MAJOR DEVELOPMENTS IN ULTRASONIC SENSOR TECHNOLOGY FOR INDUSTRIAL SAFETY & MATERIALS' RELIABILITY, AND FOR HEALTH CARE

(A partial list of Ultran's contributions from innovative developments and applications of modern ultrasound)

1. **High Intensity Guided Ultrasonic Sensors - HIGUS**
2. **Very High Temperature Transducers**
3. **LAMBDA Transducers**
4. **DRY COUPLING Transducers**
5. **AIR/GAS Propagation Transducers**

6. **Advanced Ultrasonic System - HPN: 5000**

7. **Analysis of Paper & Like Materials**
8. **Analysis of Vegetables and Fruits**
9. **Analysis of Legume, Nuts, & Other Grains**
10. **Non-Immersion Ultrasonic Imaging**

11. **Special Publications Describing More Applications & Uses of Modern Ultrasound**

For any information, please contact Mahesh C. Bhardwaj

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ultran laboratories, inc.
1020 East Boal Avenue,
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

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redefining the limits of ultrasound

ultran laboratories, inc.
1020 East Boal Avenue
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

HIGUS*
High Intensity Guided Ultrasonic Sensor

A Major Breakthrough in Ultrasound for Multiple Industrial & Medical Uses

Since its inception in 1978 Ultran has vigorously pursued the dream of developing ultrasound for materials quality and reliability. We never accepted the then limited scope of *"nondestructive testing for overt flaws in metals."* We knew that this potent wave was capable of going a very long distance, such as:

1. **For characterization and diagnostic applications:** Detection of defects and properties in the early stages of materials processing, for characterization of liquid-sensitive, porous, green, and attenuative materials; and for medical diagnostics.

2. **For chemical and physical reaction acceleration:** Formation of new compounds under ambient conditions; and unwanted tissue removal, particularly to cure the vascular disease.

We also knew that none of these applications could be realized until ultrasound itself was developed first, and that its interaction with the medium of propagation was understood in practical terms. In essence, for 15 years we have been creating this acutely needed knowledge base, besides developing the sensor technology.

Whereas at Ultran we are proud of our many advancements in ultrasound, we are particularly delighted and intrigued by our development of HIGUS*, which began as a concept several years ago. Our main objective was to create a mechanism of transporting ultrasound analogous to power transmission lines. We wanted to accomplish this in order to facilitate transmission and reception of ultrasound while the medium to be tested was either under extreme physico-chemical conditions, or access to it was arduous, or both. For medical applications, its significance was obvious - with such a mechanism we could apply ultrasound through a benign transmission line, rather than introducing complex and potentially dangerous piezoelectric and other materials inside the human body. HIGUS appears to have the characteristics that could achieve such objectives.

HIGUS is a carefully crafted geometrical acoustics combination of active ultrasonic transducer and ultrasound guiding rod/fiber. Laboratory experiments with limited frequencies have demonstrated very high intensity and true bulk wave propagation through the guide rod/fiber up to more than 25cm. We envision, even at relatively high frequencies, it should be feasible to transmit measurable, and high signal to noise ratio, ultrasound through guided rods greater than several metres long.

HIGUS can be applied to continuosly monitor ultrasonic velocity and received signal amplitude as functions of material process parameters. Industries that can benefit from this development are those that are involved with ceramic, metals, polymers, liquids, gases, and composite materials; food and drug, nuclear and utilities; and much more. HIGUS also has potential in invasive or non-invasive microsurgical and diagnostic applications.

If you are interested in the applications of HIGUS, please contact Ultran.

HIGUS: 394

**Patents pending.*

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ultran laboratories, inc.
1020 East Boal Avenue
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax
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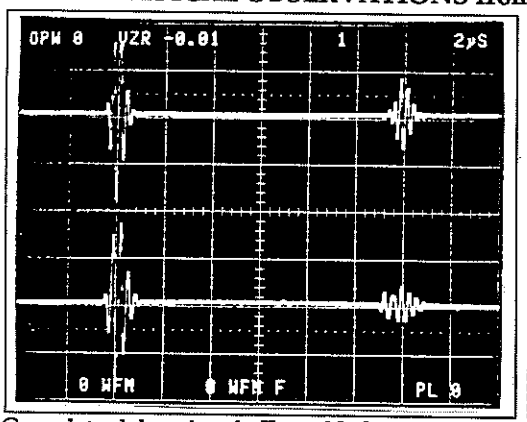
VERY HIGH TEMPERATURE ULTRASONIC TRANSDUCERS*

(Information & Offer)

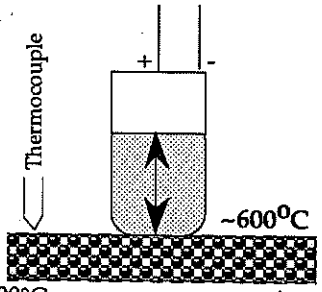
**U.S. Patent Approved*

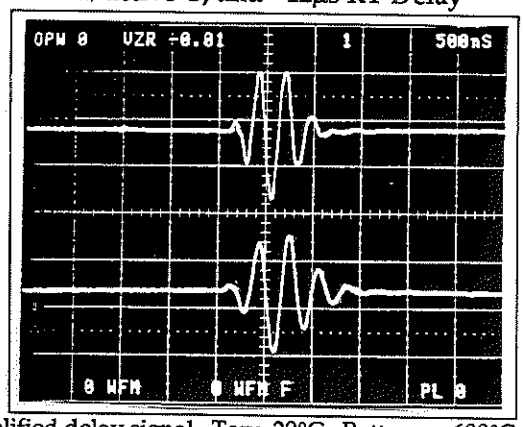
Following 20 years of relentless R&D, Ultran is pleased to announce the availability of high reliability acoustically, thermally, and mechanically stable ultrasonic transducers for high temperature uses. The current design is rated to withstand 800°C without compression, and has been successfully tested up to ~600°C for continuous use. With modifications it is possible to increase high temperature performance >1,500°C.

1. TYPICAL OBSERVATIONS from HTD50-5 - 5MHz, 0.5in (12.7mm) active Φ, and ~12μs RT Delay



Complete delay signal. Top: 20°C. Bottom: ~600°C.





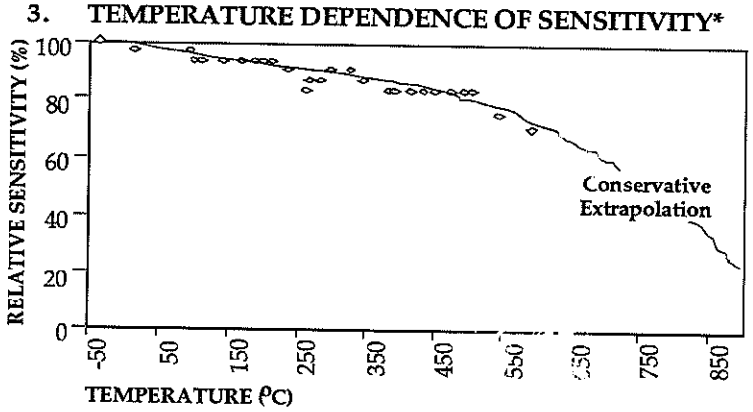
Amplified delay signal. Top: 20°C. Bottom: ~600°C

