
MAJOR ADVANCEMENTS IN
VERY LOW FREQUENCY ULTRASOUND*
Introducing Gas Matrix Piezoelectric
(GMP™) Composite Transducers
the ultran group
redefining the limits of ultrasound
*Boeing NDE Forum, Philadelphia, PA
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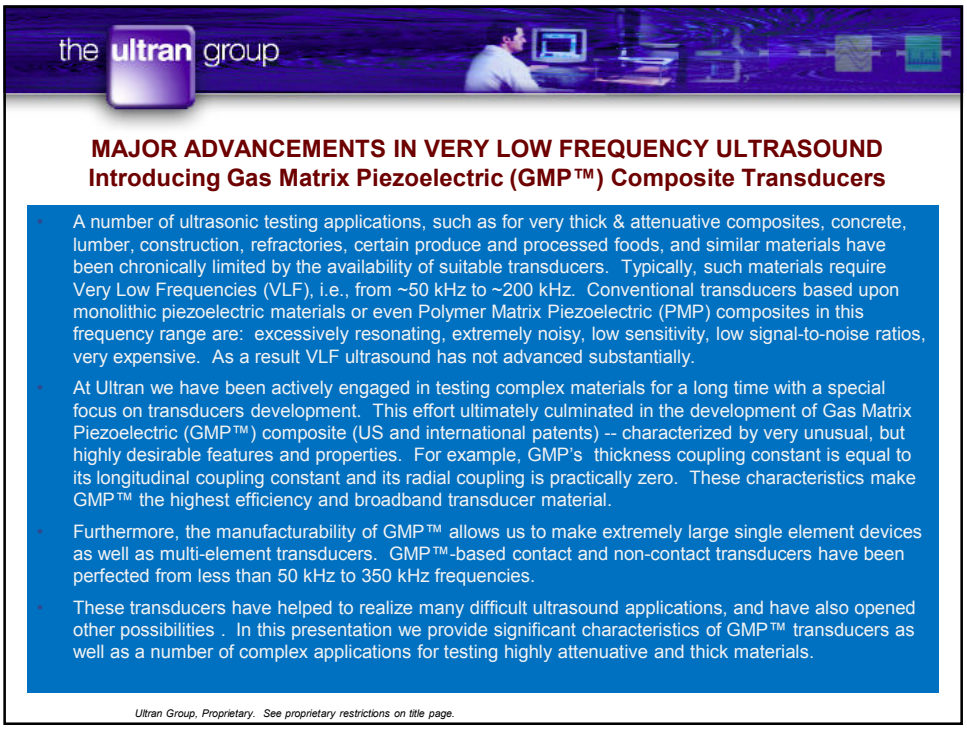
the ultran group
MAJOR ADVANCEMENTS IN VERY LOW FREQUENCY ULTRASOUND
Introducing Gas Matrix Piezoelectric (GMP™) Composite Transducers
A number of ultrasonic testing applications, such as for very thick & attenuative composites, concrete, lumber, construction, refractories, certain produce and processed foods, and similar materials have been chronically limited by the availability of suitable transducers. Typically, such materials require Very Low Frequencies (VLF), i.e., from ~50 kHz to ~200 kHz. Conventional transducers based upon monolithic piezoelectric materials or even Polymer Matrix Piezoelectric (PMP) composites in this frequency range are: excessively resonating, extremely noisy, low sensitivity, low signal-to-noise ratios, very expensive. As a result VLF ultrasound has not advanced substantially.
