Radio Communications in Large Buildings

A Fire Department Perspective

Mike Worrell
City of Phoenix FD
Phoenix, Arizona

Fire Department Communications

80% of incident volume is related to Emergency Medical – 20% fire fighting

But…

80+% of communications traffic is related to fire fighting and rescue operations

Characteristics of Fire Fighting Communications

- Incident Commander is responsible for incident
- Firefighters communicate with each other and the incident commander to accomplish tasks
- Incident Commander communicates with the dispatch center for additional resource needs
- Dispatch center monitors communications on the fire ground

Characteristics (cont.)

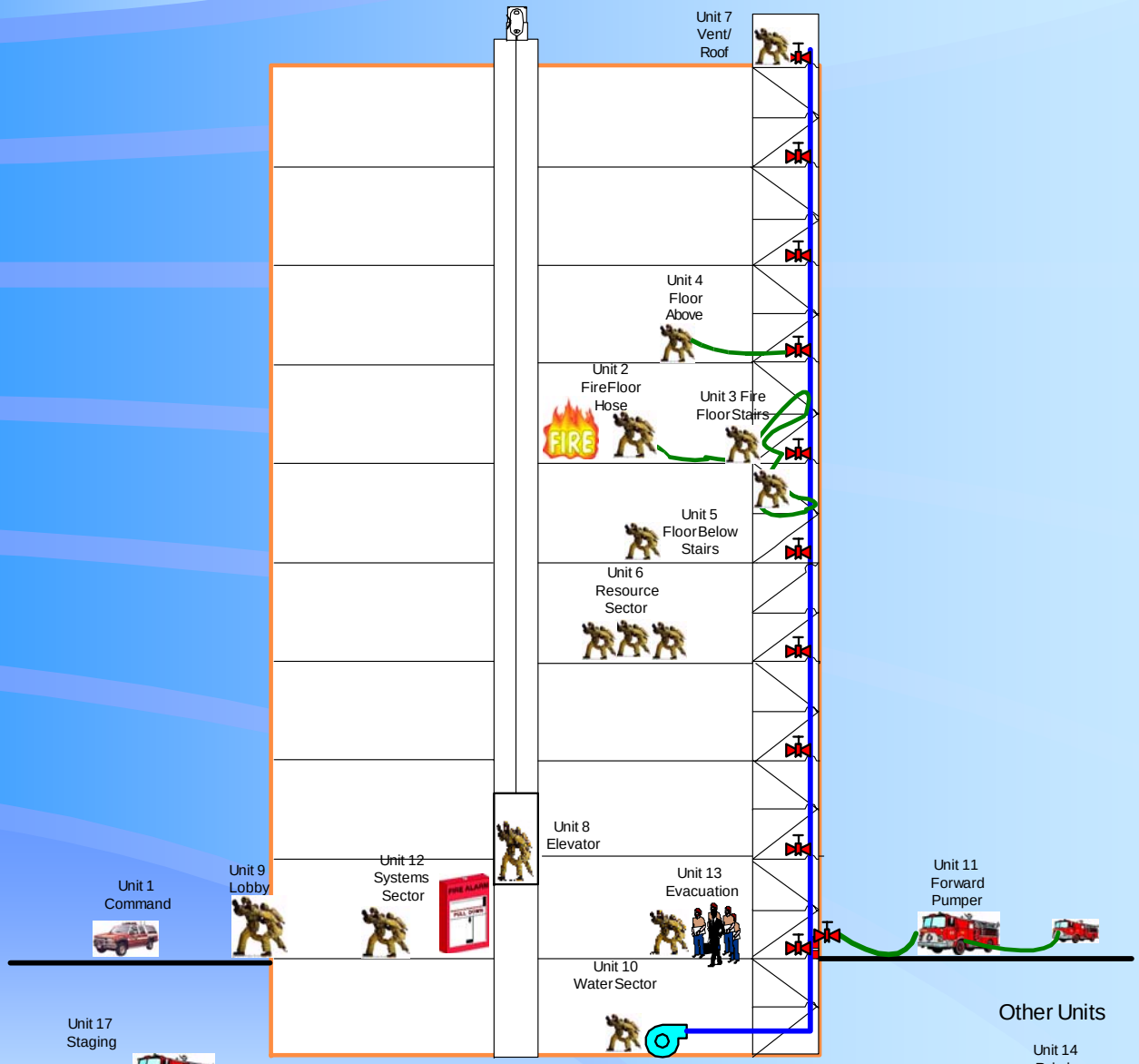
- Tactical communications - local to the incident and involves only those units on the fireground
- Staging – Local to the incident, staging officer may be located away from incident itself
- Incident commander must be able to communicate with both units on incident and the dispatch center

Fire Radio System Engineering Project

- Evaluate various communications bands and modes for fireground operations
- Analog & Digital
- VHF, 700 MHz & 800 MHz
- Direct & Trunked
- Testing based on fire fighting deployment model using simulated incidents

Testing Methodology

1. Buildings were classified by NFPA building type. Testing was performed in 4 building types.
2. Responses were based on SOP's in the type of building.
3. Personnel were placed on the interior simulating a Fire Department response.
4. 1500 Logical talk paths were tested.
5. Participants graded the communications on a 1-5 scale.
6. 30 buildings were tested.



NFPA Building Type I (Hi-Rise) Communications Positions

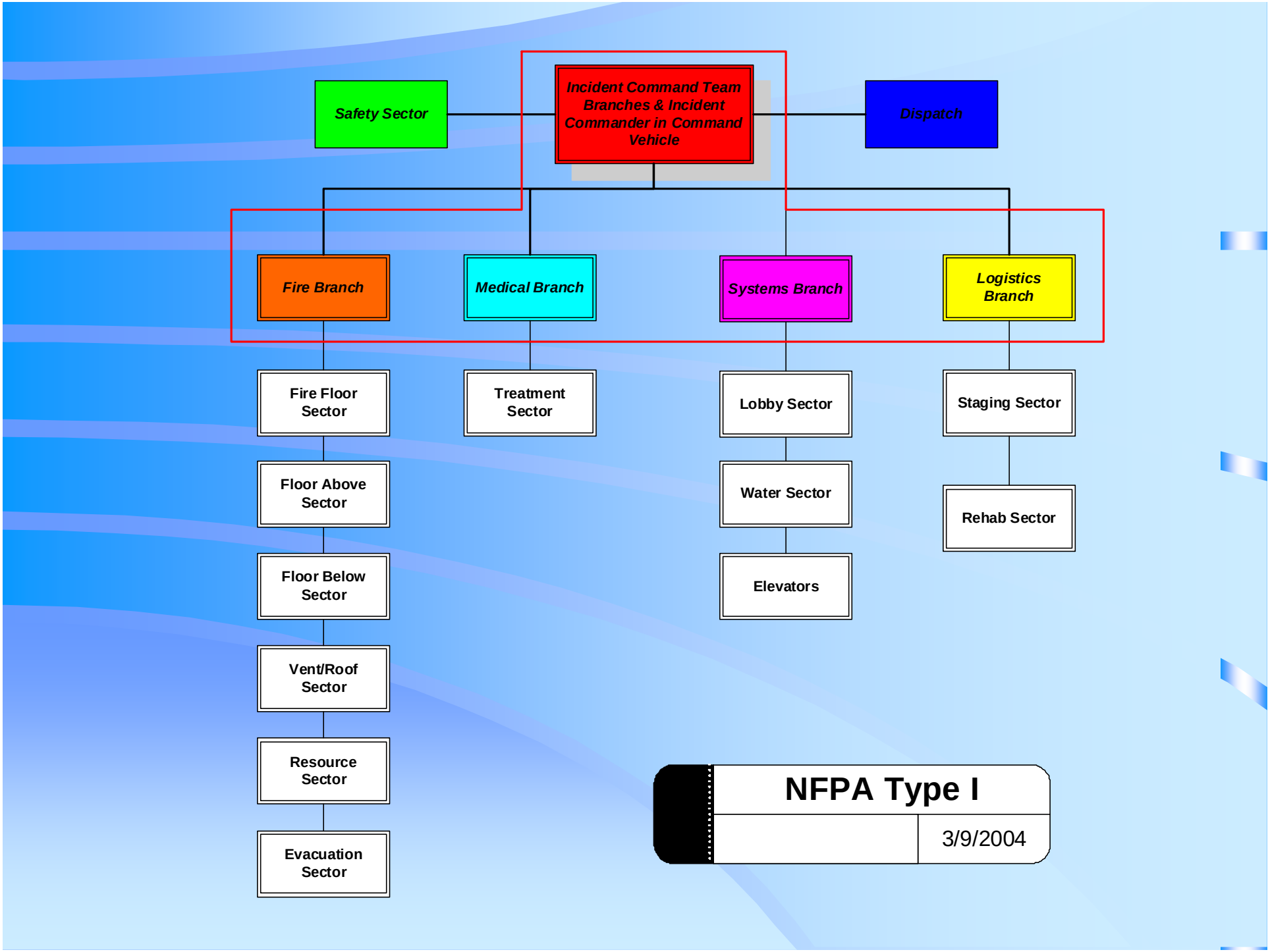
Other Units

Unit 14
Rehab

Unit 15
Treatment

Unit 16
Safety

Unit 18
Dispatch


Safety Sector
Incident Command Team Branches & Incident Commander in Command Vehicle
Dispatch
Fire Branch
Medical Branch
Systems Branch
Logistics Branch
Fire Floor Sector
Floor Above Sector
Floor Below Sector
Vent/Roof Sector
Resource Sector
Evacuation Sector
Treatment Sector
Lobby Sector
Water Sector
Elevators
Staging Sector
Rehab Sector
NFPA Type I
3/9/2004

NFPA Building Type 1

Talk Matrix

Position	18. Dispatch	17. Staging Sector	16. Safety	15. Treatmen/Transport	14. Rehab Sector	13. Evacuation Sector	12. Systems Sector	11. Forward Pumper	10. Water Sector	9. Lobby Sector	8. Elevator	7. Roof/Vent Sector	6. Resource Sector	5. Floor Below (Sector x-1)	4. Floor Above (Sector x+1)	3. Fire Floor Stairs	2. Fire Floor (Sector x)	1. Command
1. Command	W	W	F	W	W	F	F	F	F	F	F	F	F	F	F	F	F	
2. Fire Floor (Sector x)	W		F			F	F		F	F	F	F	F	F	F	F		
3. Fire Floor Stairs	W					F	F	F	F	F	F	F	F	F	F			
4. Floor Above (Sector x+1)	W		F			F	F		F	F	F	F	F	F				
5. Floor Below (Sector x-1)	W		F			F			F	F	F	F						
6. Resource Sector (x-2)	W	F	F		F	F				F	F							
7. Roof/ Vent Sector	W		F				F		F	F	F							
8. Elevator	W					F	F			F								
9. Lobby Sector	W	F	F	F	F	F	F											
10. Water Sector	W		F				F	F										
11. Forw ard Pumper	W						F											
12. Systems Sector	W		F															
13. Evacuation Sector	W		F	F														
14. Rehab Sector	W	W		W														
15. Treatment/Transport	W	W																
16. Safety	W																	
17. Staging	W																	
18. Dispatch																		

F = Fireground communications (local area)

W = Wide Area communications.

