

NASA CASE NO. LEW-15,735-1

AWARDS ABSTRACT

A METHOD AND APPARATUS FOR MEASURING HOMOGENEITY WITH A MATERIAL PART

The present invention is directed to a method and apparatus for interactively analyzing the characteristics of a material part in real-time. The invention enables the storage, calculation and display of the properties of the material part. A ultrasonic scan is performed on the material part. The material properties are then calculated from the scanned data and displayed. An image system is then used to select one point of the material part in real time and display all of the associated properties of that one point interactively.

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PRINT FIG. 1

NOTICE

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LeRC

**NASA CASE NO. LEW-15,735-1**

**A METHOD AND APPARATUS FOR MEASURING  
HOMOGENEITY WITHIN A MATERIAL PART**

ORIGIN OF THE INVENTION

5       The invention described herein was made by an employee of  
the United States Government and may be manufactured and used  
for the Government for governmental purposes without the payment  
of any royalties thereon or therefore.

10       FIELD OF THE INVENTION

The present invention is directed to a method and apparatus  
for analyzing the homogeneity within a material part. Using the  
method and apparatus disclosed in the present invention the  
component image properties of the material part are measured,  
15       displayed and then analyzed. The component image properties are  
displayed using a post-scan interactive display (PSIDD) process  
for ultrasonic scanning.

Prior art methods for obtaining ultrasonic scans are crude.  
The prior art methods would use a lubricant between the  
20       ultrasonic probe and the material part. The lubricant would  
infuse into and often cause damage to the material part and  
distort the readings of the part. In addition, once the  
information is attained, displaying the information and making  
sense of the data presented significant problems. An  
investigator could not analyze the required characteristics of  
25       the part simultaneously. Furthermore, once the analysis was  
made of one point in the material part, an investigator could

not easily analyze the characteristics of any additional points within the part, in real-time.

5 It is therefore an object of the present invention to simultaneously display the characteristics of a material part.

It is another object of the present invention to access and display the characteristics of different locations of the material part in real-time.

10 It is a further object of the invention to analyze the potential failure points within the material part using a post-scan interactive display process.

#### DESCRIPTION OF RELATED ART

15 U.S. Patent No. 3,801,741 relates to a method of image analysis used in pattern recognition. U.S. Patent No. 4,375,671 relates to a means of filtering screen data in an ultrasonic scanning system. U.S. Patent No. 4,561,019 relates to an image enhancement system used to extract given frequency components of an image by means of a set of bandwidth filtering elements.

20 U.S. Patent No. 4,783,839 relates to image enhancement methods utilizing a statistical processor in combination with a variable bandwidth filter to modify images to specified frequency ranges for enhancement. U.S. Patent No. 4,872,130 relates to an automated ultrasonic inspection system having a user friendly, interactive screen. U.S. Patent No. 5,050,226,

relates to a means of image processing in an ultrasonic scanning system which uses adaptive filtering to remove noise and to display specific frequency components of interest.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for determining homogeneity within a material part. In the present invention a self-aligning transducer assembly is used to perform an ultrasonic contact scan. The assembly enables dry coupled contact scanning of the material part. The assembly is designed using buffer rod faces so that the transducer head will make contiguous contact with the material part. The transducer assembly is then moved repeatedly across the surface of the material part to attain a full image of the entire part.

After the measurements of the material part have been made, the data is analyzed using an improved post-interactive data display process for ultrasonic imaging. The interactive display system provides for the following:

- 1) Viewing raw time-domain and fourier transformed waveform data, with or without ultrasonic scatter noise subtracted, at any point of formed ultrasonic property map using a direct access data retrieval computer algorithm, allowing a two order of magnitude increase in the data display speed over previous versions,

2) Viewing any type of property map at any frequency generated from spectral analysis of ultrasonic contact scan  
5 data,

3) Viewing ultrasonic properties at specific frequencies using independent cursor control moved over the composite waveforms display with values written to video in real-time on a composite waveform display,

4) Verifying frequencies where ultrasonic attenuation coefficient measurements and images are valid by showing attenuation coefficient error .vs. frequency on the composite waveforms display,

5) Use of a grid superimposed on a real-time location display on video which allows the user to locate the exact measurement points of interest,

6) Auto-scaling of waveforms for optimizing viewing on the composite waveforms display, and

7) An interface between a computer and an independent cursor control unit.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The objects, advantages, and novel features of the invention will be more fully apparent from the following detailed description when read in connection with the accompanying drawings in which:

Fig 1. displays a conceptual view of the ultrasonic measurement technique;

5 Fig 2. displays the full material part with a grid overlay;  
Fig 3. displays the material part with the grid overlay in conjunction with pointer pointing to a specific area within the material part;

10 Fig 4. displays a schematic of the ultrasonic scan apparatus.

Fig 5. displays the composite waveform display generated by the post interactive data display system;

Fig 6. displays a waveform of a reference pulse of a material part;

15 Fig 7. displays a waveform of a front surface reflection of the material part;

Fig 8. displays a waveform of the first back surface reflection of a material part;

20 Fig 9. displays a waveform of the second back surface reflection of a material part;

Fig 10. displays the fourier magnitude spectra of the reference waveform over the front surface reflection;

Fig 11. displays the phase spectra of the first back surface echo over the second back surface echo;

25 Fig 12. displays the waveform of the fourier magnitude spectra of the first back surface reflection/second back surface

reflection;

Fig 13. displays a waveform of the phase velocity;

5 Fig 14. displays a waveform of the phase velocity normalized  
by the cross-correlation velocity;

Fig 15. displays a waveform of the reflection coefficient  
as a function of frequency;

