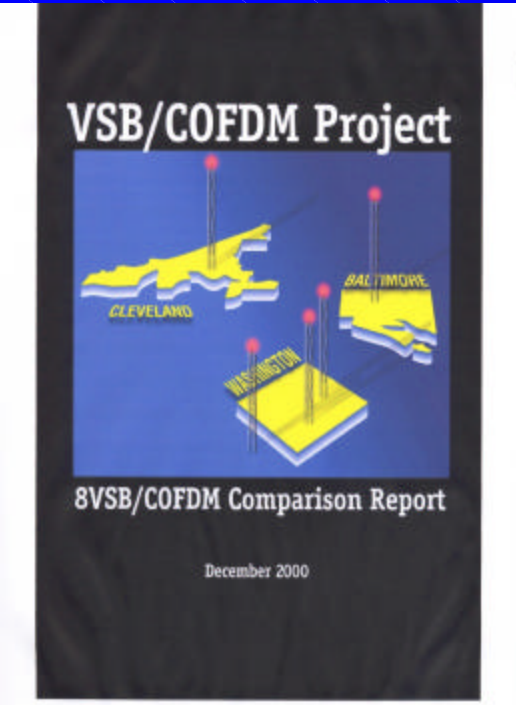
VSB/COFDM Technical Project
Technical Report



VSB/COFDM Project

- Parallel scientific and impartial investigation of VSB improvements and COFDM
  - VSB investigation
  - COFDM investigation
- Project to be completed in 2000

VSB/COFDM Project Funders (1)

- ABC/Disney
- Allbritton
- Belo
- Bonneville
- Capitol
- CBS/Viacom
- Chris-Craft
- Cosmos
- Cox
- Dispatch
- Duhamel
- Fisher
- Gannett
- Hearst-Argyle
- Hubbard
- Lee Enterprises
- LIN Television
- Media General

VSB/COFDM Project Funders (2)

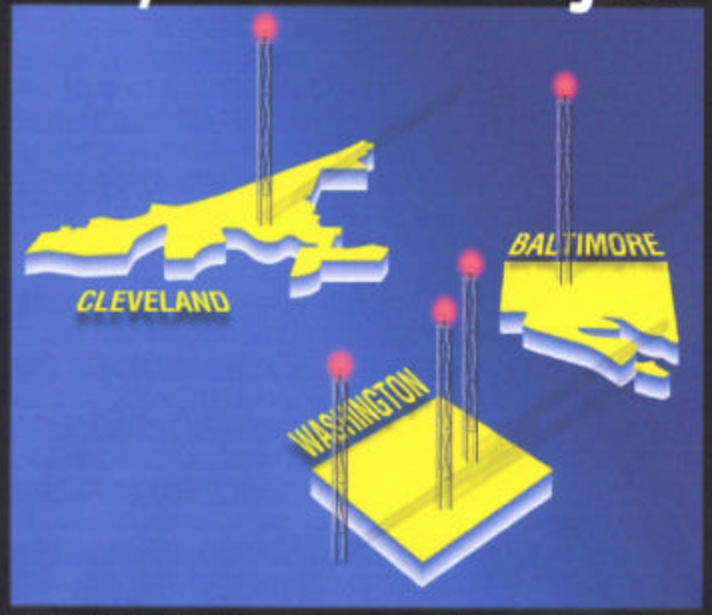
- Morgan Murphy
- MSTV
- NAB
- NBC
- Pappas
- PBS/APTS
- Post-Newsweek
- Scripps-Howard
- Sinclair
- Tribune
- Univision
- Paxson

COFDM Investigation

Goals

- Compare COFDM performance relative to 8-VSB for outdoor, indoor and portable reception conditions
- If warranted, investigate COFDM technology for possible applications in the United States (existing and new services)

VSB/COFDM Project



8VSB/COFDM Comparison Report

December 2000

Project Schedule

- Started in the Spring
- Six month timeframe
- Phase 1 report to be finished in 2000