2. MEASURED PARAMETERS

MEASUREMENT TEMPERATURE (°C)	PULSE[1] WIDTH (μs)	SIGNAL TO[2] NOISE RATIO (dB)	SENSITIVITY[3] (dB)	BANDWIDTH[4] (%)	FREQUENCY LOSS	δ_{tof}[5] (%)	MEASUREMENT[6] RANGE WITHIN DELAY SPACE (μs)
20	0.7	>34	-40	>50%	---	---	<1 to ~12
~600	1.0	>30	-44	>40%	NONE	<1	~1 to ~12

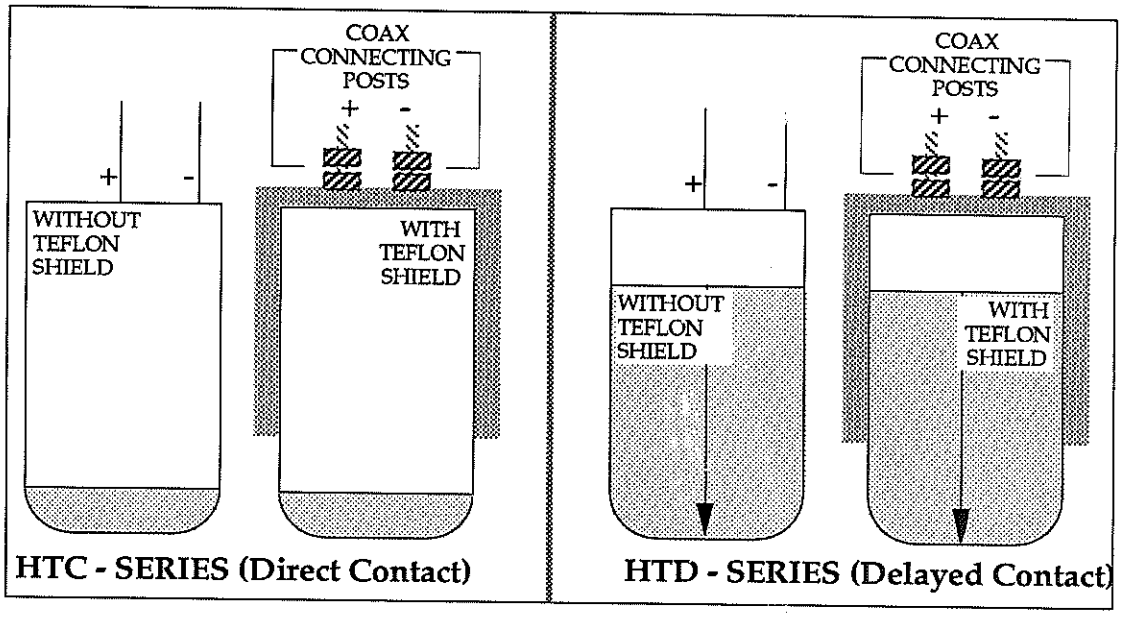
1. *Measured from trailing to leading edge of rf envelope of delay tip reflection.*
2. *Measured by correlating the highest noise signal between the first two delay reflections with the first delay reflection.*
3. *-20 Log A_1/A_2, where A_1 is amplitude of delay tip reflection and A_2 is the amplitude of the excitation pulse.*
4. *Measured as %age of bandwidth center frequency at -6dB level.*
5. *Reported as %age increase in time of flight (tof) from 20°C to ~600°C.*
6. *Between the first two delay reflections - for example, in steel from ~2mm to >35mm. Measurements can also be made well beyond 2nd and 3rd reflections.*

3. TEMPERATURE DEPENDENCE OF SENSITIVITY*



***Each data point was obtained after 10 minute waiting period at the specified temperature.**

4. STYLES OFFERED*



4.1 HTC - Series for Direct Contact Applications
Successfully Tested to >330°C (>625°F)

4.1.1 Main transducer **without** protective Teflon sleeve can be used as is for several applications, including *in situ* material process/property monitoring. At this stage the device can be adapted to customer's specific needs.

4.1.2 Main transducer **with** Teflon sleeve (optional and replaceable) can be used as an easy to handle ergonomic device where contact/immersion with high temperature liquids is not desired.

4.2 HTD - Series for Delayed Contact Applications
Successfully Tested to ~600°C (~1,110F°)

4.2.1 Main transducer **without** protective Teflon sleeve can be used as is for several applications, including *in situ* partial liquid immersion of delay tip up to 800°C (1,470°F) and higher. At this stage the device can be adapted to customer's specific needs. With modifications, high temperature limit can be raised >1,500°C (2,730°F).

4.2.2 Main transducer **with** Teflon sleeve (optional and replaceable) can be used as an easy to handle ergonomic device for several applications such as, thickness/corrosion, velocity, and other measurements.

Due to high cost of manufacture we suggest high temperature transducers with active area diameters of 0.50in (12.7mm) and 0.25in (6.3mm) within frequency range of <1.0 to ~10MHz. Ultran will be very happy to answer any questions that you may have about these special devices. If you need any assistance in your applications, we strongly encourage you to consult us.

**U.S. Patent approved*

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ultran laboratories, inc.
1020 East Boal Avenue,
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

ultran

ultran laboratories, inc.
1020 East Boal Avenue
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

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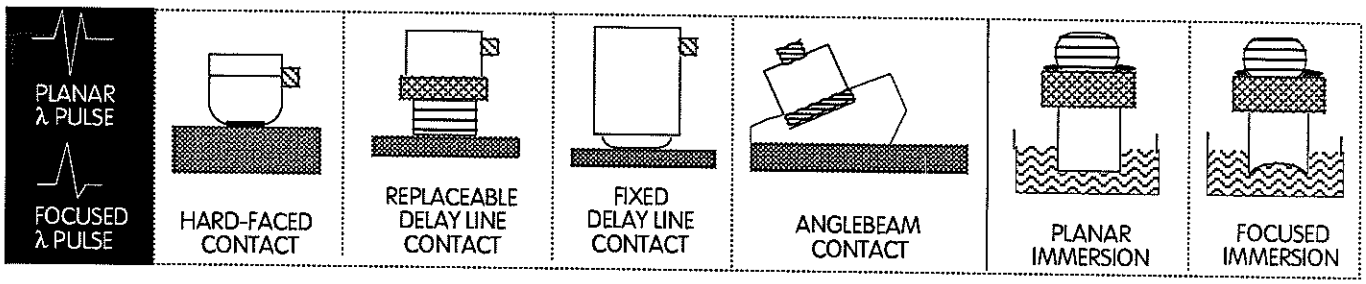
λ–SERIES ULTRASONIC TRANSDUCERS

For Ultra high resolution detectability, and microstructure characterization

Lambda Series transducers, typified by extremely short pulse widths (~0.5 to 1λ), are an Ultran original. These exceptional devices facilitate Ultra High Resolution and Detectability without using very high frequencies.* Lambda transducers have been optimized between <500KHz to >20MHz.

The following valuable tips for these unique transducers are the result of extensive experience in the development of NDC. A number of significant materials quality applications reported here would have been virtually impossible without this major development in sensor technology. If you require further information, please consult Gary Stead, Manager Applications & Marketing.



