Influences and simplifications of diffraction functions in nonlinear acoustical parameter measurement systems

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This paper presents an analytical formulation for correcting the diffraction associated with the second harmonic of an acoustic wave, that is more compact than that usually used. This new formulation resulting from an approximation of the correction applied to the fundamentals, which makes it possible to obtain simple solutions for the average second harmonic acoustic pressure but is sufficiently precise when measuring the parameter of nonlinearity B/A in the finite amplitude method. Comparisons with other expressions requiring numerical integration show that the solutions are precise in the near field. Furthermore, the effect of diffraction in the B/A parameter measurement system is discussed.

1. INTRODUCTION

In acoustic parameter measurements of a medium, it is necessary to take into account the diffraction effects of the ultrasonic source to improve the precision of measurements. The measurement cells usually used in transmission consist of two circular transducers (one used as a source and another as a detector). In these situations, the detector will translate into an electric voltage of the average acoustic pressure in its reception area. The analytical solutions describing this average pressure can be formulated as the sum of two terms, one corresponding to the propagation of a plane wave, and the other including the effects of diffraction generated by the geometry of the source-detector unit.

The attenuation α and velocity c can be obtained in the case of linear acoustics. Different authors[1–4] give exact and asymptotic expressions of the average pressure received by a circular transducer. These expressions permit correction functions of diffraction in velocity and attenuation measurements.[5,6]

On the other hand, the B/A parameter is measured in the field of nonlinear acoustics. This parameter is defined as the ratio of coefficients of quadratic term to the linear term in Taylor expansion of the state equation. Consequently, it characterizes the dominant finite-amplitude contribution to the sound speed for an arbitrary fluid.[7] The first measurements of B/A parameter by finite amplitude methods rested on an analytical expression of the second harmonic by considering the propagation of a plane wave.[8–10] Various authors[11,12] then improved the precision of these methods by including a function to correct the diffraction effect resulting from the relation established by Ingenito and Williams[13] for the average pressure exerted by the second harmonic. However, the correction of diffraction obtained is not very practical because it can be evaluated only by numerical integration.

The objective of this paper is to show that one can obtain a simple and precise form by simplifying the correction function of diffraction for the fundamental. Then we will give simple expressions of the average pressure exerted by the second harmonic, including diffraction and attenuation effects. We will show that the results obtained are equivalent to those established by Coob and validated in measurement systems.[11] But before establishing this result it is necessary to present the various corrections of diffractions applicable to the fundamental from acoustic pressure.

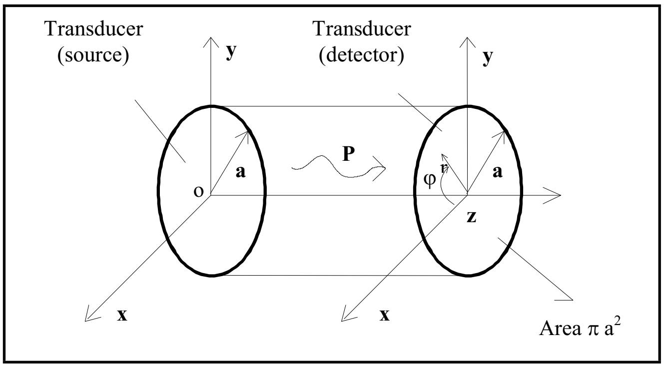

Figure 1: Geometrical configuration of the source-detector.

2. CORRECTION OF DIFFRACTION FOR THE FUNDAMENTAL

2.1. Function $D_1(z)$ of diffraction correction for the fundamental

For the nondissipative case ($\alpha_1 = 0$), Williams[1] give the exact expression of the average velocity potential (Fig. 1):

$$\langle \phi_1(r,z) \rangle = \frac{jU_0}{k} e^{jkz} - \frac{j4U_0}{k\pi} \int_0^{\pi/2} e^{jk[z^2+4a^2cos^2\theta]^{1/2}} sin^2\theta d\theta \quad (1)$$

with a being the radius of the transducer.

The first term represents the velocity potential in the case of a plane wave, therefore the average velocity potential on the