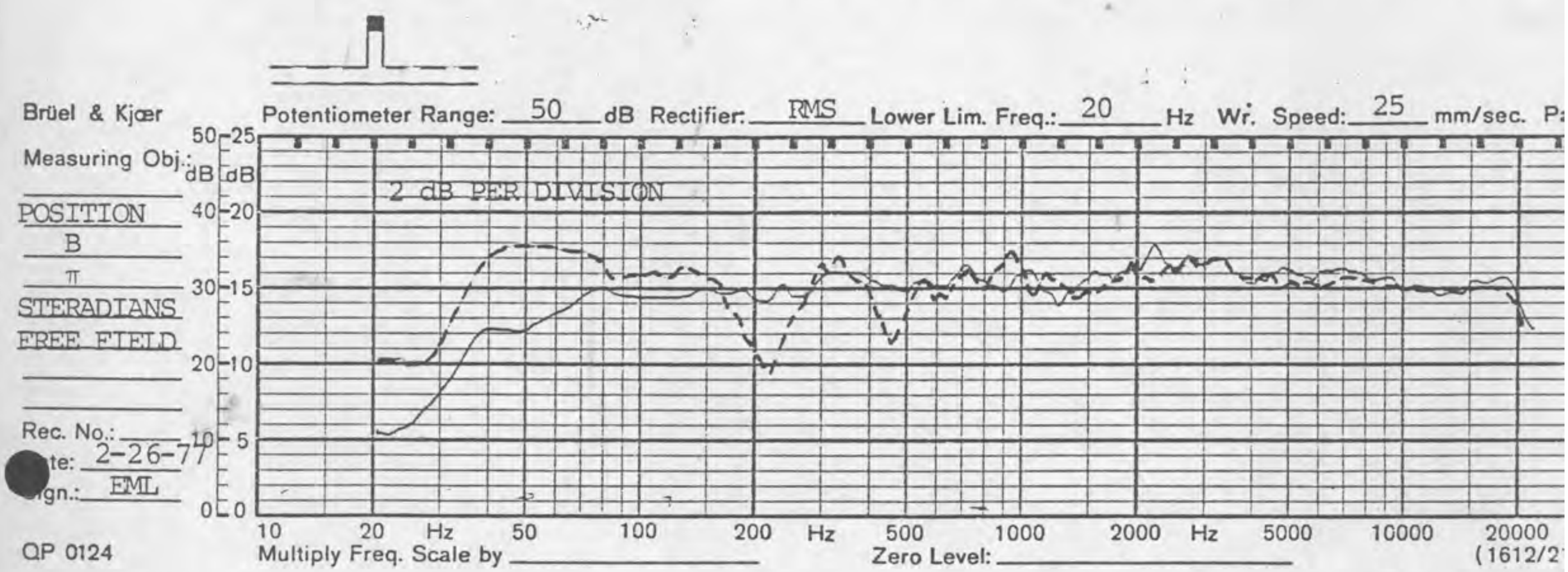

FIGURE 4. LOUDSPEAKER AT POSITION B, FLOOR WALL BOUNDARY, π STERADIANS, 2 BOUNDARIES, OTHERWISE FREE FIELD CONDITIONS (NO STANDING WAVES) (SOLID CURVE: REFERENCE)