At Ultran we have been actively engaged in testing complex materials for a long time with a special focus on transducers development. This effort ultimately culminated in the development of Gas Matrix Piezoelectric (GMP™) composite (US and international patents) -- characterized by very unusual, but highly desirable features and properties. For example, GMP's thickness coupling constant is equal to its longitudinal coupling constant and its radial coupling is practically zero. These characteristics make GMP™ the highest efficiency and broadband transducer material.
Furthermore, the manufacturability of GMP™ allows us to make extremely large single element devices as well as multi-element transducers. GMP™-based contact and non-contact transducers have been perfected from less than 50 kHz to 350 kHz frequencies.
These transducers have helped to realize many difficult ultrasound applications, and have also opened other possibilities . In this presentation we provide significant characteristics of GMP™ transducers as well as a number of complex applications for testing highly attenuative and thick materials.
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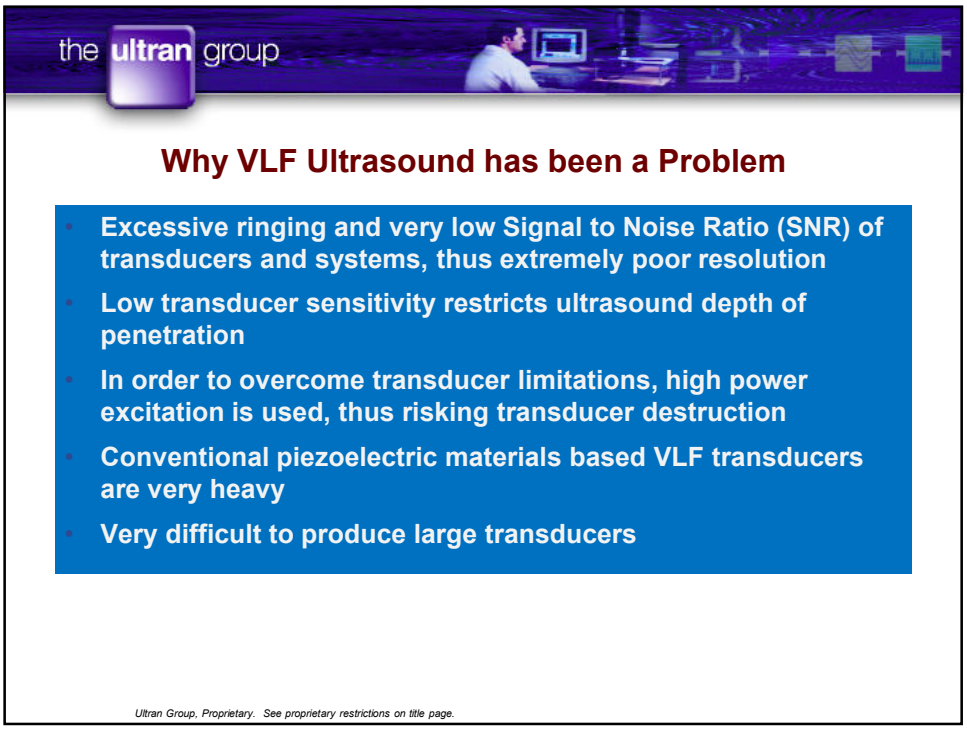
MAJOR ADVANCEMENTS IN VERY LOW FREQUENCY ULTRASOUND (VLF)

