DETERMINATION OF ALTERATIONS OF PHASE ANGLE OF ULTRASOUND TRANSMITTED THROUGH A MALIGNANT BREAST TUMOR: A Preliminary Investigation†

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INTRODUCTION

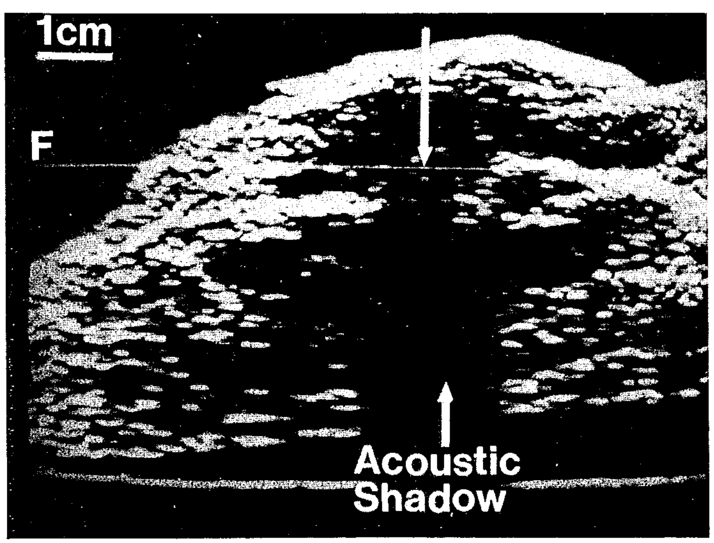
The overall experimental approach of the research discussed in this paper is the use of multidiscipline examination methods, namely, x-rays, ultrasound visualization, signal processing of ultrasound transmission data (FFT) and whole breast histology to elucidate the relation between structural features of breast tissue and their interaction with high frequency sound fields. The specific studies presented here are concerned with an attempt to determine the feasibility of using the phase angle data resulting from the FFT studies to assist in the recognition of differences between normal and malignant breast tissue.

A special preparation, namely, an excised, formalin-fixed breast with a known intact malignant tumor, was used in the investigations discussed in this paper. Examinations of such breast preparations for the purpose of detecting tissue alterations associated with the presence of the malignant mass and correlation of the results with whole breast histology has important advantages for the collection of data that is pertinent for early breast cancer detection.[1-8] The experimental studies outlining the validity of examining such preparations by ultrasound visualization and the techniques associated with this procedure have been described in detail in a previous publication.[7]

The FFT studies were considered in the nature of a feasibility study and it is in that regard they are reported in this paper. Emphasis is given in this preliminary report of the evaluation of e angle as a function of frequency as revealed by FFT tech-

EXPERIMENTAL METHODS

tumor was identified as malignant by needle biopsy and mination of the patient prior to mastectomy. After ex- f the breast, (without surgical biopsy or removal of the e breast was formalin-fixed and subsequently examined by a can, B-mode ultrasound visualization system. In addition ling information on normal and pathological regions of the the visualization echograms allowed identification of in- tructures in relation to surface landmarks, (such as the cation of the tumor). These surface landmarks were later the FFT data sampling sites.[8] The pulse-echo visualization er was the same as that described below for the FFT trans- transducer. Figure 1 is an example of the type of tissue accomplished by a single scan in the region of the tumor.



Breast tissue echogram. The top arrow shows the site of the malignant tumor.