Fig 16. displays a waveform of the attenuation coefficient  
10 plus or minus expected error; and

Fig 17. displays a waveform of the attenuation coefficient  
error.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

15 Figure 1. displays a conceptual view of the ultrasonic  
measurement apparatus disclosed above. In figure 1. a  
piezoelectric crystal that sends and receives ultrasonic  
transducer pulser/receiver 100 is separated from specimen 120  
comprising a front surface 140 and a back surface 150, by of  
buffer rods 110, which spaces the transmission and reception of  
20 the ultrasonic pulse between the specimen and the  
transmitter/receiver. The transmitter/receiver generates a  
pulse 160 toward the specimen. The pulse 160 produces the front  
surface reflection 170, a first back surface reflection 180 and  
a second back surface reflection 190. The front surface  
25 reflection 170, is a reflection of the ultrasonic pulse against  
the front-surface 140, of the specimen 120. The first back



5 surface reflection 180, is a reflection of the pulse 160 as it  
reflects off of the back surface 150 of the specimen 120. The  
second back surface reflection 190 is a reflection of the pulse  
160 after it has resonated within the specimen 120 and emerged  
as a return pulse 190.

10 Figure 2. displays the ultrasonic scan of the entire  
material part. Figure 2 displays the material part with  
darkened areas which display a lack of homogeneity within the  
part. The figure displayed in figure 2 is generated by taking  
the transducer assembly disclosed in figure 1 and scanning the  
entire material part. When this scan is taken, data reflections  
170, 180, and 190 are taken for every point scanned. The  
15 waveform characteristics for a specific point within the part  
are referenced, by using the pointer 365 in figure 2.

Figure 3 displays a grid that is placed over the material  
part by the imaging system to help the an investigator  
specifically identify a point in the material part.  
20 Therefore the pointer 366 placed within a specific location  
within the grid accesses the waveform characteristics for that  
part of the grid.

Figure 4 displays a schematic diagram of the complete  
apparatus used to display the waveform characteristics in a  
25 material part. In figure 4 a computer 240 signals an xyz  
controller 180, which moves a transducer assembly 190 across the

surface of a material part taking measurements at each point. The ultrasonic pulser receiver 200 reads these ultrasonic measurements which are in the form of analog signals and sends them to the waveform digitizer 220. The waveform digitizer 220 digitizes the analog signal and stores this information as raw data in the computer 240. The waveform characteristics of every point in the material part are then calculated in the computer. A image processor 250 then processes the waveform data and displays the material part in the display 260. When an investigator would like to view the characteristics of a specific point in the material part the cursor controller 270 is used to move the cursors 365, and 366 displayed in figures 2 and 3, respectively.

Figure 5. displays the composite waveform screen generated by the Post-Scan Interactive Data Display System for ultrasonic scans. The screen simultaneously displays the waveform characteristics of the material part. In addition, if the cursors 365 and 366 of figures 2 and 3, were moved the system would generate a similar screen for the new point denoted by the cursor in real-time. This would facilitate access to data that hereto was unattainable in real-time. Figures 6 through 17 detail the individual graphs displayed in figure 5.

Figure 6 displays the reference signal used to display the material part. Figure 7 displays the waveform associated with

the front-surface reflection 170 of figure 1. Figure 8 displays  
the waveform associated with the back-surface reflection 180 of  
figure 1. Lastly, figure 9 displays the waveform associated  
with the second back-surface reflection 190 of figure 1. Figure  
10 displays the magnitude spectra. Figure 11 displays a waveform  
of the phase angle as a function of frequency, which is commonly  
known as the phase spectra. Figure 12 displays fourier  
magnitude spectra of the first back surfac reflection over the  
second back surface reflection. The waveform of figure 13  
displays the phase velocity versus the frequency at one point in  
the material part. Figure 14 displays the phase velocity  
normalized by the cross-correlation velocity which shows how  
phase velocity compares with the cross-correlation velocity.  
Figure 15 displays the reflection coefficient as a function of  
frequency. Figure 16 displays the attenuation coefficient  
versus the frequency which shows how much the material is  
attenuating sound as a function of frequency. Lastly, figure 17  
displays the attenuation coefficient error versus the frequency.

While the preferred embodiment of the invention is disclosed  
and described it will be apparent that various modifications may  
be made without departing from the spirit of the invention or  
the scope of the subjoined claims.