TYPE & CONFIGURATION	MATERIAL SUITABILITY[1]	TYPICAL APPLICATIONS	LIMITATIONS	RECOMMENDED MODELS[2]
CONTACT TYPES				
Hard-Faced (high Z) Contact	High Z, high ρ, dense mats. (Metals, dense ceramics, etc.).	High resolution, close-surface defects, velocity/density, bond/disbond, etc.	Low Z, low ρ and high porosity mats. (Polymers and their composites, porous and like materials).	LC75-1, LC50-2, LC50-5, LC37-10, LC25-10
Replaceable Delay Line Contact	All, except porous materials.	Very high resolution thickness/thinness gauging velocity/density, bond/disbond, microstructure, etc.	Couplant application between transducer and delay line from time to time.	LRD50-5, LRD25-10
Fixed delay Line Contact	All, except porous materials.	Very high resolution thickness/thinness gauging velocity/density, bond/disbond, microstructure, etc.	None, except porous materials.	LFD50-5, LFD25-10
Anglebeam Contact Replaceable	Metals, dense ceramics, etc.	Precision detection of oblique defects, welds, etc.	None, except porous and very low density materials.	LT50-5, LT25-10
IMMERSION TYPES				
Unfocused (Planar)	All, except porous materials.	Very high resolution, big sub-surface defects, velocity/density, microstructure, etc.	None, except open porosity materials.	LS50-5, LS25-10
Focused (Point and Cylindrical)	All, except porous materials	Very high resolution, very high detectability.	None, except open porosity materials.	LS75-2-P6, LS50-5-P3 LS37-10-P3, LS25-10-P0.75 LS25-10-P1

[1]For porous, liquid-sensitive, green, and other materials applications, please inquire about available alternatives from Ultran.
Z - Acoustic Impedance; ρ - Density.

[2]Highlighted models are readily available. Experience shows that a vast majority of NDT/NDC applications can be significantly enhanced by the use of recommended models.

***For applications and instructional information, please consult:**

1. *M.C. Bhardwaj, "High Resolution Ultrasonic Nondestructive Characterization," Cer. Bull., v. 69, n. 9 (1990).*
2. *M.C. Bhardwaj and A.S. Bhalla, " Ultrasonic Characterization of Ceramic Superconductors," J. Mat. Sci. Lett., v. 10 (1991).*
3. *M.C. Bhardwaj, "NDC Begins Where NDT Stops," Interceram, Int. Cer. Rev., v. 40, n. 5 (1991).*

LAMBDA:793

DRY COUPLING ULTRASONIC TRANSDUCERS

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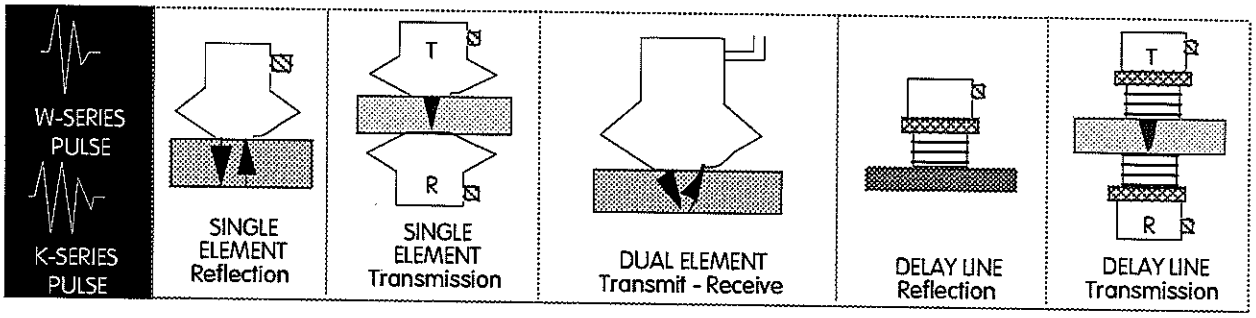
1020 East Boal Avenue
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

For Non-Destructive Characterization (NDC) of green, porous, liquid-sensitive and other materials

Dry Coupling of transducers is an original development of Ultran. It was perfected in 1982 to facilitate NDC/NDE of liquid-sensitive, green, porous, and in-process materials; or where the use of liquid couplants is simply a nuisance. These transducers have been perfected for both longitudinal and shear wave measurement from <200KHz to >20MHz.*

Following tips for these unique transducers are the result of our years of experience in the development of NDC. A number of materials quality applications would have been virtually impossible without this major development in sensor technology. If you require further information, please consult Gary Stead, Manager Applications & Marketing.



TYPE & CONFIGURATION	MATERIAL SUITABILITY[1]	TYPICAL APPLICATIONS[2] APPLICATIONS	LIMITATIONS[3]	RECOMMENDED MODELS[4]
Single Element (Reflection Mode)	Low Z, low ρ low α (plastics, CFRP, and similar materials).	Thickness, velocity, bond/ disbond, etc.	High Z, high ρ, high α cmetals, ceramics and porous materials).	**WD50-1, WD50-2, WD37-2, WD25-5 KD50-1, KD50-2**
Single Element (Transmission Mode)	All materials, but best on green, materials. Also lumber, and concrete. Highly suitable for very attenuative materials.	Velocity/density, bond/ plastic composites, and porous	None disbond, gross defects.	**WD50-0.25, WD50-0.5 WD25-5 KD50-0.25, KD50-0.5 KD50-1, KD50-2**
Dual Element (Transmit-Receive)	Low Z, low *r*, low *a* (plastics, GFRP, CFRP, green, and similar materials. Also suitable for metals and ceramics	Thickness, defects, bond/ disbond, etc. Also when surfaces are non parallel and rough.	High Z, high ρ, high α cmetals, eramics, and porous materials).	DTR50-1,DTR50-2, DTR37-5, DTR25-5
Delay Line (Reflection)	All, except porous.	Thickness, velocity/density bond/disbond in relatively thin materials.	Very thick and porous materials.	**DCB25-5, DCB25-10**
Delay Line (Transmission)	All, including lumber, concrete, etc. Highly suitable for very thick materials.	Velocity/density bond/disbond, etc.	None	DCB50-0.5 **DCB50-1, DCB50-2**

[1]Z - Acoustic Impedance; ρ - Density; α - Attenuation; GFRP: Glass Fiber Reinforced Plastic; CFRP: Carbon Fiber Reinforced Plastic.
[2]For shear wave applications, 0° incidence shear wave dry coupling transducers are also avialbale. For details, please consult Ultran.
[3]Dry coupling transducers cannot be slid over test materials.
[4]Highlighted models are readily available.