- Necessity of Very Low Frequency (VLF) Ultrasound
- Why VLF Ultrasound has been a Problem
- Limitations of Piezoelectric Materials for VLF ultrasound
- Development of Gas Matrix Piezoelectric (GMP™) Composite
- Salient Characteristics of GMP™ Transducers
- Comparison of GMP™ with other Piezoelectric VLF Transducers
- Examples of GMP™ VLF Transducer Applications
- What Ultran provides
- Conclusions

Necessity of Very Low Frequency (VLF) Ultrasound ~50 kHz to 200 kHz

- Highly attenuative materials excessively scatter frequencies, generally above 300 kHz
- Suitable and high quality transducers below 300 kHz are at best very difficult to produce
- Therefore, materials such as concrete, thick composites, dampening materials, wood & lumber, refractories, certain produce, processed foods, etc. cannot be properly tested with ultrasound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Why VLF Ultrasound has been a Problem
Excessive ringing and very low Signal to Noise Ratio (SNR) of transducers and systems, thus extremely poor resolution
Low transducer sensitivity restricts ultrasound depth of penetration
In order to overcome transducer limitations, high power excitation is used, thus risking transducer destruction
Conventional piezoelectric materials based VLF transducers are very heavy
Very difficult to produce large transducers
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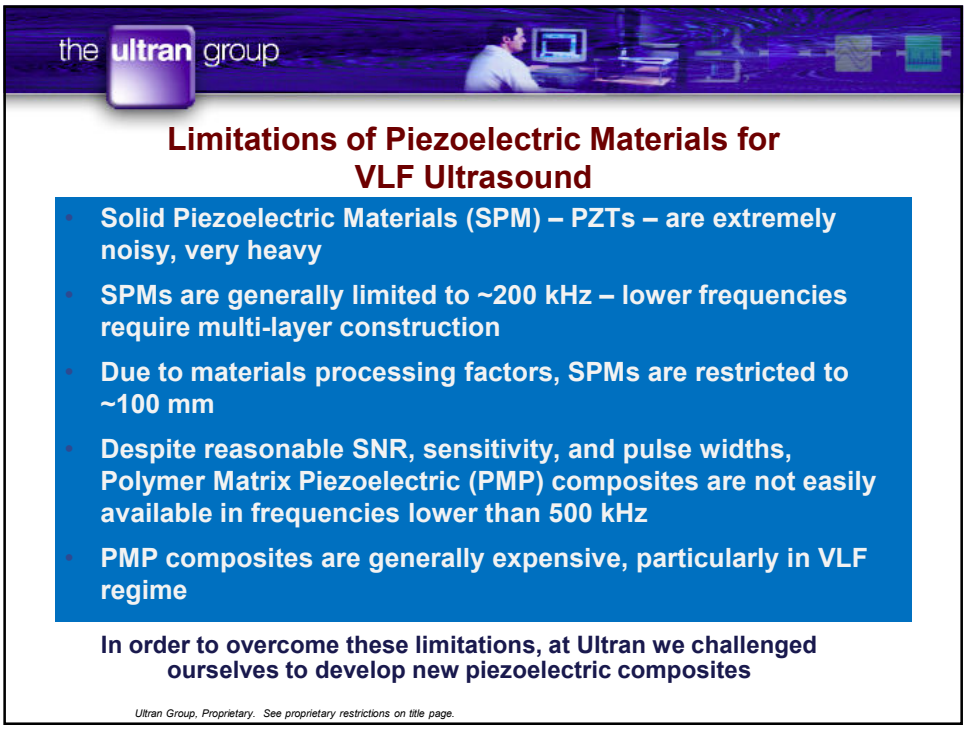
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Limitations of Piezoelectric Materials for VLF Ultrasound
Solid Piezoelectric Materials (SPM) – PZTs – are extremely noisy, very heavy
SPMs are generally limited to ~200 kHz – lower frequencies require multi-layer construction
Due to materials processing factors, SPMs are restricted to ~100 mm
Despite reasonable SNR, sensitivity, and pulse widths, Polymer Matrix Piezoelectric (PMP) composites are not easily available in frequencies lower than 500 kHz
PMP composites are generally expensive, particularly in VLF regime
In order to overcome these limitations, at Ultran we challenged ourselves to develop new piezoelectric composites
Ultran Group, Proprietary. See proprietary restrictions on title page.

Development of Gas Matrix Piezoelectric (GMP™) Composite in 2002*

- A unique piezoelectric material in which polymer filling of PMP has been replaced by gas, thus, its name

  Gas Matrix Piezoelectric (GMP™) composite*

- By doing so, this material yields the most unusual features and properties known in any piezoelectric material

*US and International Patents

Salient Characteristics of GMP™ Composite*

- Thickness coupling factor, k_t = Longitudinal coupling factor, k_{33}
- Mechanical quality factor Q_m = <1, Extremely high bandwidth
- Sensitivity: Extremely high
- Acoustic cross talk k_p: Negligible
- Dielectric constant: Very low
- Very easy to excite even by very low energy excitation source
- Density: <3 g/cc
- Signal to Noise Ratio (SNR): Very high
- Unusually strong even harmonics
- GMP manufacturability allows construction of very large transmitters and very small arrays
- Mechanical Strength: Extremely high
- Built-in heat dissipation mechanism

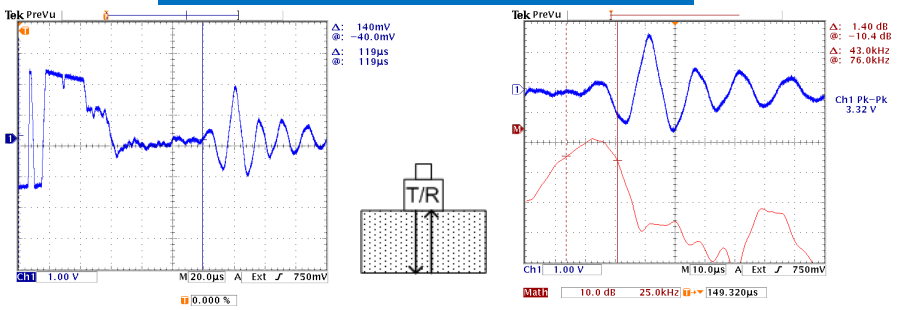
GMP™-Based & other Novel Transducers from Ultran

