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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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 over 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 continuously 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.*
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

![Graphs showing typical observations](image)

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

2. MEASURED PARAMETERS

<table>
<thead>
<tr>
<th>MEASUREMENT TEMPERATURE</th>
<th>PULSE WIDTH</th>
<th>SIGNAL TO NOISE RATIO</th>
<th>SENSITIVITY</th>
<th>BANDWIDTH</th>
<th>FREQUENCY LOSS</th>
<th>MEASUREMENT RANGE WITHIN DELAY SPACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(°C)</td>
<td>(μs)</td>
<td>(dB)</td>
<td>(dB)</td>
<td>(%)</td>
<td>(%)</td>
<td>(μs)</td>
</tr>
<tr>
<td>20</td>
<td>0.7</td>
<td>&gt;34</td>
<td>-40</td>
<td>&gt;50%</td>
<td>NONE</td>
<td>&lt;1 to ~12</td>
</tr>
<tr>
<td>-600</td>
<td>1.0</td>
<td>&gt;30</td>
<td>-44</td>
<td>&gt;40%</td>
<td>~1</td>
<td>~1 to ~12</td>
</tr>
</tbody>
</table>

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 A1/A2, where A1 is amplitude of delay tip reflection and A2 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*

![Graph showing temperature dependence of sensitivity](image)

*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 (~100°F)

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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VHT: 294
Lambda Series transducers, typified by extremely short pulse widths (~0.5 to 1 μs), are an Ultrason original. These exceptional devices facilitate Ultra High Resolution and Detectability without using very high frequencies. Lambda transducers have been optimized between <50 KHz to >20 MHz.

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 Sted, Manager Applications & Marketing.

### Type & Configuration

<table>
<thead>
<tr>
<th>Contact Types</th>
<th>Material Suitability</th>
<th>Typical Applications</th>
<th>Limitations</th>
<th>Recommended Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard-Faced (high Z)</td>
<td>High Z, high ρ, dense mats. (Metals, dense ceramics, etc.)</td>
<td>High resolution, close-surface defects, velocity/density, bond/disbond, etc.</td>
<td>Low Z, low ρ and high porosity mats. (Polymers and their composites, porous and like materials).</td>
<td>LC75-1, LC50-2, LC50-5, LC37-10, LC25-10</td>
</tr>
<tr>
<td>Replaceable Delay Line Contact</td>
<td>All, except porous materials.</td>
<td>Very high resolution thickness/thickness gauging velocity/density, bond/disbond, microstructure, etc.</td>
<td>Couplant application between transducer and delay line from time to time.</td>
<td>LRD50-5, LRD25-10</td>
</tr>
<tr>
<td>Fixed delay Line Contact</td>
<td>All, except porous materials.</td>
<td>Very high resolution thickness/thickness gauging velocity/density, bond/disbond, microstructure, etc.</td>
<td>None, except porous materials.</td>
<td>LFD50-5, LFD25-10</td>
</tr>
<tr>
<td>Anglebeam Contact Replaceable</td>
<td>Metals, dense ceramics, etc.</td>
<td>Precision detection of oblique defects, welds, etc.</td>
<td>None, except porous and very low density materials.</td>
<td>LT50-5, LT25-10</td>
</tr>
</tbody>
</table>

### Immersion Types

<table>
<thead>
<tr>
<th>Contact Types</th>
<th>Material Suitability</th>
<th>Typical Applications</th>
<th>Limitations</th>
<th>Recommended Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfocused (Planar)</td>
<td>All, except porous materials.</td>
<td>Very high resolution, big sub-surface defects, velocity/density, microstructure, etc.</td>
<td>None, except open porosity materials.</td>
<td>LS50-5, LS25-10</td>
</tr>
<tr>
<td>Focused (Point and Cylindrical)</td>
<td>All, except porous materials.</td>
<td>Very high resolution, very high detectability.</td>
<td>None, except open porosity materials.</td>
<td>LS75-2-P6, LS80-5-P3, LS37-10-P3, LS25-10-P0.75, LS25-10-P1</td>
</tr>
</tbody>
</table>

1 For porous, liquid-sensitive, green, and other materials applications, please inquire about available alternatives from Ultrason.

2 Acoustic Impedance; ρ - Density.

3 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.

4 For applications and instructional information, please consult:

LAMBD:793
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.