***For applications and instructional information, please consult:**

1. *M.C. Bhardwaj and K. Trippett, "Nondestructive Characterization of Green and Sintered Ceramics," in Proceedings of the First International Symposium on the Science of Engineering Ceramics, S. Kimura and K. Niihara Editors, Ceramic Society of Japan, Tokyo (1991).* *169, Japan*
2. *M.C. Bhardwaj, "NDC Begins Where NDT Stops," Interceram, Int. Cer. Rev., v. 40, n. 5 (1991).*

DC: 793

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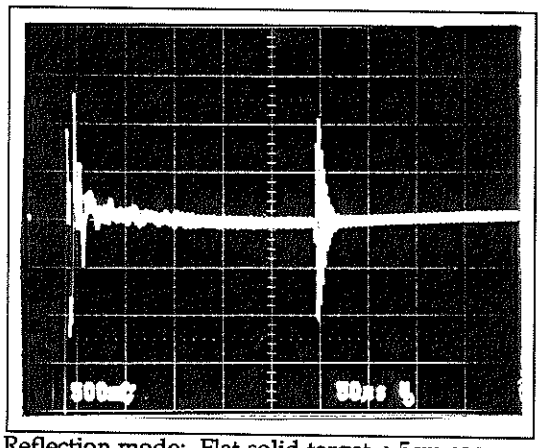
ultran laboratories, inc.
1020 East Boal Avenue
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

AIR/GAS PROPAGATION ULTRASONIC TRANSDUCERS

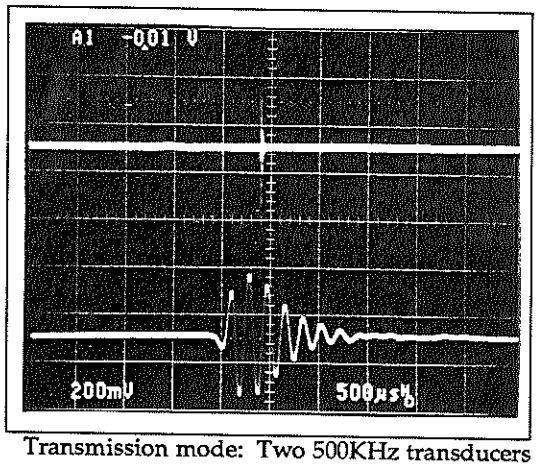
For level & remote sensing, non-contact profiling, object identification, gas analysis, and other uses.

Following the success of dry coupling transducers, in 1983 we thought of the possibility of high frequency ultrasound propagation in air. This simple curiosity finally led to the development of air/gas propagation transducers up to frequencies as high as ~5MHz. Strictly as receivers we have also produced such devices up to at least 20MHz. Today, these devices are finding interesting applications such as analysis of gases, remote sensing, non-contact surface profiling and imaging. If you believe you can benefit from this unusual development in ultrasound, please contact Ultran.

TYPICAL OBSERVATIONS OF REFLECTION AND TRANSMISSION MODE OPERATION OF AIR/GAS PROPAGATION TRANSDUCERS



Reflection mode: Flat solid target, >5cm away from 1.00MHz transducer in air.



Transmission mode: Two 500KHz transducers are separated by ~1.0m in air.
Top: Complete signal. Bottom: Amplified received signal.

AVAILABILITY - Following Air/Gas propagation devices are readily available*

FREQUENCY (MHz)	ACTIVE Φ in	ACTIVE Φ mm	FOCAL LENGTH* in	FOCAL LENGTH* mm	CATALOG NUMBER W-Series	CATALOG NUMBER K-Series
0.25	1.0	25	—		WG100-0.25	KG100-0.25
	1.0	25	2.0	51	WG100-0.25-P2	KG100-0.25-P2
0.5	1.0	25	—		WG100-0.5	KG100-0.5
	1.0	25	2.0	51	WG100-0.5-P2	KG100-0.5-P2
1.0	0.75	25	—		WG75-1	KG75-1
	0.75	25	2.0	51	WG75-1-P2	KG75-1-P2
	1.0	25	—		WG100-1	KG100-1
	1.0	25	2.0	51	WG100-1-P2	KG100-1-P2
2.0	0.50	13	—		WG50-2	KG50-2
	0.50	13	1	25	WG50-2-P1	KG50-2-P1
	0.75	25	—		WG75-2	KG75-2
	0.75	25	2.0	51	WG75-2-P2	KG75-2-P2
	1.0	25	—		WG100-1	KG100-2
	1.0	25	2.0	51	WG100-1-P2	KG100-2-P2

**If your application requires different styles, frequencies, and active area dimensions for Air/Gas propagation transducers, or if you need technical assistance, please contact Gary Stead, Manager, Applications and Marketing.*

VLF-394

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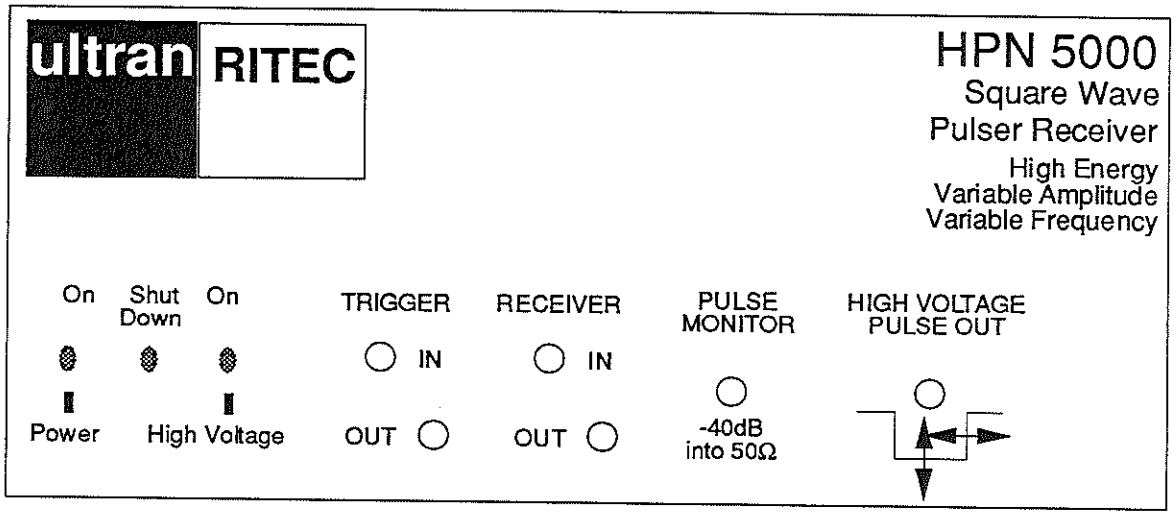
ultran laboratories, inc.
1020 East Boal Avenue,
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

HPN-5000
Advanced Ultrasonic System
(Introduction & Specifications)

HPN-5000 is a novel computer-controlled pulser-receiver incorporating the most advanced electronic components and innovative design circuitry. Ultran is pleased to offer this unique system for a variety of NDC (NonDestructive Characterization) and other novel uses of modern ultrasound.



HPN-5000, not only outperforms conventional ultrasonic systems, but with Ultran's advanced transducers, it also facilitates nondestructive examination of extremely diverse materials ranging all the way from attenuative and porous materials to liquids, and air and gaseous media.

By utilizing the frequency synthesizer of HPN-5000 you may use either a single square wave pulse or a burst of square wave pulses up to a total of 255 in the burst. By doing so, you can now fully optimize the transducer excitation and amplification characteristics with respect to your test materials applications.

These highly desirable applications have been made possible by the relentless R&D efforts of industry's two giants: Gary Peterson, the world renowned expert in RF systems engineering, and Mahesh Bhardwaj's innovative transducer technology and ultrasonic know-how. Now their combined expertise is available for materials reliability and safety, and for bio-medical applications.

You may purchase HPN-5000 as a single unit, or in a fully configured state dedicated to your specific problem-solving. Please consult Ultran for various options.