Contact & Immersion Transducers from 50 kHz to 500 kHz

Non-Contact Transducers from 50 kHz to 5.0 MHz

Comparison of GMP™ vs. PMP and SPM Transducers

50 kHz 100 x 100 mm GMP™ Transducer
Reflection from 150 mm Polystyrene

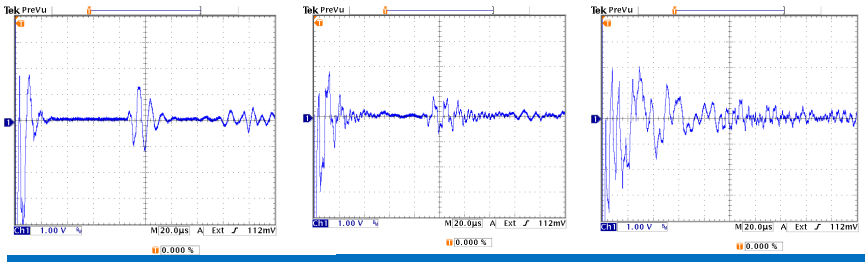


Excitation: Only -80 Spike. Amplification: 0 dB
Bandwidth Center Frequency: 55 kHz
Bandwidth @ -6 dB: 43 kHz

At the time of this test, PMP and SPM of 50 kHz were not available for comparison

Comparison of GMP vs. PMP and SPM Transducers
Resolution & Signal to Noise Ratio

100 kHz 50 mm Diameter Transducers
Complete Reflection signal from 100 mm Polystyrene

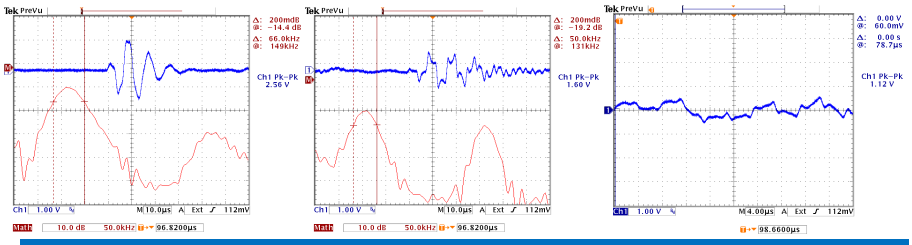


GMP™	PMP	SPM -- PZT
Gas Matrix Composite	Polymer Matrix Composite	Solid Piezoelectric Material

Excitation: -80 Spike. Amplification: 0 dB
Test: Pulse Echo from 100 mm Polystyrene

Comparison of GMP™ vs. PMP and SPM Transducers
Time & Frequency Domain

100 kHz 50 mm Diameter Transducers
Far side Reflection from 100 mm Polystyrene

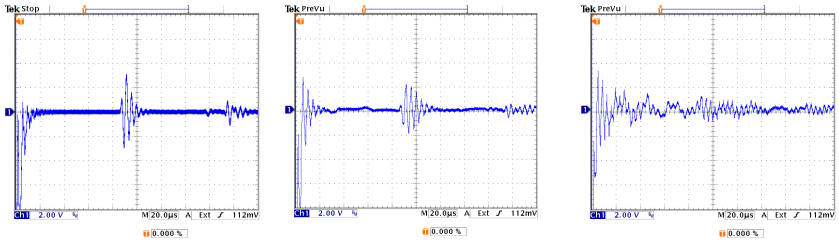


GMP™	PMP	SPM -- PZT
Gas Matrix Composite	Polymer Matrix Composite	Solid Piezoelectric Material

Excitation: -80 Spike. Amplification: 0 dB
Test: Pulse Echo from 100 mm Polystyrene

Comparison of GMP vs. PMP and SPM Transducers
Resolution and Signal to Noise Ratio

200 kHz 50 mm Diameter Transducer
Complete Reflection Signal from 100 mm Polystyrene

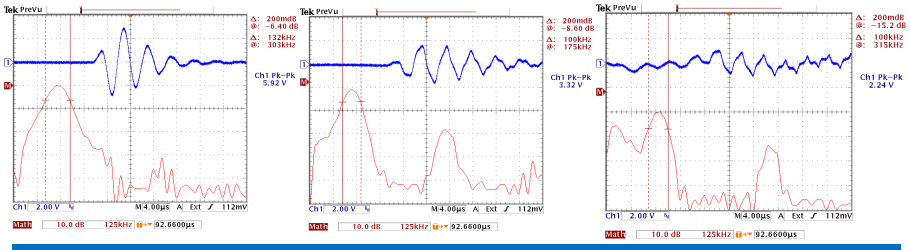


GMP™	PMP	SPM -- PZT
Gas Matrix Composite	Polymer Matrix Composite	Solid Piezoelectric Material

Excitation: -80 Spike. Amplification: 0 dB
Test: Pulse Echo from 100 mm Polystyrene

