TIME DOMAIN

Ultra Wideband Technology for Precision Proximity Fuzing

49th Annual Fuze Conference
NDIA
Seattle, WA
April 2005

Bob White bob.white@timedomain.com
Alt. POC: Adrian Jennings
adrian.jennings@timedomain.com
Time Domain Corporation
Huntsville, AL
256 922-9229

Disclaimer

Forward-looking statements in this presentation are made pursuant to the Safe Harbor provisions of Section 27A of the Securities Act of 1933, as well as other applicable State and Federal laws, rules and regulations. You are cautioned that statements in this presentation that are not strictly historical statements constitute forward-looking statements which involve risks and uncertainties. These forward-looking statements include, without limitation, statements regarding potential markets and applications for Time Domain's UWB® technology, the types of products and the expected performance of products which will utilize UWB® , Management's plans and objectives for future operations and Management's assessment of competition, underserved market potential and other market factors. Other forward-looking statements which involve risks and uncertainties can be identified because the content of the statement will usually contain words such as "expects," "estimates," "could," "should," or "may" or words of similar import. The risks and uncertainties applicable to these forward-looking statements could cause actual results or events to differ significantly from the results and events discussed in the forward-looking statements. These risks and uncertainties include, without limitation, Time Domain's ability to further develop its products to meet market expectations and to obtain market share, reliance upon strategic relationships for further development and marketing of specific applications using Time Domain's chip sets, obtaining less restrictive FCC and NTIA approvals, the technological risks inherent in the development of any highly complex product line, the enforceability of Time Domain's patent portfolio, dependence on a sole source silicon germanium chip provider, market acceptance of Time Domain's products, the need to quickly bring products to market and the need to focus on particular first to market applications, obtaining adequate working capital, the risks associated with competition and competitive pricing pressures, and the risks applicable to any development stage company. You are urged to consider these factors carefully in evaluating the forward-looking statements and you are cautioned not to place undue reliance upon them.

Time Domain Corporation

- Founded in 1987, Expanded in 1996, Reorganized in 2003, Recapitalized in 2004
- Focused on UWB Technology :
  - Electromagnetics, Optics & Acoustics
- Privately Owned : Individual, Institutional & Corporate Investors
- $100M Accumulated Investment
- Intellectual Property Portfolio
  - 172+ Patents, awarded or pending, world-wide coverage
- 80 employees, 60 + in Engineering, Science, Technical & Program Support functions
- Huntsville Headquarters : 33,500 sq.ft.
  Laboratory & Field Station : 5,500 sq.ft. & 99 acres

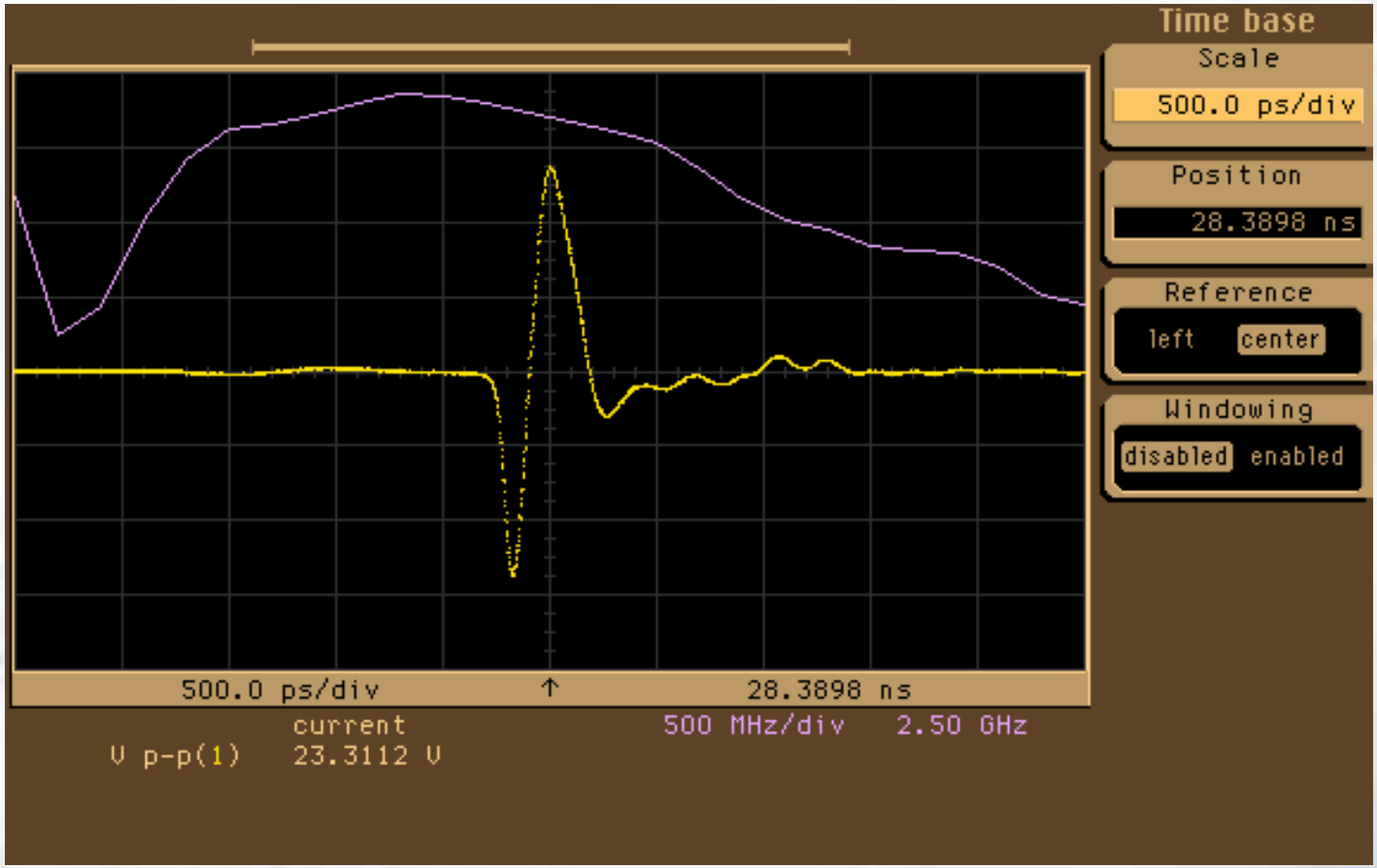
Questions to Be Addressed

- What is ultra wideband?
- How is it useful?
- What does it offer proximity fuzing?
- What is the current state of UWB proximity fuzing?