RED = Test Path

BLACK = Redundant path

VHF Analog Direct

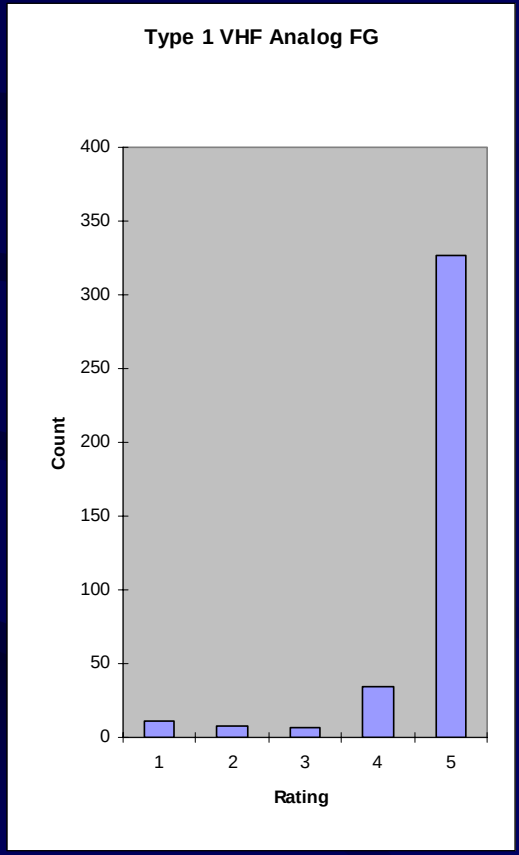
Pros

- No infrastructure needed for field communications.
- Non-repeated system.
- In-building treatments not needed.
- Simple system.
- No audio delays.
- Seamless interoperability with Federal law enforcement and land management agencies (wildland firefighting)

Cons

- Systems must meet FCC narrowbanding requirements by 2013.
- Interoperability with other agencies on 800-700 MHz systems not seamless.
- Analog equipment may not be available in future due to digital migration.

VHF Analog Data



700-800 MHz Analog Direct

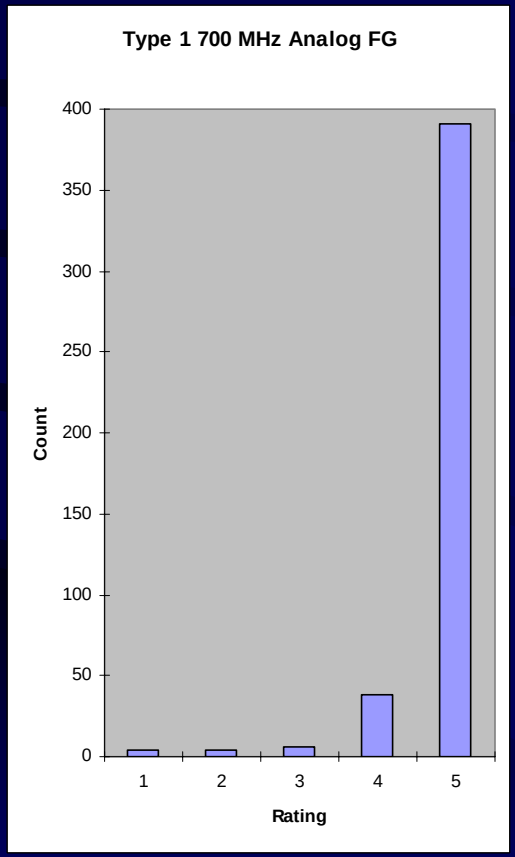
Pros

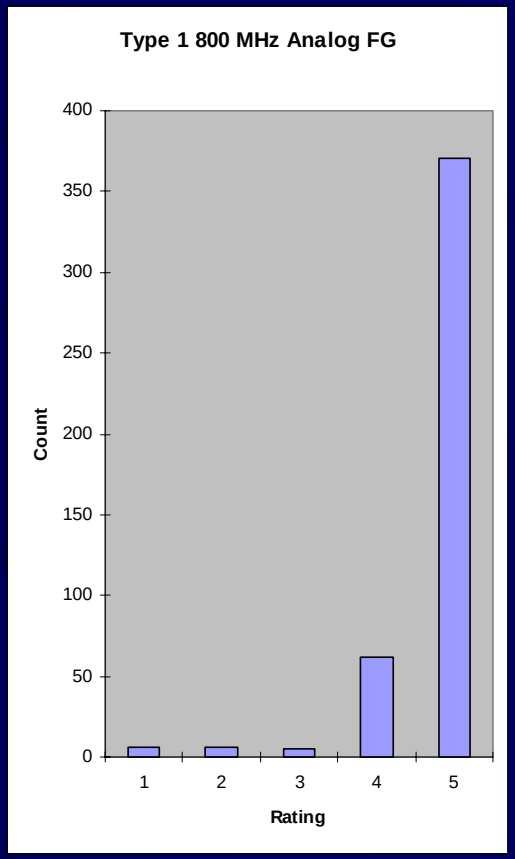
- No infrastructure needed for field communications.
- Non-repeated system.
- In-building treatments not needed.
- Simple system
- No audio delays
- Allows direct interoperability with other 700-800MHz users.

Cons

- Use of Analog in the 700 MHz band allowed on secondary basis only.
- 700 MHz frequencies are not available in all areas at present.
- Restriction on number of conventional channels per license

700-800 MHz Analog Data





700-800 MHz Digital Direct

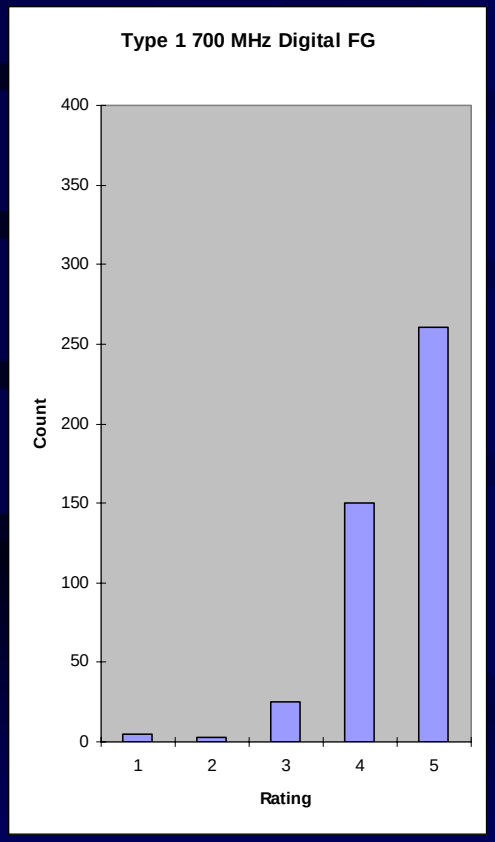
Pros

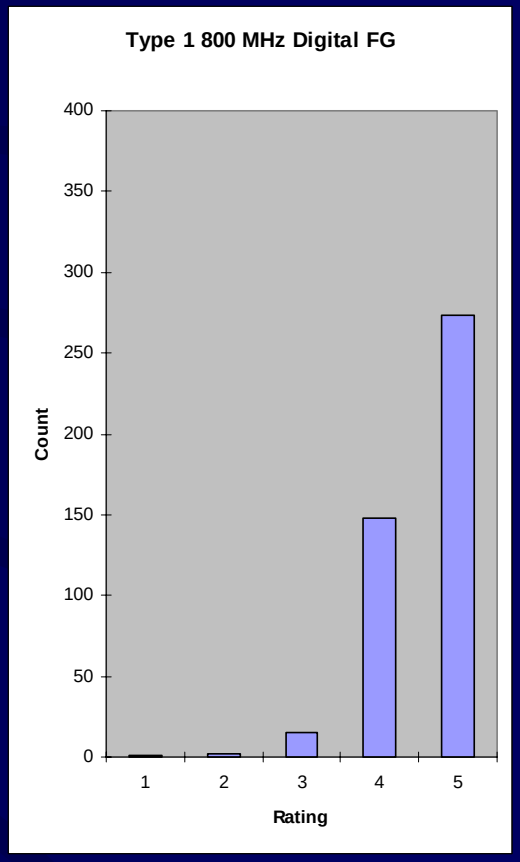
- No infrastructure needed for field unit communications.
- Non-repeated system.
- In-building treatments not needed.
- Simple system
- Allows direct interoperability with other 700-800 MHz users
- Digital signaling allows more features.

Cons

- Digital signaling has inherent problems:
  - Units keying up simultaneously
  - Poorer Audio Quality
  - No warning of fading as in analog
- 700 MHz frequencies are not available in all areas at present.