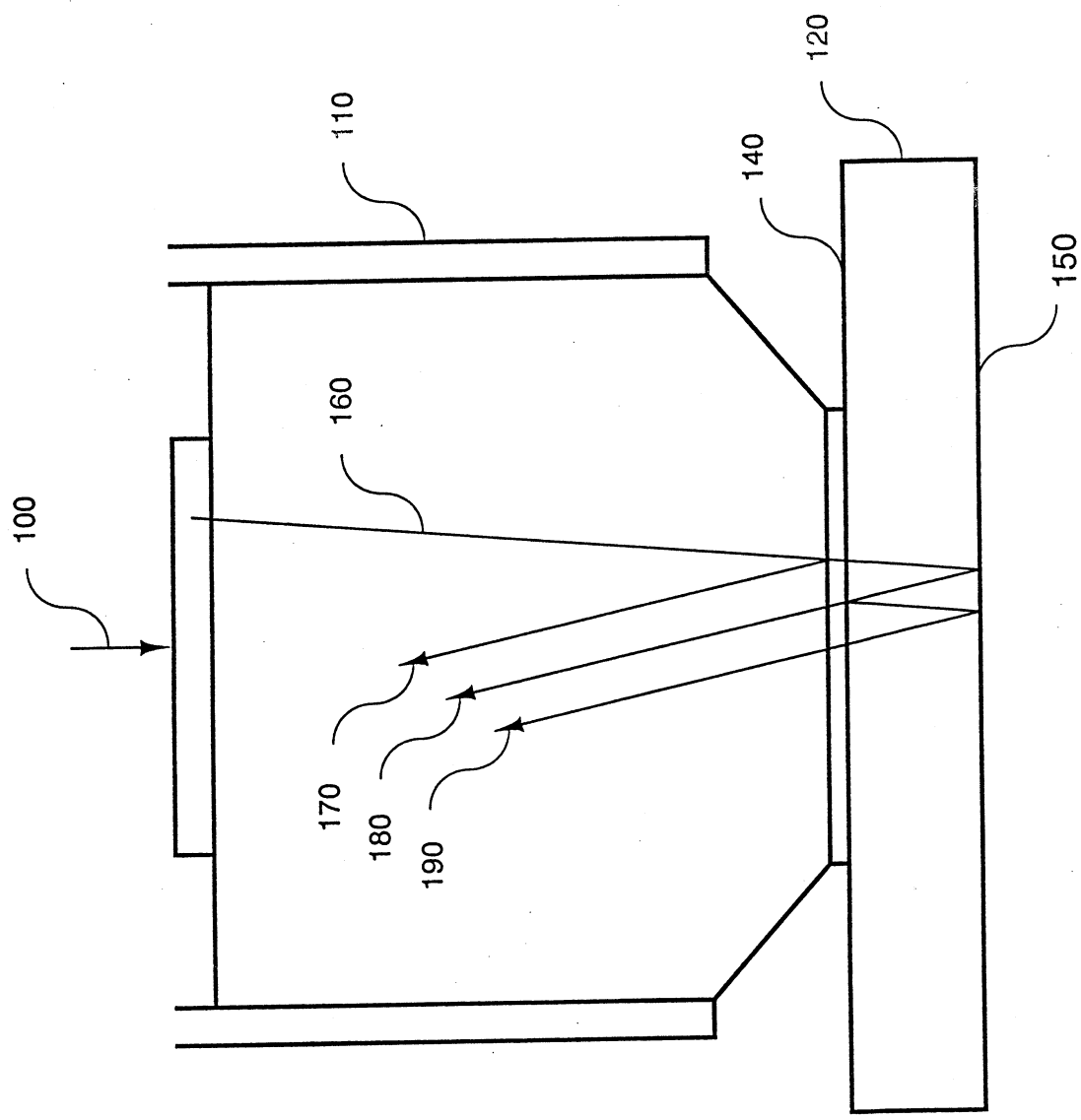


FIG. 1

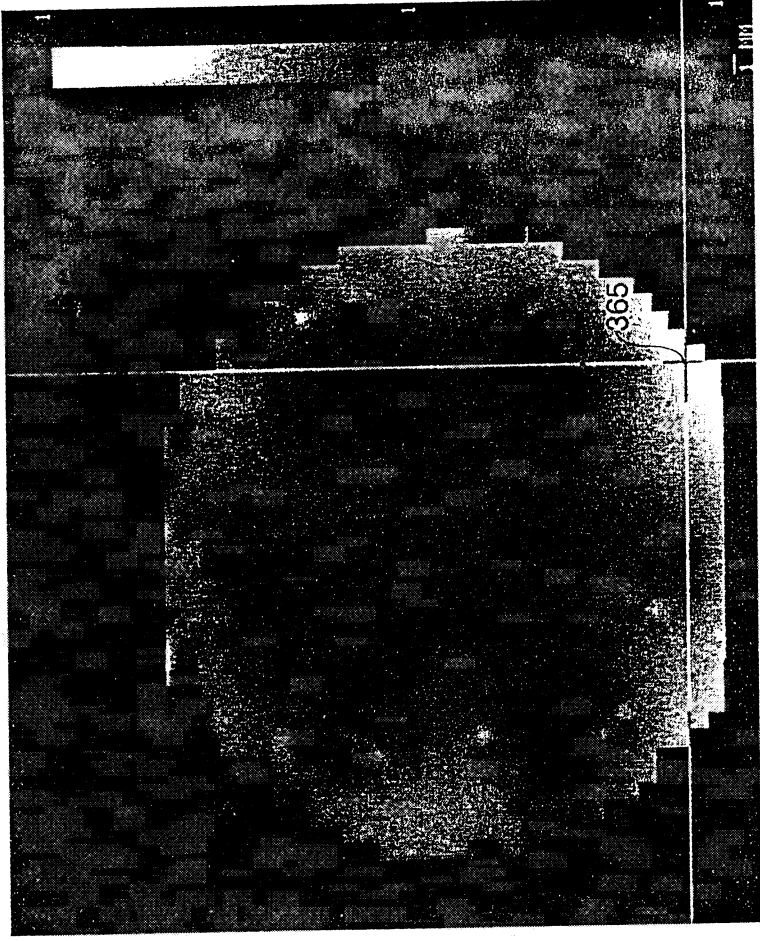


FIG. 2

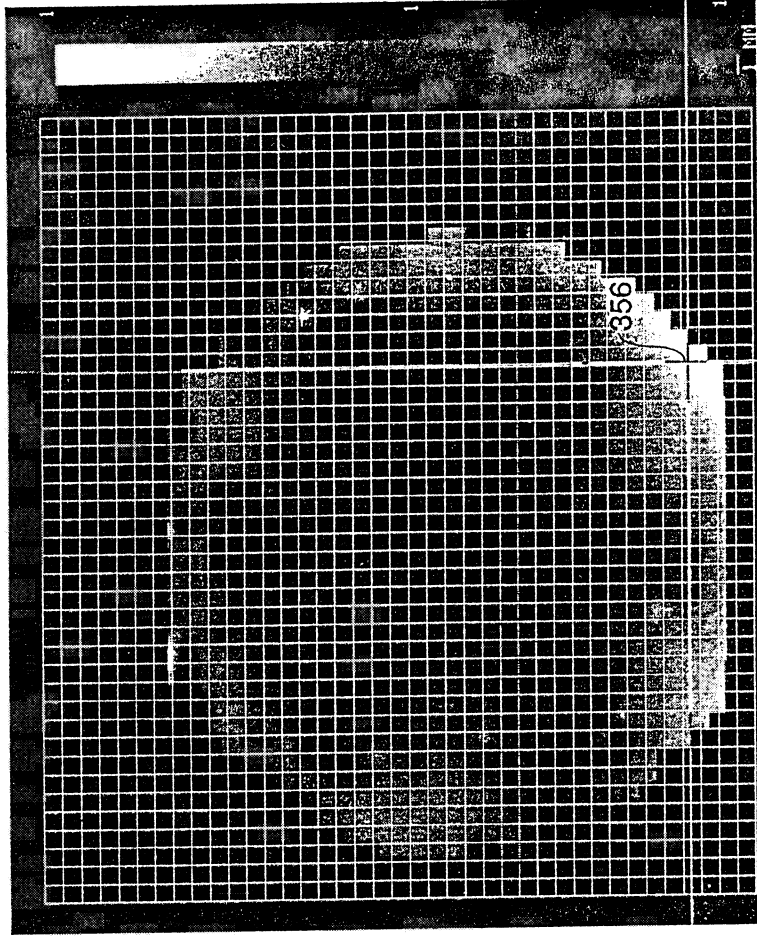