Comparison of GMP vs. PMP and SPM Transducers
Time & Frequency Domain

200 kHz 50 mm Diameter Transducers
Far Side Reflection from 100 mm Polystyrene



GMP™	PMP	SPM -- PZT
Gas Matrix Composite	Polymer Matrix Composite	Solid Piezoelectric Material

Excitation: -80 Spike. Amplification: 0 dB
Test: Pulse Echo from 100 mm Polystyrene

Table of Comparison of GMP, PMP, AND SPM (PZT) Transducers*

Piezoelectric material	Round Trip Sensitivity (dB)	Bandwidth @ -6 dB (% at center frequency)	SNR** (dB)
GMP	-30	70	30
PMP	-34	50	14
SPM (PZT)	-37	20	3

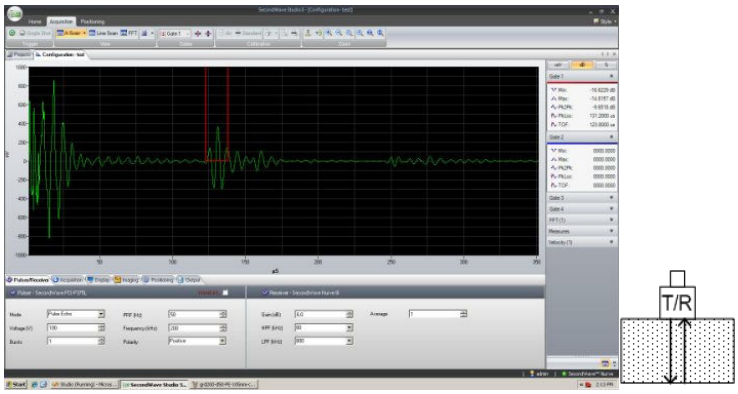
*As a function of 100 kHz 50 mm active diameter transducers operated in pulse-echo mode, excited by 80 volt –ve spike pulse with 100 mm polystyrene reference block

**Reference signal is the far side reflection from test material Noise is within the liberal proximity of the reference signal

Examples of Complex Materials Testing with GMP™ Transducers

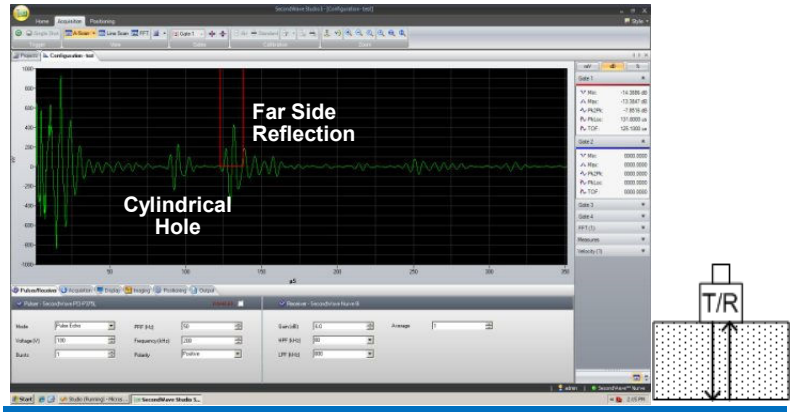
1. Thick GFRP Composite
2. Rocket Motor Insulation
3. Graphite Refractory
4. Aggregate Concrete Block
5. Asphalt Concrete Cylinder
6. Aggregate Concrete Component

Thick GFRP Composite Testing by GMP™ Transducers in Pulse-Echo Mode



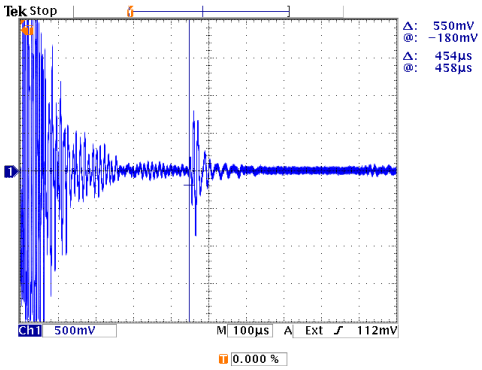
Transducer: GRD200-D50 – 200 kHz 50 mm active diameter
Ultran M510 Ultrasonic & Signal Analysis System
Far side reflection from 235 mm GFRP composite

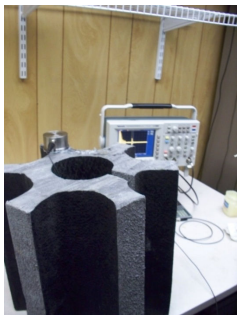
Thick GFRP Composite Testing by GMP™ Transducers Defect Detection in 235 mm Material Section in Pulse-Echo Mode