700-800 MHz Digital Data





Digital 800 MHz Trunked

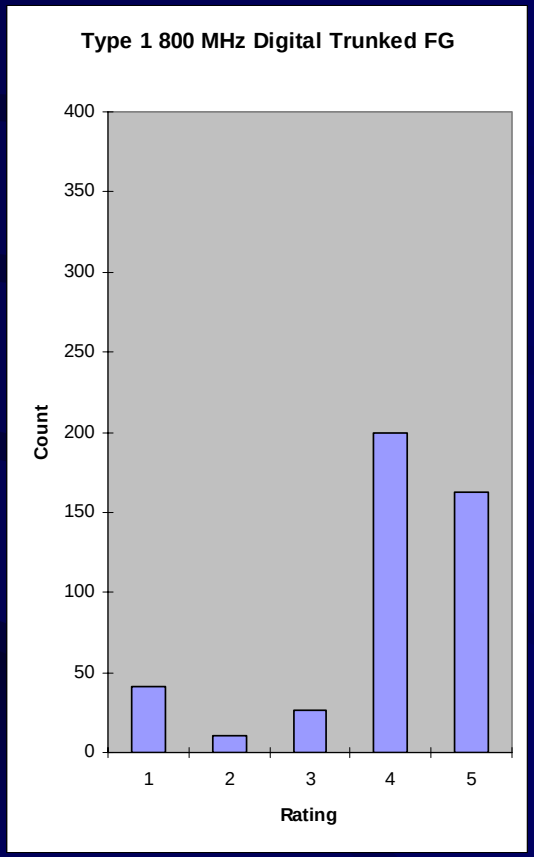
Pros

- Wide Area Coverage
- Digital Signaling Features (Unit ID's, Emergency)
- Interoperability with other standards-based trunking systems
- Talk Group creation flexibility
- Encryption and Over the Air Rekeying

Cons

- Complex Infrastructure
- Complex failure modes
- Loss of system coverage = no communications.
- Repeater based, requires in-building treatments.
- Unknown number of buildings need to be treated.
- Inconsistent interior communications.
- Noticeable audio delays.

800 MHz Digital Trunked Data



Fire Radio System Engineering Project Observations

1. Analog audio quality for clarity.
2. Direct modes for reliability.
3. All direct modes allowed Command to communicate with all FG positions.
4. Trunked Coverage inconsistent.
5. VHF direct was used to communicate when trunked coverage was not present.
6. Coverage was difficult to predict based on building type alone.
7. Negligible building penetration difference between frequency bands.

Nationwide Survey of Departments Using Trunking

- Most surveyed departments use direct communication as a backup.
- Many departments developed this after their current system was completed.
- Many do not have an SOP and often use frequencies meant for other purposes (interoperability channels).
- All report unexpected loss of communications inside buildings.

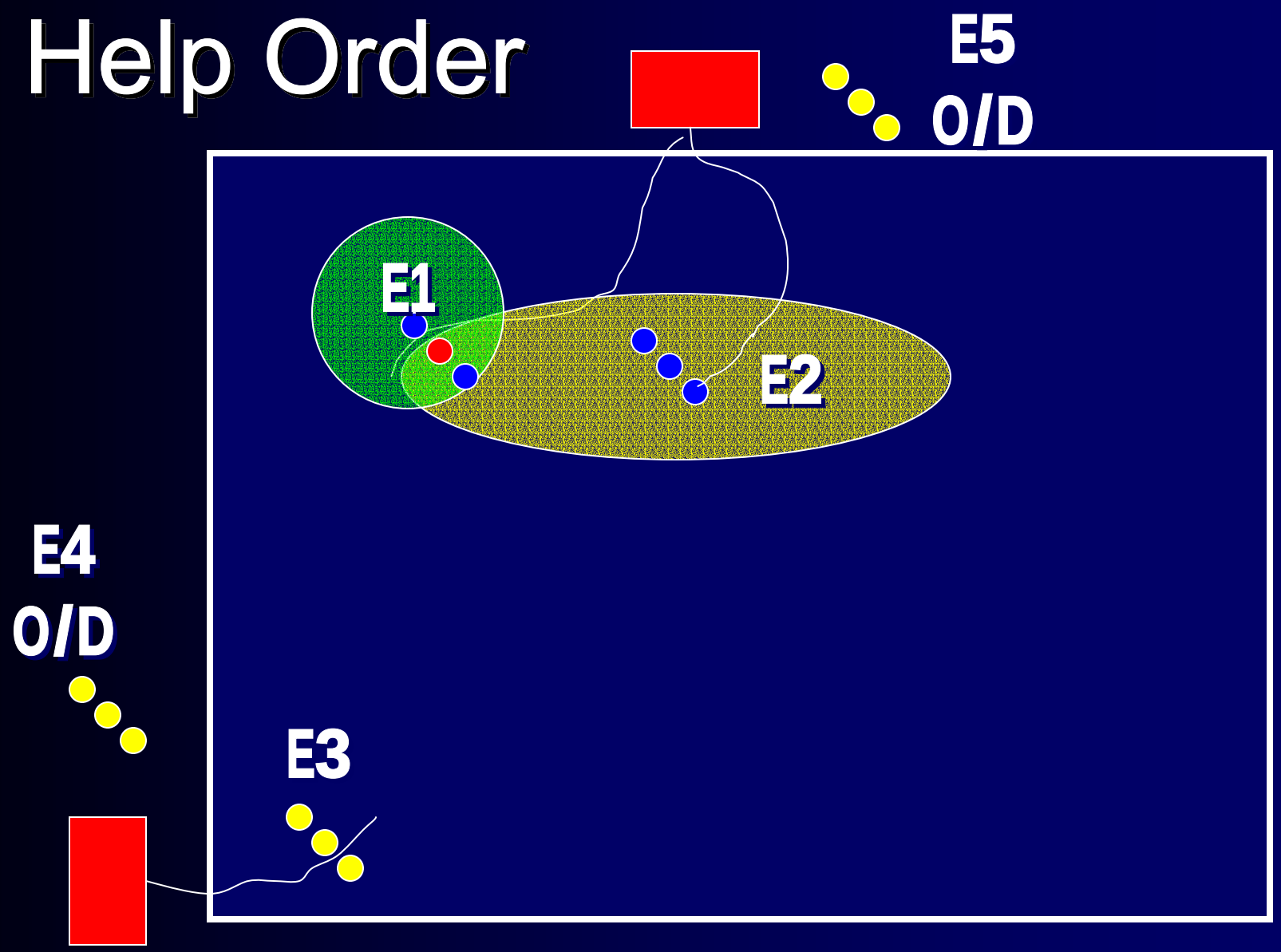
Effect of Trend To Trunking on Firefighting Communications

- Increases capacity for support operations.
- Decreases reliability of communications for fireground operation when compared to direct mode.
- Increases system complexity and therefore reliability (all else being equal, more parts = more failures).
- Failure of key equipment disables all communications on fireground.

Why is this important to the fire service?

- Operations in the hot zone are very risky.
- Closest units have the best opportunity to effect a rescue.
- Coordination between units in hot zone is critical.
- Unit to unit and unit to IC communications take precedence over all others.

Help Order



For More Information

http://www.phoenix.gov/fire/radioreport.pdf

Captain Mike Worrell
Phoenix Fire Department
mike.g.worrell@phoenix.gov

Improved Communications for First Responders

NIST Electromagnetics Division

Kate A. Remley, Marc Rutschlin, Robert Johnk,
Dylan Williams, Galen Koepke, Chris Holloway

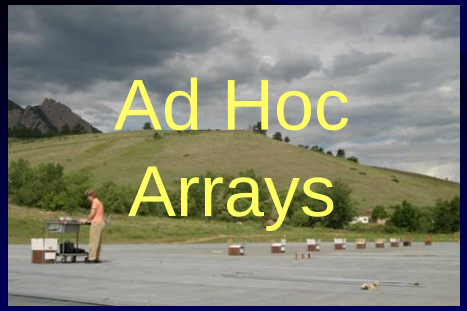
Sponsored by: DOJ (COPS),
DHS, NIST OLES

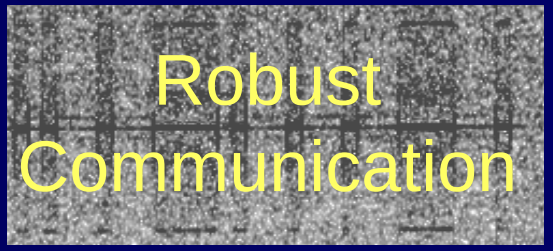
Project Goals

- Better understanding of complex radio propagation environments faced by first responders
- Straightforward, cost effective, robust methods to improve radio communications and location for first responders in difficult signal environments

Focus: Techniques and data immediately useful to first responders and system designers!