What is UWB?

- The use of very short RF pulses
- Since short pulses have very wide frequency bandwidth, it is termed “Ultra WideBand” or “UWB”
- FCC defines UWB as a 10 dB bandwidth > 500 MHz or > 20%
- TDC’s systems are typically > 2 GHz and > 60%

Actual UWB Pulse and Its Spectrum



UWB Pulses Can…

- Communicate robustly
  - Complex environments
  - LPI/LPD
- Precisely determine position
  - Autonomous vehicle followers
  - Asset Tracking
- Provide high fidelity radar
  - Small/Low cost
  - Precision with penetration
- Do combinations of the above
  - Comms and tracking for firefighters
  - Intelligent, unattended ground sensors
- And much more…

TIME DOMAIN

SoldierVision® / RadarVision®

Through-wall imaging radar

Finding Survivors in Rubble

- RCLAD Specs
  - Detect breathing up to 10 ft. down
  - Through up to 24” of rubble
  - Within 40 seconds
  - Weigh less than 10 lbs.

- Delivering 20 prototypes this year
- Commercial RubbleVision™ under development

UWB Advantages to Prox Fuzing

- Precision ranging
- Penetrates visual obscurants
  - Unaffected by aerosols, including dust, smoke, and fog
  - Only slightly affected by heavy (4”/hr) rain
- Day/night operation

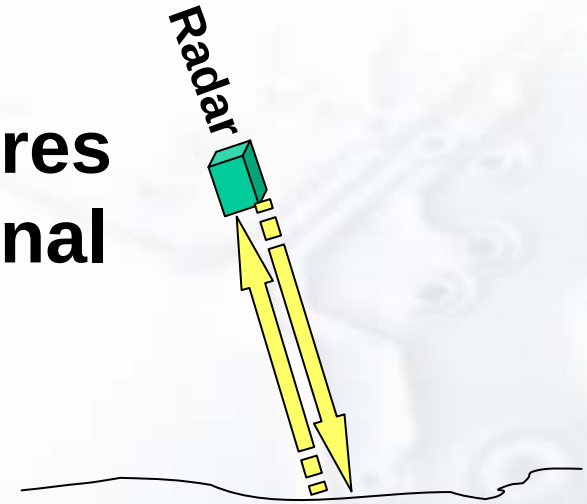
Continued …

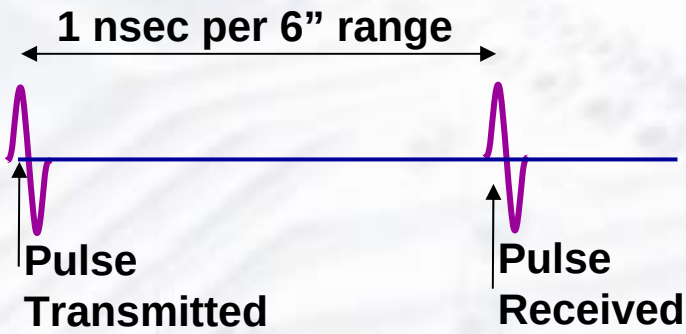
UWB Advantages to Prox Fuzing (cont.)

- More dependable than narrowband
- Jam resistant
- Supports co-located devices
- Simple, low cost, low power
- Very short blind range
- Precision with penetration
  - Large fractional bandwidth

UWB offers precision ranging …

Timing of the pulse measures range, just as in conventional radar.





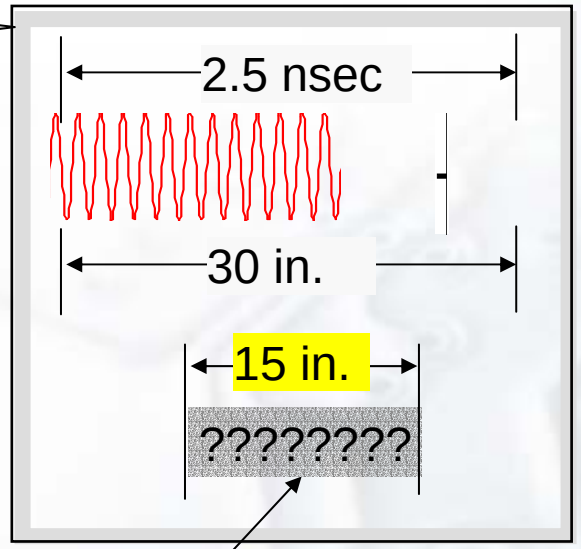
As in conventional radar, range resolution is given by

$$\Delta Range = \frac{c}{2 \bullet BW}$$

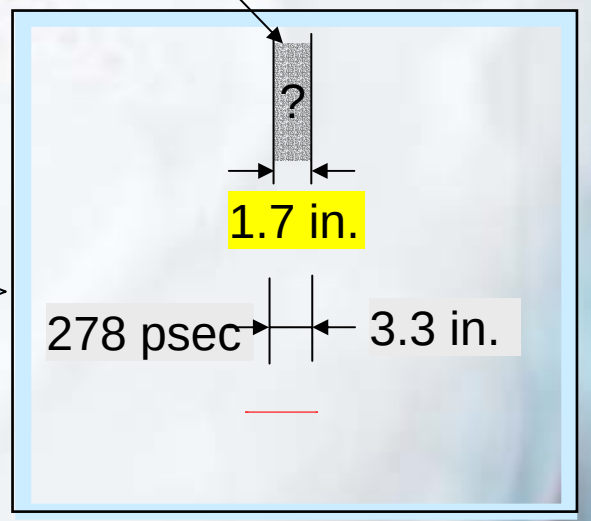
Continued

Conventional radar vs. UWB

Parameter	Conv.	UWB
Ctr. Freq.	8 GHz	8 GHz
Bandwidth%	5%	45%
Bandwidth	400 MHz	3.6 GHz
Pulse Duration	2.5 nsec	278 psec
Pulse Length	30 in	3.3 in.
Resolution	15 in	1.65 in
Range Error	> 15 in	> 1.65 in

