SOUND INTENSITY TERMINOLOGY

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INTRODUCTION

During the last four years, interest in sound intensity and intensity measurements in general, has increased dramatically. Many organisations and committees are at work on the preparation of standards for the determination of sound power using sound intensity. In the effort to quantify the measurement environment and the intensity measurement system several new concepts have had to be introduced and defined. For the common good, divergence in the terminology should be avoided as far as possible. This paper suggests a number of definitions and methods of employment of some commonly used concepts in the field of sound intensity measurement.

THE SOUND FIELD

It is logical to begin by attempting to classify the types of sound fields which can occur. At a given point in a sound field there will be an acoustic pressure, p, and a particle velocity, u_r. One way of classifying the sound field could be to define the situation where p and u_r are uncorrelated as a diffuse sound field. Where p and u_r are correlated, a further subdivision is possible. The situation where p and u_r are in phase can be defined as an active sound field. An example of a purely active sound field is a plane wave propagating in a free field (a free field is defined in ISO 3745 as a homogeneous isotropic medium free of boundaries). In this situation, a phase gradient exists but no amplitude gradient. All the acoustic energy is transmitted and none is stored [1]. The situation where p and u_r are in quadrature, that is 90° out of phase, can be defined as a reactive sound field. In the general case where p and u_r are non-zero and correlated then the sound field may be considered to consist of an active and a reactive sound field.

SOUND INTENSITY

In the document "Acoustical Terminology" ANSI S1.1 - 1960 (R 1971) it states: "The sound intensity in a specified direction at a point is the average rate of sound energy transmitted in the specified direction through a unit area normal to this direction at the point considered." Sound intensity is thus a vector quantity that describes the net amount and direction of energy flow at a given point in space. In general, sound intensity is a complex vector, the complex sound intensity consisting of a real part and an imaginary part. The real sound intensity or simply the sound intensity (sometimes called the active intensity) describes the active energy propagation. The imaginary sound intensity, or imaginary intensity (sometimes called the reactive intensity) is related to the non-propagating part of the sound field.

SOUND FIELD AND MEASUREMENT SYSTEM INDICATORS

Before any intensity measurements are performed, the measuring system must be calibrated. A complete calibration would include a control of the amplitude gain in each channel, the relative phase between the two channels, the density of air (which depends on the ambient pressure and temperature) and the effective microphone separation. Furthermore, the residual intensity, the residual intensity index and the dynamic capability of the measuring system as functions of frequency must also be measured together with the reactivity index of the measurement task. The definitions of these quantities and their use in determining the validity of intensity measurements are given below and depicted in Fig.1. [2].

RESIDUAL INTENSITY $L_{I,R}$

The sound intensity level measured when a sound intensity system is exposed to a sound field with zero intensity is the residual intensity of the system. One way of simulating such a field is to feed the same signal to both channels of the measuring system. There will then be no phase gradient between the signals and therefore no intensity. The phase match of the analyser can be checked by measuring the residual intensity and plotting the results on the intensity-pressure-phase nomogram or simply the intensity nomogram (Fig.2). The residual intensity can be regarded as the inherent noise of the intensity system.

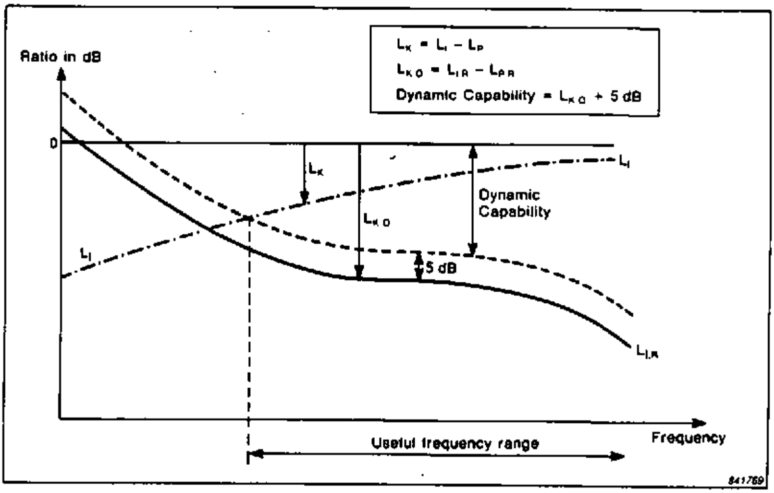

Fig.1. Relationship between sound field and measurement system indicators for a given microphone spacing using the two microphone technique

