

Introduction

December 3, 1999

On that day, six fire fighters lost their lives in a tragic cold storage warehouse fire in Worcester, MA.

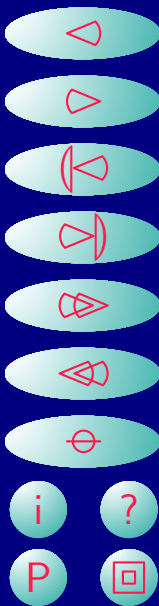
Two fire fighters initially got lost and then two search teams became lost in the maze due to zero visibility from the dense smoke.

Our goal: Create technology to aid and rescue those who put the mission of our safety before personal safety

X-Fighter Precision Location

First focus area: Precision, ad hoc, geolocation and associated exchange of information for situational awareness and command for x-fighters...

- Firefighters
- Crimefighters
- Warfighters
- First-responders
- Corrections officers



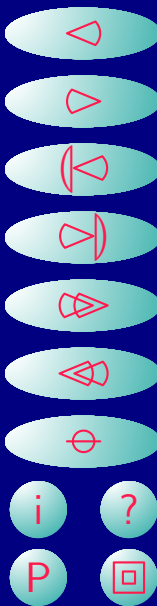
Possible Geolocation Technologies

How do we achieve transportable (no infrastructure) precision geolocation on the order of several cm accuracy indoors?

GPS and DGPS?

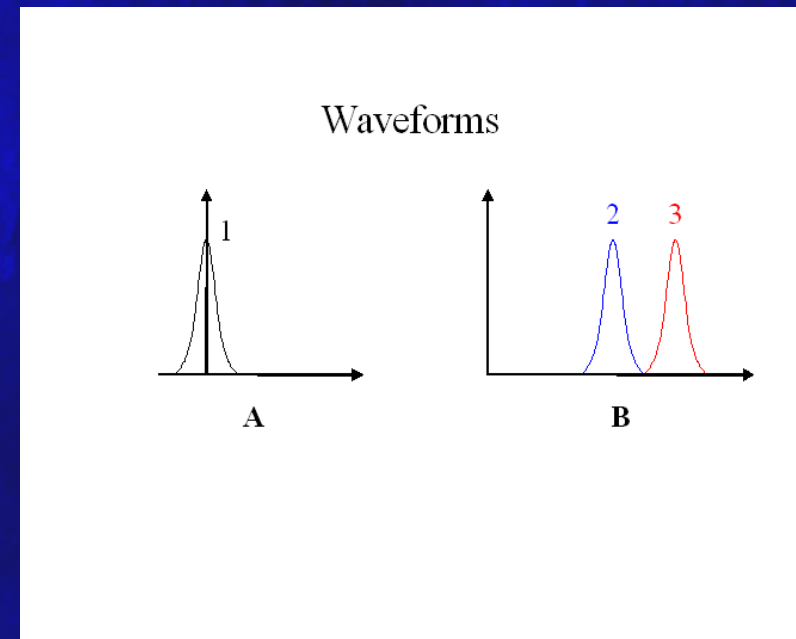
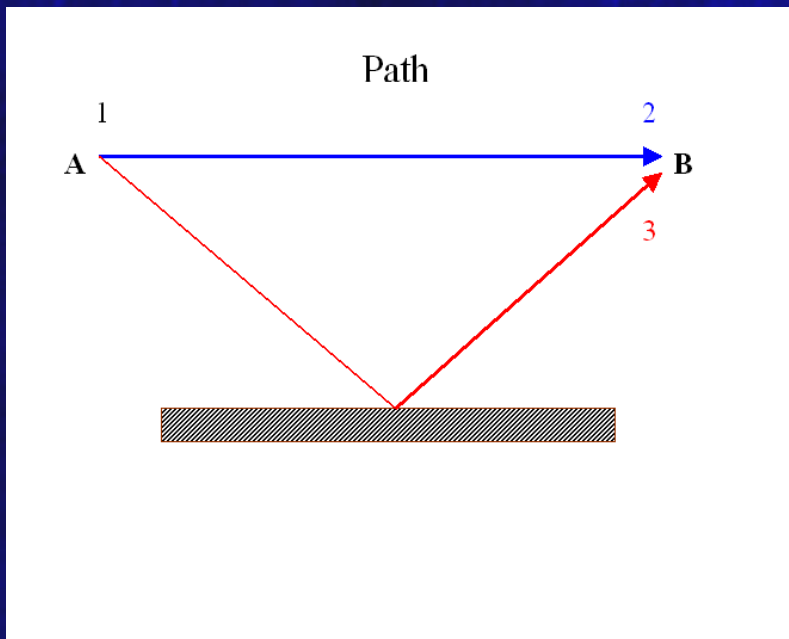
- Insufficient resolution (10 m)
- Insufficient signal strength inside buildings
- Multi-path degraded