An array of communications projects for first responders





“All report unexpected loss of communications inside buildings” - Phoenix FD Study

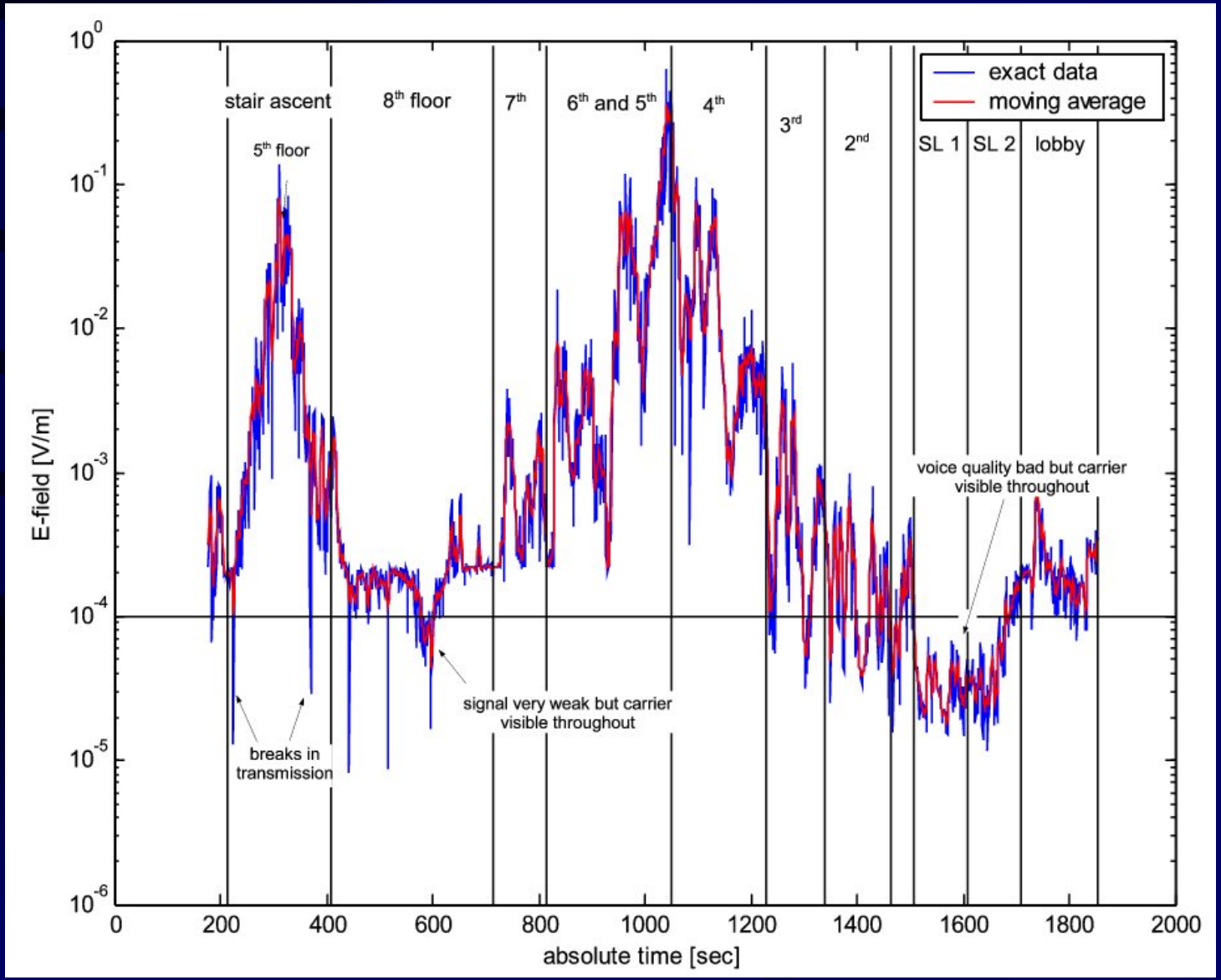
Understanding building penetration and indoor radio propagation environment is key to improving system performance

Building Propagation Studies and Weak-Signal Detection

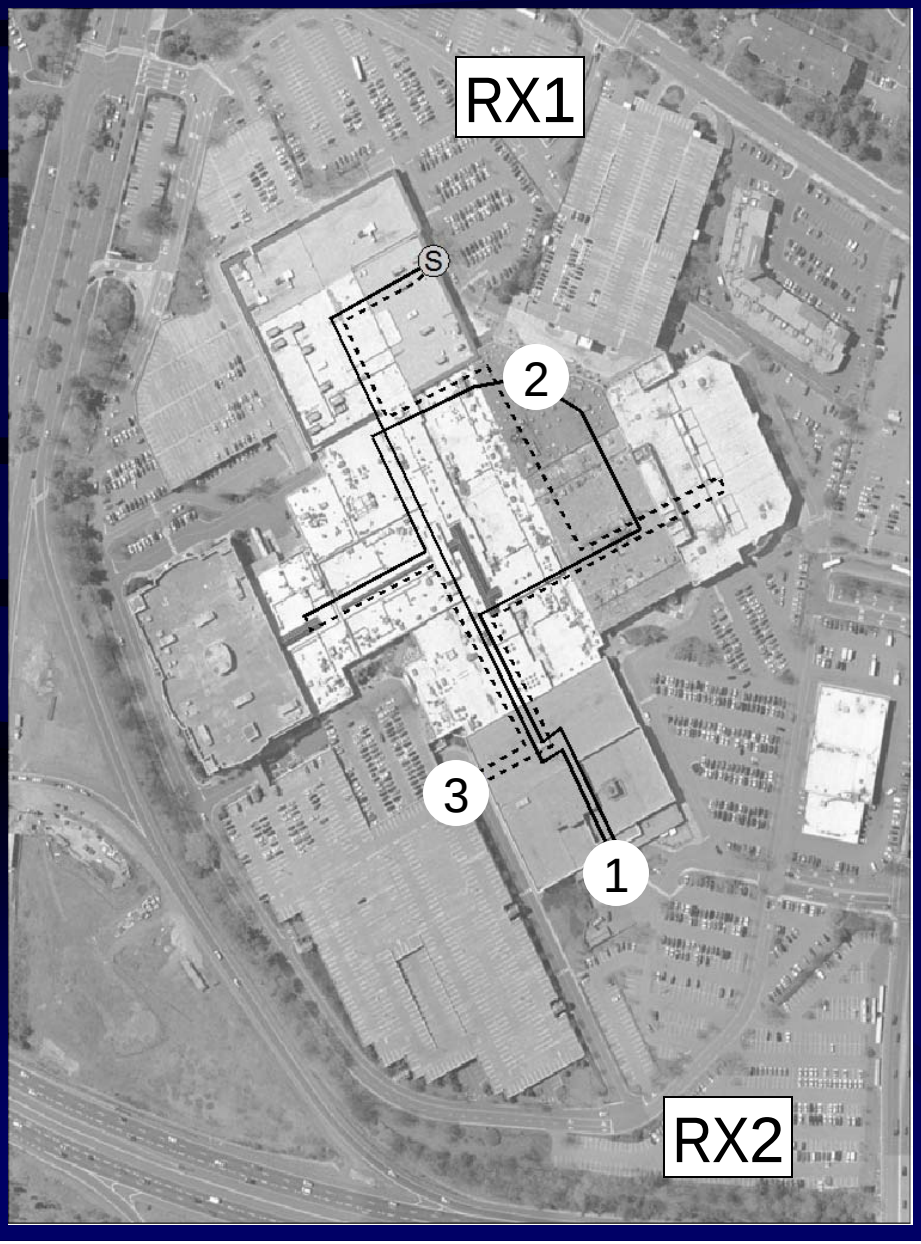
Receiver used to find areas of weak reception for system assessment and emergency scenarios