<table>
<thead>
<tr>
<th>TYPE &amp; CONFIGURATION</th>
<th>MATERIAL SUITABILITY</th>
<th>TYPICAL APPLICATIONS</th>
<th>LIMITATIONS</th>
<th>RECOMMENDED MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Element (Reflection Mode)</td>
<td>Low Z, low ρ, low α (plastics, CFRP, and similar materials).</td>
<td>Thickness, velocity, bond/dishbond, etc.</td>
<td>High Z, high ρ, high α (metals, ceramics and porous materials).</td>
<td>WD50-1, WD50-2, WD37-2, WD25-5, KD50-1, KD50-2</td>
</tr>
<tr>
<td>Single Element (Transmission Mode)</td>
<td>All materials, but best on green, materials. Also lumber, and concrete. Highly suitable for very attenuative materials.</td>
<td>Velocity/density, bond/plastic composites, and porous materials.</td>
<td>None</td>
<td>WD50-0.25, WD50-0.5</td>
</tr>
<tr>
<td>Dual Element (Transmit-Receive)</td>
<td>Low Z, low ρ, low α (plastics, CFRP, green, and similar materials. Also suitable for metals and ceramics</td>
<td>Thickness, defects, bond/dishbond, etc.</td>
<td>High Z, high ρ, high α (metals, ceramics, and porous materials).</td>
<td>DTR50-1, DTR50-2, DTR50-5, DTR25-5</td>
</tr>
<tr>
<td>Delay Line (Reflection)</td>
<td>All, except porous.</td>
<td>Thickness, velocity/density bond/dishbond in relatively thin materials.</td>
<td>Very thick and porous materials.</td>
<td>DCB25-5, DCB25-10</td>
</tr>
<tr>
<td>Delay Line (Transmission)</td>
<td>All, including lumber, concrete, etc. Highly suitable for very thick materials.</td>
<td>Velocity/density bond/dishbond, etc.</td>
<td>None</td>
<td>DCB50-0.5, DCB50-1, DCB50-2</td>
</tr>
</tbody>
</table>

1 Z - Acoustic Impedance; ρ - Density; α - Attenuation; CFRP: Glass Fiber Reinforced Plastic; CFRP: Carbon Fiber Reinforced Plastic.

2For shear wave applications, 0° incidence shear wave dry coupling transducers are also available. For details, please consult Ultran.

3Dry coupling transducers cannot be slid over test materials.

4Highlighted models are readily available.

*For applications and instructional information, please consult:


DC: 793
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*

<table>
<thead>
<tr>
<th>FREQUENCY (MHz)</th>
<th>ACTIVE Φ in</th>
<th>FOCAL LENGTH* in mm</th>
<th>CATALOG NUMBER</th>
<th>W-Series</th>
<th>K-Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>1.0 25</td>
<td></td>
<td></td>
<td>WG100-0.25</td>
<td>KG100-0.25</td>
</tr>
<tr>
<td></td>
<td>1.0 25</td>
<td></td>
<td></td>
<td>WG100-0.25-P2</td>
<td>KG100-0.25-P2</td>
</tr>
<tr>
<td></td>
<td>1.0 25</td>
<td>2.0 51</td>
<td></td>
<td>WG100-0.5</td>
<td>KG100-0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KG100-0.5-P2</td>
<td>KG100-0.5-P2</td>
</tr>
<tr>
<td>0.5</td>
<td>1.0 25</td>
<td></td>
<td></td>
<td>WG75-1</td>
<td>KG75-1</td>
</tr>
<tr>
<td></td>
<td>1.0 25</td>
<td></td>
<td></td>
<td>KG75-1-P2</td>
<td>KG75-1-P2</td>
</tr>
<tr>
<td></td>
<td>0.75 25</td>
<td>2.0 51</td>
<td></td>
<td>KG100-1</td>
<td>KG100-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KG100-1-P2</td>
<td>KG100-1-P2</td>
</tr>
<tr>
<td>1.0</td>
<td>0.75 25</td>
<td></td>
<td></td>
<td>KG50-2</td>
<td>KG50-2</td>
</tr>
<tr>
<td></td>
<td>1.0 25</td>
<td></td>
<td></td>
<td>KG50-2-P1</td>
<td>KG50-2-P1</td>
</tr>
<tr>
<td></td>
<td>0.75 25</td>
<td>1 25</td>
<td></td>
<td>KG75-2</td>
<td>KG75-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KG75-2-P2</td>
<td>KG75-2-P2</td>
</tr>
<tr>
<td></td>
<td>1.0 25</td>
<td>2.0 51</td>
<td></td>
<td>KG100-2</td>
<td>KG100-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KG100-2-P2</td>
<td>KG100-2-P2</td>
</tr>
</tbody>
</table>

*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.
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.

Specifications.
### 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.
- Typically, 5ns into 50Ω
- Typically 8ns into 50Ω
- Computer or either +ve or -ve TTL from an external source.
- 0.17Hz to 10KHz in 1, 1.7, 2.5, 5 sequence.
- 0 to 255 pulses in single pulse steps.
- 1. Full power - BNC connector.
- 2. Output Monitor: -40dB into 50Ω

#### Receiver Section
- Frequency Range: From 20KHz to 10MHz
- 20KHz, 100KHz, and 500KHz
- 2, 5, and 10MHz
- -80dB
- -10 to 68dB in 2dB steps.
- 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.