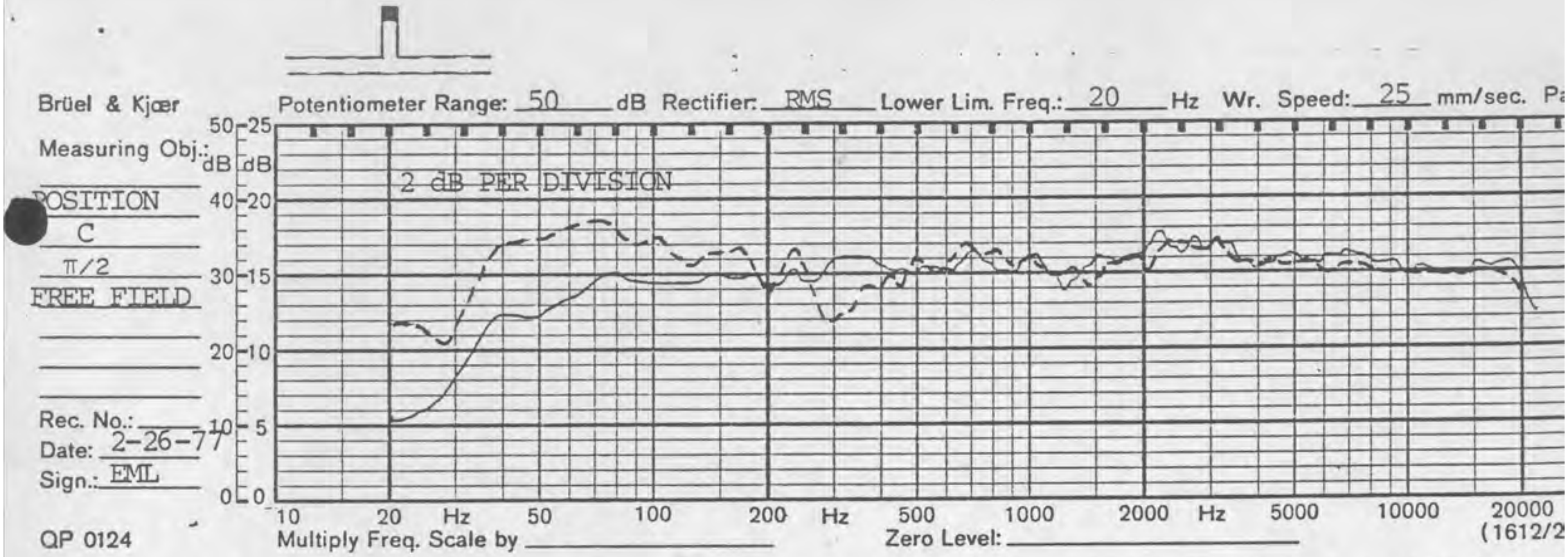

FIGURE 5. LOUDSPEAKER IN POSITION C, CORNER BOUNDARIES, π/2 STERADIANS, 3 BOUNDARIES, OTHERWISE FREE FIELD CONDITIONS (NO STANDING WAVES) (SOLID CURVE: REFERENCE)

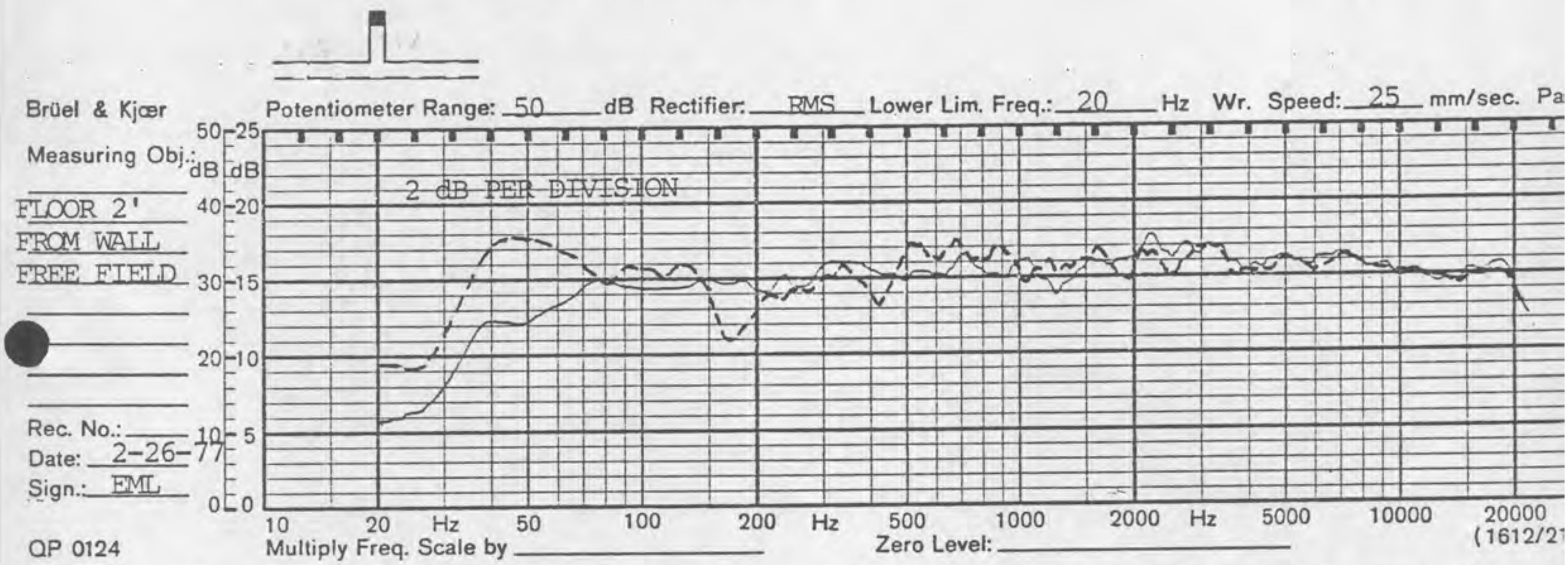

FIGURE 6. LOUDSPEAKER ON FLOOR, 2 FEET OUT FROM WALL. CANCELLATION SHIFTED DOWN IN FREQUENCY FROM FIG. 4. (FREE FIELD, NO STANDING WAVES) (SOLID CURVE: REF.)