The Basic Game Plan

- Test multiple stations
- Test in different cities
- Test different receiving conditions
- Use the best COFDM and 8VSB receivers available

8VSB/COFDM Test Participants

- COFDM modulator/receiver tests contract
  - ✓Communications Research Centre
- 8-VSB laboratory tests contract
  - ✓Advanced Television Technology Center
- Field test contract
  - ✓Wallace & Associates

8VSB/COFDM Test Participants (Cont'd)

- Oversight contract
  - ✓Cavell, Mertz & Davis Inc.
    - ✓Contract achieved through competitive bid process
- 8VSB/COFDM Laboratory tests for coverage and interference study
  - ✓Zenith laboratory facilities
  - ✓Test administration by Cavell, Mertz & Davis Inc.

Who, What, When and Where

- Who?
  - DVB-T (COFDM) versus ATSC (8VSB)
- What?
  - Field tests
  - Comparative spectrum analysis
- When?
  - Mid August through mid December 2000
- Where?
  - Field tests in Washington/Baltimore & Cleveland

The Basic Test Plan

- Test program is a comparison of two digital modulation schemes
  - Not intended as an indicator of general availability of DTV service
  - Comparison of DTV with NTSC in Cleveland
    - No comparison of DTV with NTSC in Washington/Baltimore