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*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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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. 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 composition. 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.

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.

**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.

<table>
<thead>
<tr>
<th>Material</th>
<th>CD Measurement ToF:</th>
<th>Velocity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newspaper</td>
<td>27μs</td>
<td>3,760 m/s</td>
</tr>
<tr>
<td>MD Measurement</td>
<td>34μs</td>
<td>2,990 m/s</td>
</tr>
<tr>
<td>Cardboard</td>
<td>27μs</td>
<td>3,760 m/s</td>
</tr>
<tr>
<td>MD Measurement</td>
<td>48μs</td>
<td>2,100 m/s</td>
</tr>
</tbody>
</table>

**Observations**

*Technique and equipment*

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

2.2 In-thickness determination of ultrasonic velocities

![Diagram of ultrasonic propagation through different materials]

**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: $t_1 - t_2$.

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*

<table>
<thead>
<tr>
<th>Paper Type</th>
<th>Thickness (mm)</th>
<th>T-R Distance (mm)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(for in-plane testing)</td>
<td>Machine Direction</td>
</tr>
<tr>
<td>Copy Paper</td>
<td>0.089</td>
<td>101.6</td>
<td>3,240</td>
</tr>
<tr>
<td>Bond Paper</td>
<td>0.127</td>
<td>101.6</td>
<td>3,200</td>
</tr>
<tr>
<td>Cover Stock</td>
<td>0.228</td>
<td>101.6</td>
<td>2,860</td>
</tr>
<tr>
<td>Cardboard</td>
<td>1.016</td>
<td>101.6</td>
<td>2,100</td>
</tr>
<tr>
<td>Newspaper</td>
<td>0.094</td>
<td>101.6</td>
<td>2,950</td>
</tr>
<tr>
<td>Manila Folder</td>
<td>0.254</td>
<td>101.6</td>
<td>2,710</td>
</tr>
<tr>
<td>GlossyPlotter</td>
<td>0.127</td>
<td>101.6</td>
<td>3,440</td>
</tr>
<tr>
<td>Facial Tissue</td>
<td>0.075</td>
<td>101.6</td>
<td>--</td>
</tr>
</tbody>
</table>

*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.

[Ultran Laboratories, Inc.]

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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. 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 composition. 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.1

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: 80m/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

<table>
<thead>
<tr>
<th>VEGETABLE/FRUIT</th>
<th>CONDITION</th>
<th>VELOCITY (m/s)</th>
<th>REL ATTEN.</th>
<th>OPTIMUM FREQUENCY (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato (Idaho)</td>
<td>Ripe</td>
<td>800</td>
<td>Low</td>
<td>250KHz to ~1.0MHz</td>
</tr>
<tr>
<td>Potato (Florida)</td>
<td>Ripe</td>
<td>700</td>
<td>Low</td>
<td>250KHz to ~1.0MHz</td>
</tr>
<tr>
<td>Apple (Red)</td>
<td>Ripe</td>
<td>150</td>
<td>V. High</td>
<td>~50KHz to 100KHz</td>
</tr>
<tr>
<td>Potato (Idaho)</td>
<td>Partly rotten</td>
<td>600</td>
<td>High</td>
<td>~50KHz to 250KHz</td>
</tr>
<tr>
<td>Yam (N. Carolina)</td>
<td>Ripe</td>
<td>250</td>
<td>V. High</td>
<td>50KHz to 100KHz</td>
</tr>
<tr>
<td>Banana (Unpeeled)</td>
<td>Ripe</td>
<td>250</td>
<td>V. High</td>
<td>50KHz to 100KHz</td>
</tr>
<tr>
<td>Banana (Peeled)</td>
<td>Ripe</td>
<td>270</td>
<td>V. High</td>
<td>~50KHz to 100KHz</td>
</tr>
<tr>
<td>Carrot (Closer to leaves)</td>
<td>Ripe</td>
<td>550</td>
<td>High</td>
<td>50KHz to 250KHz</td>
</tr>
<tr>
<td>Carrot (Middle)</td>
<td>Ripe</td>
<td>600</td>
<td>High</td>
<td>50KHz to 250KHz</td>
</tr>
<tr>
<td>Carrot (Deeper in ground)</td>
<td>Ripe</td>
<td>580</td>
<td>High</td>
<td>50KHz to 250KHz</td>
</tr>
<tr>
<td>Turnip (Radial)</td>
<td>Ripe</td>
<td>240</td>
<td>V. High</td>
<td>&lt;50KHz to 100KHz</td>
</tr>
<tr>
<td>Turnip (Along root)</td>
<td>Ripe</td>
<td>220</td>
<td>V. High</td>
<td>&lt;50KHz to 100KHz</td>
</tr>
<tr>
<td>Daikon (Closer to leaves)</td>
<td>Ripe</td>
<td>280</td>
<td>V. High</td>
<td>&lt;50KHz to 100KHz</td>
</tr>
<tr>
<td>Daikon (Middle)</td>
<td>Ripe</td>
<td>300</td>
<td>V. High</td>
<td>&lt;50KHz to 100KHz</td>
</tr>
<tr>
<td>Daikon (Deeper in ground)</td>
<td>Ripe</td>
<td>370</td>
<td>V. High</td>
<td>&lt;50KHz to 100KHz</td>
</tr>
<tr>
<td>Asian Pear (Whole unpeeled)</td>
<td>Ripe</td>
<td>240 (76)</td>
<td>V. High</td>
<td>&lt;50KHz to 100KHz</td>
</tr>
<tr>
<td>Asian Pear (Cut)</td>
<td>Ripe</td>
<td>2,600</td>
<td>Low</td>
<td>500KHz to 2MHz</td>
</tr>
<tr>
<td>Grape (Seedless, axial)</td>
<td>Ripe</td>
<td>1,800</td>
<td>Low</td>
<td>500KHz to 2MHz</td>
</tr>
<tr>
<td>Grape (Seedless, radial)</td>
<td>Ripe</td>
<td>1,300</td>
<td>Low</td>
<td>500KHz to 1MHz</td>
</tr>
</tbody>
</table>