Transducer: GRD200-D50 – 200 kHz 50 mm active diameter
Ultran M510 Ultrasonic & Signal Analysis System

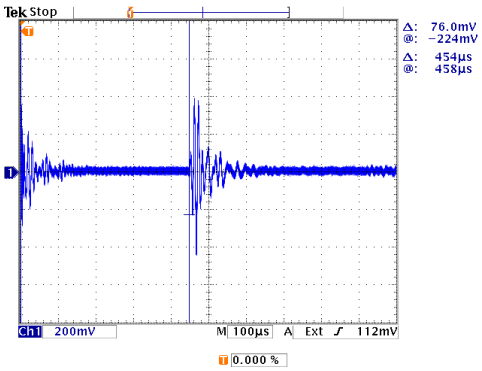
Rocket Motor Insulation Testing by GMP™ Transducers in Pulse Echo Mode

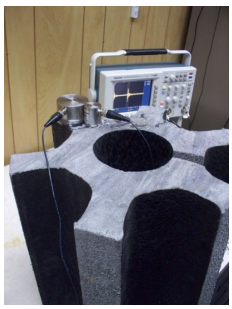




Transducer: GRD140-D50 – 140 kHz 50 mm active diameter
Excitation: ONLY -200 VOLT SPIKE
Far side Reflection from 380 mm Material Section

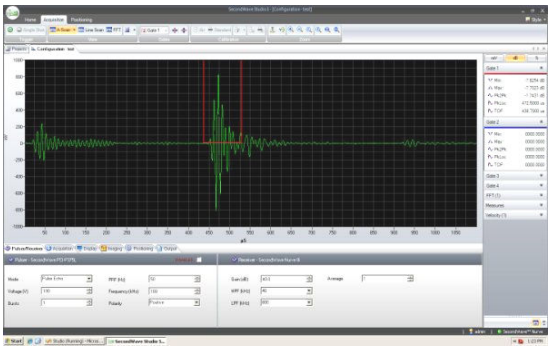
Rocket Motor Insulation Testing by GMP™ Transducers in Pitch-Catch Mode

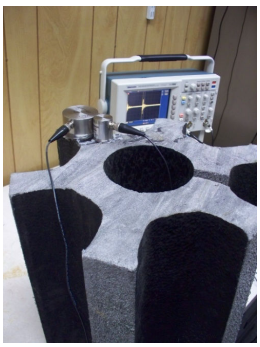




Transducer: GRD 140 kHz 50 mm & 25 mm active diameters
Excitation: ONLY -200 VOLT SPIKE
Far side Reflection from 380 mm Material Section

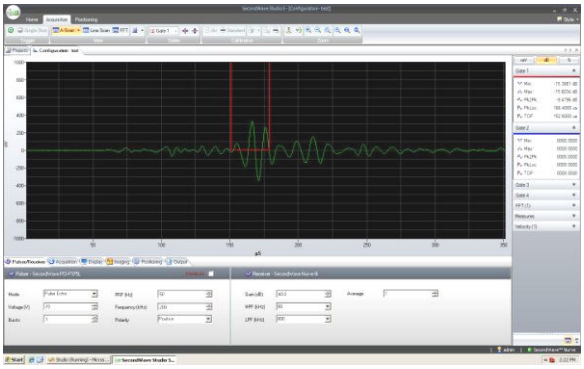
Rocket Motor Insulation Testing by GMP™ Transducers in Pitch-Catch Mode

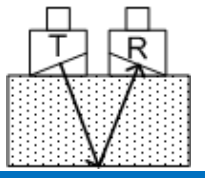




Transducer: GRD 140 kHz 50 mm & 25 mm active diameters
Excitation: Ultran M510 Ultrasonic & Signal Analysis System – only 100 V single burst!
Far side Reflection from 380 mm Material Section

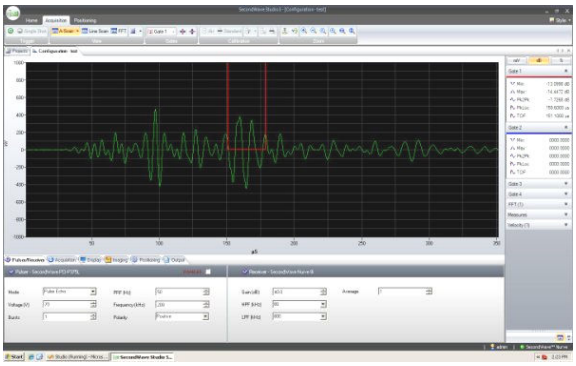
Graphite Refractory Testing by GMP™ Transducers in Pitch-Catch Mode