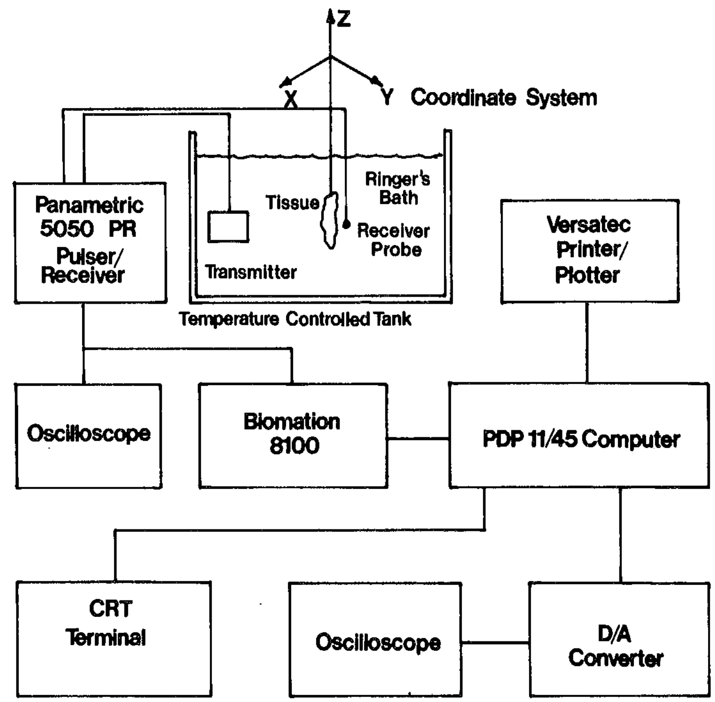


Fig. 2 Data acquisition systems block diagram.

Figure 2 is a block diagram of the instrumentation used for the subject studies. An axisymmetric focused transducer was used as a transmitter, and a 10 MHz center frequency, 4 mm diameter PZT ceramic sandwich-type piezoelectric probe used as a receiver. A Panametrics Model 5050R unit pulse-excited the transmitter and a series unit attenuated the ultrasonic signals prior to their entrance into the amplifier receiver. The sending transducer was 1.9 cm in diameter, had a focal length of 7.5 cm, and a midband frequency response of 4.4 MHz. The breast preparation was mounted on a three-motion coordinate system in a temperature controlled mammalian Ringer's bath (average temperature 25°C) and positioned between the sending and receiving transducers, with the anterior aspect of the tissue facing the sending transducer. With this arrangement, any area of the tissue could be easily examined and the tissue could be moved in 1 mm steps in the three-axis coordinate system.

In order to record the system's reference waveform, transmitter and receiver transducers were placed facing each other and d in position to receive the optimum amplitude signals. A ty test of the system was performed by setting the attenua- t at different values and comparing the corresponding outputs FFT spectrum. The system was found to be accurate to ± 1 dB usable frequency band, for any particular transmitting trans- The received ultrasonic waveforms were digitized at a samp- te of 10 or 20 nanoseconds using a Biomation Model 8100 er and were parallel transferred to the PDP-11/45 computer. as four waveforms were digitized at each point of interest, on the computer disc, and later analyzed using a 1024 point he tissue was sampled at points previously identified by und visualization, by moving the specimen across the ultra- eam on the three-axis system. The anatomical points of in- discussed in this paper are the malignant tumor tissue path o back surface of breast for path that includes the tumor nd the upper, inner aspect of the breast, which was assumed epresentative of a normal, fatty region of breast tissue.[8]

ch of these waveforms represented sound transmission through nt areas of the same region of interest. In general, each n recorded represented sound transits at entrance points ed by 2 mm of surface tissue. In order to obtain attenuation se-speed versus frequency plots, they were deconvolved with ginal system's reference waveform. The waveforms were trans- into the frequency domain and the absolute amplitude for veform was compared with the amplitude of the reference wave- r the relative attenuation measurement. To obtain the phase nformation for each waveform, the phase was compared with erence waveform and later linearized for each frequency. imum frequency resolution, appropriate sampling intervals lected on the Biomation digitizer. The output was presented aphical form in three different formats, namely, normalized e amplitude, attenuation and phase-speed spectra. The pres- plitude and attenuation data was previously published.[8]

RESULTS

e phase angle plots derived from transmission through a nor- ty region of the breast tissue, namely, the upper, inner t, are shown in Fig. 3. The linear nature of these plots in- no substantial acoustic velocity changes as the wave passes such tissue.

gure 4 shows the phase angle plot for the waveforms that were through the tumor region tissue paths. The non-linearity dom nature of these plots are in sharp contrast to those n Fig. 3. The variations of the phase angle are indicative stic waves that are going through a velocity dispersion or isturbances.