FIG. 3

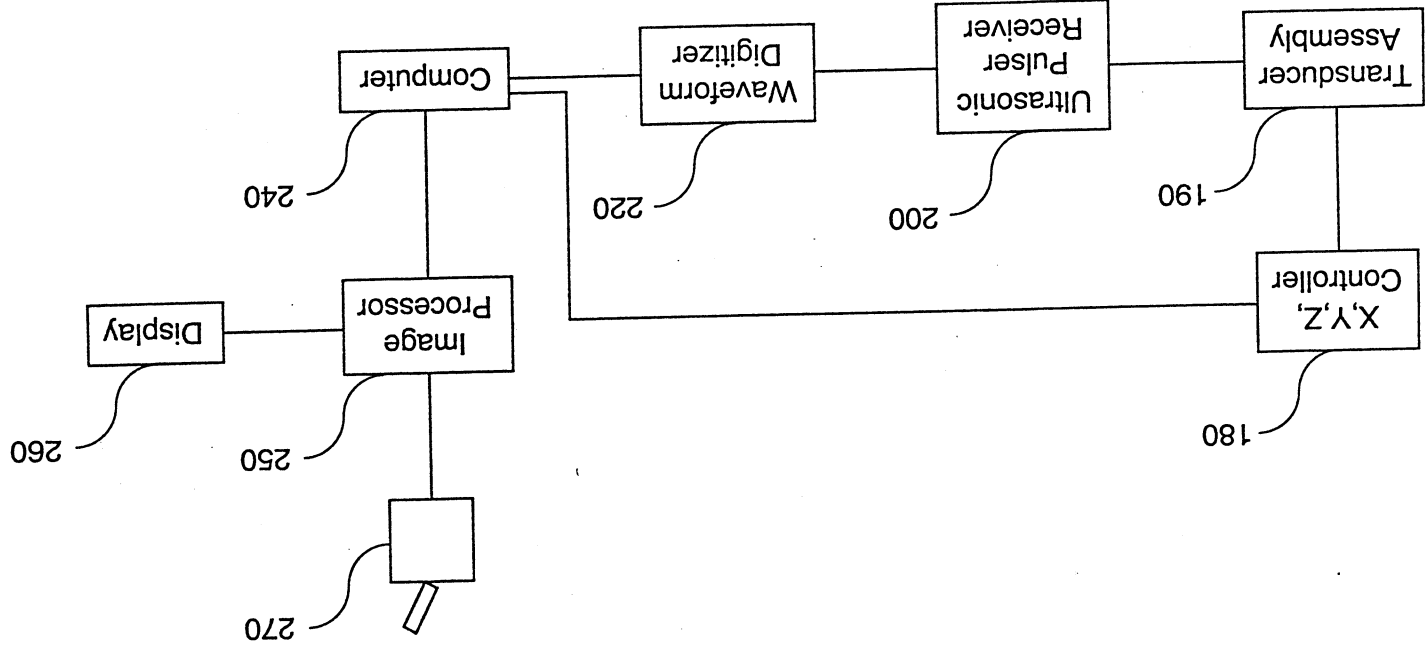


FIG. 4

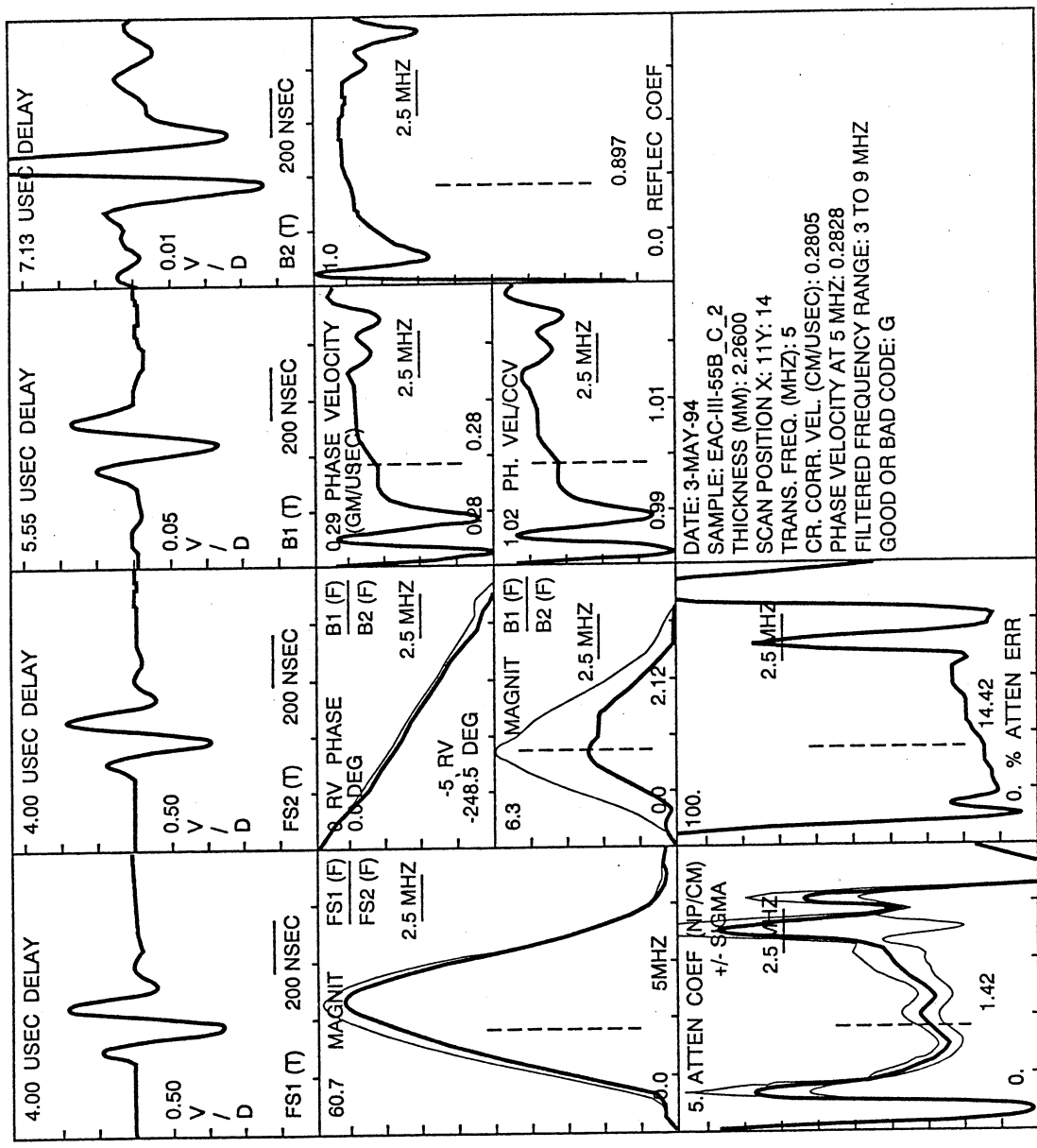


FIG. 5



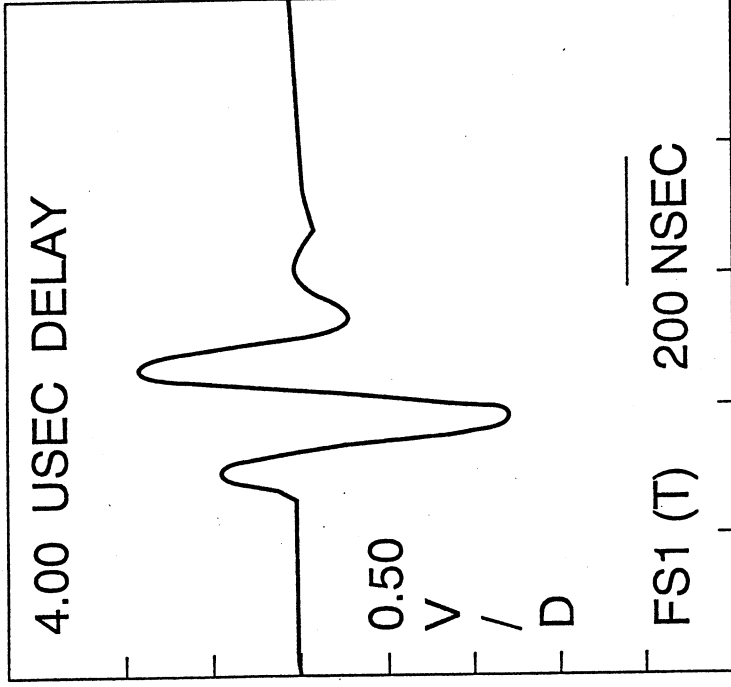