HPN-5000 SPECIFICATIONS*

(All pulser and receiver parameters are computer controlled and can be adjusted from the set up menu)

Pulser Section	
Pulse Amplitude:	-400 to -25Volts in 256 (8bits) steps
Output Impedance:	<4Ω during the pulse and <8Ω during the time-off
Width Control:	Pulse width adjustable from <25ns to >10ms. Accomplished with four 8 bit ranges. Range switch is under automatic computer control and pulse width can be changed from the menu.
Fall Time (Leading edge):	Typically, 5ns into 50Ω.
Rise Time (Trailing edge):	Typically 8ns into 50Ω.
Trigger Source:	Computer or either +ve or -ve TTL from an external source.
Repetition Rate:	0.17Hz to 10KHz in 1, 1.7, 2.5, 5 sequence.
Cycle Counter:	0 to 255 pulses in single pulse steps.
Outputs:	1. Full power - BNC connector. 2. Output Monitor: -40dB into 50Ω.
Receiver Section	
Frequency Range:	From 20KHz to 10MHz
High Pass Filters:	20KHz, 100KHz, and 500KHz
Low Pass Filter:	2, 5, and 10MHz
Total Gain:	~80dB
Gain Control Range:	-10 to 68dB in 2dB steps.
Input Impedance:	50W and High.
Mechanical	
Physical Dimensions (approx.):	H,W,D: 9, 17, 14in (23, 43, 35cm).
Weight (approx.):	25lb (11.4kg).
Power	
Standard:	110V or 220V.
Custom:	Specify.

**Furnished with computer interface card at no extra cost*
All specifications are subject to change without notice.
If you have special requirement or need technical assistance, please contact Ultran.

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ultran laboratories, inc.
1020 East Boal Avenue,
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

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1020 East Boal Avenue,
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

Ultrasonic NDC of Papers, Thin Films, Coatings and like materials

*Performed by HPN-5000 Advanced Ultrasonic System and Novel Transducer Technology

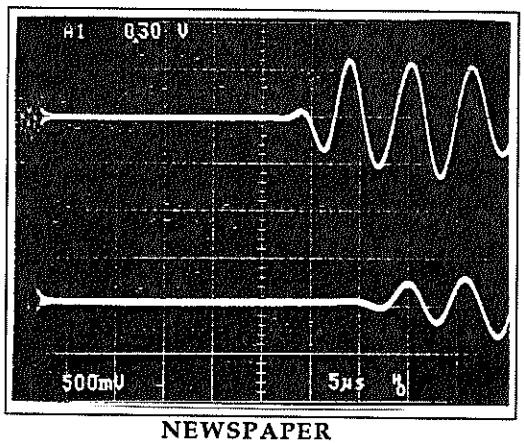
1. INTRODUCTION

It is now well-established that ultrasound is capable of providing useful processing and applications related information about any material through which it can be propagated.[1] For example, velocities of ultrasound can be directly correlated to density, porosity, humidity, pH, elastic and other properties of isotropic and anisotropic materials. Similarly, frequency-dependence of ultrasonic attenuation/absorption can provide important information about materials microstructure and composotion. Whereas ultrasonic techniques have been well developed in the metals industry, the same isn't true for the non-metals industries. These limitations have been greatly overcome by Ultran's 20 years of intense research into the science of ultrasound and development of techniques that can be adapted under manufacturing/factory conditions.[2]

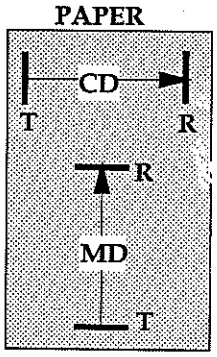
In this short applications note we are pleased to provide the feasibility of NonDestructive Characterization (NDC) of papers, paper products, thin films, coatings, etc. - for quality enhancement and for the conservation of our natural resources.

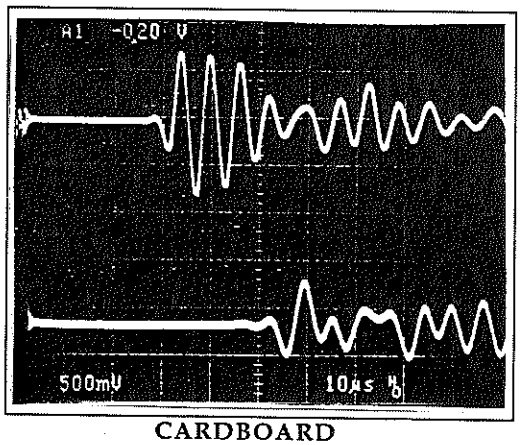
2. SELECTED EXAMPLES, OBSERVATIONS, AND TECHNIQUES

2.1 In-plane determination of ultrasonic velocities.



NEWSPAPER





CARDBOARD

Explanation of the terms

Top Traces in both photos correspond to ultrasound propagation in CD (Cross Direction).
Bottom Traces in both photos correspond to ultrasound propagation in MD (Machine Direction).
Distance between T (Transmitting transducer) and R (Receiving transducer) in all cases is 101.6mm.

Observations

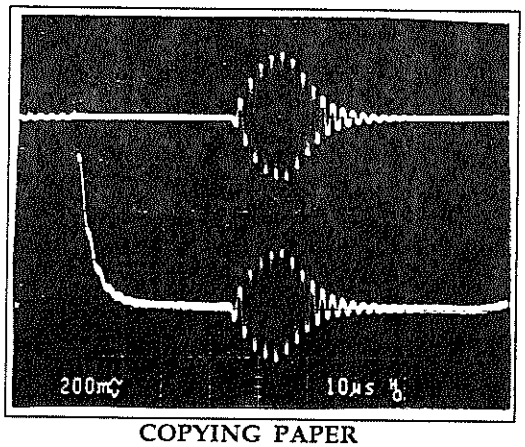
Newspaper	Cardboard
CD Measurement: ToF: 27µs, Velocity: 3,760m/s	CD Measurement ToF: 27µs, Velocity: 3,760m/s
MD Measurement: ToF: 34µs, Velocity: 2,990m/s	MD Measurement ToF: 48µs, Velocity: 2,100m/s

***Technique and equipment**

TECHNIQUE: Line contact dry coupling technique - ULTRAN.
TRANSDUCERS: Special line contact surface wave - ULTRAN.
HARDWARE: HPN-5000, an advanced computer-controlled ultrasonic system - ULTRAN

1. *M.C. Bhardwaj, "Evolution, Practical Concepts, and Examples of Ultrasonic NDC," Ceramic Monographs, Interceram 41 (1992) [7/8] #4.5 and 42 (1993) [1] #4.5, Handbook of Ceramics, Verlag Schmidt GmbH, Freiburg, Germany.*
2. *Ultran Laboratories, Inc., "Some Recent Developments in Ultrasonic Sensor and Related Applications Technologies from Ultran," an Ultran Publication U-1093.*

2.2 In-thickness determination of ultrasonic velocities



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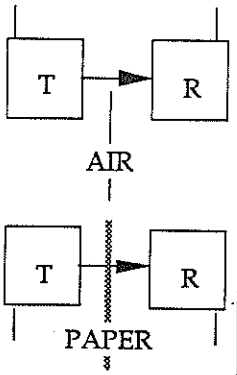

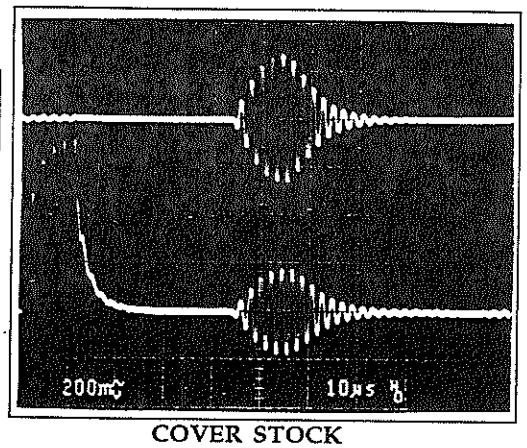

COVER STOCK

Explanation of the terms.