What about Impulse UWB?



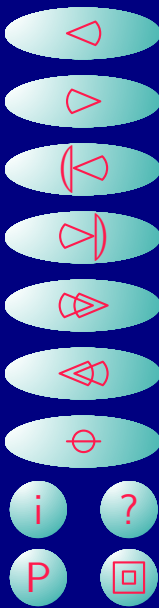
Impulse Ultra-Wide Band

- Extremely narrow (hence ultra-wide bandwidth) pulses provide the localization precision required
- Precise pulse discrimination is tantamount to separability of multi-path from direct path signals



Impulse UWB Problems

- Extremely narrow pulses are also tantamount to large signal acquisition times and difficult tracking!
- Pulse generation and time-windowing at receiver may require exotic circuitry
- Maintenance of pulse characteristics requires extremely low distortion transmitter and receiver antennas over huge bandwidths



More Impulse UWB Problems

- Conflict with regulators:
 - Industry claims no spectral allocation needed
 - Regulators claim all existing services at risk
- Conflicting claims by industry:
 - High penetration capability enabled by low frequency components
 - High precision ranging enabled by high frequency components
- Claims of Warfighter LPD are challenged by an o-scope!



What is the true benefit of I-UWB?

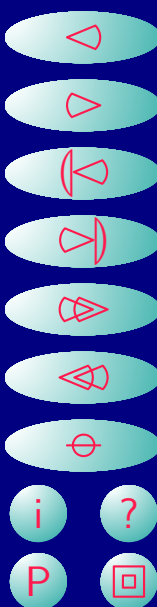
- **Marketing:**

- The approach is immediately appealing because of the vivid transparency of its operation

- * Its short pulses on direct path transmission arrive before any reflections and hence allow multipath elimination and precise location.

- **The reality is:**

- This compelling picture obscures the fact that short pulses are not needed for precision location



Multi-Carrier Ultra-Wideband

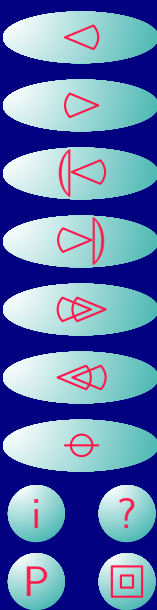
The solution appears to lie in a mix of two recent innovations:

- Super-resolution SAR/ISAR Radar

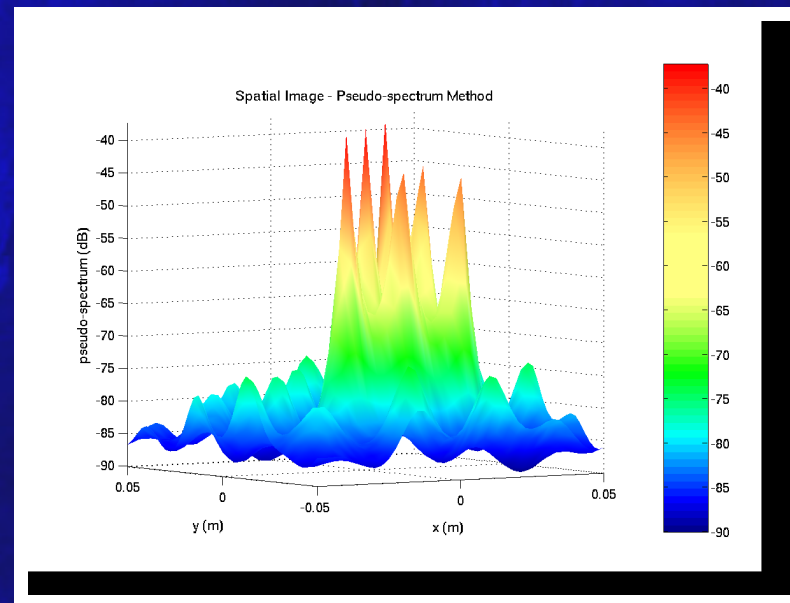
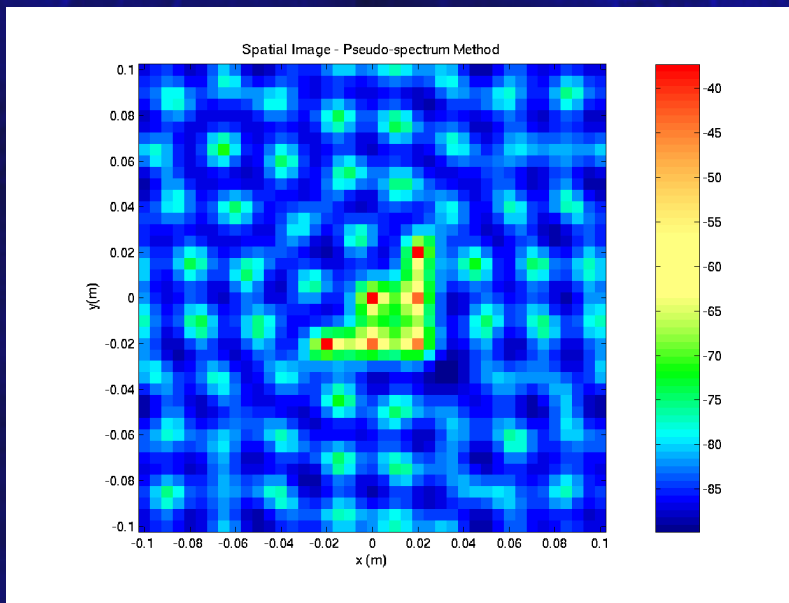
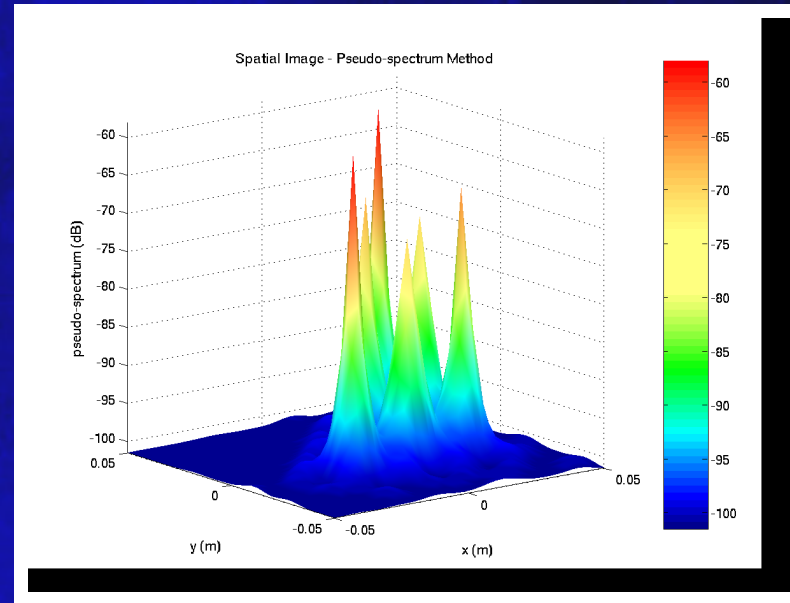
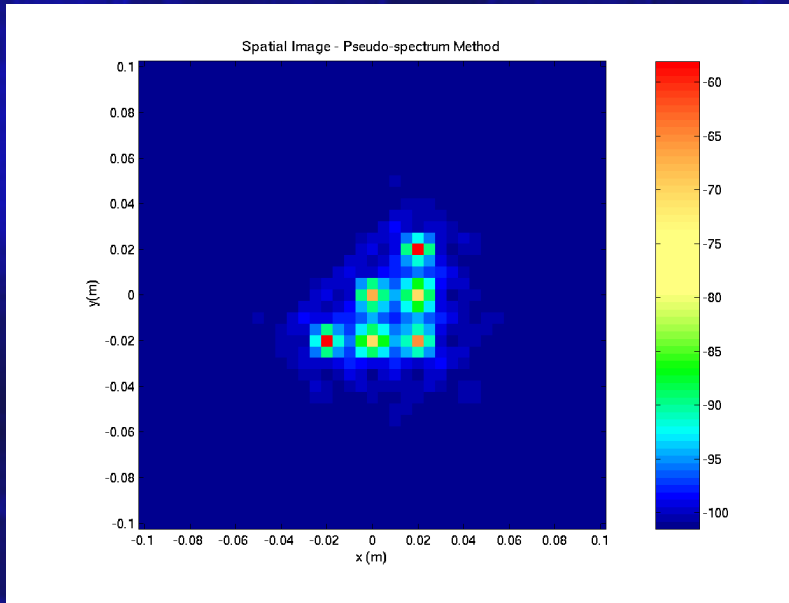
Enhances Radar resolution to centimeters and similarly improves angular resolution of SONAR systems.