FIG. 6

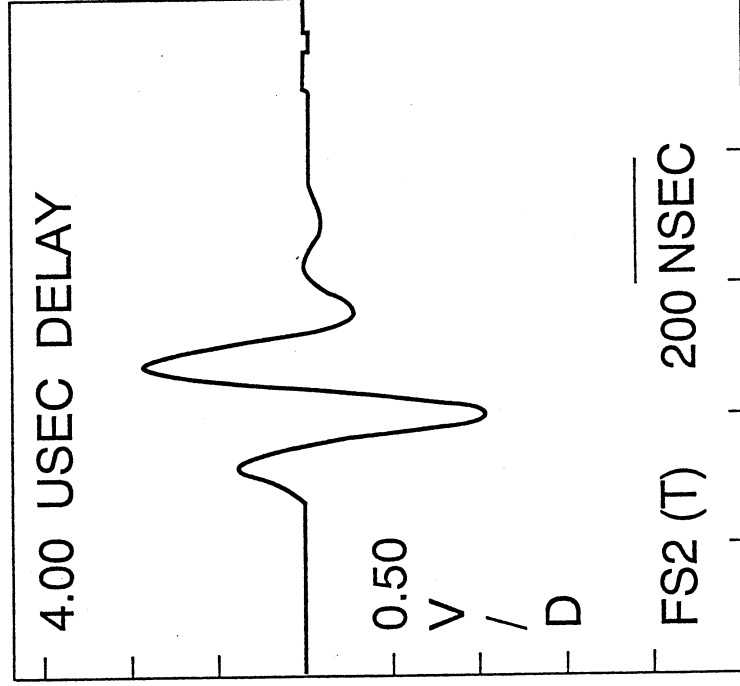


FIG. 7

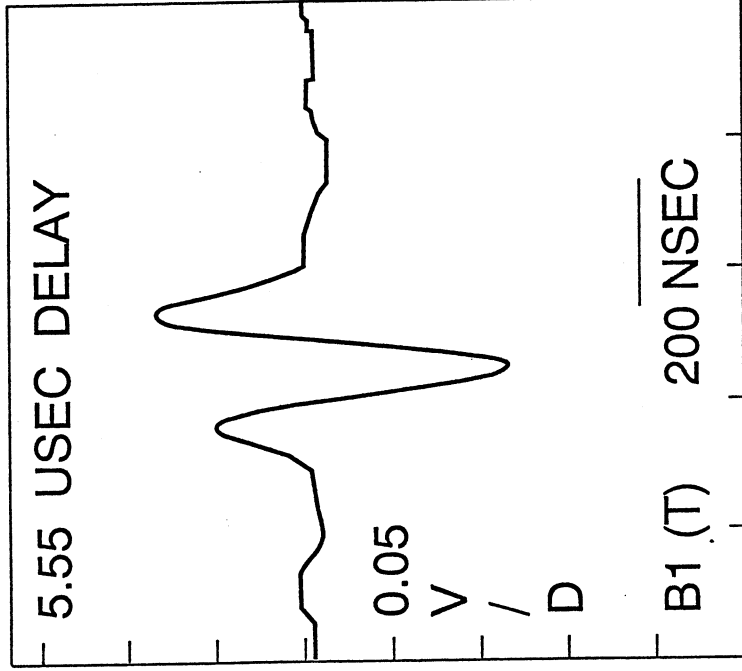


FIG. 8

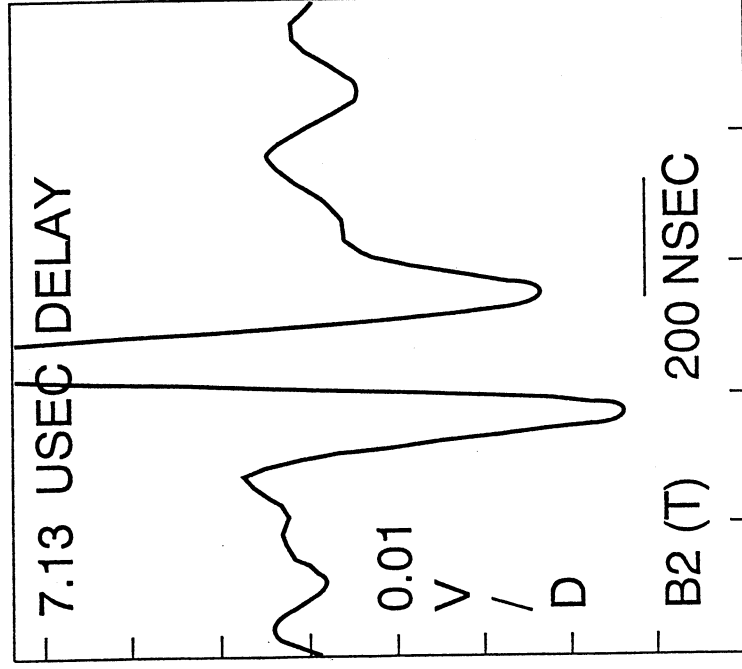


