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MEASURE AND VISUALIZATION IN THE NEAR ZONES OF TRANSIENT ULTRASONIC FIELDS GENERATED BY BROADBAND TRANSDUCERS IN LIQUID MEDIA

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Abstract - This paper presents an experimental technique for analyzing the propagation of transient ultrasonic patterns generated by broadband thickness-resonant discs in water over the near zones. The amplitude peak detection of the received signals from focused and unfocused single element transducers is made by using shifting narrow temporal gates. The 3D and 2D pressure plots obtained, allow the snapshot visualization of the pulsed wavefronts, they also provide information on the vibration pattern of the transducer face, which results in the detection of possible constructed anomalies on the piezoelectric disc of the emitters.

1 - INTRODUCTION

In a previous work [1], an analysis in the temporal domain of the broadband pressure signals generated in water by thickness vibrating circular sources was presented. Some discrepancies between the experimental results and the temporal behaviour predicted by the radiating piston theory, in some particular points of the field, were discussed. Two non-predicted components, "head wave" type, were observed with characteristics similar to those shown by other workers [2], [3], [4], [5], in very thick piezoelectric transducers. Through out the present work, we will focus our attention on the obtention of pressure-plots related to: very near zones of the transducer surface (plane aperture case), and regions close to the focus (curved aperture case). The temporal components of the transversal beam profile, in the focus line, will be detected through a chopping process performed every 50 ns. In this way, some effects of certain importance in high spatial and temporal resolution imaging systems, which remain hidden in conventional plots, will be detected.

2 - THE VISUALIZATION AND MEASURE SYSTEM

A full account of the experimental system used, to make measurements and visualizations of transient ultrasonic wavefronts, is available as a previous publication [6], and only a brief description is given here. A broadband pulse generator drives the transducer [7] with spike-voltages ranging up to 500 v and rise-times of 10 ns. The transmitting transducers studied were manufactured from heavily damped discs of lead metaniobate (PMN) and lead zirconate titanate (PZT-5A). The PMN emitter is commercially available from Panametrics (A305; 8=19 mm; f =2.25 MHz) as long as PZT-5A focused (8=28 mm; f =4 MHz) and unfocused (8=26 mm; f =3 MHz) sources were made in our laboratory. The small receiving probes used to make field point pressure measurements were a PZT needle type hydrophone with an active diameter of 0.3 mm and a PVDF microprobe of about 0.8 mm in diameter. These are broadband microtransducers usable in the frequency range 0.5-10 MHz.

Both acoustic emitter and receiver are located in an automatic scanning water tank which gives positional resolution of up to 20 μm, and an accuracy of ±1 μm by means of numerical control equipment. The amplitude of the pulsed waveforms is detected by an adjustable gated peak detection stage, through a wideband head amplifier. 3D-plots were made by recording the detected pressure amplitude as the Y-coordinate on an analog XY-recorder. In parallel, the reset of the holder circuit in the peak detection process can be externally controlled by an IBM PC/AT computer. This allows the obtention of acoustic patterns from different perspectives, normalization of the pressure values, contour plots, ... etc.
3 - EXPERIMENTAL PROCEDURE