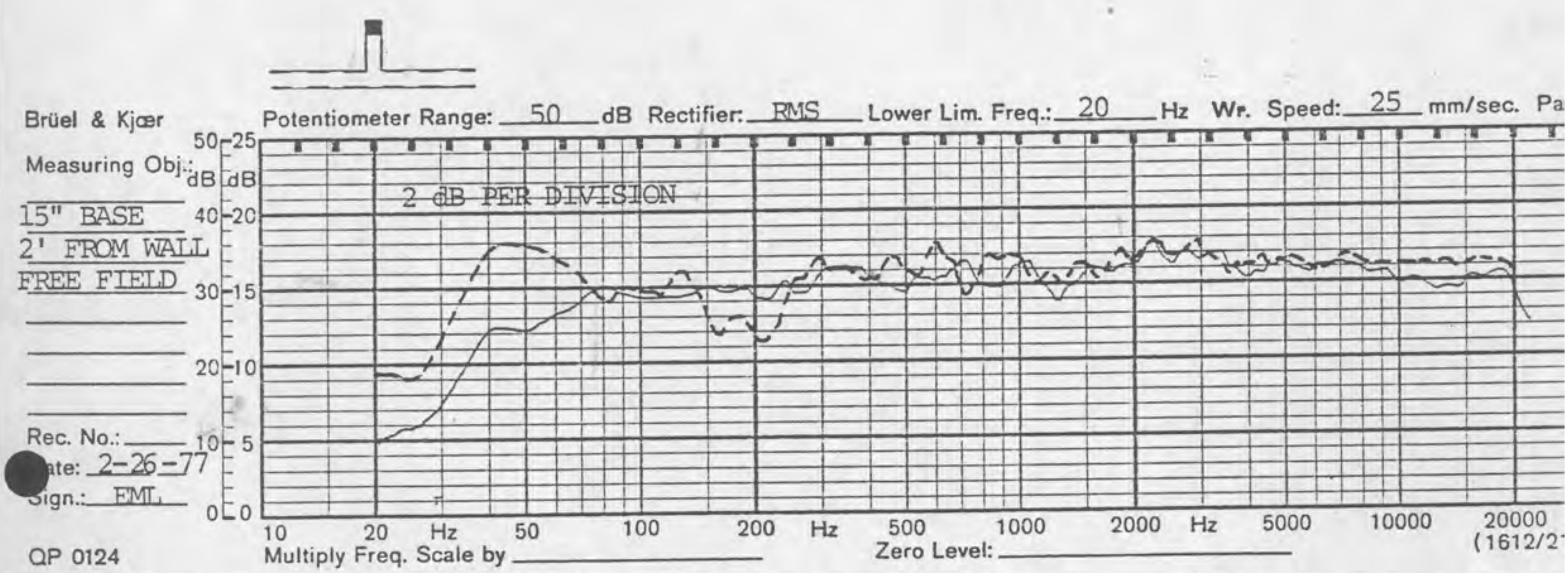

FIGURE 7. LOUDSPEAKER AS IN FIG. 6 BUT UP ON 15" BASE. LARGER DEPRESSION FROM 125 TO 300 HZ FROM WALL AND FLOOR CANCELLATION WAVE. (SOLID CURVE: REFERENCE)

