

Tracking, Safety, and Navigation System for Firefighters

**Wayne C. Haase, Ph.D.
Summit Safety, Inc.**

Outline

- Introduction
- Locating/Finding Techniques
- Technology Choices
- Personnel Ultrasonic Locating Safety Equip
- Existing Systems
- Summary

Introduction

- Background
- Search Techniques
- PASS and TIC
- December 1999 Fire in Worcester, MA

Locating/Finding Techniques

- Location vs Path: Search vs Rescue
- Blind Search
- Homing Beacon
- Active Search
- Triangulation

Technology Choices

- Optical: Visible
- Optical: Infrared
- Radio
- Acoustic: Audible
- Acoustic: Ultrasonic

Wavelength

$$c = f \lambda$$

Visible	3×10^8 m/s	4×10^{14} Hz	0.75 μ m
Infrared	3×10^8 m/s	3×10^{14} Hz	1.0 μ m
Infrared	3×10^8 m/s	2×10^{13} Hz	14 μ m
Ultrasound	330 m/s	40 KHz	8.25 mm
Radio (uw)	3×10^8 m/s	2.4 GHz	125 mm
Radio (GPS)	3×10^8 m/s	1.575 GHz	191 mm
Sound	330 m/s	1 KHz	330 mm
Radio (FM)	3×10^8 m/s	100 MHz	3 m
Radio (AM)	3×10^8 m/s	1 MHz	300 m

Optical: Visible

- E-M Waves
- Line of Sight
- Reflected Only by Mirrors
- No Wall Penetration
- Penetrates Glass
- Rayleigh Scattering

Optical: Infrared (Thermal)

- E-M Waves
- Line of Sight
- Reflected by Gold Mirrors
- No Wall Penetration
- No Glass Penetration
- Limited Rayleigh Scattering
- Image Inversion
- Thermal Overload/Masking

Radio

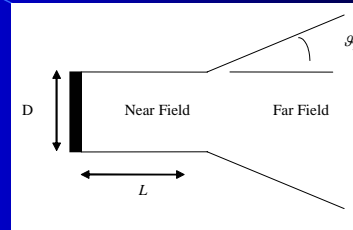
- E-M Waves
- Wall Penetration at Lower Frequencies
- Dielectric Absorption at Higher Freq (GPS)
- No Rayleigh Scattering
- Blocked by Metals
- “Line of Sight”

Acoustic: Audible & Ultrasound

- Longitudinal Pressure Waves
- Reflected by Solid Surfaces
- Penetrate Porous Materials
- No Rayleigh Scattering
- Attenuation at Very High Frequencies
- Acoustic Path
- Interference at Lower Frequencies

Frequency Choice

- Beam Pattern
- $L = D^2/4\lambda$
- $\theta_z = 1.22 \lambda/D$
- All Waves



KHz	D [in]	D/λ	L [mm]	θ_z	$2 \theta_z$
40	3	9.2	176	7.6	15
20	3	4.6	88	15	30
4	3	0.9	18	76	151
4	7	2.5	96	32	65
1	7	0.5	24	130	259

Why Ultrasound?

- Not Affected by Fire Environment
- Small, Directional Receiver
- No Rayleigh Scattering
- Reflected Waves: Locate Behind Obstacles, Behind Doors, and Around Corners
- No Blind Alleys
- Indicates Path

Pulse System

- Personnel Ultrasonic Locating Safety Equip
- Beacon: Omnidirectional Transmitter
- Tracker: Directional Receiver
- Firefighter, Exit, Tot-Finder Beacons
- Range: 150+ feet
- Time: 2-5 minutes (typical)

Beacon

- Ultrasonic Transmitter
- Motion Sensor
- Audible Annunciator
- LED Indicators
- 2 Reset Switches
- Alarm Switch
- Activation Clip
- Monitor/Pre-Alarm/Alarm



Tracker

- Directional U/S Receiver
- LED Bargraph for Signal
- Mode Switch & LEDs
- Audible Annunciator
- LED Bargraph for Battery



Other Systems

- Personal Alert Safety System (PASS)
 - Difficult to Locate w/o Ultrasound
- Thermal Imaging Camera (TIC)
 - Line of Sight
 - Debris
 - Thermal Masking/Overload
 - Could Use Pulse Technology

Summary

- Technologies
 - Optical, Radio, Acoustic
- Locating Techniques
 - Location vs Path
- Pulse System
 - Beacon & Tracker