Study of large public buildings: hotel

Colorado Springs Hotel



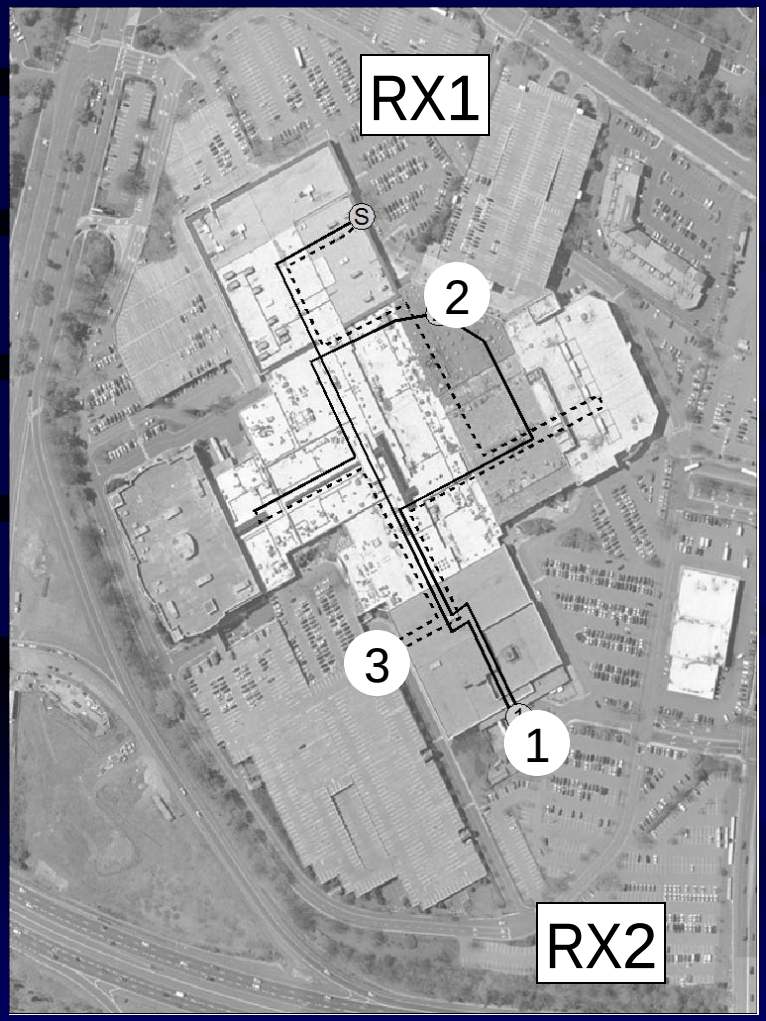
Virginia Shopping Mall

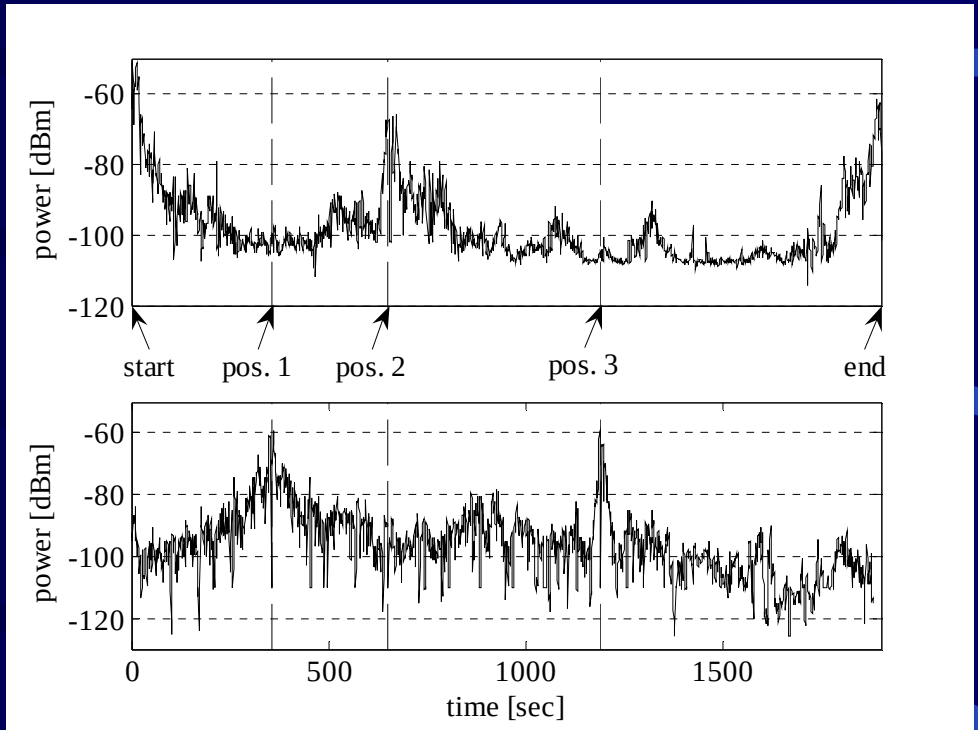


Transmitters were carried on the route shown

Two receivers monitored continuously

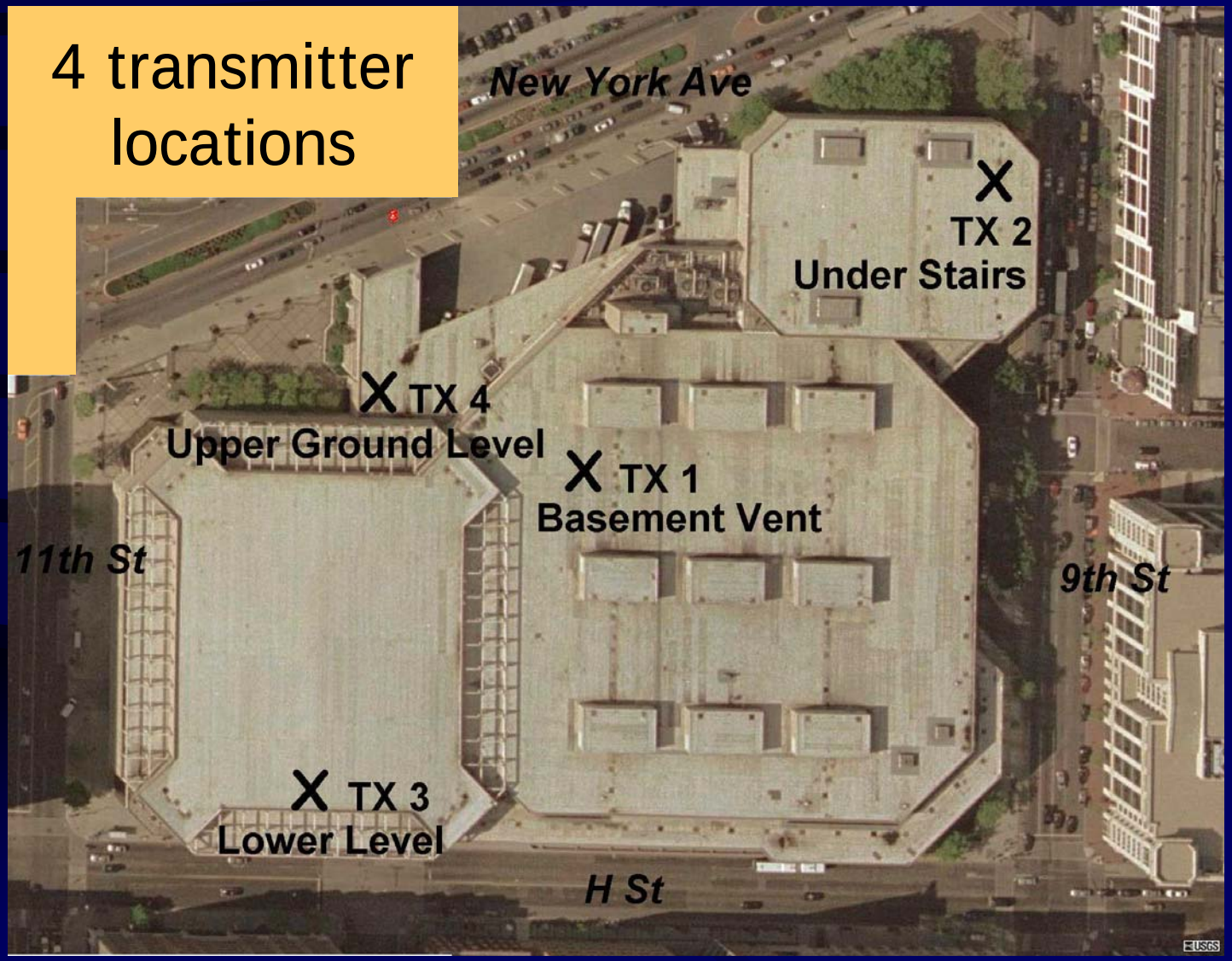
Shopping Mall



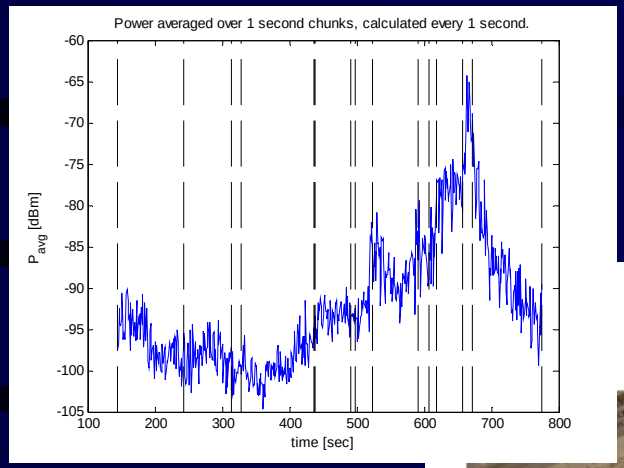


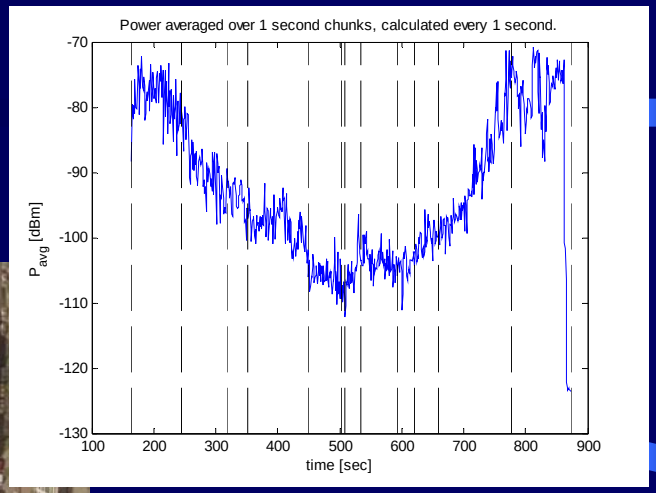
Washington, D.C. Convention Center

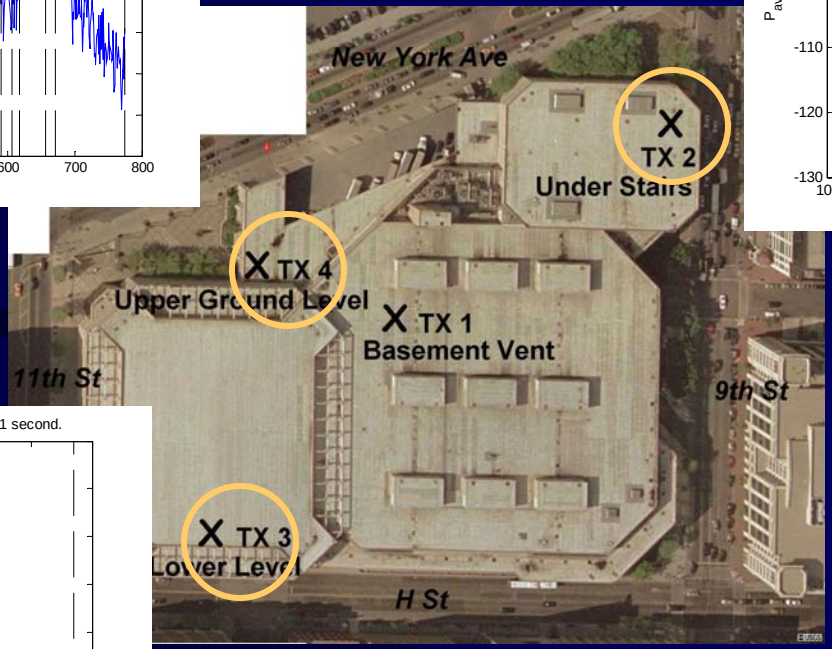
4 transmitter locations

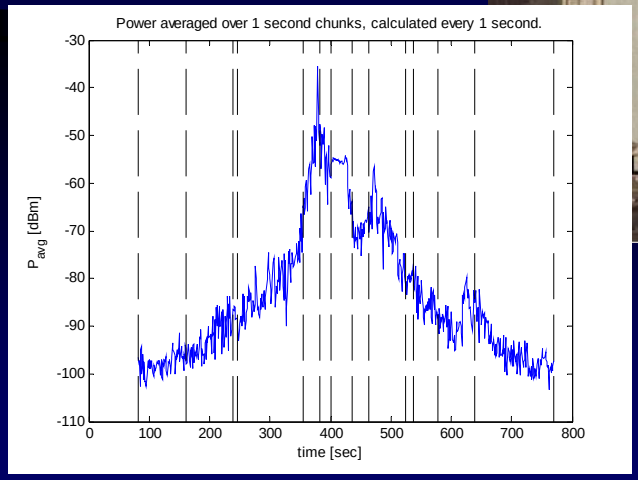


Measured Results





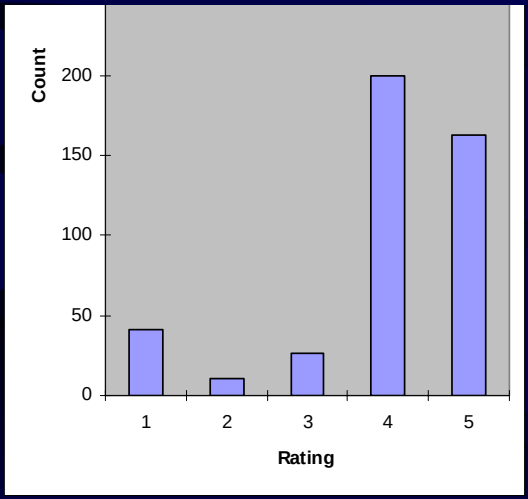




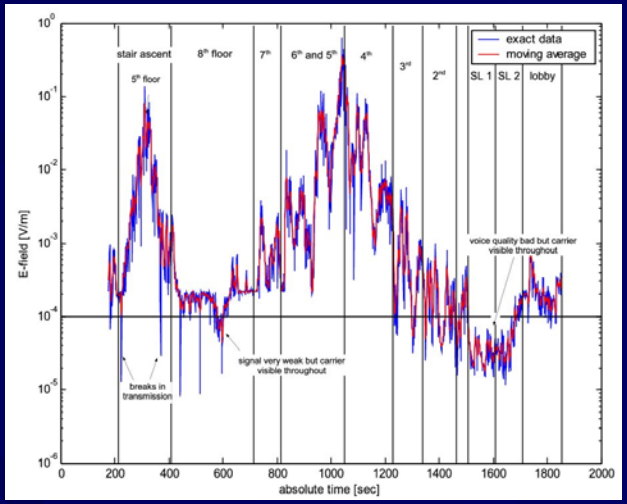
Transmitters tuned near cell phone bands

Phoenix FD study generated a wealth of data