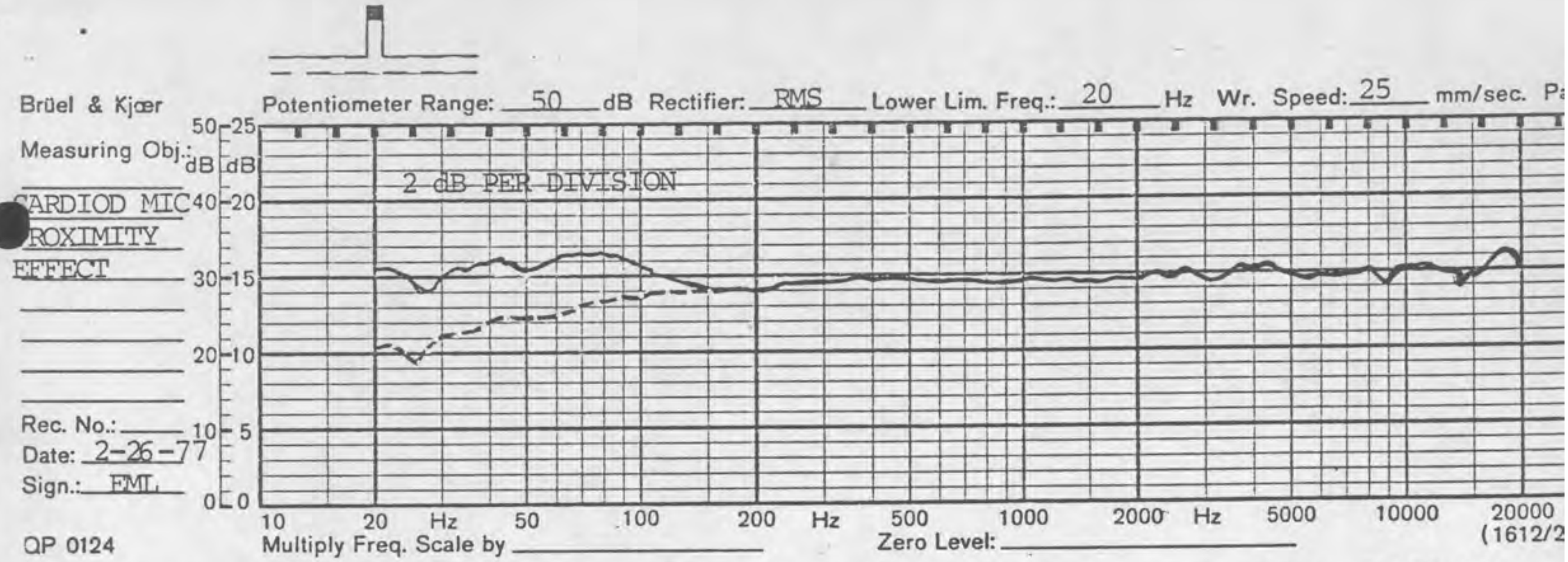

FIGURE 8. DASHED CURVE: HIGH QUALITY CARDIOID CONDENSER MICROPHONE NORMAL RESPONSE. SOLID CURVE: EFFECT OF SOUND SOURCE WITHIN 6 INCHES, (PROXIMITY EFFECT).