FIG. 9

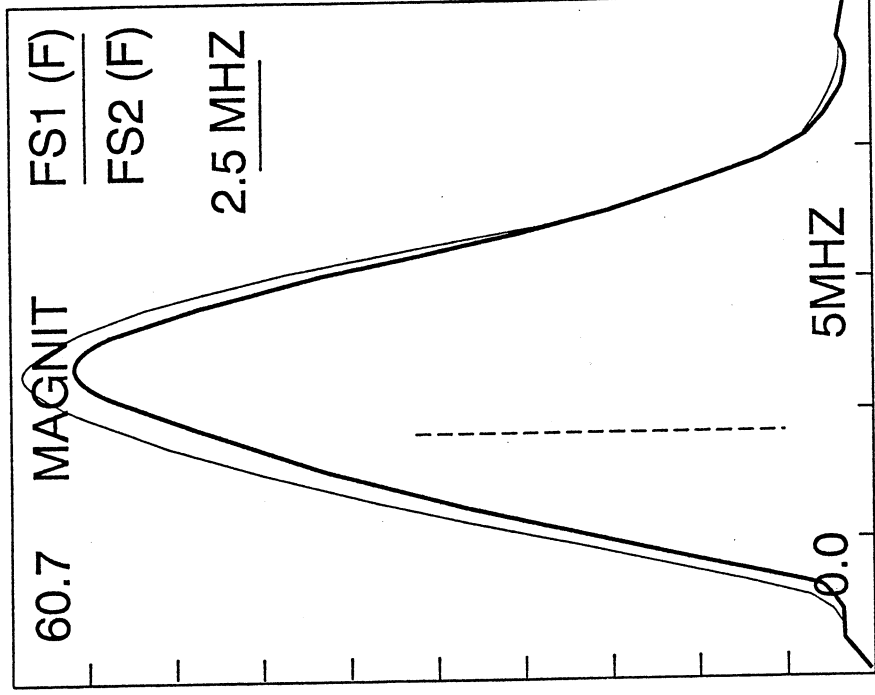


FIG. 10

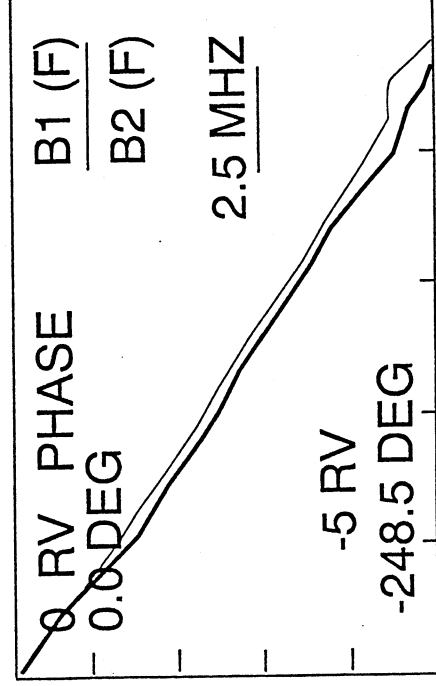


FIG. 11