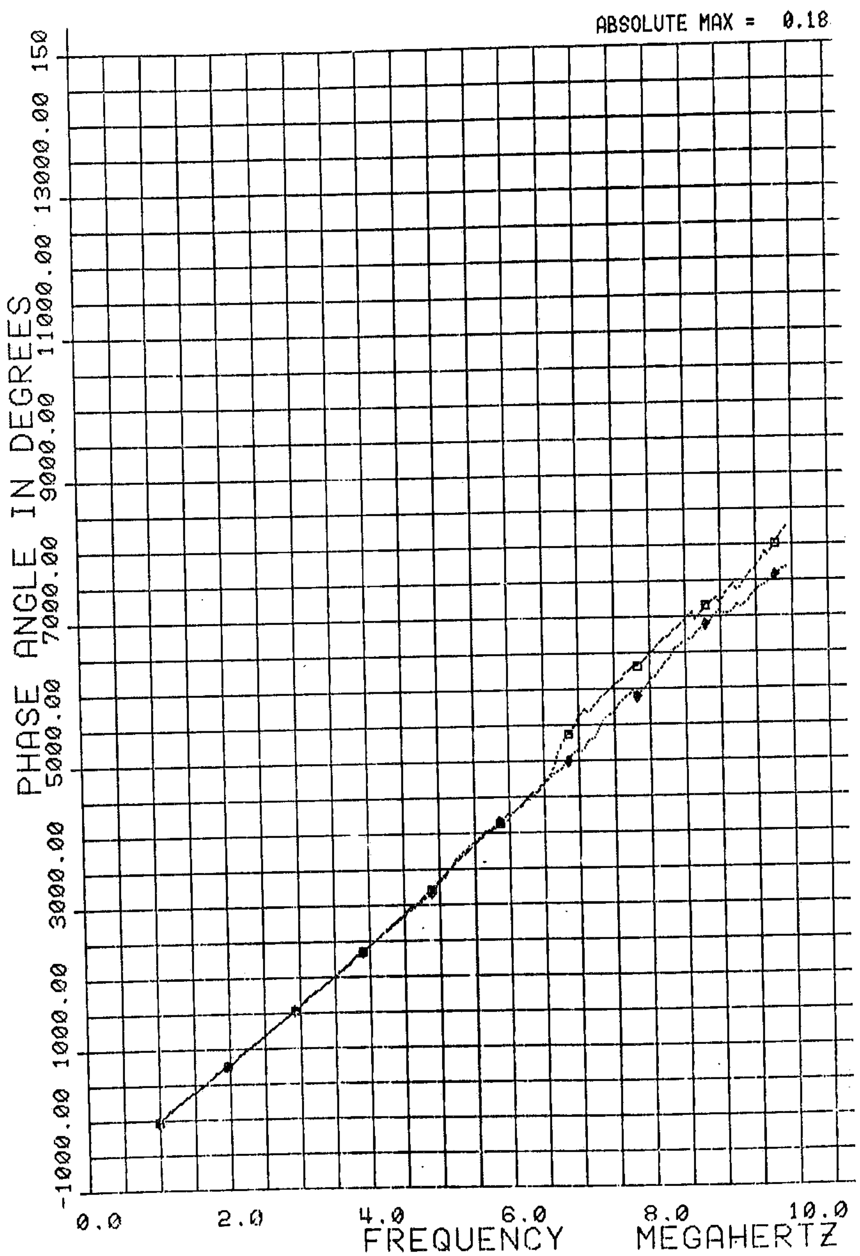