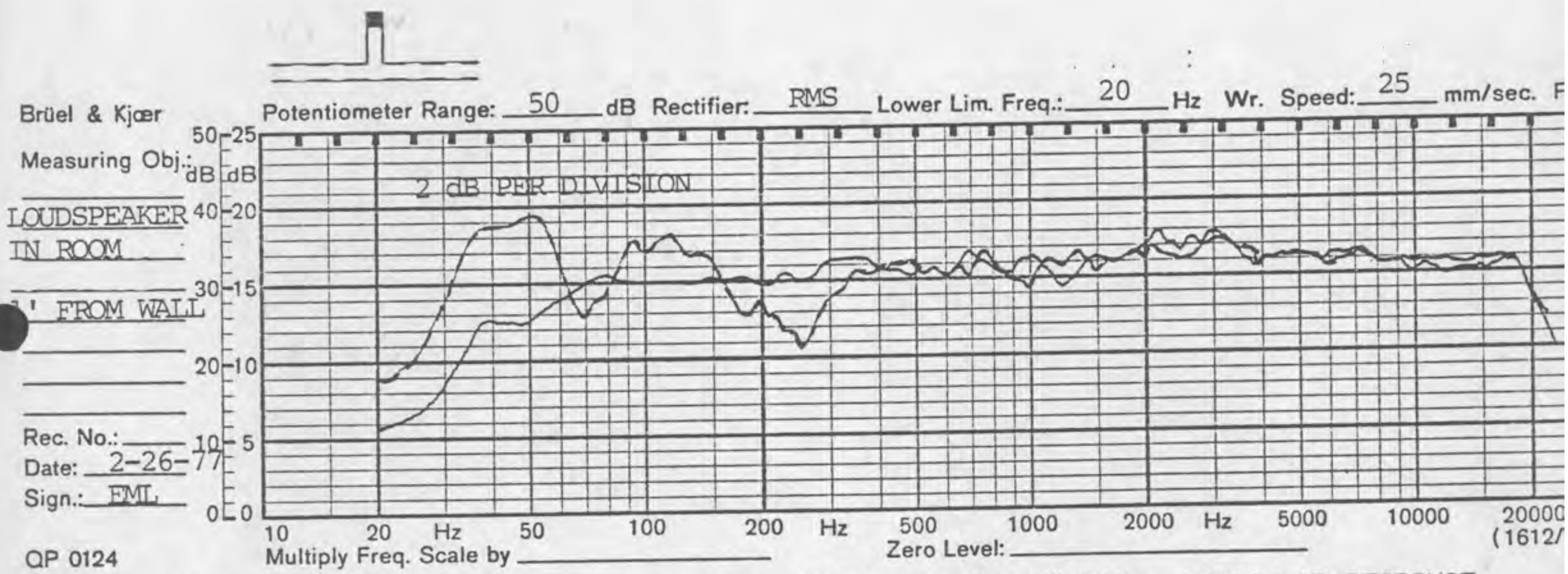

FIGURE 10. LOUDSPEAKER IN ROOM, ONE FOOT FROM WALL ON 15" BASE. IRREGULAR RESPONSE IS CAUSED BY BOUNDARY AND STANDING WAVE EFFECTS. (SOLID CURVE: REFERENCE).

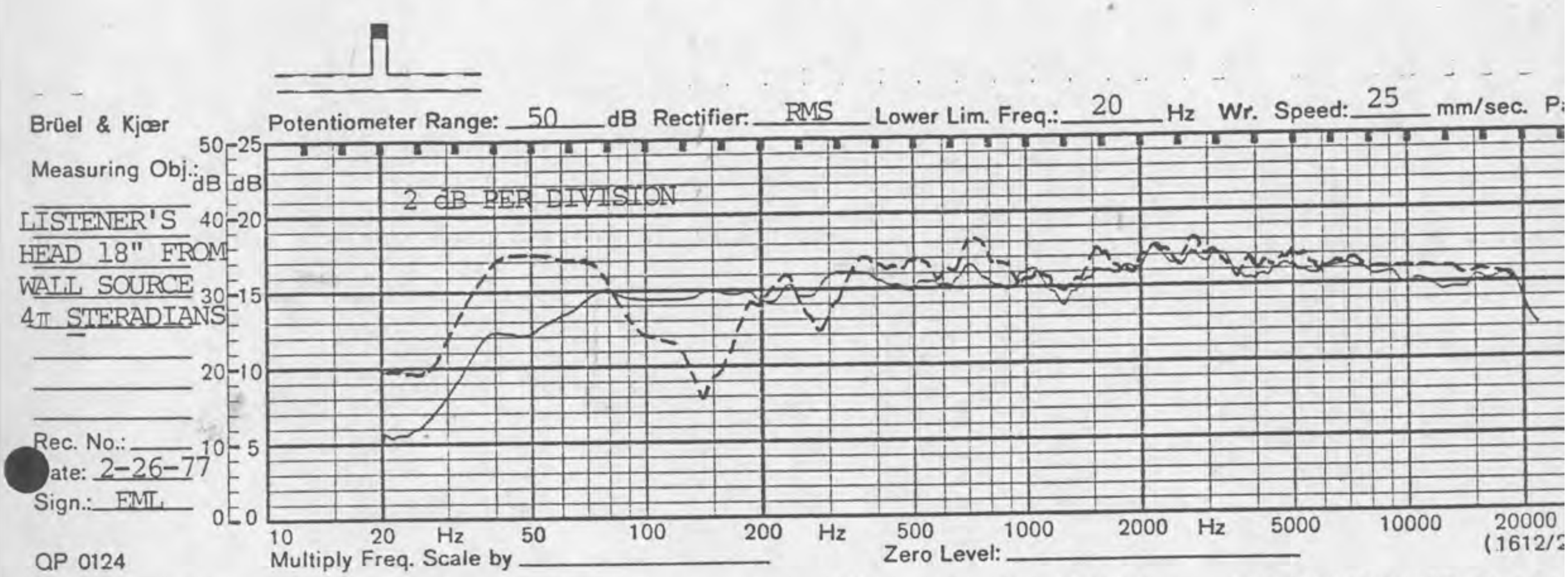

FIGURE 11. EFFECT UPON RESPONSE OF LISTENER'S HEAD 18" FROM WALL. SOURCE WAS OPERATING UNDER 4π STERADIAN, FREE FIELD CONDITIONS. (SOLID CURVE: REFERENCE SOURCE).