Top Traces in both photos correspond to ultrasound propagation in column of ~15mm air between T (Transmitting transducer) and R (Receiving transducer)., giving Time of Flight (ToF): t_1

Bottom Traces in both photos correspond to ultrasound propagation in the paper sandwiched between air column, giving Time of Flight ToF: t_2

Therefore, ToF in paper: $t_1 - t_2$.

Observations

Copying paper
Velocity of ultrasound in copying paper: 220m/s

Cover stock
Velocity of ultrasound in cover stock paper: 370m/s

***Technique and equipment**

TECHNIQUE: Non-Contact - ULTRAN.
TRANSDUCERS: High frequency air/gas propagation - ULTRAN.
HARDWARE: HPN-5000, an advanced computer-controlled ultrasonic system - ULTRAN

3. TABLE OF ULTRASONIC VELOCITIES OF A FEW PAPERS AND LIKE MATERIALS*

PAPER TYPE	THICKNESS (mm)	T-R DISTANCE (mm) (for in-plane testing)	VELOCITY (m/s)		
			Machine Direction	Cross Direction	Thickness Direction
Copy Paper	0.089	101.6	3,240	4,100	220
Bond Paper	0.127	101.6	3,200	4,230	300
Cover Stock	0.228	101.6	2,860	4,020	370
Cardboard	1.016	101.6	2,100	3,760	400
Newspaper	0.094	101.6	2,990	3,760	200
Manila Folder	0.254	101.6	2,710	3,830	320
GlossyPlotter	0.127	101.6	3,440	3,700	500
Facial Tissue (Single ply)	0.075	101.6	—	—	300

**All observations at 20°C, RH 50%. All materials are commercial.*

If you are interested in this or any other solution that modern ultrasound can produce, we strongly encourage you to contact Ultran.

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Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

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Ultrasonic NDC of Agricultural Products*
(Vegetables & Fruits)

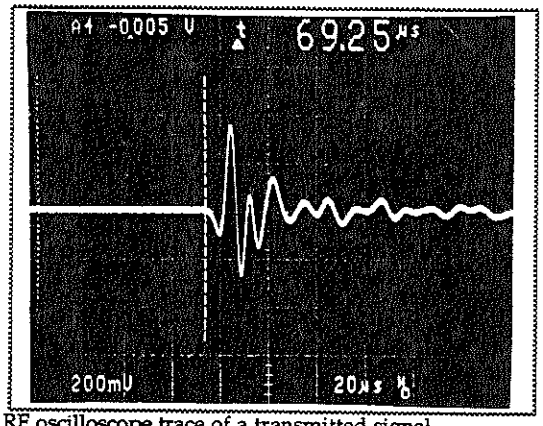
*Performed by HPN-5000 Advanced Ultrasonic System and Novel Transducer Technology

1. INTRODUCTION

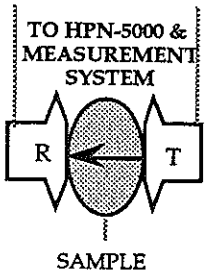
It is now well-established that ultrasound is capable of providing useful processing and applications related information about any material through which it can be propagated.[1] For example, velocities of ultrasound can be directly correlated to density, porosity, humidity, pH, elastic and other properties of isotropic and anisotropic materials. Similarly, frequency-dependence of ultrasonic attenuation/absorption can provide important information about materials microstructure and composotion. Whereas ultrasonic techniques for industrial materials are well-developed, the same isn't true for biological products. These limitations have been greatly overcome by Ultran's 20 years of intense research into the science of ultrasound and development of techniques that can be adapted for the investigation of botanical products.[2]

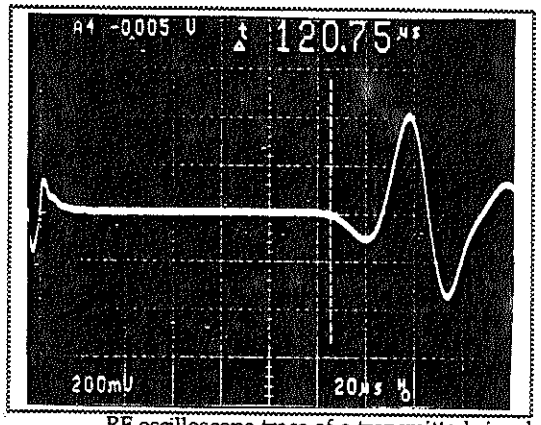
In this short applications note we are pleased to provide the feasibility of NonDestructive Characterization (NDC) of vegetables and fruits - for quality enhancement and good health. **If you are interested in using this application, please contact Ultran.**

2. SELECTED EXAMPLES, OBSERVATIONS, AND TECHNIQUES



RF oscilloscope trace of a transmitted signal from ripe unpeeled potato. Frequency: 250KHz
Technique: Direct Transmission. Velocity: 800m/s





RF oscilloscope trace of a transmitted signal from ripe cut red apple. Frequency: ~100KHz.
Technique: Direct Transmission. Velocity: 140m/s

3. TYPICAL ULTRASONIC CHARACTERISTICS OF SOME COMMON VEGETABLES AND FRUITS

VEGETABLE/FRUIT	CONDITION	VELOCITY (m/s)	REL ATTEN.	OPTIMUM FREQUENCY (range)
Potato (Idaho)	Ripe	800	Low	250KHz to <1.0MHz
Potato (Florida)	Ripe	700	Low	250KHz to <1.0MHz
Apple (Red)	Ripe	150	V. High	<50KHz to 100KHz
Potato (Idaho)	Partly rotten	600	High	50KHz to 250KHz
Yam (N. Carolina)	Ripe	250	V. High	50KHz to 100KHz
Banana (Unpeeled)	Ripe	250	V. High	<50KHz to 100KHz
Banana (Peeled)	Ripe	270	V. High	<50KHz to 100KHz
Carrot (Closer to leaves)	Ripe	550	High	50KHz to 250KHz
Carrot (Middle)	Ripe	600	High	50KHz to 250KHz
Carrot (Deeper in ground)	Ripe	580	High	50KHz to 250KHz
Turnip (Radial)	Ripe	240	V. High	<50KHz to 100KHz
Turnip (Along root)	Ripe	220	V. High	<50KHz to 100KHz
Daikon (Closer to leaves)	Ripe	280	V. High	<50KHz to 100KHz
Daikon (Middle)	Ripe	300	V. High	<50KHz to 100KHz
Daikon (Deeper in ground)	Ripe	370	V. High	<50KHz to 100KHz
Asian Pear (Whole unpeeled)	Ripe	240 (?)	V. High	<50KHz to 100KHz
Asian Pear (Cut)	Ripe	2,600	Low	500KHz to 2MHz
Grape (Seedless, axial)	Ripe	1,800	Low	500KHz to 2MHz
Grape (Seedless, radial)	Ripe	1,300	Low	500KHz to 1MHz

