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MICROPHONES: THEORY AND PRACTICE

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1. INTRODUCTION

In this paper we discuss real-world performance of microphones. Many people, especially consultants, make measurements without accounting for the error we call "microphone-use-error." This error comes about by lack of information on the limitations of microphone (called "mike" for brevity) data.

Most users know of the 'free-field (FF)," or "random-incidence (RI)," or "pressure" mike. Each type has a defined frequency response curve based on measurements or on theoretical corrections, or both. The frequency response holds when appropriate orientations or corrections are used. (We'll assume pressure and RI mikes are similar for this paper.)

Which mike is appropriate for any given measurement condition? Often there is no choice, since a sound level meter usually comes with a single microphone. In the USA, ANSI S1.4 requires the use of RI response to obtain a Type 1 measurement. Europe, and most of the rest of the world, with IEC 804, IEC 651, and the draft IEC 1672, use a FF microphone. Random-incidence mikes are being used more and more for reverberation room measurements [1]. But for laboratories, the issue of mike choice is not hard. With many mikes to choose from, and with a well-defined sound field and test with proscribed instruments, no rocket science is needed.

But each of these mike versions has a distinct frequency response curve only for very well defined and controlled conditions. These conditions may, in fact, not be met in either a test room or in the actual field test environment. A true free-field or random incidence field is rarely found. So, when measuring in non-ideal fields, what does the mike do to the results?

In ordinary measurements of traffic noise, community noise, HVAC noise, employee occupational exposure, etc., the sound field is complex.

We suspect the ordinary users (not readers of this paper) have no way of determining the true frequency response of the mike. The measurement repeatability is often unknown so, the errors induced by the microphone, and their limits, in non-ideal conditions is unknown. This paper discusses some measurements in an attempt to determine the variations obtained by using a mike with a known frequency response in an unknown field with poorly-defined sounds.

We show variations resulting from the microphone-use-error by making sound pressure level measurements in non-ideal conditions with a RI and FF mikes. We avoided the impulse to attach standard deviations to the results since that would imply some well controlled experiment, which this was not. We wanted to put some bounds in the error but could not.

2. PROCEDURE

Only a cursory description of the system is given because, in non-controlled conditions, the chance of anyone repeating these measurements is slim. Also, the magnitude of the results are more interesting than the exact numbers.

The RI- and the FF- mike responses were flat, ±0.5 dB, to 10 kHz and to 20 kHz, respectively. One mike of each type (RI and FF) was used, in each channel, of a dual-channel 1/3rd octave band real-time-analyzer with mid-frequency range of 25 Hz to 10k Hz. The mikes were mounted at varying heights above the ground, indoors and outdoors. The measurements were simultaneous so the locations of the microphones, being separated by a finite distance, about 2" (5cm) apart, affected the results to some extent. Each channel sensitivity was within ± 0.1 dB.

Indoor noise sources were radios, speech, and household sounds. Outdoor noises were from overhead aircraft (distances unknown), far away freight railroad with air horn (500m), fountain splash, leaf blowers (heard but not located), wind chimes, and ordinary street sounds (close and distant cars, drive-by shootings, etc.) In all cases channel-1 was connected to the RI mike, channel-2 to the FF mike. We also made a measurement of directionality differences between mikes in ordinary spaces, keeping a loudspeaker fixed and rotating the microphones.

3. RESULTS

Fig. 1 shows the difference between two separate (#5 & #4) mike-pair responses when the mikes are face-to-face in a room in which the sound level is varying in time and in space. The two responses were a result of two distinct measurements. A negative number indicates the FF mike read higher than the RI mike.

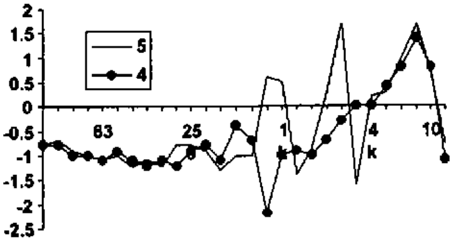

Fig. 1 Face-to-face mikes measured twice.

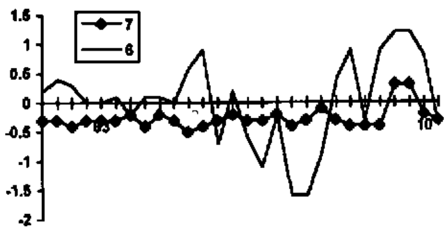

Fig. 2 Mikes perpendicular.

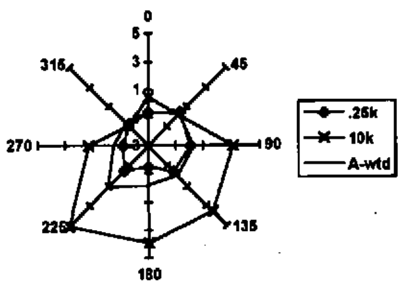

Fig. 3 Directionality difference in ordinary room by frequency.

Fig. 2 shows measurements with a set of perpendicular mikes in a room. A measurement difference for mikes near a reflecting plane (#7) and in the center of the room (#6).

Fig. 3 shows the difference in directional response between two mikes in an ordinary space. The FF mike facing the pink noise source was at 0°. The 90° and 270° positions are when mikes are perpendicular to the source. The 4 kHz directivity difference was virtually identical to the A-weighted difference. At frequencies, both higher and lower, there was no clear pattern.

We obtained variable and non-repeatable results with mikes in various locations, some, easily replicating a workplace noise.

Interestingly, a test was done measuring the ambient outdoor noise. Often ambient noise is measured when the source is not clearly located, or when the field is not defined. In that case, the difference between the two mikes varied from a high of +3.2 dB at 160 Hz to a low of -1.9 dB at 400 Hz. The A-weighted difference between the spectra was 2.0.

4. CONCLUSIONS

We have shown by a series of arbitrary measurements that the frequency response of a given measurement in an unknown field is unpredictable for whatever mike used.

While free-field conditions may be met close to a known source, this is not an option generally available. Often the source is not well defined, especially when measuring ambient noise indoors or out, or if the source is moving, in which case the mike choice is not clear. And, clear or not, the measurements will still result in differences. We suspect that, for pass-by measurements, a vertical random response mike will be more accurate than a FF mike where sharp directionality changes often produce large errors.

The results show a) the slight displacement of mikes could contribute to a difference of measured sound, b) it appears that a 2 dB difference between types of mikes is very possible at mid and high frequencies, and c) even A-weighted sound level can vary.

The effect of mike use error on the measurement is just one part of a very complex question: given a measuring system with a known frequency response and accuracy, what do the unknowns in the measurement contribute to the overall error? In a recent IEC meeting [2],[3], the discussion of overall measurement error was deferred because of the difficulty in addressing the subject, also not resolved was the effect of including calibration laboratory uncertainty on overall sound level meter performance. The implication of these two uncertainty areas is that the overall error in any given measurement is unknown.

The continuing efforts to tighten the specifications of instrument tolerances are rather ludicrous when examined in the light of these real-world errors which would not be improved by any modifications of the electrical specifications in the standards.

References

[1] ISO DIS 3741 "Acoustics- Determination of sound power levels of noise sources using sound pressure-Precision methods for reverberation rooms (Revision of ISO 3741:1988 and ISO 3742:1988)"

[2] TC 29(Pretoria/WG 4) 12 "Day Report IEC/TC/29/WG4: Sound level meters"

[3] TC 29(Pretoria/ad hoc) 16 "Statements of conformity in standards of TC 29"