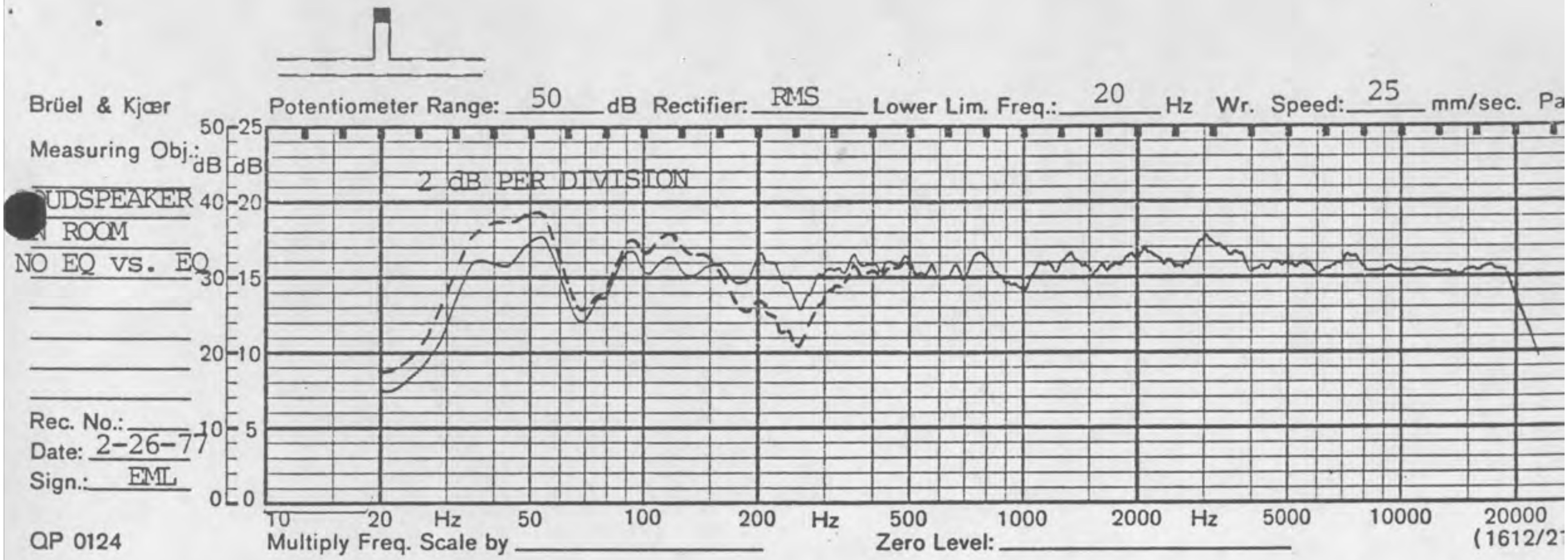

FIGURE 12. REFERENCE LOUDSPEAKER IN ROOM ONE FOOT FROM WALL ON 15" BASE (NOT RECOMMENDED FOR ALL CASES. ONLY TO SHOW EQ.) DASHED CURVE: NO EQ; VS. SOLID CURVE: EQUALIZATION.