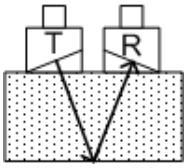




Transducer: GRD140 kHz 50 mm & 25 mm active diameters
Ultran M510 Ultrasonic & Signal Analysis System
Far side Reflection from 200 mm Material Section

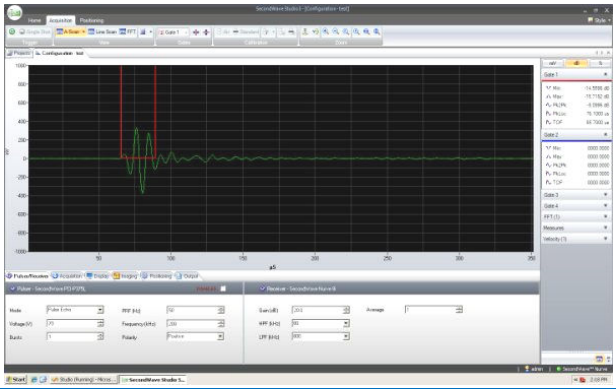
Graphite Refractory Testing by GMP™ Transducers in Pitch-Catch Mode for Defect Detection

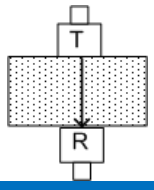




Transducer: GRD140 kHz 50 mm & 25 mm active diameters
Presumably internal defects
Ultran M510 Ultrasonic & Signal Analysis System

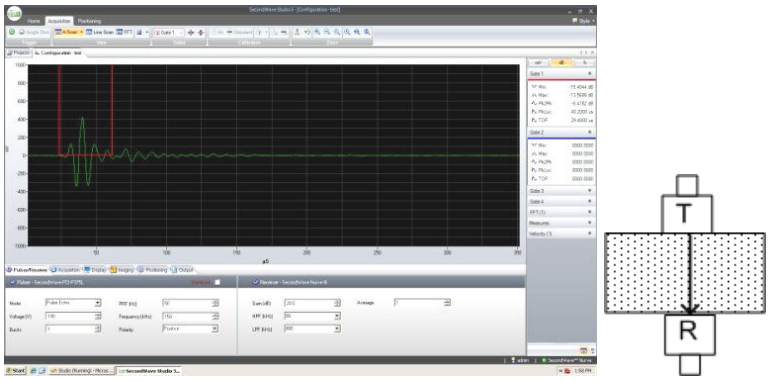
Graphite Refractory Testing by GMP™ Transducers in Direct Transmission Mode





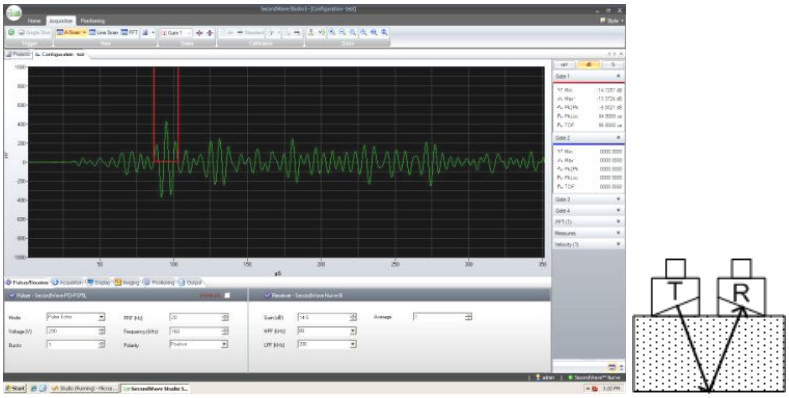
Transducer: GRD140 kHz 50 mm & 25 mm active diameters
Received Signal from 200 mm Material Section
Ultran M510 Ultrasonic & Signal Analysis System

Asphalt Aggregate Concrete Testing by GMP™ Transducers in Direct Transmission Mode