Idea: Translate Phoenix voice-quality ratings (1 to 5)



to field-strength data (V/m)



Qualitative & Quantitative Data

1-5 ratings used in other scenarios, WTC report.
Field strength provides common “language.”

Phoenix study goals:

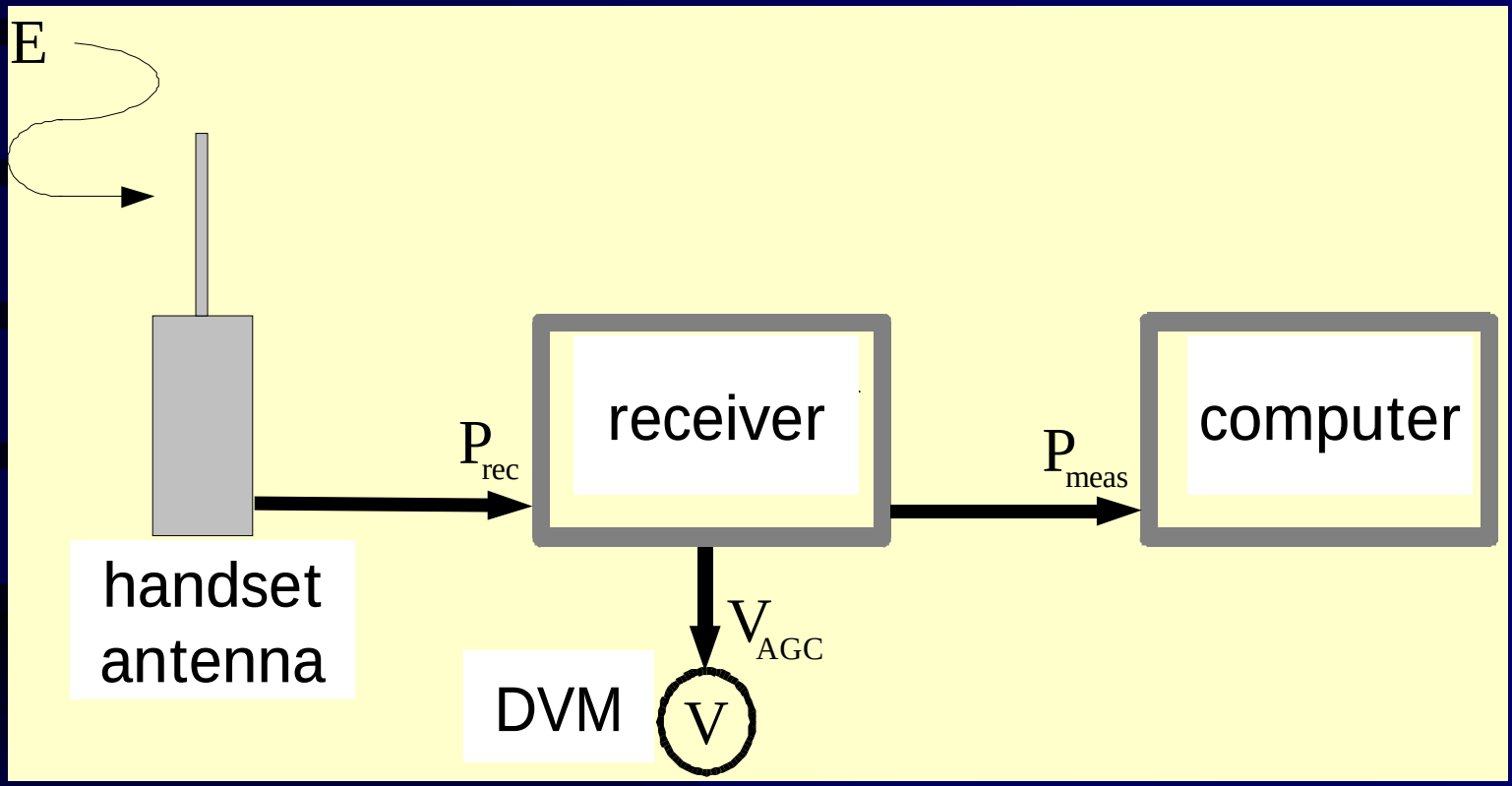
- understand building penetration issues
- improve system design
- assess deployment techniques

Test Procedure

Use calibrated receiver system side-by-side with Phoenix Fire in select tests

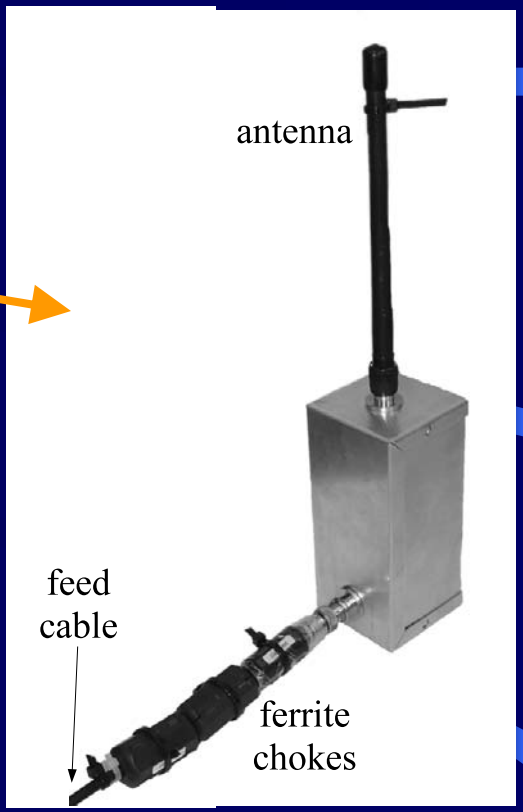
Calibration removes effects of antenna, cables, receiver to achieve field strength measurements

Calibrated Receiver System



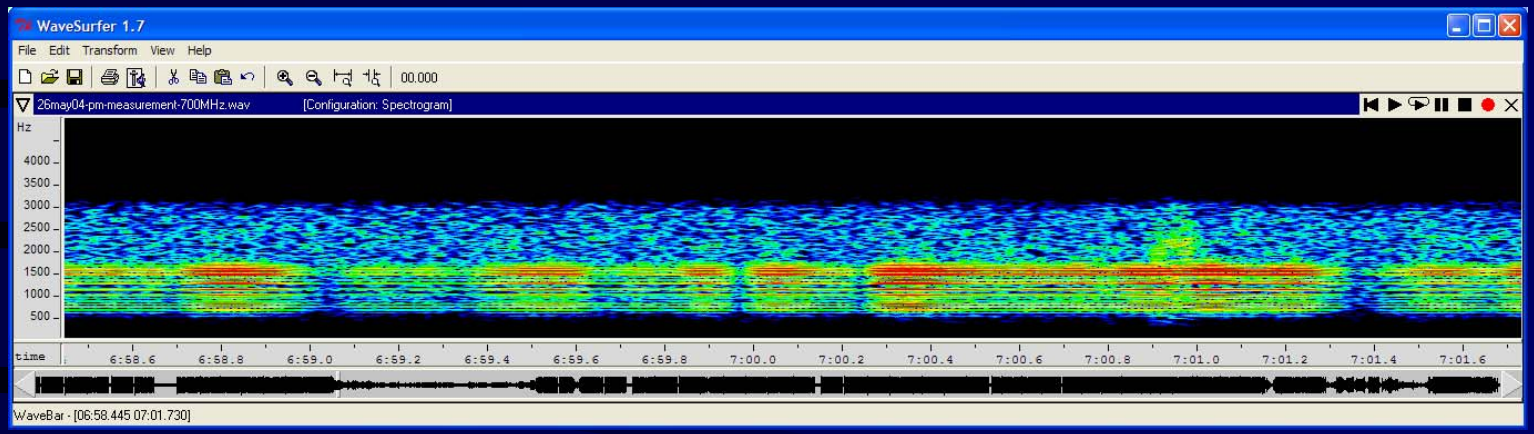
Commercially available receiver and PC sound card are inexpensive and straightforward to use