   #4.5 and 42 (1993) 11 #4.5, Handbook of Ceramics, Verlag Schmidtt GmbH, Freiburg, Germany.

EPN-294-1
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. 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 composition. 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.

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


Frequency: 2MHz. Technique: Direct Transmission DRY COUPLING

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

<table>
<thead>
<tr>
<th>LEGUME/GRAIN</th>
<th>CONDITION</th>
<th>VELOCITY (m/s)</th>
<th>REL ATTN.</th>
<th>OPTIMUM FREQUENCY</th>
<th>(range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lima bean (large)</td>
<td>Ripe</td>
<td>2.100</td>
<td>Low</td>
<td>1 to &lt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Small white bean</td>
<td>*</td>
<td>1.950</td>
<td>Low</td>
<td>1 to &lt;3MHz</td>
<td></td>
</tr>
<tr>
<td>Black eye bean</td>
<td>*</td>
<td>2.700</td>
<td>Low</td>
<td>2 to &lt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Northern bean</td>
<td>*</td>
<td>1.700</td>
<td>Low</td>
<td>1 to &lt;3MHz</td>
<td></td>
</tr>
<tr>
<td>Pea (split yellow)</td>
<td>*</td>
<td>3.100</td>
<td>Low</td>
<td>2 to &gt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Garbanzo bean</td>
<td>*</td>
<td>2.500</td>
<td>Low</td>
<td>1 to &lt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Pea (split green)</td>
<td>*</td>
<td>3.100</td>
<td>Low</td>
<td>2 to &gt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Lentil</td>
<td>*</td>
<td>3.000</td>
<td>Low</td>
<td>2 to &gt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Black bean (Mexican)</td>
<td>*</td>
<td>3.000</td>
<td>Low</td>
<td>2 to &gt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Cranberry bean</td>
<td>*</td>
<td>2.800</td>
<td>Low</td>
<td>2 to &gt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Kidney bean (red)</td>
<td>*</td>
<td>1.400</td>
<td>High</td>
<td>500KHz to 2MHz</td>
<td></td>
</tr>
<tr>
<td>Kidney bean (black)</td>
<td>*</td>
<td>2.300</td>
<td>Low</td>
<td>1 to &lt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Moong (green)</td>
<td>*</td>
<td>4.700</td>
<td>V. low</td>
<td>2 to &gt;10MHz</td>
<td></td>
</tr>
<tr>
<td>Urad (black Moong)</td>
<td>*</td>
<td>2.500</td>
<td>Low</td>
<td>2 to &lt;5MHz</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>*</td>
<td>1.100</td>
<td>High</td>
<td>500KHz to 2MHz</td>
<td></td>
</tr>
<tr>
<td>Peanut (Raw unsplit)</td>
<td>*</td>
<td>1.700</td>
<td>Low</td>
<td>1 to &lt;3MHz</td>
<td></td>
</tr>
<tr>
<td>Soya bean</td>
<td>*</td>
<td>2.200</td>
<td>Low</td>
<td>2 to 5MHz</td>
<td></td>
</tr>
<tr>
<td>Cashew nut (Raw unsplit)</td>
<td>*</td>
<td>1.500</td>
<td>Low</td>
<td>1 to &lt;3MHz</td>
<td></td>
</tr>
</tbody>
</table>


EPN-294-2
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
PUBLISHED WORK


INTERNAL PUBLICATIONS


ULTRAN: PL-894