1. *M.C. Bhardwaj, "Evolution, Practical Concepts, and Examples of Ultrasonic NDC," Ceramic Monographs, Interceram 41 (1992) [7/8] #4.5 and 42 (1993) [1] #4.5, Handbook of Ceramics, Verlag Schmidt GmbH, Freiburg, Germany.*
2. *Ultran Laboratories, Inc., "Some Recent Developments in Ultrasonic Sensor and Related Applications Technologies from Ultran," an Ultran Publication U-1093.*

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Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

Ultrasonic NDC of Agricultural Products*
(Legume, Nuts, & other Grains)

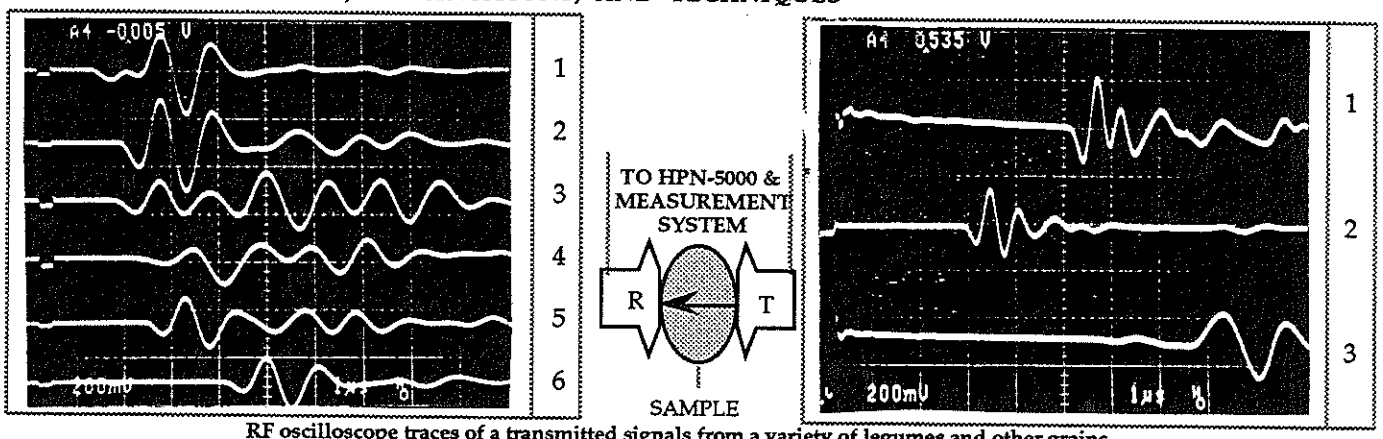
*Performed by HPN-5000 Advanced Ultrasonic System and Novel Transducer Technology

1. INTRODUCTION

It is now well-established that ultrasound is capable of providing useful processing and applications related information about any material through which it can be propagated.[1] For example, velocities of ultrasound can be directly correlated to density, porosity, humidity, pH, elastic and other properties of isotropic and anisotropic materials. Similarly, frequency-dependence of ultrasonic attenuation/absorption can provide important information about materials microstructure and composotion. Whereas ultrasonic techniques for industrial materials are well-developed, the same isn't true for biological products. These limitations have been greatly overcome by Ultran's 20 years of intense research into the science of ultrasound and development of techniques that can be adapted for the investigation of botanical products.[2]

In this short applications note we are pleased to provide the feasibility of NonDestructive Characterization (NDC) of legume, nuts, and other grains - for quality enhancement and good health. **If you are interested in using this application, please contact Ultran.**

2. SELECTED EXAMPLES, OBSERVATIONS, AND TECHNIQUES



RF oscilloscope traces of a transmitted signals from a variety of legumes and other grains

#1. Rice. #2. Split pea. #3. Lentil. #4. Green Moong bean. #5. Mexican black bean. #6. Garbanzo bean.

#1. Peanut. #2. Soyabean. #3. Cashew nut

Frequency: 2MHz. Technique: Direct Transmission DRY COUPLING

3. TYPICAL ULTRASONIC CHARACTERISTICS OF COMMON LEGUME, NUTS, AND OTHER GRAINS

LEGUME/GRAIN	CONDITION	VELOCITY (m/s)	REL ATTEN.	OPTIMUM FREQUENCY (range)
Lima beam (large)	Ripe	2,100	Low	1 to <3MHz
Small white bean	"	1,950	Low	1 to <3MHz
Black eye bean	"	2,700	Low	2 to <5MHz
Northern bean	"	1,700	Low	1 to <3MHz
Pea (split yellow)	"	3,100	Low	2 to >5MHz
Garbanzo bean	"	2,500	Low	1 to <5MHz
Pea (split green)	"	3,100	Low	2 to >5MHz
Lentil	"	3,000	Low	2 to >5MHz
Black bean (Mexican)	"	3,000	Low	2 to >5MHz
Cranberry bean	"	2,800	Low	2 to >5MHz
Kidney bean (red)	"	1,400	High	500KHz to 2MHz
Kidney bean (black)	"	2,300	Low	1 to <5MHz
Moong (green)	"	4,700	V. low	2 to ~10MHz
Urad (black Moong)	"	2,500	Low	2 to <5MHz
Rice	"	1,100	High	500KHz to 2MHz
Peanut (Raw unsplit)	"	1,700	Low	1 to <3MHz
Soyabean	"	2,200	Low	2 to 5MHz
Cashew nut (Raw unsplit)	"	1,500	Low	1 to <3MHz

