ABSTRACT

ULTRASONIC BROAD BAND PULSE-ECHO BEAM PROFILE ANALYSIS IN NONATTENUATING AND ATTENUATING MEDIA

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Ultrasonic pulse-echo beam profiles provide a means of estimating the resolution capabilities of a transducer-pulser-receiver network when such a system is employed for clinical scanning. Most studies on beam profiles have been carried out by examining the changes in the amplitudes of the echo signals from transmitted pulses striking single targets in an ultrasonic field. The choice of path is normally water or a low attenuating liquid. The purpose of this dissertation is to experimentally determine broad band pulse-echo beam profiles for paths containing soft tissues or tissue-equivalent media which is similar to tissue in physical density and acoustic speed of sound and attenuation coefficient. These profiles are compared to similar profiles derived in nonattenuating media and to predictions derived from models based on continuous wave transmission.

The principle differences between the pulse-echo beam profiles obtained in attenuating media and those obtained in nonattenuating media are: first, an enlargement of the profiles in the far field of broad band transducers; second, an increased rate of pulse-echo beam divergence as a function of increasing depth;

and third, a shift in the distance of the focal region closer to the face of weakly focused transducers. In addition, the pulse-echo beam profiles, when presented in the form of two-dimensional, equal echo amplitude contours in planes parallel to the face of the transducer, often exhibit an axial asymmetry and an off-axis deflection of the position of the peak echo amplitude for paths through soft tissue samples. Scatterer size, distribution and acoustical impedance are found to play a major role in the deformations and the deflections present in these beam profiles through soft tissue.

A prediction of the broad band pulse-echo profile enlargement and divergence effects is derived from an extension of continuous wave transmission theory for idealized sources. This extension is based on the assumption that the maximum amplitude of a radio frequency (RF), broad band waveform, corresponding to a pulse reflected from a target in the beam, may be characterized by a super-position of continuous beams using a spectral weighting function derived from the pulse's frequency distribution. The predicted profile enlargement in attenuating media is within 3% of the actual measured profile enlargement when using an "effective" source diameter for the transducer.

In addition, the changes in the peak axial pulse-echo response and in the width of the central lobe of weakly focused broad band beams are found to also be predictable using equations derived for continuous wave transmission and employing a single frequency to represent the broad band pulse. Observed differences in focal characteristics of transducers of different source diameters, center and mean frequencies, or radii of curvature of the source element are consistent with the predicted differences derived from this model. When either of these models are employed, a more realistic estimate of the resolution, and hence, imaging capabilities of a particular transducer-pulser-receiver system can be made than if one only depends on data from a water path.