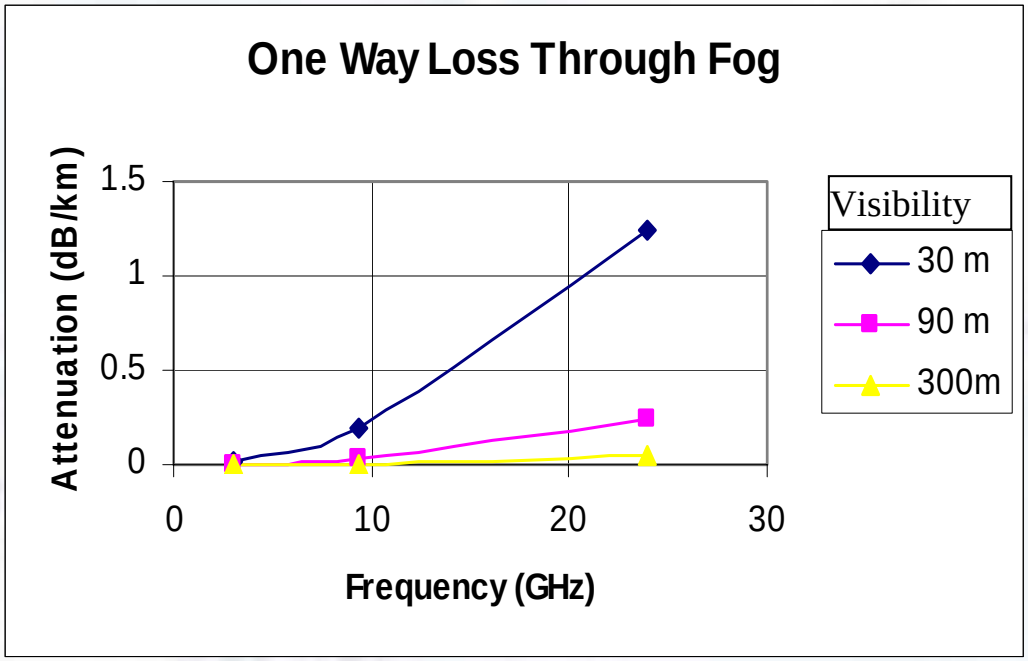


Target is where?

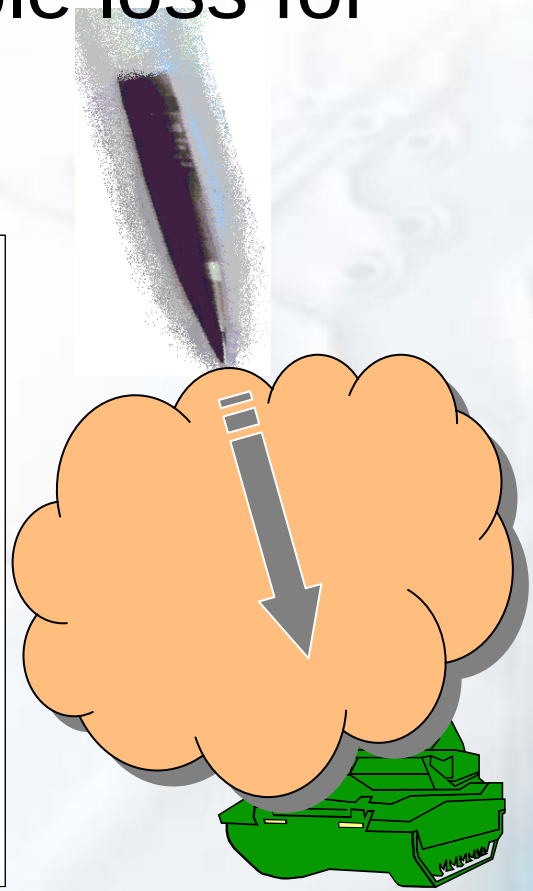


UWB Through Obscurants

- Fog and smoke. Negligible loss for the ranges of interest.



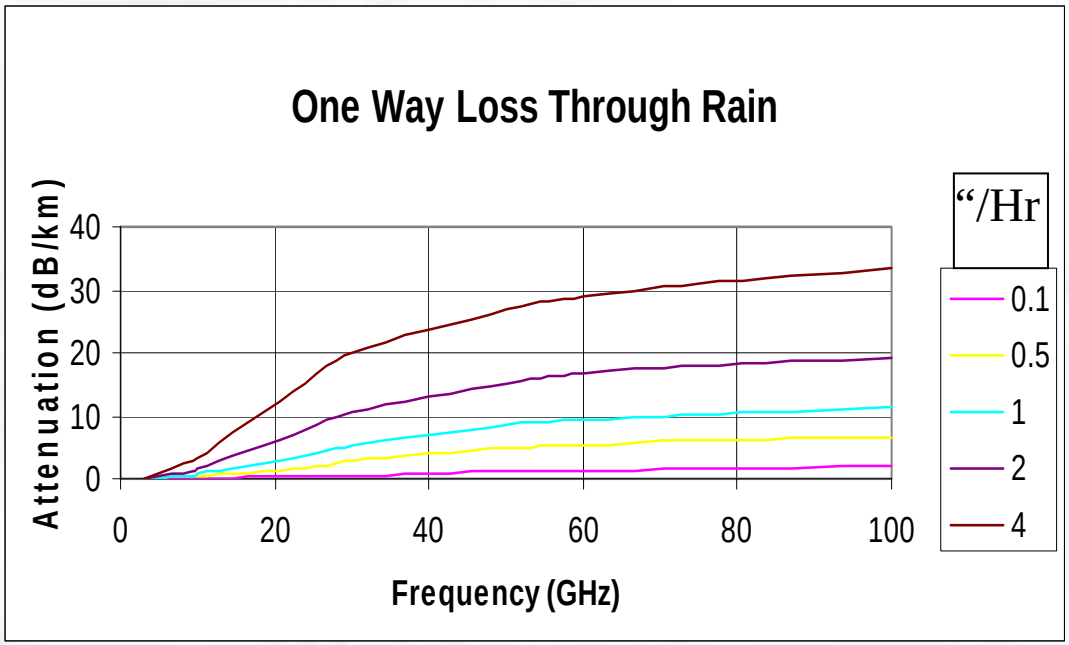
Saxton and Hopkins, Proc. IEE, Vol. 98, 1951