Calibrated Receiver System

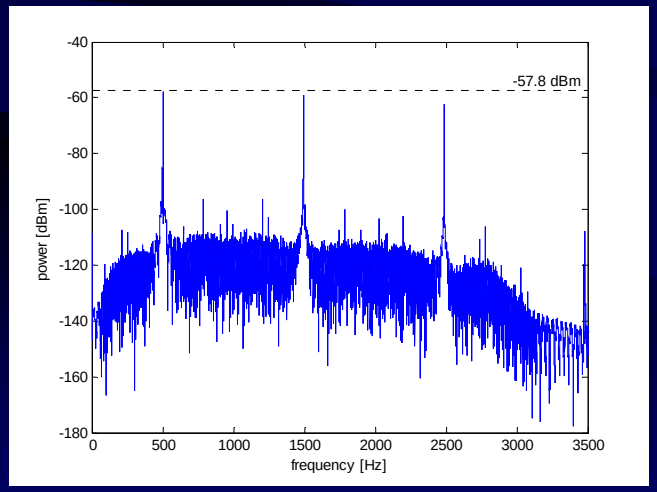


Handset emulator mimics first-responder radio

Receiver Output



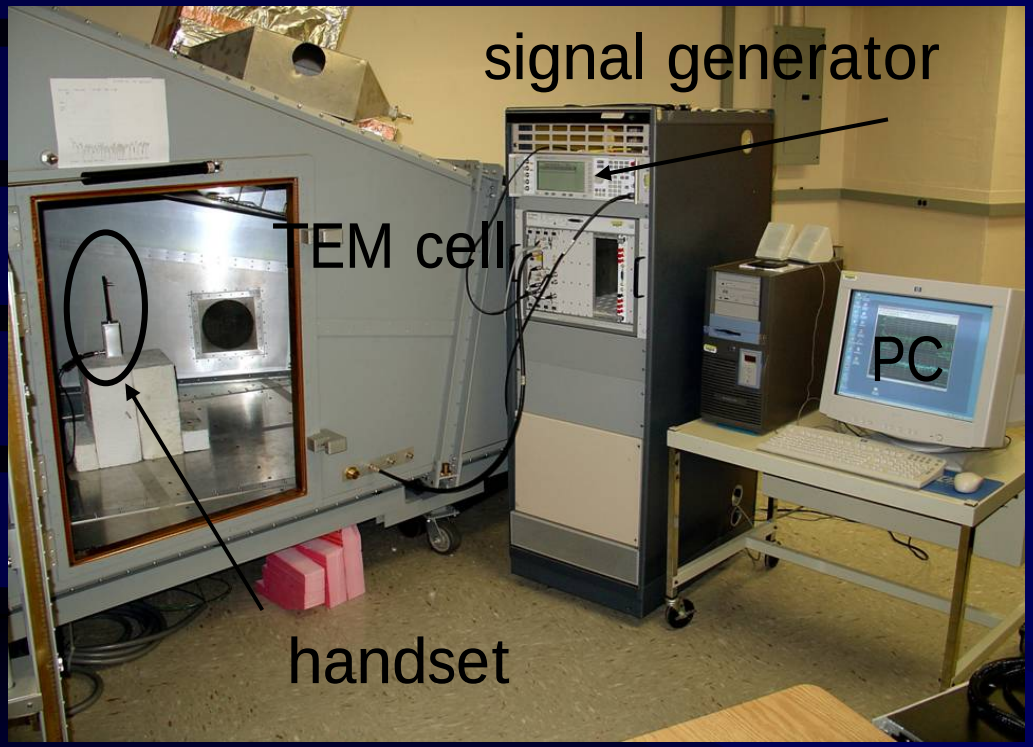
raw data



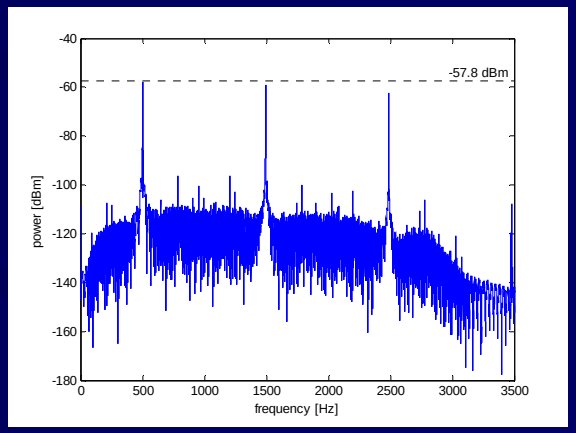
processed spectrum

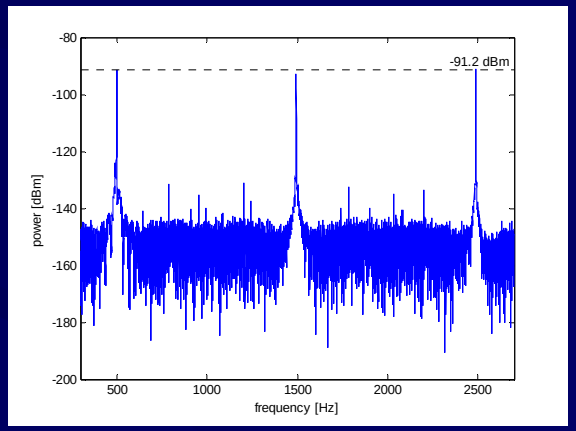
We can detect signals orders of magnitude weaker than with standard equipment!

Calibration steps



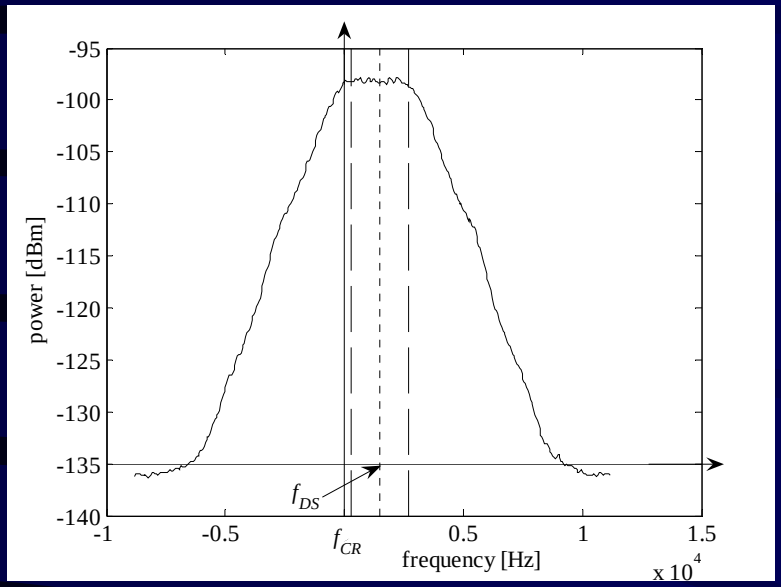
Find antenna factor



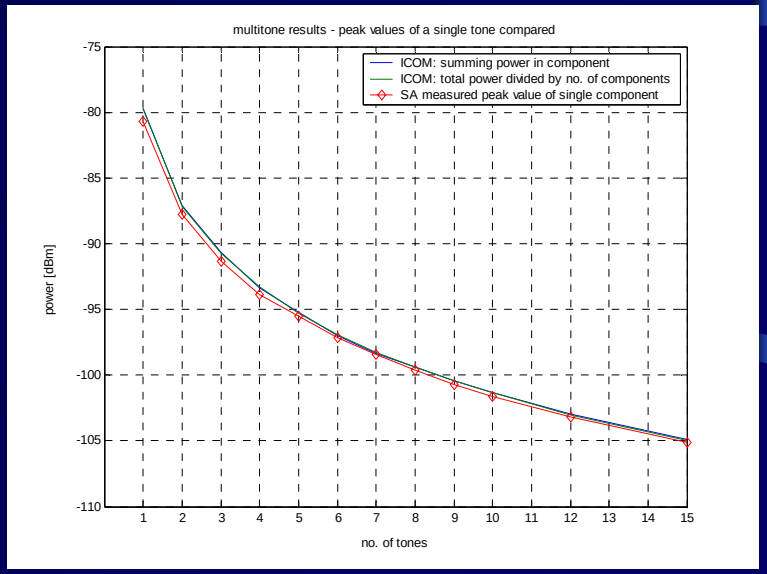


Level correction using AGC voltage

Calibration Steps (cont.)