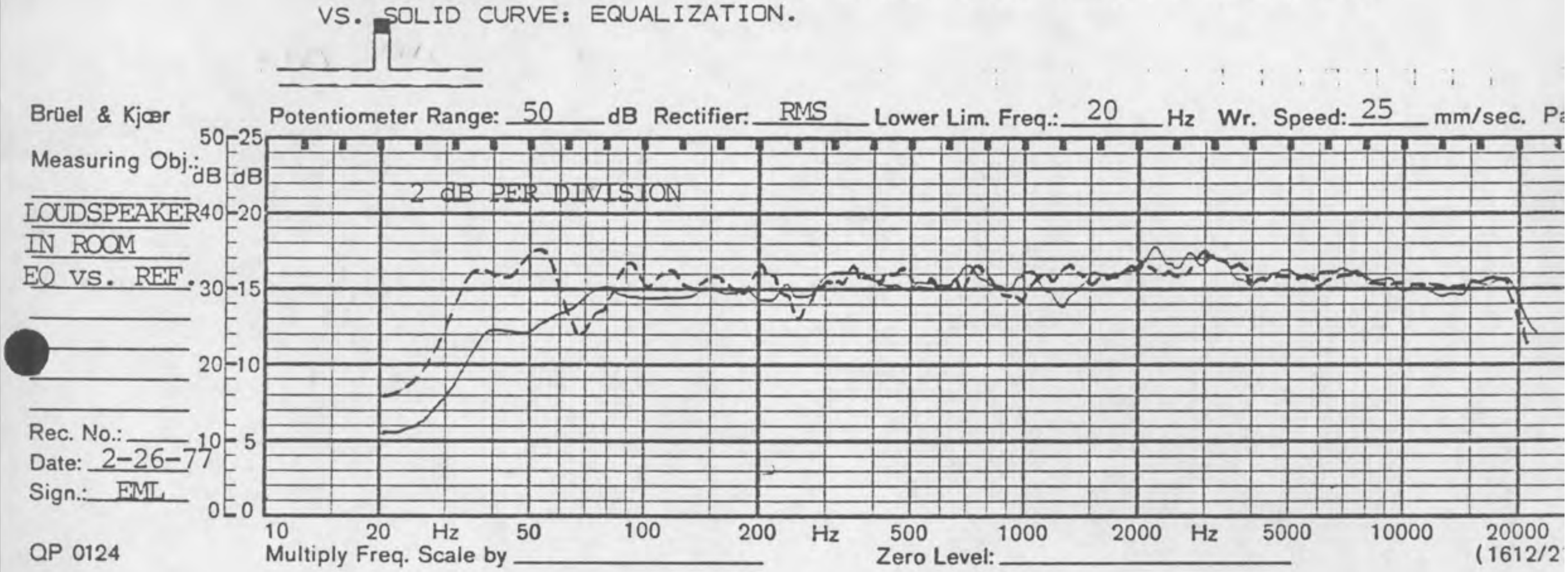

FIGURE 13. REFERENCE LOUDSPEAKER IN ROOM ONE FOOT FROM WALL ON 15" BASE (SEE ABOVE COMMENT IN FIG. 12). DASHED CURVE: EQUALIZATION; SOLID CURVE: 4π REF.

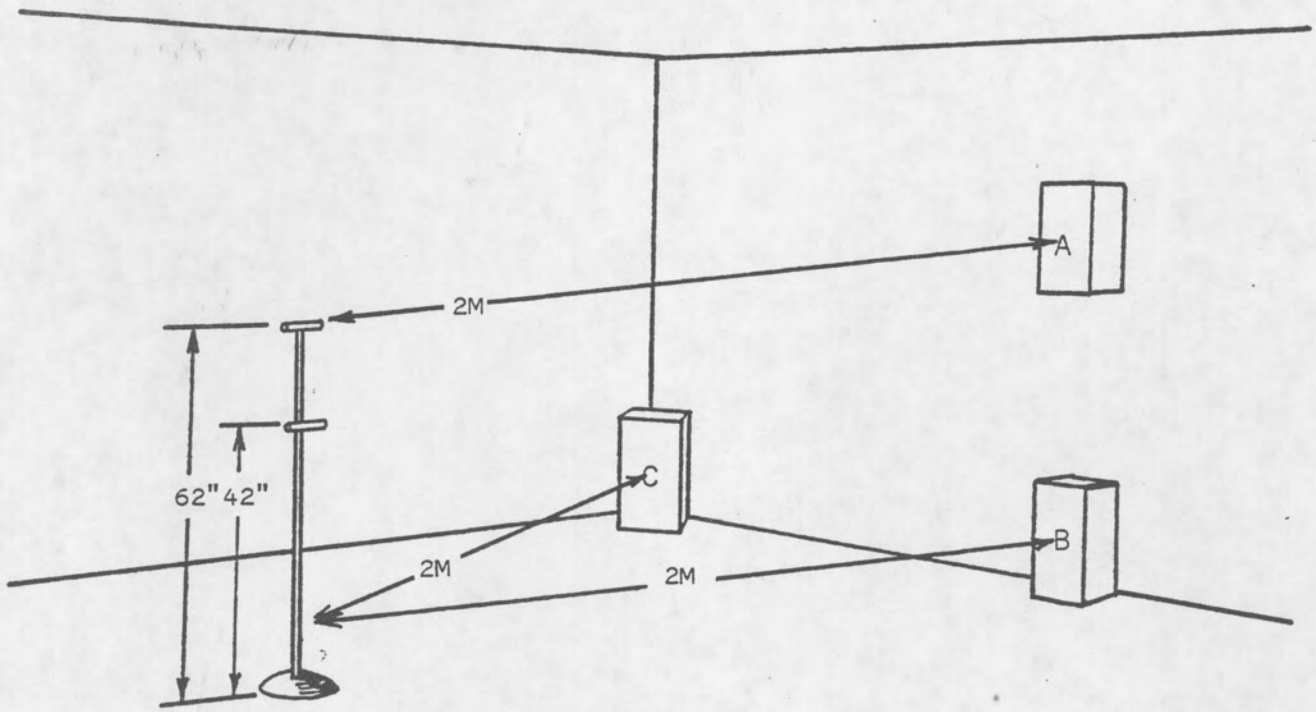

FIGURE 2. ACOUSTICAL MEASUREMENT ARRANGEMENT FOR GATHERING BOUNDARY EFFECT DATA. SPEAKER POSITION A : 2π STERADIANS; POSITION B : π STERADIANS; POSITION C : π/2 STERADIANS. MICROPHONE HEIGHT ADJUSTED FOR SEATED LISTENER (42") AND STANDING LISTENER (62"). FOR BOUNDARY DATA ONLY THE FLOOR AND TWO SIDE WALLS WERE PRESENT DURING MEASUREMENTS. NO ROOM STANDING WAVE MODE EFFECTS WERE PRESENT. ROOM MODES WERE PRESENT IN LATER, ROOM EFFECT MEASUREMENTS. (SEE TEXT).