1. *M.C. Bhardwaj, "Evolution, Practical Concepts, and Examples of Ultrasonic NDC," Ceramic Monographs, Interceram 41 (1992) [7/8] #4.5 and 42 (1993) [1] #4.5, Handbook of Ceramics, Verlag Schmidt GmbH, Freiburg, Germany.*
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Boalsburg, PA 16827 USA
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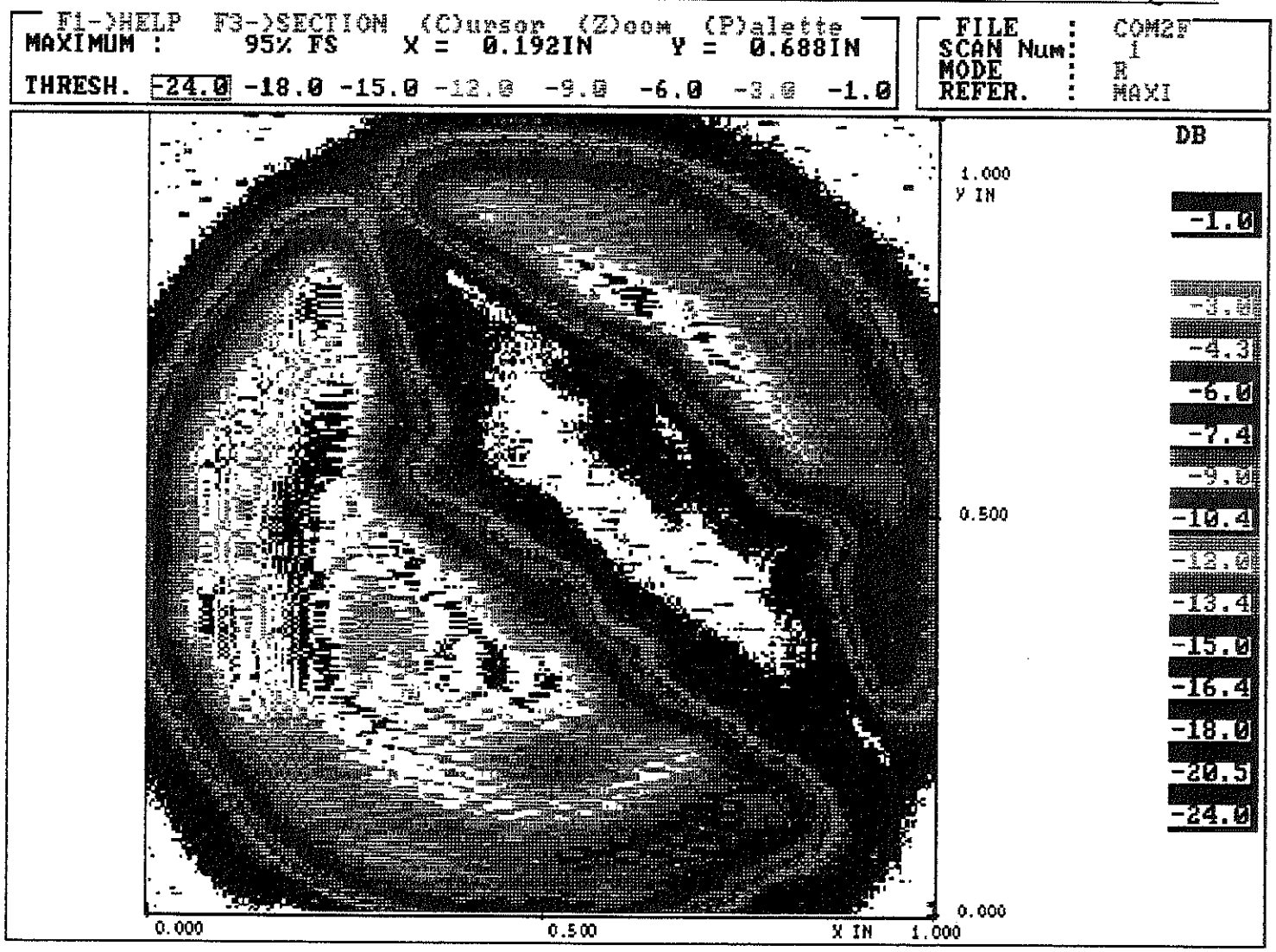
NON-IMMERSION ULTRASONIC IMAGING
Preliminary Observations

Sample: 8-ply GFRP - 1.6mm thick.
Area scanned: ~25mmx25mm

ULTRASONIC IMAGE OF AN IMPACT-DAMAGED GRAPHITE FIBER REINFORCED PLASTIC COMPOSITE BY NON-IMMERSION TECHNIQUE.



Sample Thickness: 1.6mm - 8-ply
Scanned Area: ~25mmx25mm
Technical Details: Proprietary

Center of the picture is indicative of artificially impact damaged region.

For any information, please contact Mahesh C. Bhardwaj at Ultran.

January 1993
MCB: cbm

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ultran laboratories, inc.
1020 East Boal Avenue,
Boalsburg, PA 16827 USA
814 466 6200 phone
814 466 6847 fax

Salient Publications on Transducer & Novel NDC Development from ultran

PUBLISHED WORK

1. Bhardwaj, M.C., "**An Industrialist's Perspective of Ultrasonic Characterization of Materials,**" J. Wave Mat. Interaction, v. 1, n. 3 (1986).
2. Bhardwaj, M.C., "**Principles and Methods of Ultrasonic Characterization of Materials,** " Adv. Cer. Mat., v. 1, n. 4 (1986).
3. Bhardwaj, M.C., "**Importance and Use of Very High Frequency Ultrasound in Nondestructive Characterization of Materials,**" Cer. Bull., v. 65, n. 11 (1986).
4. Bhardwaj, M.C., "**Fundamental Developments in Ultrasonics for Advanced NDC,**" in Nondestructive Testing of High Performance Ceramics, A. Vary, Editor, Am. Cer. Soc., Westerville, OH (1987).
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6. Brunk, J.A., Valenza, C.J., and Bhardwaj, M.C., "**Applications and Advantages of Dry Coupling Ultrasonic Transducers for Materials Characterization and Inspection,**" in Acousto-Ultrasonics, Theory and Applications, John C. Duke, Jr., Editor, Plenum Press, New York (1988).
7. Bhardwaj, M.C., "**Modern Ultrasonic Concepts of NDC,**" Ad. Mat. Processes, v. 5 (1989).
8. Bhardwaj, M.C., "**Simple Ultrasonic NDC for Advanced Ceramics Development & Manufacture,**" in Advanced Metal and Ceramic Composites, Bhagat, Clauer, Kumar, and Ritter, Editors, Minerals, Metals, and Materials Society, Warrendale, PA (1990).
9. Bhardwaj, M.C., Trippett, K, and Bhalla, A., "**Microstructure Characterization of Superconductors by Wideband Ultrasonic Spectroscopy,**" in Superconductivity and Ceramic Superconductors, K.M. Nair, Editor, Am. Cer. Soc., Westerville, OH (1990).
10. Bhardwaj, M.C., "**High-Resolution Ultrasonic Nondestructive Characterization,**" Cer. Bull., v. 69, n. 9, (1990).
11. Bhardwaj, M.C. and Bhalla, A., "**Ultrasonic Characterization of Ceramic Superconductors,**" J. Mat. Sci. Lett., v. 10 (1991).
12. Bhardwaj, M.C., "**NDC Begins Where NDT Stops,**" Quality, June 1991.
13. Bhardwaj, M.C. and Trippett, K., "**Nondestructive Characterization of Green and Sintered Ceramics,**" Proceedings of the First International Symposium of Engineering Ceramics, eds. S. Kimura and K. Niihara, Koda, Aichi-Prefecture, Japan, October 21-25, 1991, The Ceramic Society of Japan.
13. Bhardwaj, M.C., "**Evolution, Practical Concepts and Examples of Ultrasonic NDC,**" Ceramic Monographs, Supplements to Interceram 41 (1992) [7/8] #4.5 and 42 (1993) [1] #4.5 - Handbook of Ceramics, Verlag Schmidt GmbH, Frieburg, Germany
14. Kulkarni, N., Moudgil, B. and Bhardwaj,M., "**Ultrasonic Characterization of Green and Sintered Ceramics: I, Time Domain,**" Am. Cer. Soc., Cer. Bull, Vol. 73, No. 6, (1994).
15. Kulkarni, N., Moudgil, B. and Bhardwaj,M., "**Ultrasonic Characterization of Green and Sintered Ceramics: II, Frequency Domain,**" Am. Cer. Soc., Cer. Bull, Vol. 73, No. 7, (1994).
16. Bhardwaj, M.C. and Langron, M.E., "**Very High Temperature Ultrasonic Transducers for In-Situ and Intermittent Applications,**" in progress.

INTERNAL PUBLICATIONS

1. "**Lambda Transducers: Their Features and Applications in Nondestructive Characterization of Materials,**" EPN-104, an Ultran Laboratories, Inc. Publication (1982).
2. "**Ultrasonic NDC - A Historical Perspective and Practical Concepts,**" EPN-101a, an Ultran Laboratories, Inc. Publication (1982).
3. "**Dry Coupling, Lambda, and Geometrical Acoustics Transducers - Three Jewels for Ultrasonic NDC,**" EPN-101b, an Ultran Laboratories, Inc. Publication (1987).