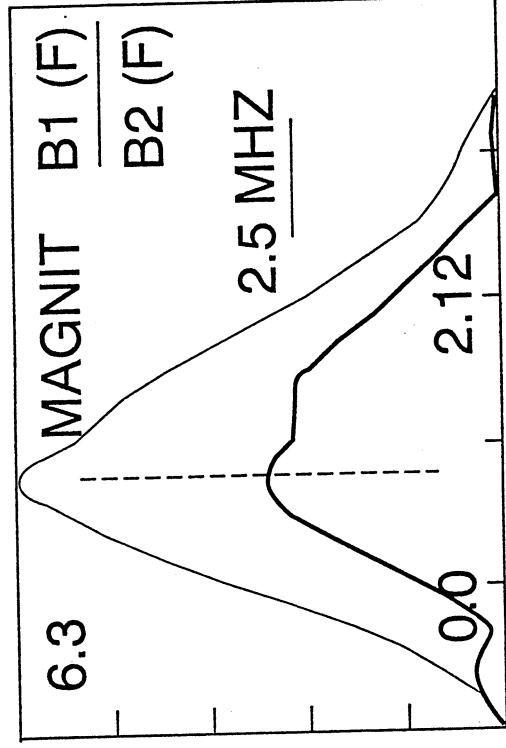


FIG. 12

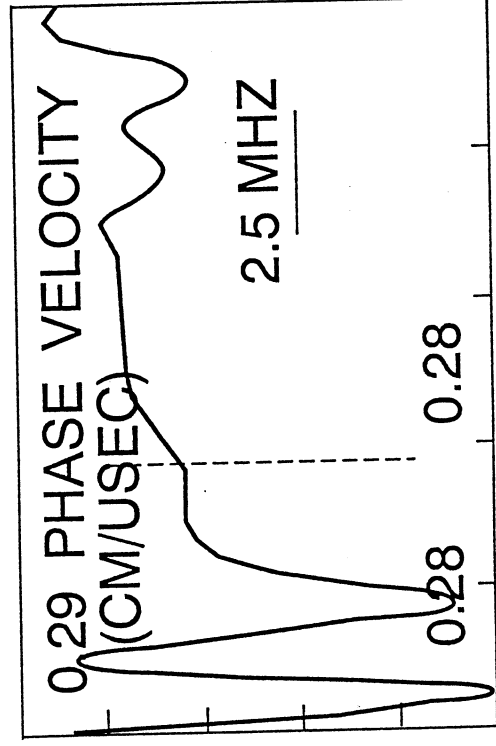


FIG. 13

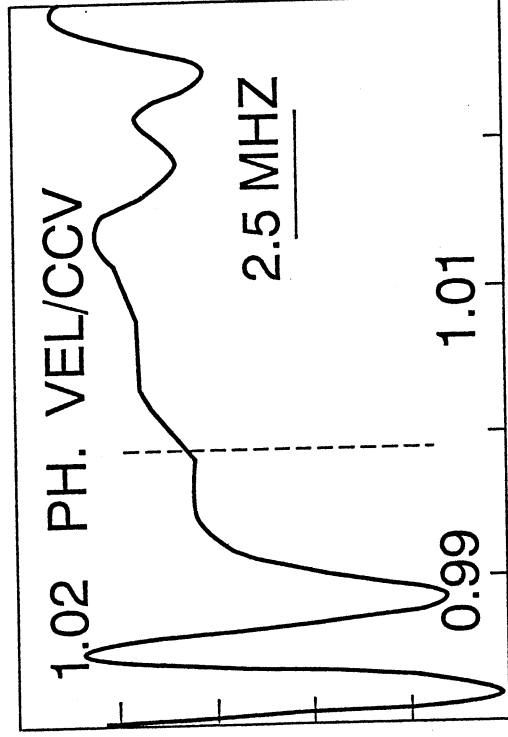


FIG. 14