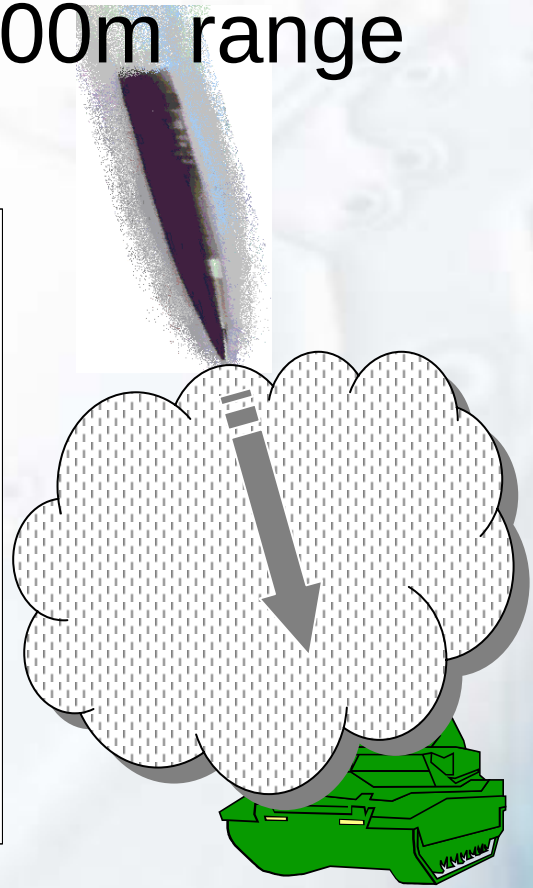
Continued …

UWB Through Obscurants

- Rain. Small effect, but not negligible.
- @20 GHz, 4”/hr rainfall, 100m range
  => 2.6 dB two way loss



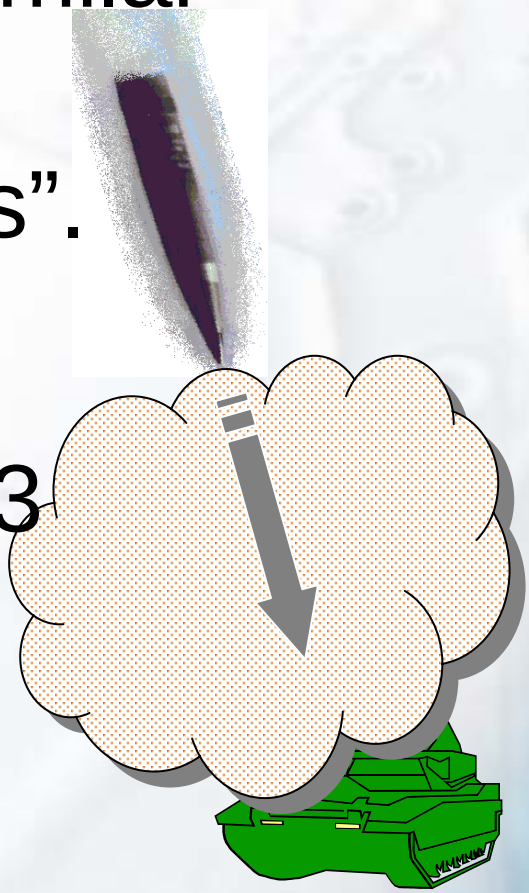
Burrows & Atwood, NDRC, 1949



Continued …

UWB Through Obscurants

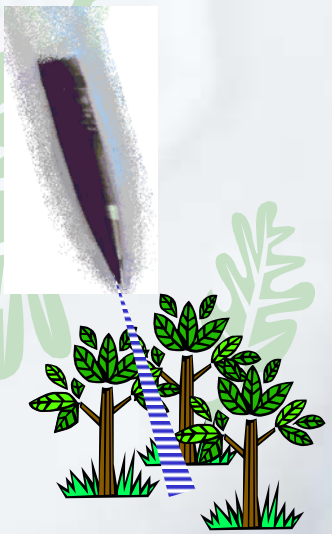
- Ice/Snow/Sleet/Hail; Similar to rain for wet “drops”, negligible for dry “drops”.
- Dust: Negligible for the ranges of interest. (~0.3 dB/km at 24 GHz*)



***Comparetto, G.;*The Impact of Dust and Foliage on Signal Attenuation in the Millimeter Wave Regime*;J. of Space Comm.;Vol.11, No.1, pp.130-20, July, 1993**

FOPEN

- At any given center frequency, UWB offers much improved range resolution through bandwidth
- UWB offers the possibility of operating at a low enough frequency to penetrate foliage, yet maintain the required high resolution
- The fuze can see into foliage and accurately sense the ground.