As it was shown in [61], acoustic methods produce field quantitative plots by measuring the peak of the individual pressure or intensity values at each point of a XY-plane (parallel to the emitter vibrating surface) or XZ-plane (beam pattern). The amplitude gated detection of the highest peak of the pulsed waveforms is made by using temporal windows wide enough to contain the whole time evolution of the ultrasonic transient signals. In these cases it has been confirmed by us that important aspects about wavefront behaviour can remain masked in many zones. This is owing to the fact that the conventional type 2D-plots use to be the projection over a plane of events happened in a relatively long interval of time, thus preventing information belonging to insonifications, that can be non-simultaneous, to be appreciated. For these reasons we propose the use of shifting narrow temporal gates with $t_d$ delay time from the mainbang) of its propagation, is shown. This agrees with the passing of the pulse by the focal point $(0,0.21) \text{ mm}$ ($Z$ is refered to the transducer edge), being also remarkable the analogy, along $Z$-axis, between spatial (Fig. 1a) and temporal progressions (Fig. 1b) of the transient signal, and the short time needed to make the analog-record. In Figs. 2 and 3, on the contrary, 3D and 2D-snapshots were obtained through the computer with spatial sampling intervals of $\Delta z=0.1 \text{ mm}$ and $\Delta x=0.5 \text{ mm}$, in the very near field ($t_d=10 \mu s$; Fig. 2) and behind the focus zone ($t_d=40 \mu s$; Fig. 3). Two curved wavefronts clearly appear corresponding to the transducer curved shape, and the spherical pulse-form in the far field region. Slightly different results are presented in Figs. 4 and 5, where XZ-plots are shown. These graphics were made maintaining the gate position as before (in Figs. 1a and 3a), but with sampling intervals of $\Delta x=0.2 \text{ mm}$ and $\Delta z=0.2 \text{ mm}$. A temporal sequence of the diverse spatial-forms adopted by the beam profile along the X-axis, at a fixed depth of $z=21 \text{ mm}$, can be seen in Fig. 6a. The contributions to the integrated pattern obtained, with $t_d=50 \text{ ns}$, appear individualized and can be compared with the plot performed (Fig. 6b) by using a wide temporal gate ($t_d=3.5 \mu s$). Finally, in Fig. 7, the XY-plots of the sound field near to the emitter surface ($z=0.5 \text{ mm}$) were carried out for the transducers (B) and (C), providing detailed information on the vibration pattern of the transducer face. In case (B) it is easily seen that there is a $\phi=15 \text{ mm}$ lump of tin solder on the disc of the transducer, whereas in case (C) the presence of a diametral electrode on the disc is also clearly detected.

4 - RESULTS

This section presents selected results for the single element transducers (A) 4 MHz-focussed, (B) 3 MHz and (C) 2.25 MHz-unfocused, operating in a pulse mode. The 3D-experimental plots were carried out through a fine control of the visualization system gate (only negative half-cycles of pressure values have been plotted), where $t_d=50 \text{ ns}$ is its lower temporal width which corresponds to $\approx 1/9-1/5$ of the signal "equivalent" periods. In Fig. 1 and analog ZX view of a traveling wavefront, generated by emitter (A) at an instant $t_d=20.3 \mu s$ ($t_d$=delay time from the mainbang) of its propagation, is shown. This agrees with the passing of the pulse by the focal point $(0,0,21) \text{ mm}$ ($Z$ is refered to the transducer edge), being also remarkable the analogy, along $Z$-axis, between spatial (Fig. 1a) and temporal progressions (Fig. 1b) of the transient signal, and the short time needed to make the analog-record. In Figs. 2 and 3, the contributions to the integrated pattern obtained, with $t_d=50 \text{ ns}$, appear individualized and can be compared with the plot performed (Fig. 6b) by using a wide temporal gate ($t_d=3.5 \mu s$). Finally, in Fig. 7, the XY-plots of the sound field near to the emitter surface ($z=0.5 \text{ mm}$) were carried out for the transducers (B) and (C), providing detailed information on the vibration pattern of the transducer face. In case (B) it is easily seen that there is a $\phi=15 \text{ mm}$ lump of tin solder on the disc of the transducer, whereas in case (C) the presence of a diametral electrode on the disc is also clearly detected.

5 - CONCLUSIONS

This work has demonstrated the applicability of the measure and visualization system and the usefulness of shifting narrow temporal gates with $t_d=50 \text{ ns}$, in the obtention of 3D and 2D-snapshot plots of ultrasonic transient wavefronts, in the frequency range 0.5-10 MHz. The experimental procedure here presented also provides information on the vibration pattern of the emitter surface, which permits the detection of whether constructed anomalies are presented or not on the piezoelectric disc of the transducers.

6 - REFERENCES

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