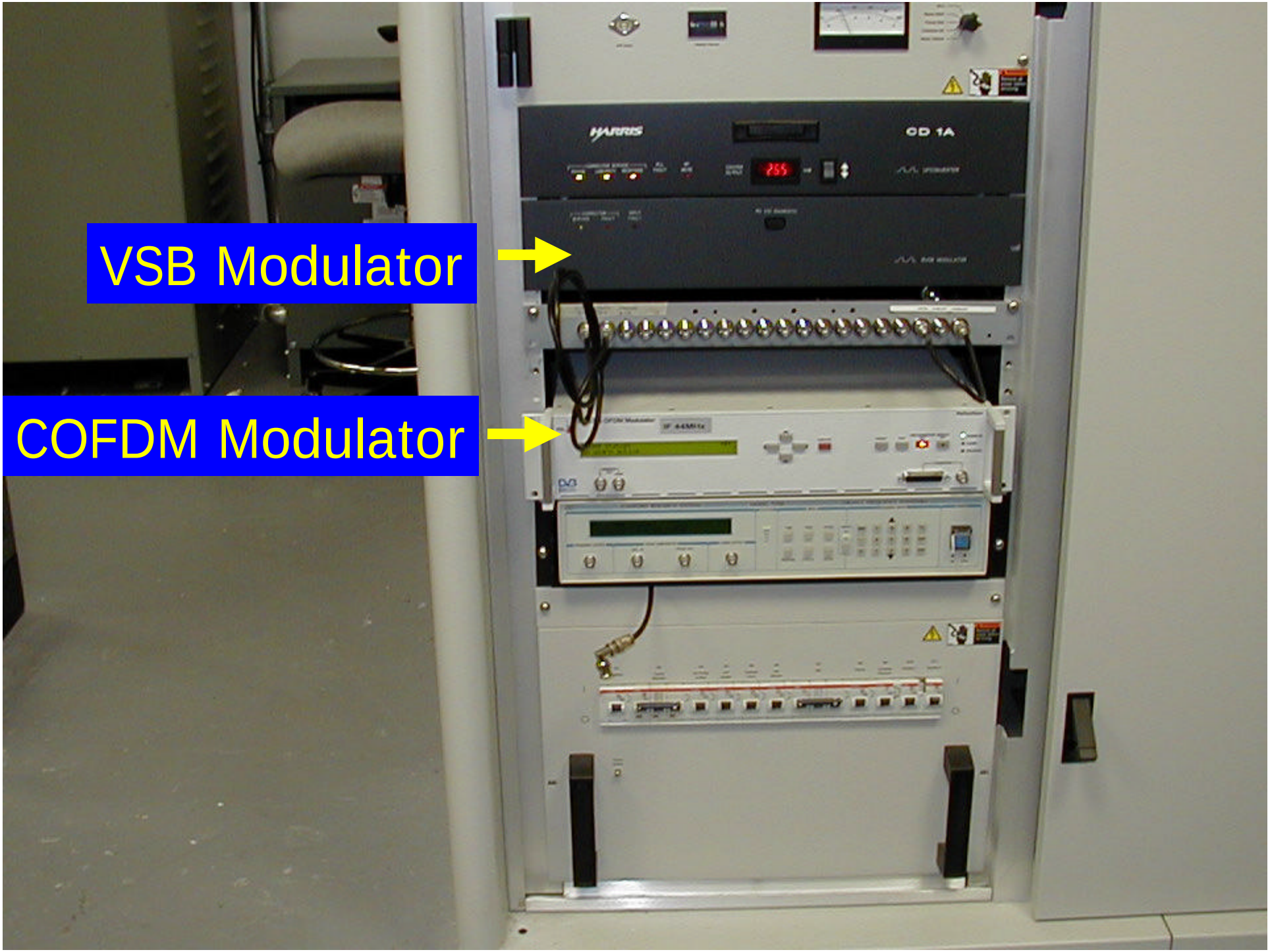
Stations Tested in Washington/Baltimore

- **WUSA**
  - NTSC Channel 9
  - DTV Channel 34
  - 646 kW, 673 feet
- **WRC**
  - NTSC Channel 4
  - DTV Channel 48
  - 813 kW, 636 feet
- **WETA**
  - NTSC Channel 26
  - DTV Channel 27
  - 75 kW, 414 feet
- **WBAL**
  - NTSC Channel 11
  - DTV Channel 59
  - 255 kW, 998 feet

Station Tested in Cleveland

- WKYC
  - NTSC Channel 3
  - DTV Channel 2
  - 7.2 kW, 823 feet


WETA DTV Transmitter


VSB Modulator
COFDM Modulator
HARRIS
OD 1A

Washington/Baltimore Measurement Sites

- Arcs
  - 40 miles from DC
  - 30 miles from Baltimore
- Grids/Clusters (8/1)
- Extended radials 45-55 miles from station (6)
- Indoor
  - 45 homes
- 250 sites total

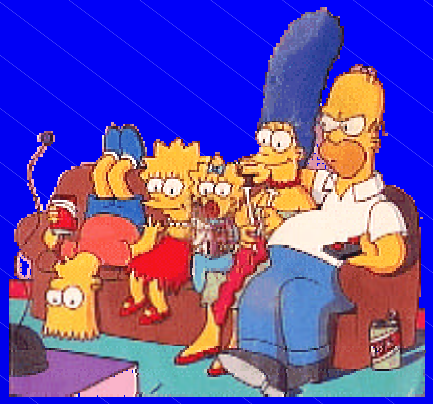
Cleveland Measurement Sites

- Arcs
  - 25 miles from Cleveland
  - 50 miles from Cleveland
- Grids (2)
- Radials out to 60 miles from station (3)
- 25 Indoor sites
- 125 sites total