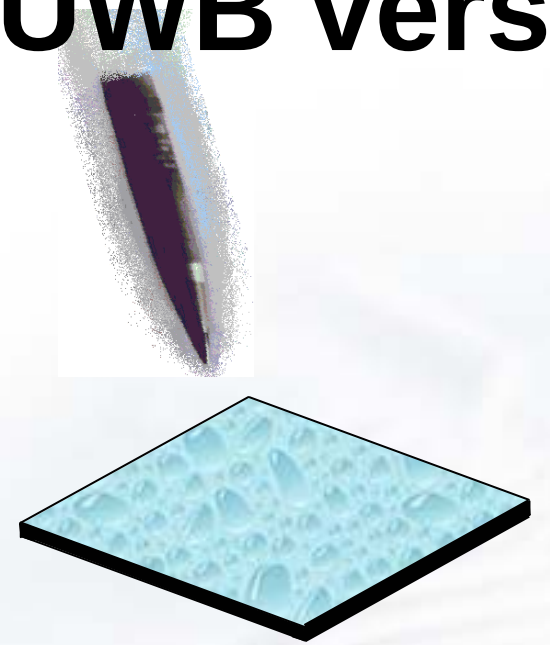
UWB is more dependable than narrowband

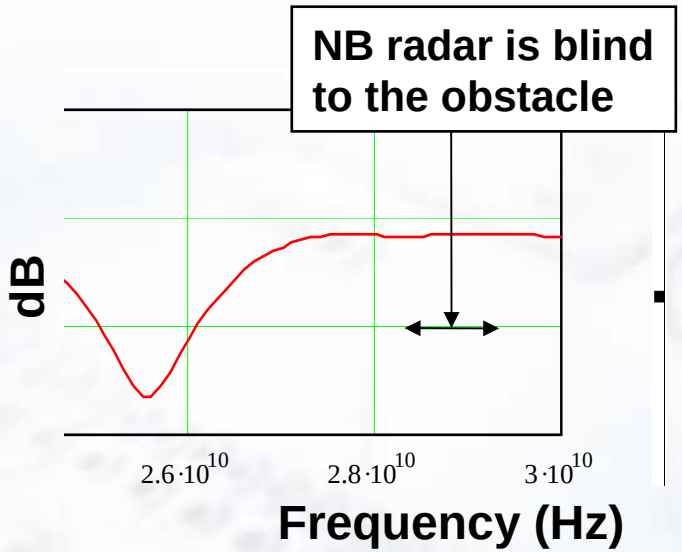
- A contrived, but feasible scenario:
- The munition approaches a flat sheet of metal. It is winter.
- The metal is covered with a .29” thick layer of rime ice with dielectric constant = 8 and loss tangent = 0.04.*
- Note: Metal is easily analyzed, but the actual surface might be smooth concrete.

* Feasible values. See D.J. Daniels, **Surface Penetrating Radar** p.49

Continued …

UWB versus NB

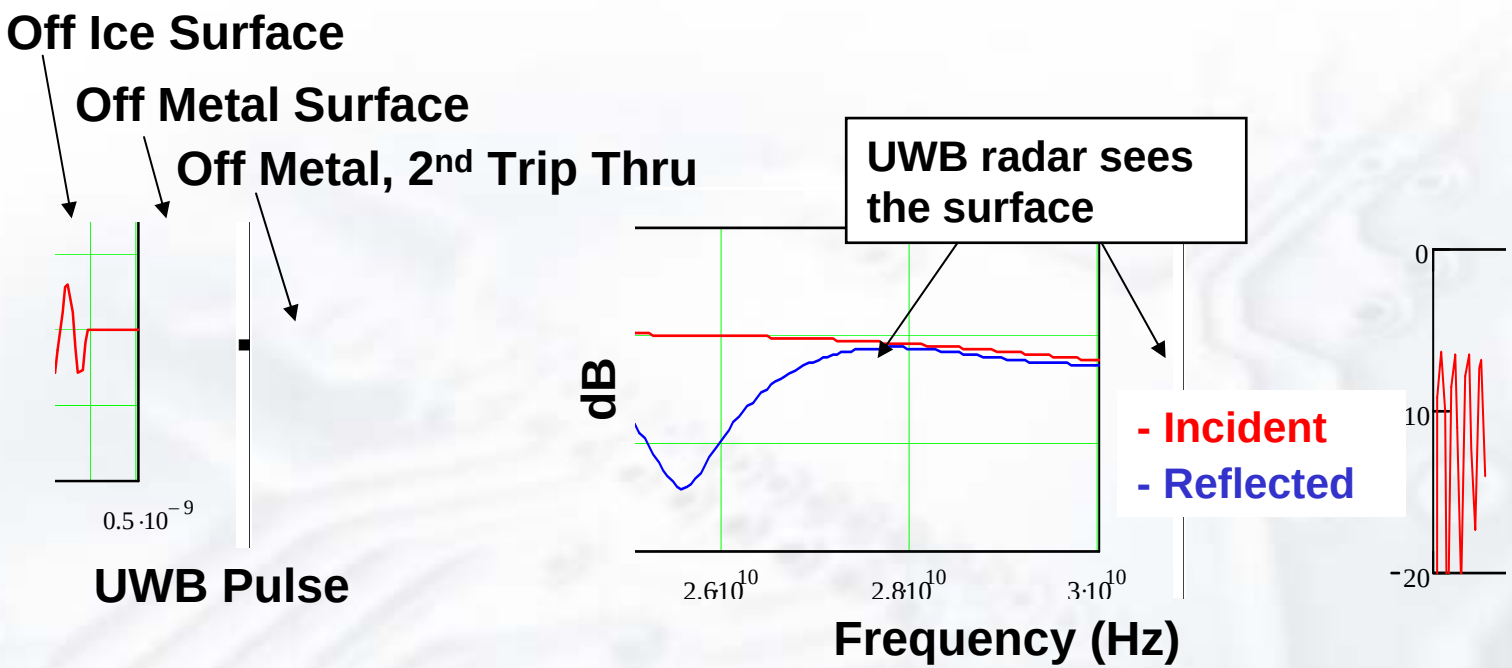




- **A narrowband radar is blind to the target, due to destructive interference between returns off the ice and the metal.**
- **The ice is acting as tuned microwave absorber.**