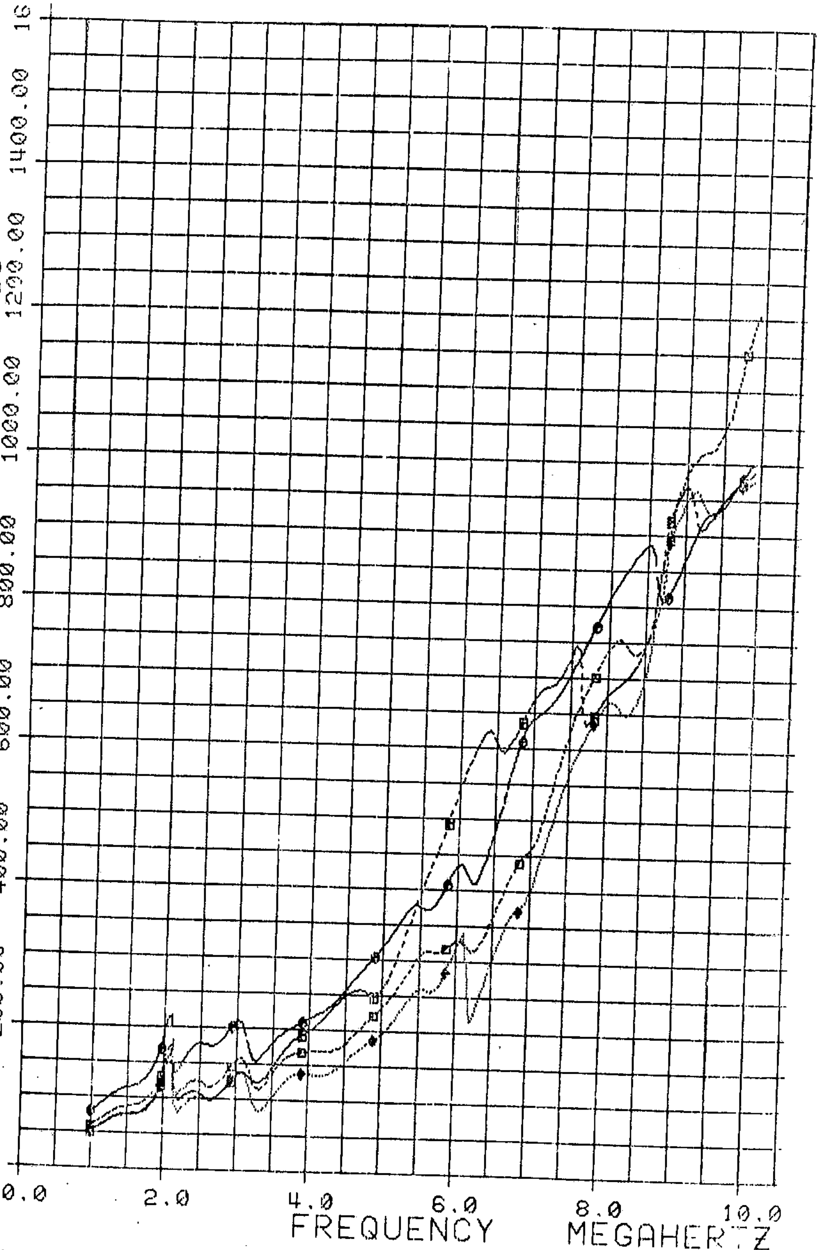