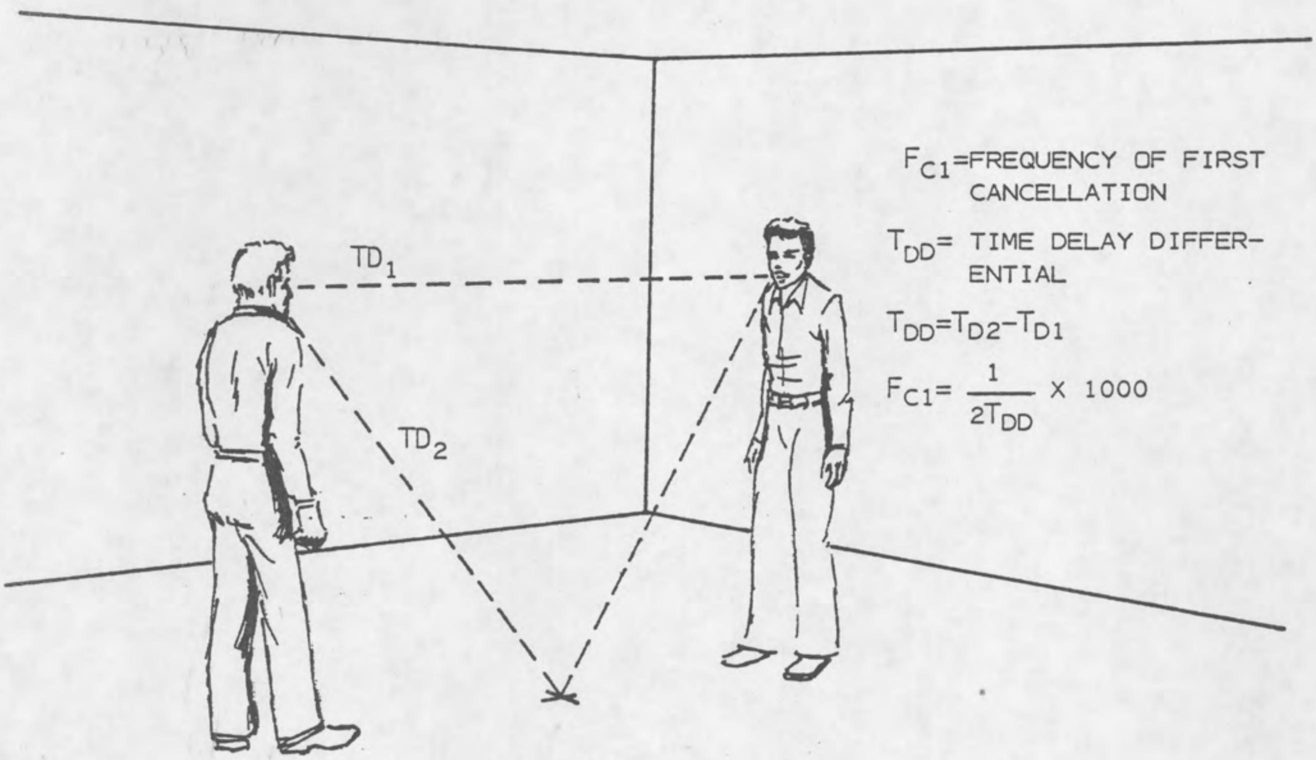

FIGURE 9. FLOOR BOUNCE CANCELLATION EFFECT. THE FREQUENCY AT WHICH THE MAJOR CANCELLATION OCCURS CAN BE CALCULATED USING THE FORMULAS ABOVE. THE CANCELLATION OF ACOUSTICAL ENERGY IN THE RANGE FROM 100 TO 500 HZ, CAUSED BY NEARBY BOUNDARIES, ESPECIALLY A FLOOR, IS MISSING IN CLOSE-MIC RECORDINGS, GIVING THE EFFECT OF SOMEONE CLOSE. WHEN THE LOUDSPEAKER PRODUCING THE SOUND IS AT A DISTANCE FROM THE LISTENER, AN UNNATURAL EFFECT IS PRODUCED. PLACING THE LOUDSPEAKER UP ON A PEDESTAL CAN HELP CORRECT THIS BY CAUSING FLOOR CANCELLATION. THIS CAN MAKE CLOSE MIC RECORDINGS MORE NATURAL BUT PUT A DOUBLE CANCELLATION IN THE ENERGY SPECTRUM OF AMBIENCE RECORDINGS.