Continued …

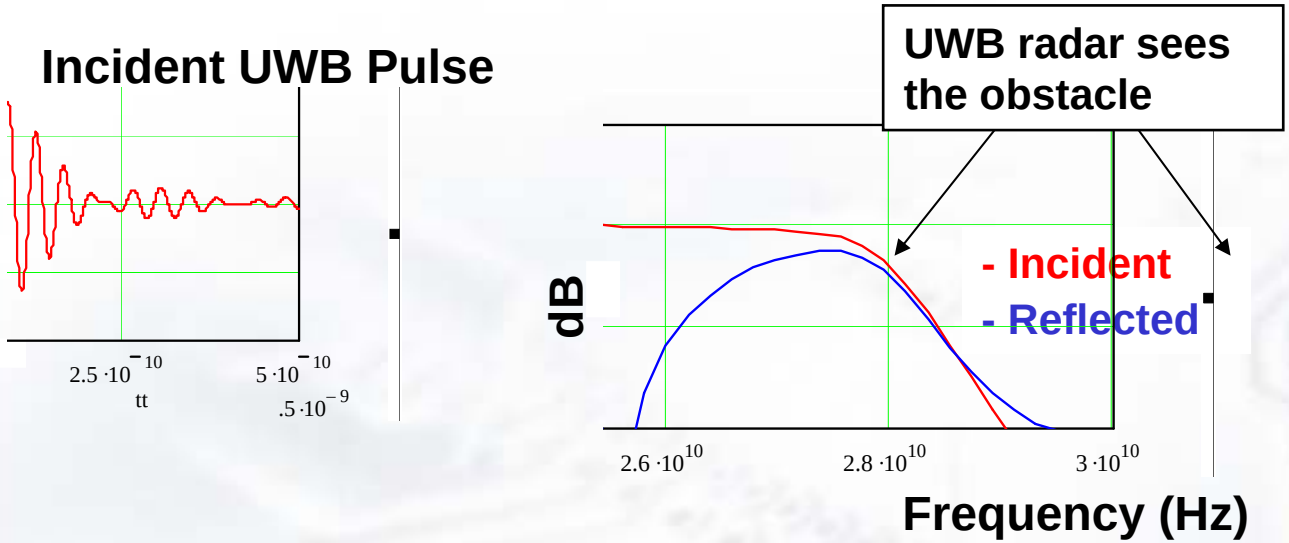
Extreme UWB vs. NB



- **This extreme-UWB radar sees the individual surfaces, but what about a realistic UWB radar?**

Continued …

UWB versus NB



- The pulses of this 6 GHz wide UWB radar partially overlap, but it still senses the surface.
- Many similar scenarios exist: UWB radar sees an obstacle, NB does not.

Another Contrived but Feasible Example

- The munition approaches flat concrete.
- The concrete is cracked and one section is l/4 higher than the adjacent one (0.3” for a 10 GHz radar.)
- A narrowband radar will be blind to the target.
- UWB will detonate on time because the slab reflections only cancel at the radar’s center frequency.

Co-Located Fuzes

- Multiple UWB devices can coexist through coding.
- This is the same technique CDMA cellular phones use to coexist.
- This technique is already successfully employed in TDC's products.

Anti-Jam Capability

- The same PN coding that allows multiple UWB fuzes to coexist also provides anti-jam capability.
- The correlating PN code in the receiver reduces the noncoherent jammer power.
- Second tier anti-jam capability can come from filters to notch out jammers.
- Both techniques are being successfully used in TDC UWB products.

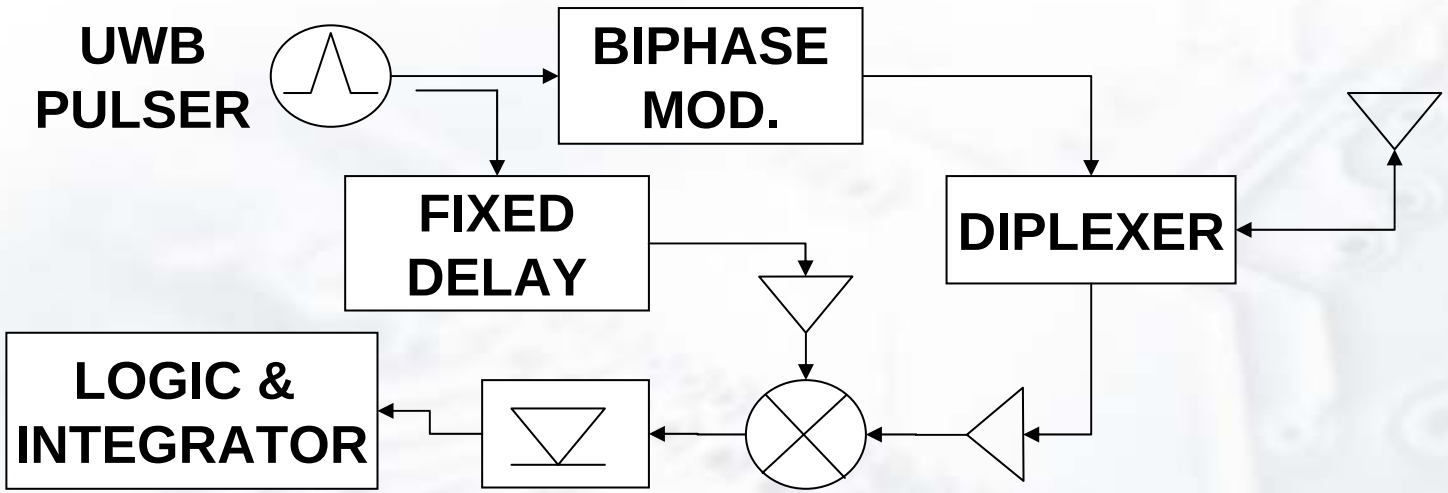
Simple Architecture

- UWB system architecture and circuits are inherently simple.
- Many functions can be implemented in ASICs (many have already.)
- This allows small packaging, low power and relatively low cost.