Bandwidth correction for digital signals



Verification by comparison to other methods

NIST Phoenix Study

Transmitter carried slowly through stairwell

- Firefighters rate voice quality
- NIST records signal strength

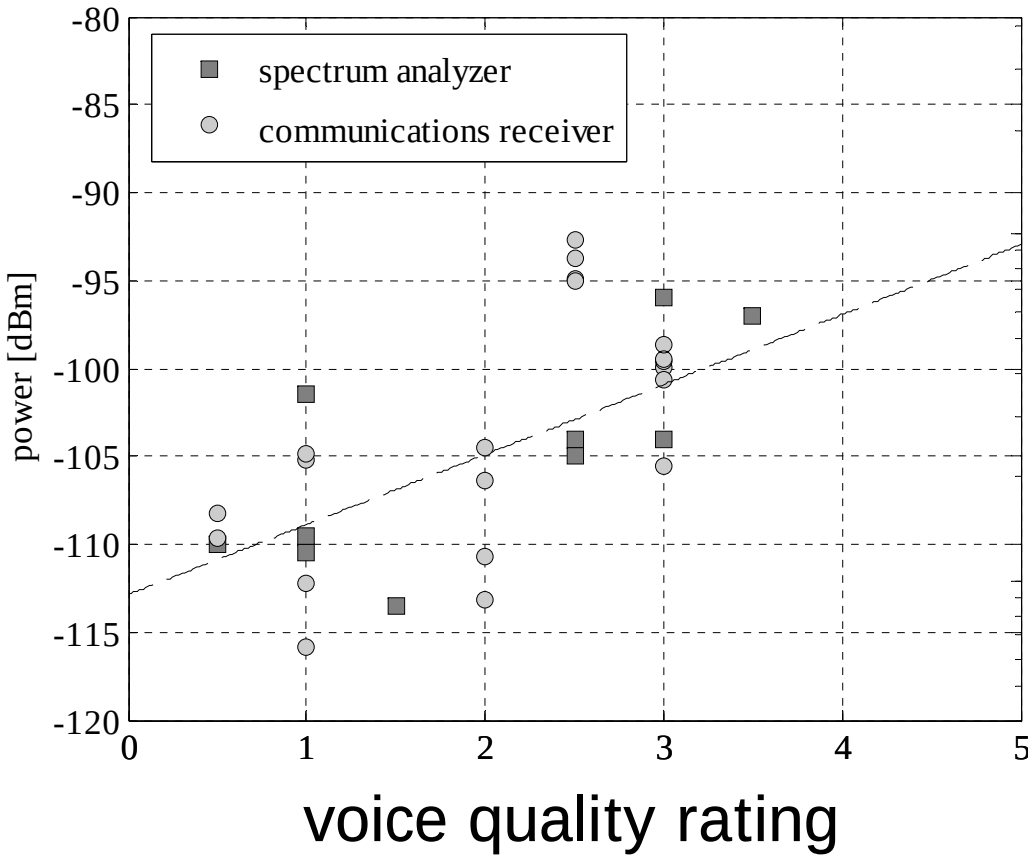
Phoenix Study

Measurements:

- 156 MHz, analog
- 860 MHz, analog
- 860 MHz, digital

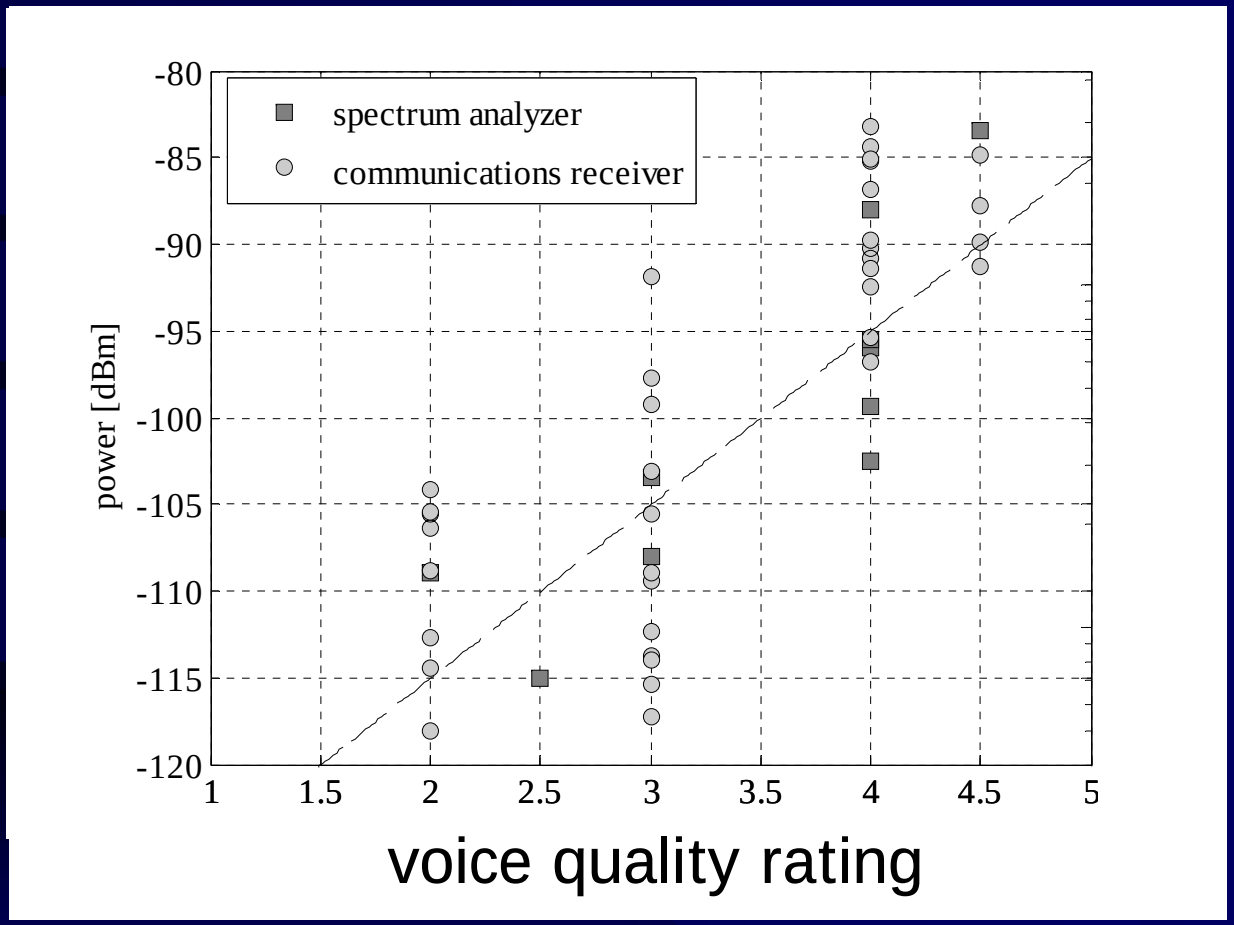
Repeat measurements, various locations ensure consistent results

Measurement Results



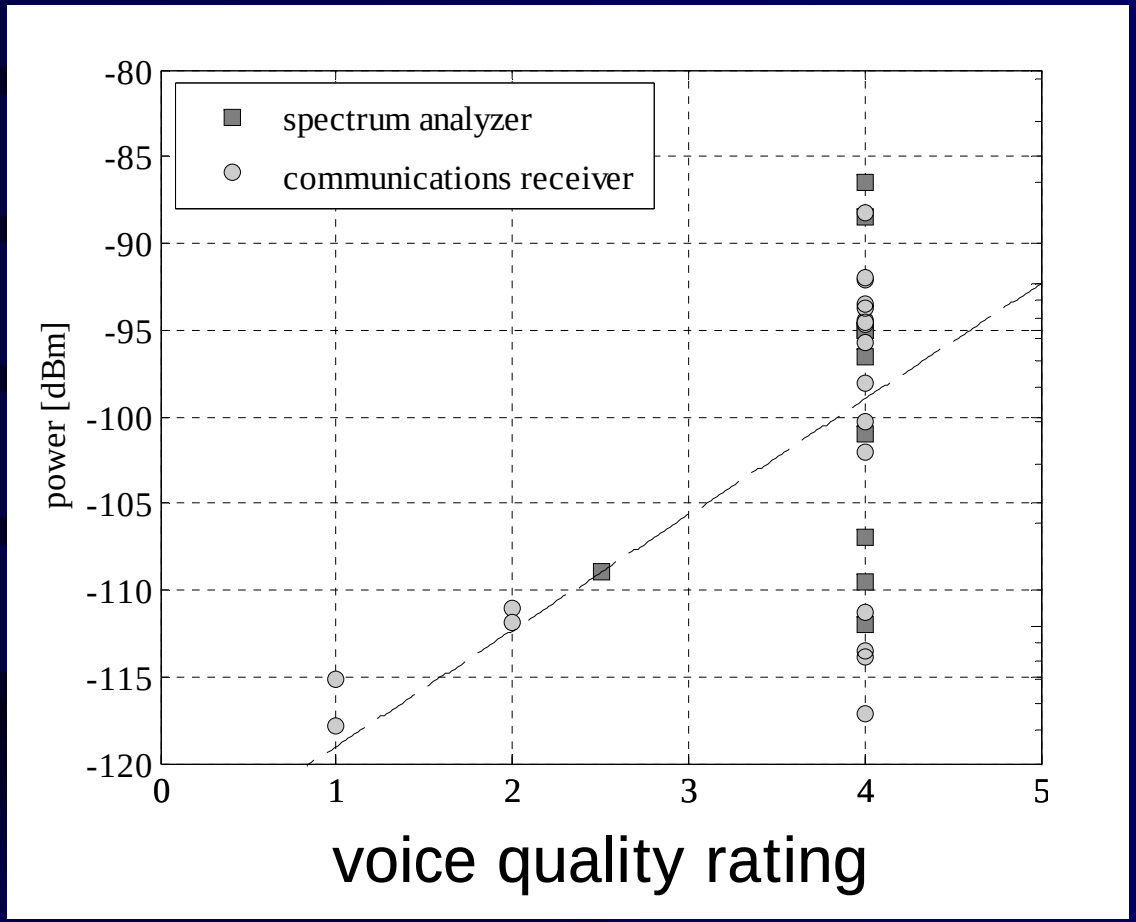
150 MHz, analog modulation

Measurement Results



800 MHz, analog modulation

Measurement Results



800 MHz, digital modulation

Phoenix Study Summary

- Results translate subjective voice quality ratings into quantitative data.
- May be used to develop improved system design, deployment guidelines, to facilitate data sharing between organizations.

Propagation Studies and Weak-Signal Detection

- Public domain data for large public buildings at public-safety frequencies.
- Improved emergency communications strategy
- Improved public safety radio system design
- A low-technology, low-cost solution for communicating with first responders in weak-signal conditions

Sponsored by: DOJ (COPS), DHS, NIST OLES

NIST National Institute of Standards and Technology

Questions?