- Orthogonal Frequency Division Multiplexing (OFDM)

Allows DSL transmission of many Mb/sec over existing subscriber loop twisted copper telephone pairs and provides new means to enhance fixed and mobile radio services in high multipath environments.

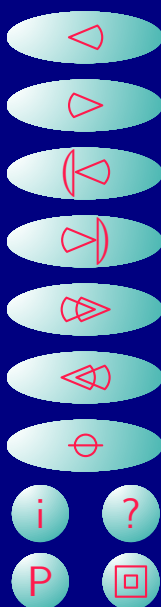
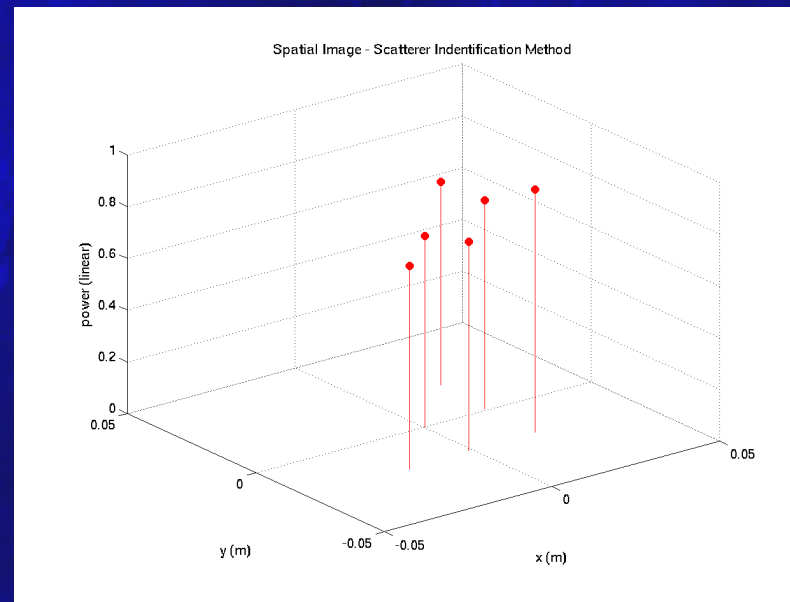
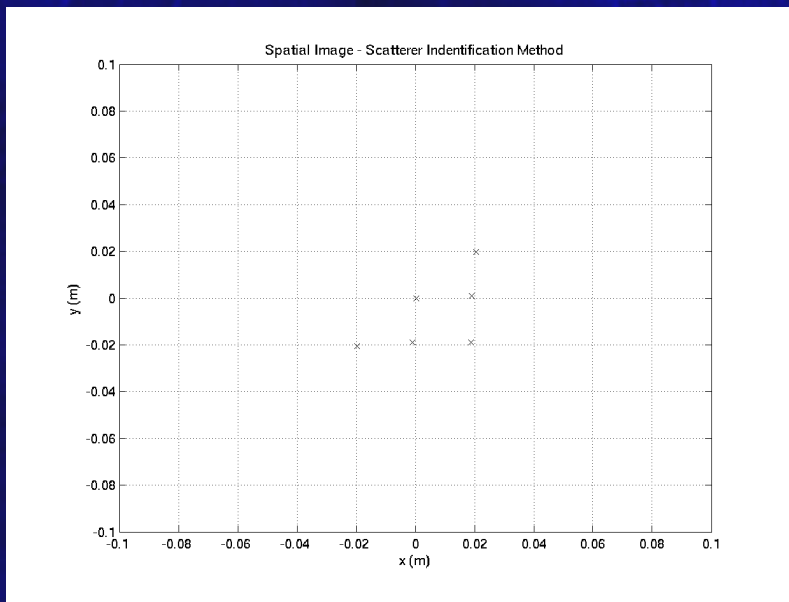
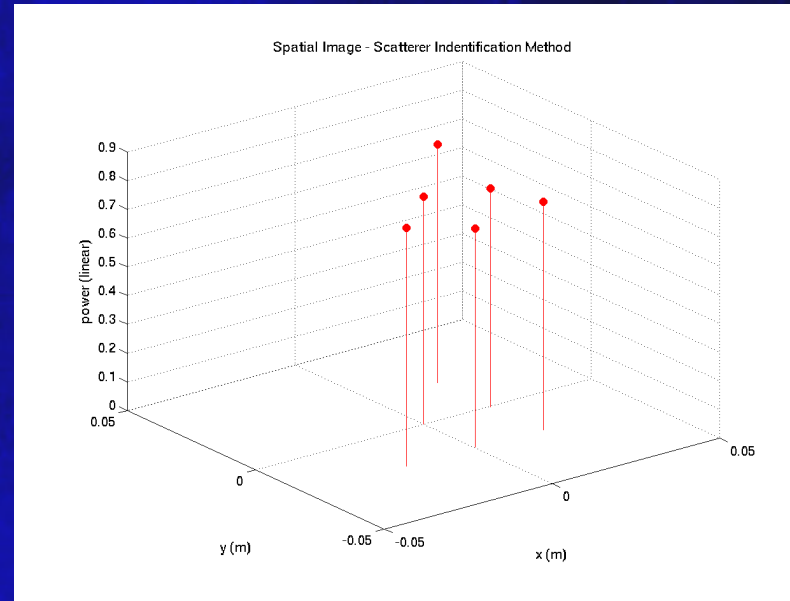
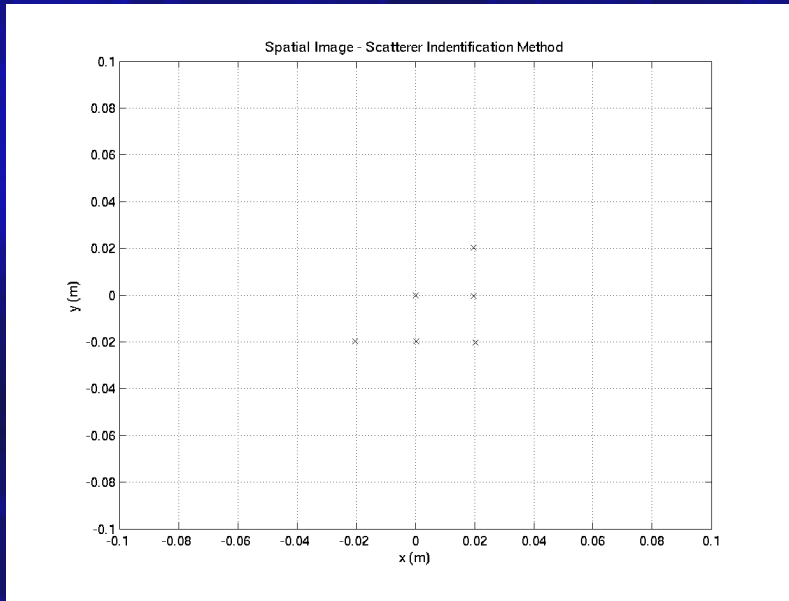


