Microwave Interferometry (MI) Techniques inside Detonating High Explosives

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Abstract

RF energy at microwave frequencies is used inside bulk high explosives to characterize the moving detonation wave. This poster describes the concept, current results, other investigations and our path forward.

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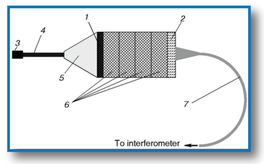
Background

Cook, Doran, Morris, "Measurement of Detonation Velocity by Doppler Effect at Three-Centimeter Wavelength", Journal of Applied Physics April 1955→Standoff approach from sample, samples were 5 cm dia and ~30 cm long

Cawsey, Farrands, Thomas, "Observations of detonation in solid explosives by microwave interferometry", Proc of Royal Society of London, Dec 9, 1958→Packed a section of waveguide, 34.5 GHz operation.

Microwave Diagnostics of Shock-Wave and Detonation Processes, V. M. Bel'skii,1 A. L. Mikhailov, A. V. Rodionov,1 and A. A. Sedov1
Translated from *Fizika Goreniya i Vzryva, Vol. 47, No. 6, pp. 29–41, November–December, 2011.*
Original article submitted March 22, 2011.
A method for measuring the parameters of shock-wave and detonation processes using a microwave interferometer is proposed. The experimental technique used in the study and the employed method of processing experimental data are described. Examples of experimental studies carried out using a radio interferometer of the three-millimeter range are considered.
Key words: detonation, shock-wave processes, diagnostics, radio interferometer, microwave radiation.



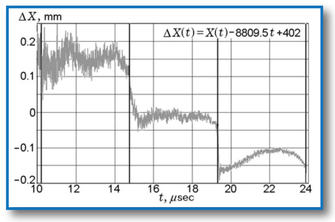
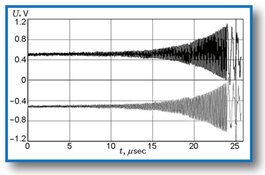


Fig. 2. Setup for measuring the velocity of steady detonation in a compound sample of an explosive: **1)** additional detonator; **2)** plate of PMMA; **3)** electric blasting cap; **4)** bar of a plastic explosive; **5)** detonation lens; **6)** compound sample of the test explosive; **7)** dielectric waveguide with an antenna.



Approach

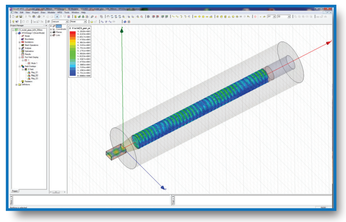
Since most high explosives (HE) are good dielectrics, we can use them as waveguide materials in either a metal or a plastic body and measure the signal that reflects from the moving shock front.

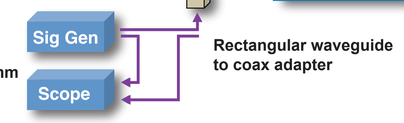
To calculate a front velocity, we need just the HE dielectric constant. With one or two physical reference points such as we get from ionization pins we can cross-check the front velocity and position.

Successful experiments: DDT (Deflagration to Detonation Transition) and Disk Acceleration eXperiment (DAX)

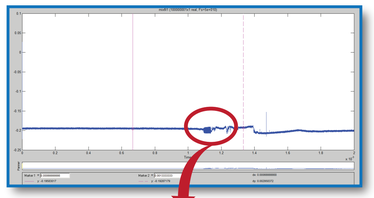
DDT

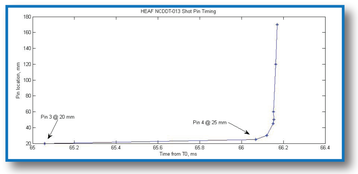
25.4 mm diameter cylinder of HMX
342.8 mm length
Thermite igniter at the top
15 pins distributed along length
RF waveguide attached to bottom
12.5 GHz incident RF to glass window
Power to waveguide connector ~ 13 dBm
Forward and scattered RF signal coupling
50 GHz multichannel Tek oscilloscope