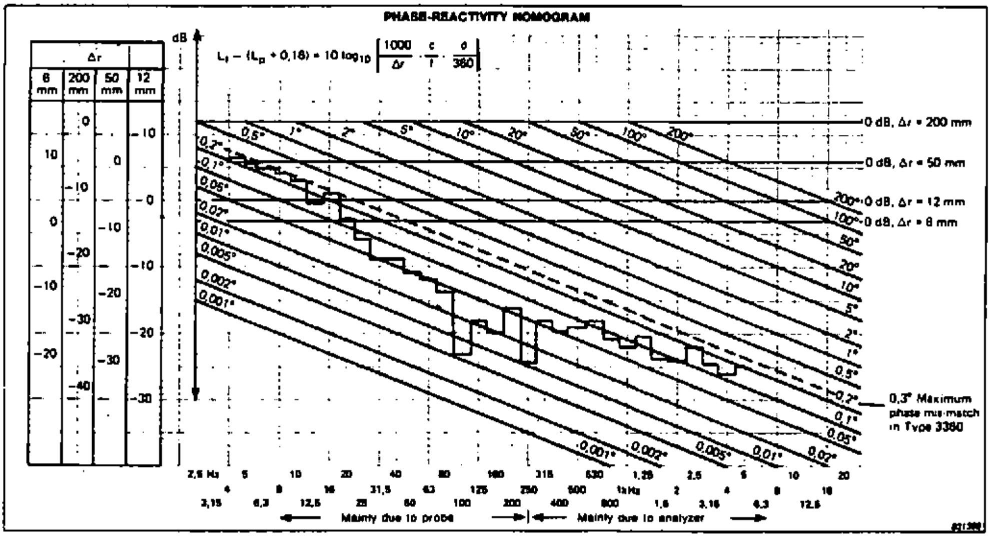

Fig.2. The intensity nomogram showing a typical residual intensity curve

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RESIDUAL INTENSITY INDEX $L_{K,O}$

The difference between the indicated intensity level and the measured sound pressure level when the same signal is fed into both channels of the measuring system is known as the residual intensity index of the system. This index is normally negative.

REACTIVITY INDEX L_K

For a particular measurement task, the reactivity index in a given direction at a point is defined as the difference between the sound intensity level and the sound pressure level measured in the given direction at that point. In practice the reactivity index is normally negative. For intensity measurements the numerical value of the reactivity index must be smaller than the dynamic capability of the system to ensure that the amount of errors due to phase mismatch is sufficiently small. The reactivity index can be regarded as an indicator of the signal to noise ratio or more correctly the signal to signal plus noise ratio of the measurement.

DYNAMIC CAPABILITY

The dynamic capability of an intensity measuring system is determined by adding normally 5 dB to the residual intensity index. This ensures a measurement error due to phase mismatch of less than ± 2 B (see Fig.3).