UWB Misconceptions

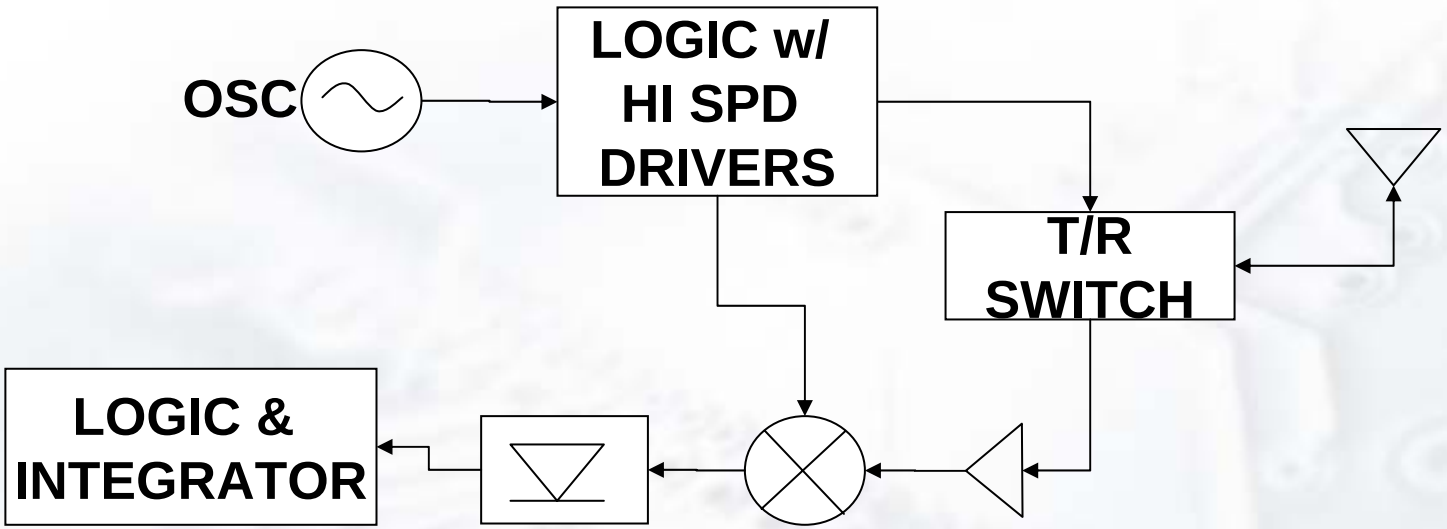
- UWB is a spark gap radio
  - No, UWB pulses are carefully crafted, with precise timing and bandwidth
  - Captures full radiated spectrum
- UWB is complex
  - Some applications can be, but UWB proximity sensing is the epitome of simple.
- UWB is high power
  - No, TDC UWB is typically lower than unintentional radiators (your computer)
- UWB is inherently expensive
  - No, the simple architecture can be reduced to SiGe/CMOS ASICs

UWB Fuze Architecture #1



- Simple
- Fixed set point
- Adjustable PRF
- Very low power consumption
- Very low blind range

UWB Fuze Architecture #2

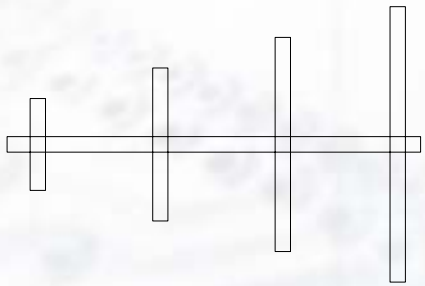


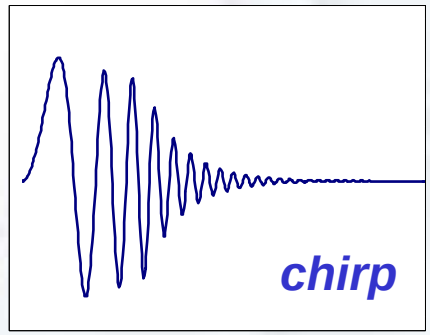
- Simple
- Adjustable set point
- Fixed PRF

UWB Antennas

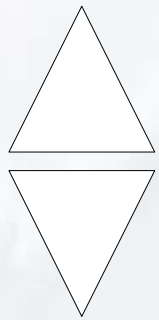
- We desire a phase center that is non-dispersive
- We also need low Q elements to avoid resonances

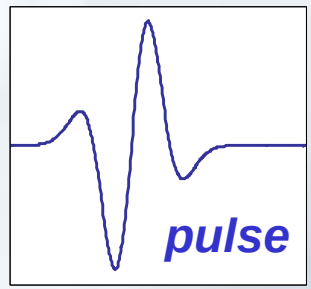
Dispersive
(e.g. Log-Periodic)