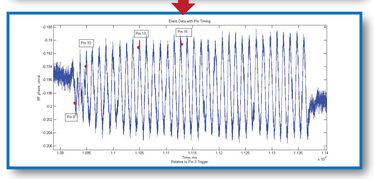




Pin#	Time	Location	Dt	
3				
4	65.05815	20mm	0ms	Trigger signal
5	66.067	25	1.0089	
8	66.120	30	1.06185	
9	66.151	45	1.09285	
10	66.154	50	1.09585	
13	66.153	60	1.09485	
15	66.163	120	1.09485	
	66.171	170	1.11285	



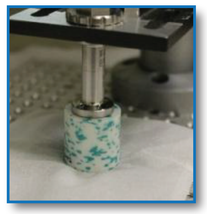




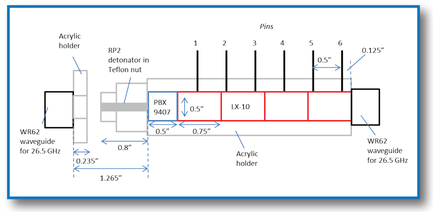
HE Dielectric Constant Measurement with a Coaxial Probe

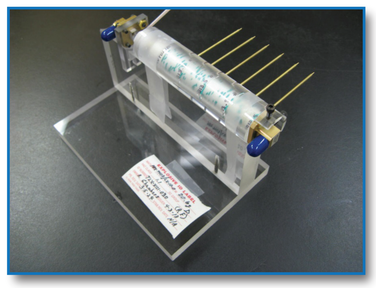
Calculated relative dielectric constant ϵ_r at 10 GHz.

Explosive	Binder, fraction (wt%)	Density (%TMD)	ϵ_r at 10 GHz for 100% TMD, Teflon normalized
LX-04 (HMX)	Viton A, 15	95.6	3.8
LX-14 (HMX)	Estane-5702, 4.5	95.9	4.1
LX-10 (HMX)	Viton A, 5	98.2	3.9
UF TATB	N/A	92.9	4.6

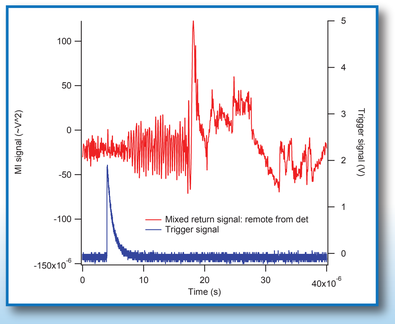


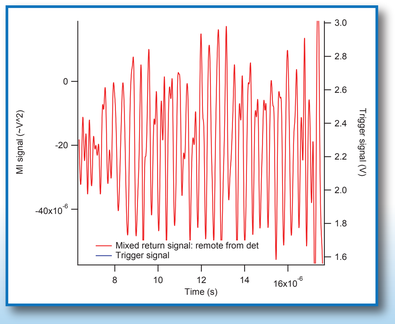
DAX





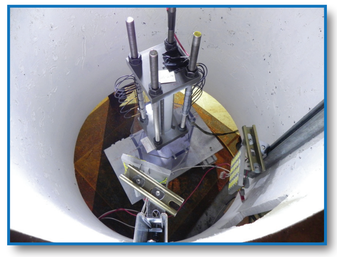
Velocity estimates:Pins→8.87 ± 0.1 mm/ms
RF cycles→8.84 mm/ms





Results

This is a work-in-progress effort with limited resources, but we have demonstrated it is possible to make velocity measurements on a continuous time basis inside HE. This adds critical information in HE experiments, supplementing the laser-based photonic doppler velocimeter (PDV) data that measures the outside surface motion at a point. Research in Russia (e.g. Belskii et al., 2011) indicates that detonation transitions across explosive interfaces may also be observable.



Feb 2012: Data reduction in process

Next Steps

Improve our techniques and assemble dedicated equipment for future experiments.
General instruments have been used to date.

1D - continuous velocity measurements
- performance across interfaces

2D - simple imaging in slabs and other 2 dimensional systems
- some imaging of direction changes

3D - it may be possible to characterize shockwave shape, more complex HE geometries (ambitious)

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