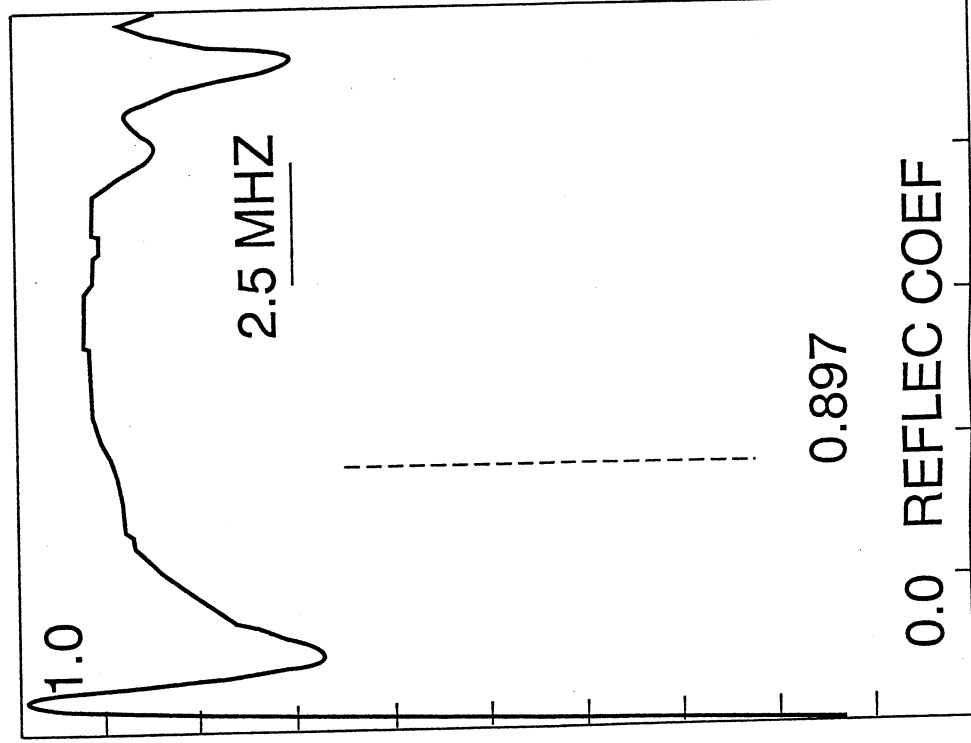


FIG. 15

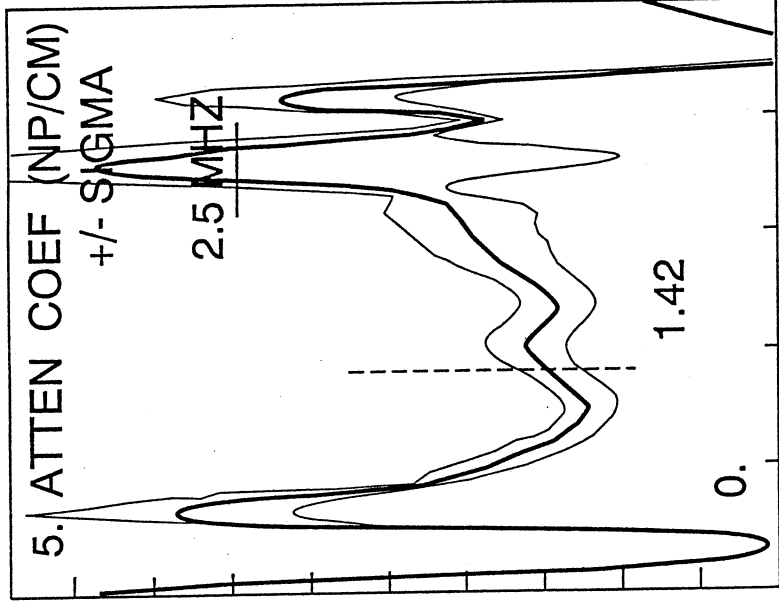


FIG. 16

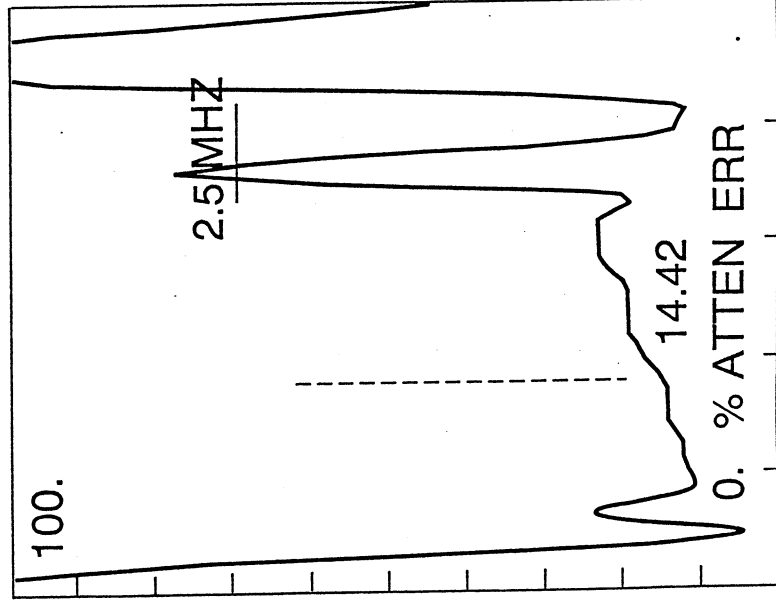


FIG. 17