Fig. 3 Phase-frequency plot for the fatty tissue of the breast.



4 Phase-frequency plot for the tumor region tissue path.

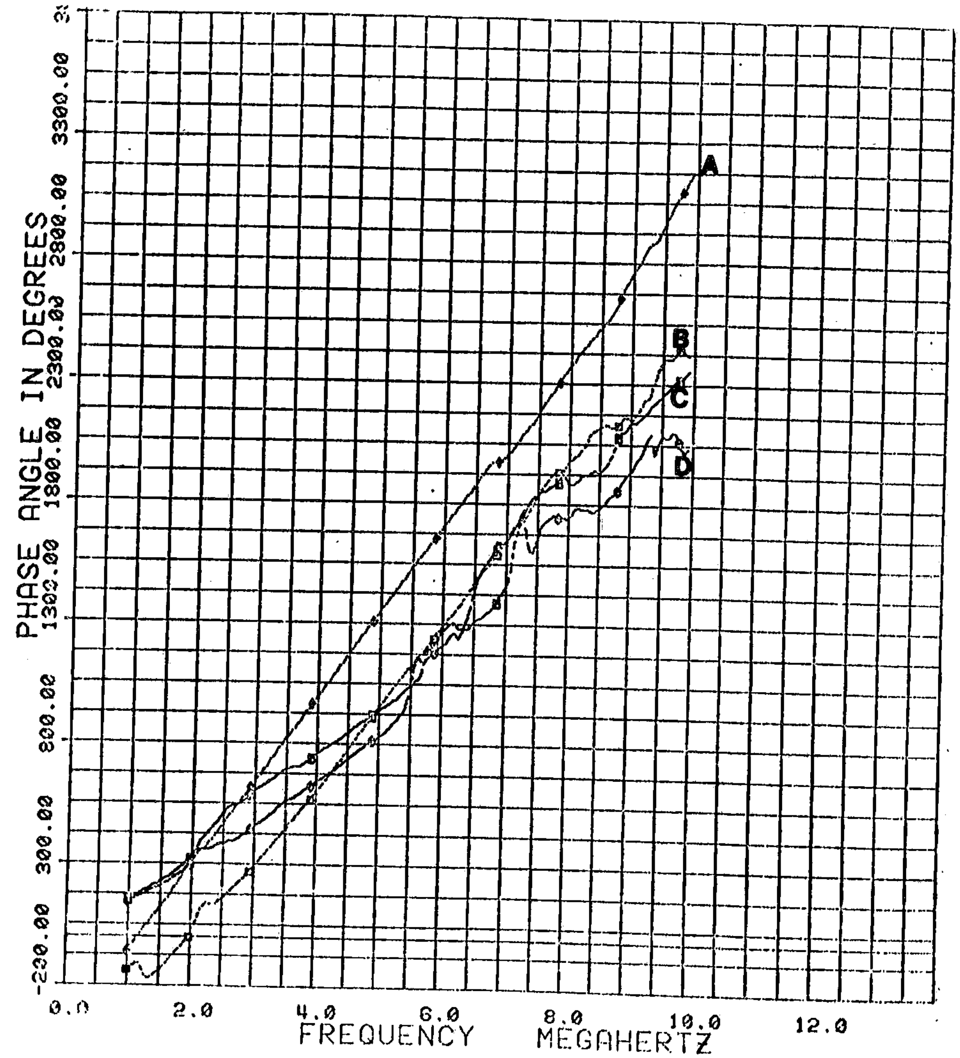


Fig. 5 Phase-frequency plot for a tumor region tissue path which apparently consists of a mixture of tissue types (see text).

gure 5 shows results obtained from four sound transits
another area of the tumor tissue path. Before considering
se angle data for this region of the tumor path, it is of
t to discuss the conjectured character of the tissues of the
ass itself, as indicated by the attenuation values previous-
ined for the tumor mass in this specific region.[8] In that
the attenuation values indicated: (1) the tissue repre-
y plot A consisted of fat; (2) that represented by plot B
ably made up of a mixture of normal and malignant tissue
that C and D were more characteristic of the most malignant
the tumor.

phase angle data of Fig. 5 apparently is in agreement with
lusions based on the attenuation data, i.e., the phase angle
plot A of Fig. 5 is comparable to that found for normal
ssue; plot B has reasonable linear characteristics in the
ies below 7 MHz but shows non-linearity beyond that fre-
nd, finally, the phase angle data of plots C and D are non-
n character.

CONCLUSION

is proposed that consideration be given to the apparently
alteration of phase angle versus frequency in the tissue
ch includes both normal tissue and malignant tumor in com-
o the phase angle versus frequency of the tissue paths
sist of only normal tissue, and further that these alter-
e considered in terms of the structure of the tumor as de-
by whole breast histology. Preliminary data seems to in-
significant difference in patterns for phase angle versus
for the tumor region in comparison to normal fatty regions
ssue. If such pattern differences are valid, this infor-
uld be valuable in making differentiated diagnoses of
mors. In view of the serious need for more definitive
reast tumor structures, these preliminary results are of
t interest to recommend that further phase angle data
e carried out.

the time of writing of this paper, the histological stud-
ot been completed.

s research was supported by the Showalter Residuary Trust,
lis, Indiana.

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