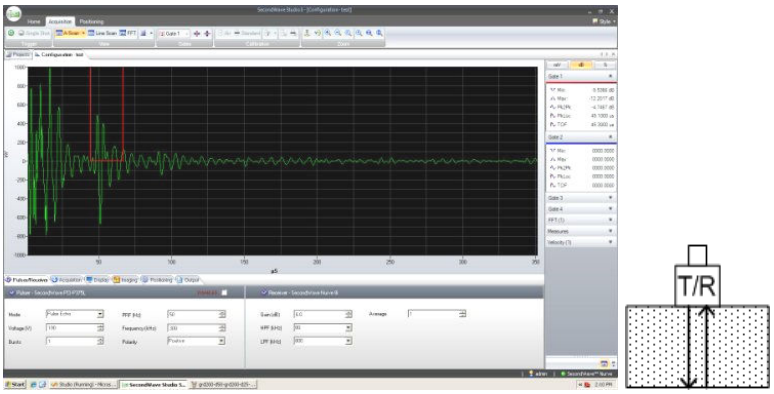
Transducer: GRD200 kHz 50 mm & 25 mm active diameters
Received Signal from 90 mm Material Section
Ultran M510 Ultrasonic & Signal Analysis System

Aggregate Concrete Testing by GMP™ Transducers in Pitch-Catch Mode



Transducer: GRD200 kHz 50 mm & 25 mm active diameters
Received Signal from 150 mm Material Section
Ultran M510 Ultrasonic & Signal Analysis System

Aggregate Concrete Testing by GMP™ Transducers in Pulse-Echo Mode



Transducer: GRD200 kHz 50 mm active diameter
Received Signal from 105 mm Material Section
Ultran M510 Ultrasonic & Signal Analysis System

What Ultran Provides

- Complete array of GMP™ based Contact, Immersion, and Non-Contact transducers
- A fully digitized tone burst ultrasonic system with extraordinary materials analysis software
- Analytical services for feasibility, transducer optimization, and other services
- We not only transfer ultrasonic technology, but also scientific know how relative to materials
- Ultran is a team of extraordinary ultrasound and materials scientists supported by equally strong systems and software experts and technicians

Conclusions

- We have provided significant details and applications of our new GMP™ composite, transducers in VLF regime and their superiority over other devices
- High quality ultrasonic testing of complex and highly attenuative materials, such as refractories, concrete, thick composites, rubbers, dampening materials, wood, etc.
- A chronic gap in ultrasound relative to VLF has been successfully bridged by GMP™ transducers

To use GMP™ transducers for most applications, you do not need special instruments – GMP™ is very easy to excite.

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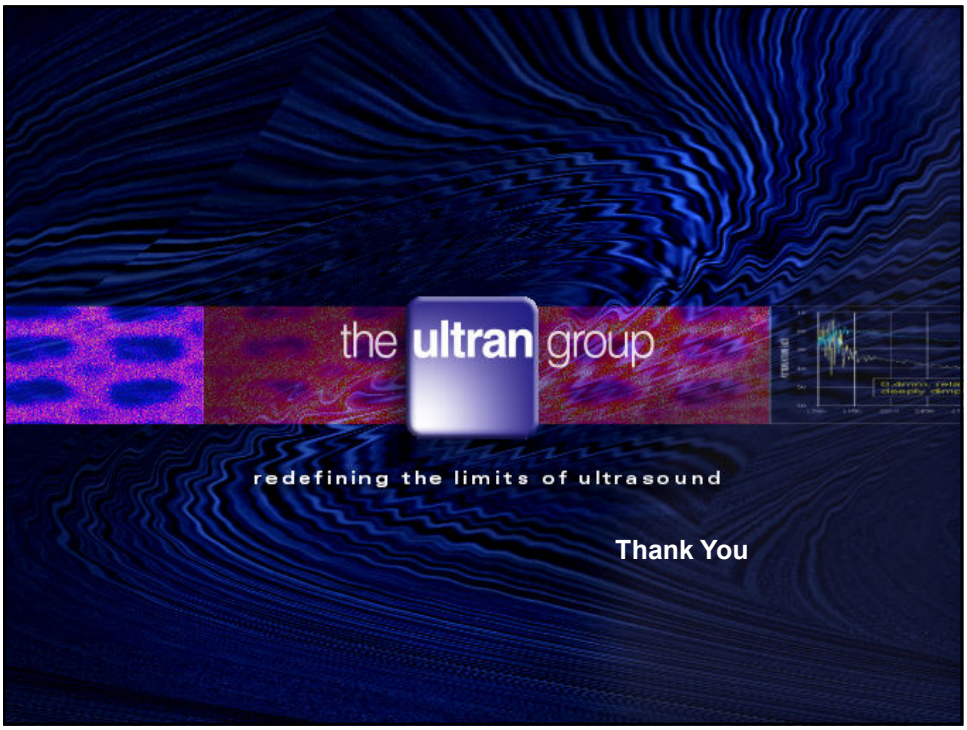

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