INTRODUCTION

The geometrical acoustics theory is still an approach widely used when it comes to applications of ultrasonic methods to non destructive tests and characterization of acoustic properties of materials. In biomedical applications, however, results have demonstrated limited success, particularly in attempts to construct images of ultrasonic biological tissue parameters (wave velocity, amplitude attenuation, scattering, etc.). The main reason for this may be the great complexity of ultrasonic wave interactions with the living matter, not adequately covered by the assumptions of geometrical acoustics. Nevertheless this theory must still be explored in the biomedical field, starting from simple situations where a small number of variables can be considered (Shung, 1990, Liu, 1991).

Following this principle we have already developed geometrical acoustics models to simultaneously estimate the thickness and the wave velocity of multilayered media (Pereira, 1992). The first model assumed a focused beam and was based on the measurement of the time-of-flight (TOF) collected at two different locations. Experiments with a 1.9 MHz/19 mm diameter transducer and a 0.6 mm diameter PVDF hydrophone pointed to the potentiality of the method but also for the need of an accurate alignment of the experimental apparatus (Pereira, Leeman and Machado, 1992; Pereira and Machado, 1992).

In this work we present a new geometrical acoustics model that estimates the thickness and the wave velocity of multilayered media, simultaneously. This model simplifies the experimental conditions to measure the TOF's that are collected at different locations.
The model considers the situation of figure 1 where a transmitting transducer ($T_x$) emits an ultrasonic (US) wave towards a target that is away from its face by a distance $Z$. After reflection the wave front travels back to $T_x$ and also to another transducer, called receiver ($R_x$). The beam is assumed to be focused with focus at $F$ and a least mean square method to estimate the focal point is used (Pereira, Simpson and Machado, 1992).

\[ T_0 = \frac{2 \cdot Z}{c} \]  

(1)

where $c$ is the US wave velocity in the medium. In a similar way $T_1$ (TOF for the wave to reach the receiver $R_x$) can be written as:

\[ T_1 = \frac{F}{c} + \frac{2 \cdot Z - F}{c \cdot \cos \theta} \]  

(2)

After dividing $T_1$ by $T_0$, this results in equation (3) where $c$ has been eliminated and $\cos \theta$ has also been taken from the figure.

\[ \frac{T_1}{T_0} = \frac{F + \sqrt{X^2 + (2 \cdot Z - F)^2}}{2 \cdot Z} \]  

(3)

Parameter $X$ is the distance $T_x - R_x$. So equation (3) can be used to estimate the thickness $Z$, once the parameters $X$ and $F$ are known and $T_0$ and $T_1$ are measured. After obtaining $Z$, the velocity $c$ can be taken from equations (1) or (2). The equations developed here can be extended to a multilayered medium, bearing recursive equations.