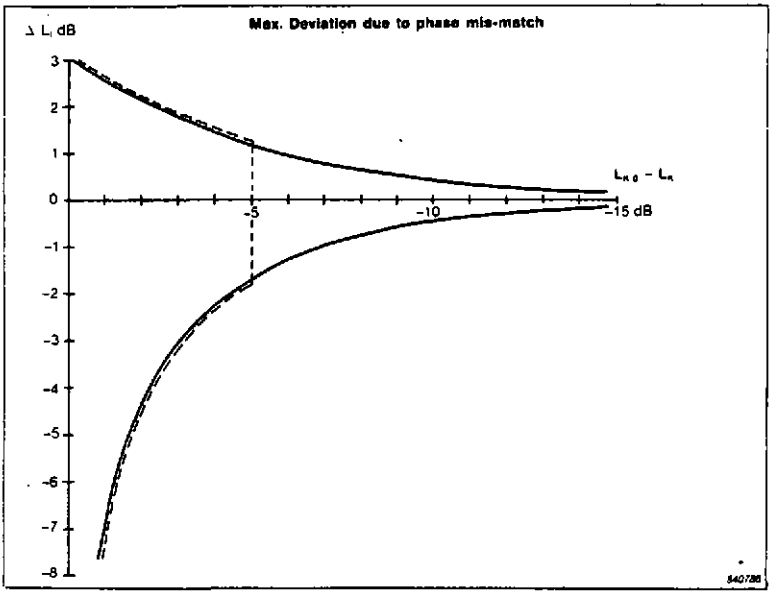

Fig.3. The error due to phase mismatch expressed as a function of residual intensity index $L_{K,O}$ minus the reactivity index L_K

VALIDITY OF INTENSITY MEASUREMENTS

A sound intensity measuring system based on the two microphone technique has certain limitations which can affect the accuracy of the measured results. At high frequencies there is a bias error due to the approximation of the pressure gradient by a finite difference. At low frequencies the phase mismatch of the system becomes comparable to the phase to be measured which leads to an error in the resulting measured intensity. This error can be expressed directly in dB as a function of the difference between the residual intensity index measured during calibration of the system and the reactivity index of the sound field at the measurement position and direction (Fig.3) [3]. When intensity measurements are performed in fields which are not purely active sound fields then a significantly greater BT product (bandwidth-multiplied by averaging time) is necessary to obtain the same confidence level as in active sound fields [4]. The greater the averaging time the less will be the random error associated with the intensity measurements [Fig.4].

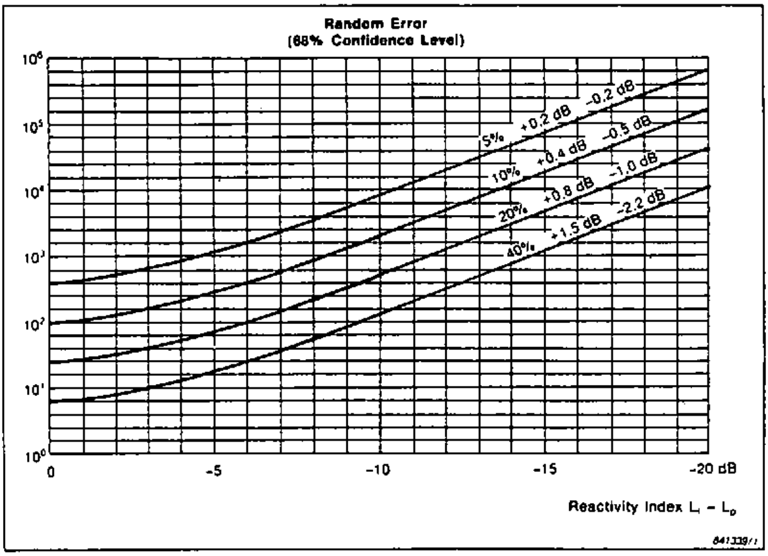

Fig.4. The relationship between the reactivity index of the sound field $L_I - L_P$ and the BT product for a given confidence level in intensity measurements

CONCLUSION

The accuracy of an intensity estimate depends on the phase difference between the transducer locations and the phase match of the instrumentation. The terminology defined in this paper is thus intimately connected with phase relationships. However the user of an intensity measuring system is usually more interested in intensity levels and associated errors in dB rather than a phase in degrees. By using appropriate measurement indicators it is possible to express the errors associated with intensity measurements directly in dB without mentioning phase.

REFERENCES

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