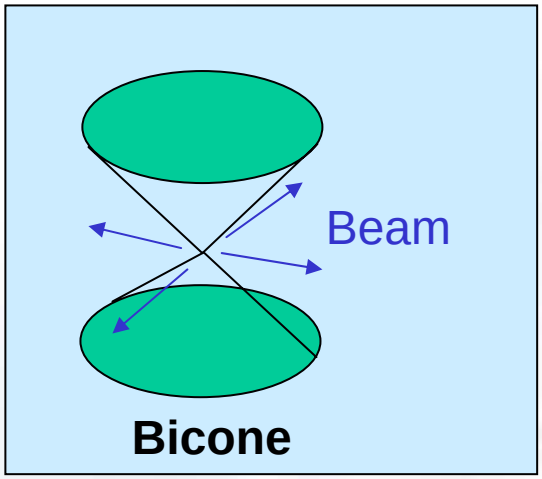


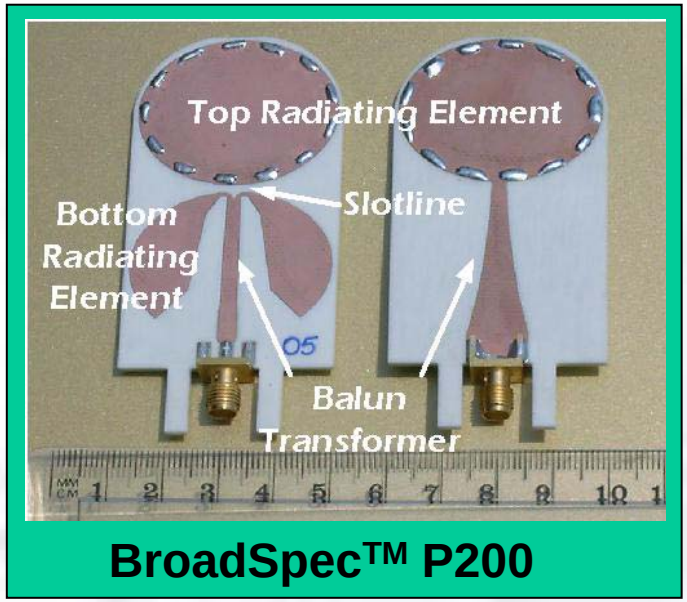
Non – Dispersive
(e.g. Diamond Dipole)

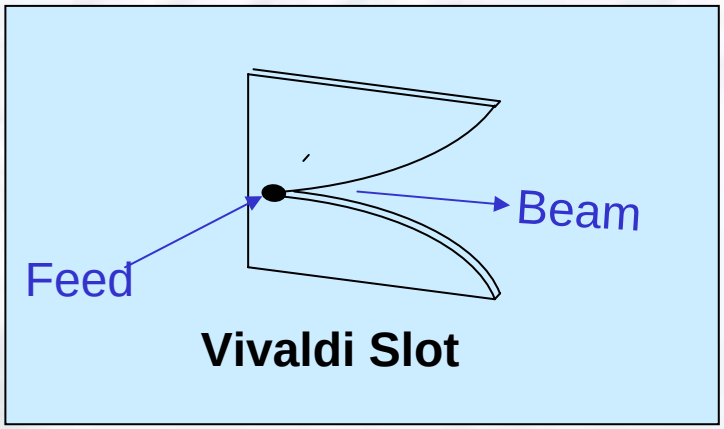




UWB Elements (cont.)







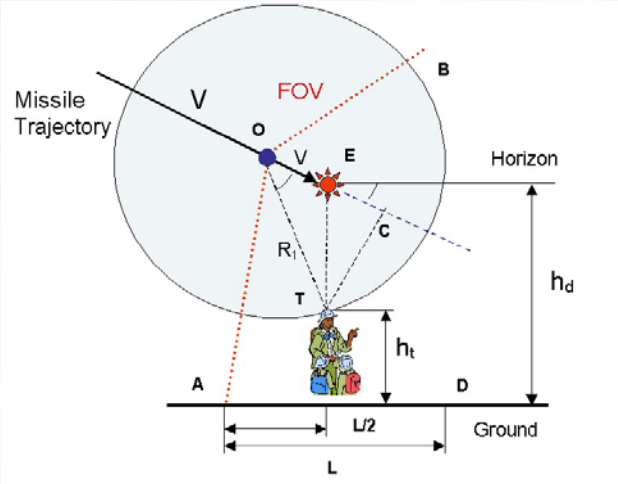
- Cross for CP
- Make conformal to radome

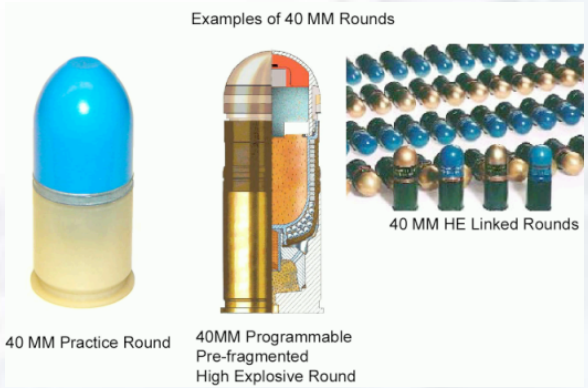
Recent UWB Fuze Experiment

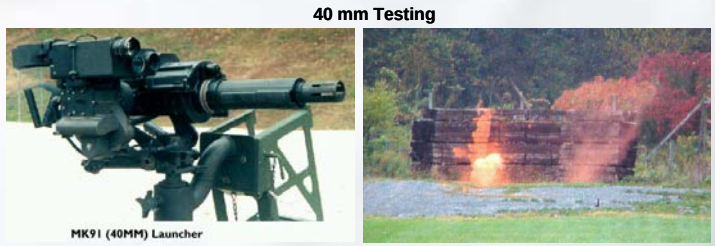
- Time Domain built a POC UWB fuze for Action Mfg.
- Rocket Ball testing at Redstone Arsenal, Huntsville, AL this year was quite successful.
- Accuracy of < 6” was demonstrated.

Proximity Fuzing

- TDC recently won an SBIR for UWB fuzing in non- lethal 40mm grenades







40 mm Fuze

- UWB's high resolution makes it particularly attractive
- Significant challenges include
  - Packaging the electronics in the space
  - Generating power for an active fuze

UWB Advantages to Prox Fuzing

- Precision ranging
- Penetrates visual obscurants
  - Unaffected by aerosols, including dust, smoke, and fog
  - Only slightly affected by heavy (4”/hr) rain
- Day/night operation

Continued …

UWB Advantages to Prox Fuzing (cont.)

- More dependable than narrowband
- Jam resistant
- Supports co-located devices
- Simple, low cost, low power
- Very short blind range
- Precision with penetration
  - Large fractional bandwidth