Pseudo Spectrum ISAR

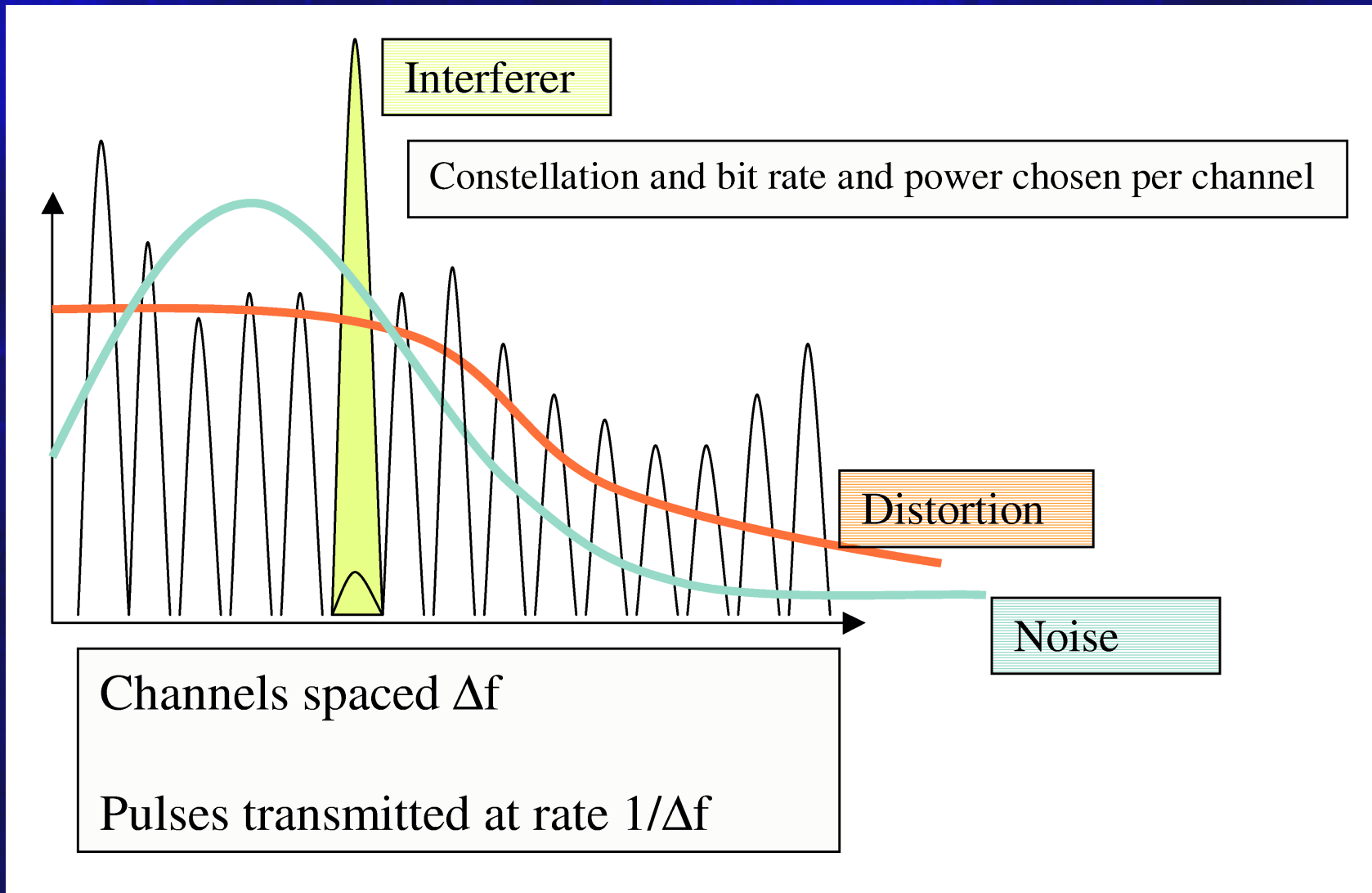


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Scatterer Identification ISAR



OFDM Channels



Lessons learned from OFDM

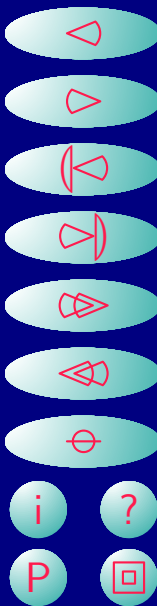
High data rate transmission via multicarrier modulation does not require a single wide band channel with:

- Low distortion (in amplitude and/or phase response)
- Narrow pulses
- Uniform noise
- Absence of interferers
- Precise synchronization

Multi-carrier Super-res Location

Combining scatterer identification from super-res radar and multi-carrier modulation from OFDM we obtain:

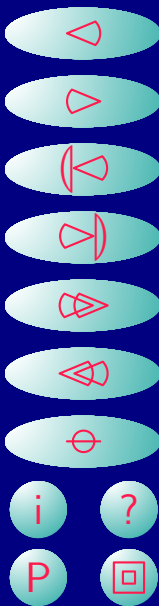
- Subwavelength precision location
- Amelioration of multi-path by **imaging** the scatterers!
- Spectral compatibility with existing services
- Dynamic response to interferers
- Freedom from electronic and EM design constraints
- Covertness in time and frequency
- Combined location and high bandwidth communication



Demonstration

We have constructed a proof of concept demonstration

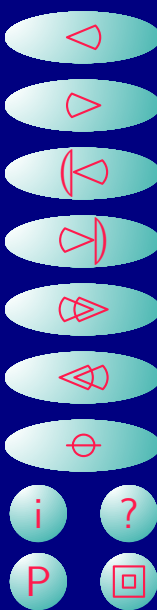
- Uses audio, not RF - greatly eased troubleshooting
- Top audio frequency has wavelength in air of 4.5 in
- 1:1 scale behavior with an RF bandwidth of 2.625 GHz
- Implements real-time location system using MATLAB
- Off the shelf microphone/speaker components could be used thanks to the OFDM like channelization
- Displays true location solution as well as multipath solutions



The Architecture

Emergency vehicles will be equipped with two or more receiver based reference stations, distributed in height.

- The vehicles should be distributed so as best to surround the area of operations
- The reference stations also maintain an out-of-band 802.11 data channel for exchanging information and sharing fix solutions.
- The multi-carrier transmitters are simple: they simply, continuously transmit a single waveform.
- Personal fix via 802.11 data channel.



The Strategy: Two teams

- Prof. Cyganski and RAs: Signals and Location software implementation and performance analysis.
- Prof. Michalson and RAs: RF hardware implementation and performance analysis/testing.
- Keep it simple
 - Use as much off-the-self hardware as possible
 - Build a demonstrator not a finished product
- Small steps, or “wing-walking”
 - Demonstators that function at each milestone.