Receiving Configurations

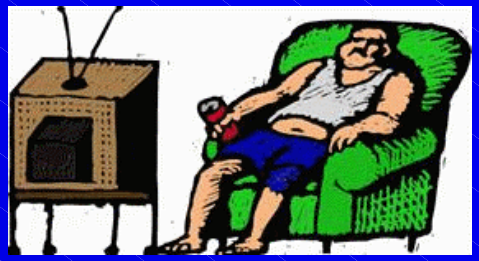
Standard 30 foot outdoor antenna

But not mobile reception

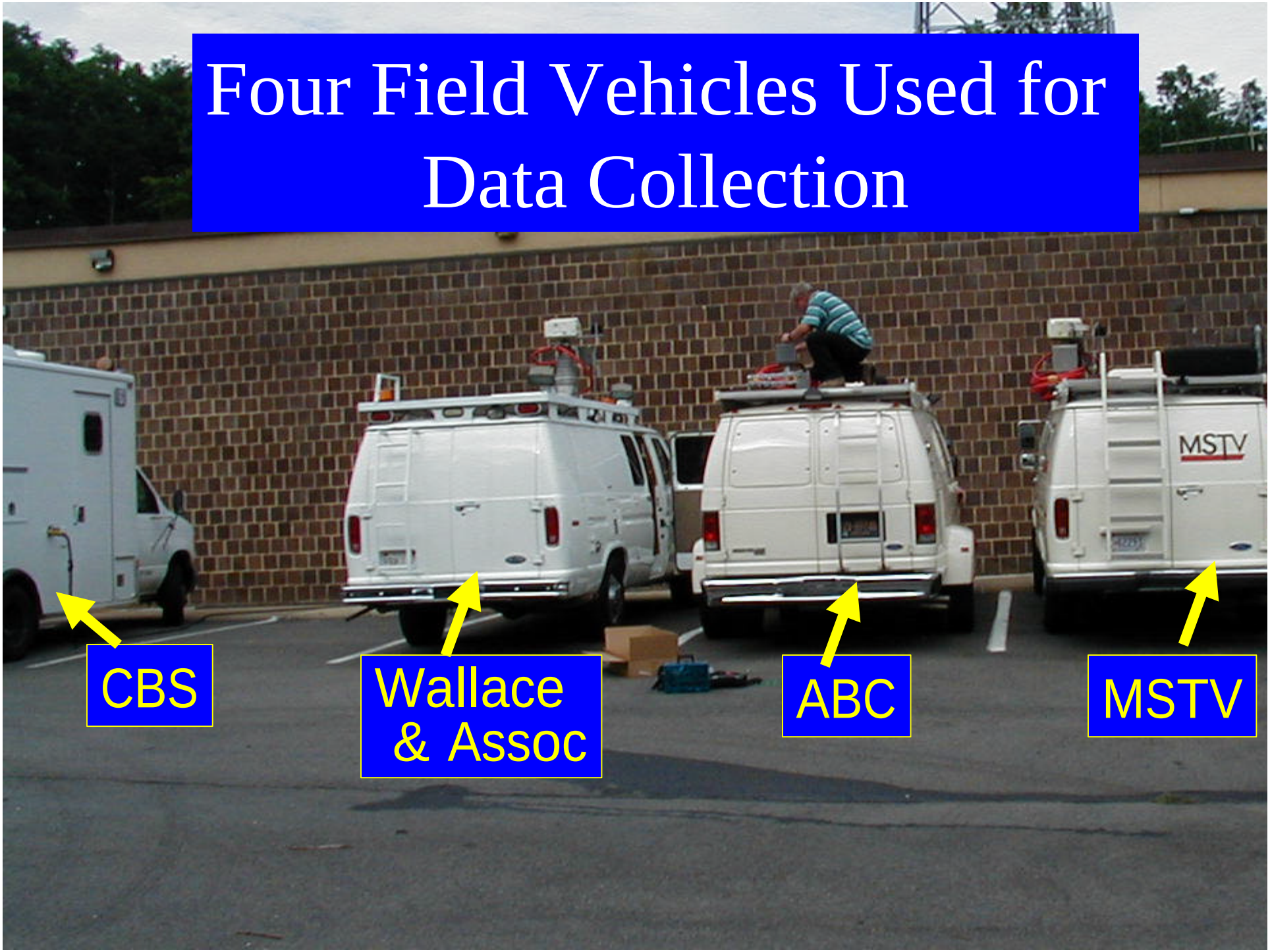


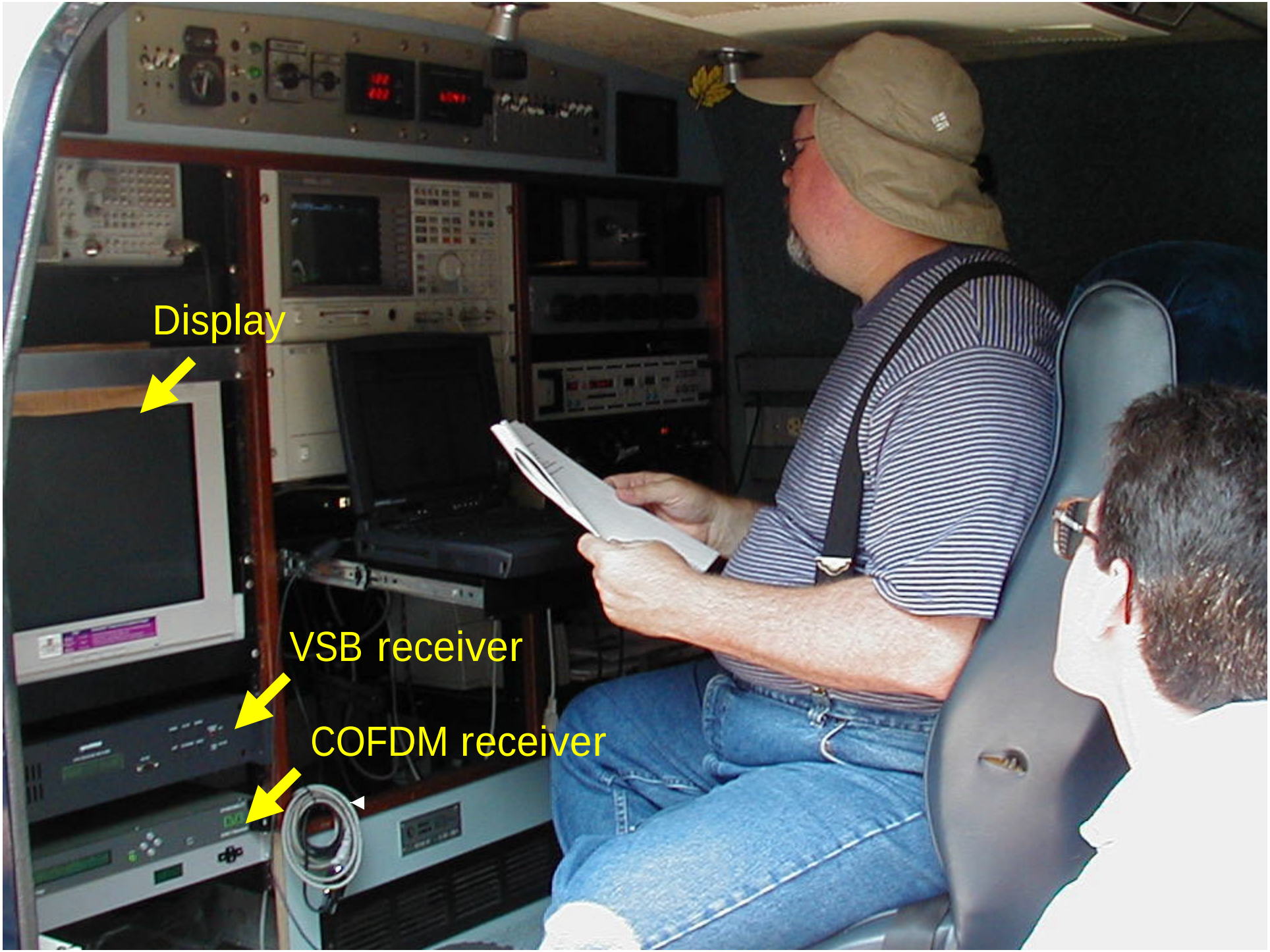
Indoor antenna

6 foot outdoor antenna (Portable reception)



Four Field Vehicles Used for Data Collection




Display
VSB receiver
COFDM receiver

Receive Antennas Used

- Outdoor
  - Washington (UHF)
    - Directional log periodic antenna
  - Cleveland (VHF)
    - VHF/UHF antenna
- Indoor
  - Washington (UHF)
    - Bowtie antenna
    - “Antiference Silver Sensor” set top antenna
  - Cleveland (VHF)
    - Megawave set top antenna

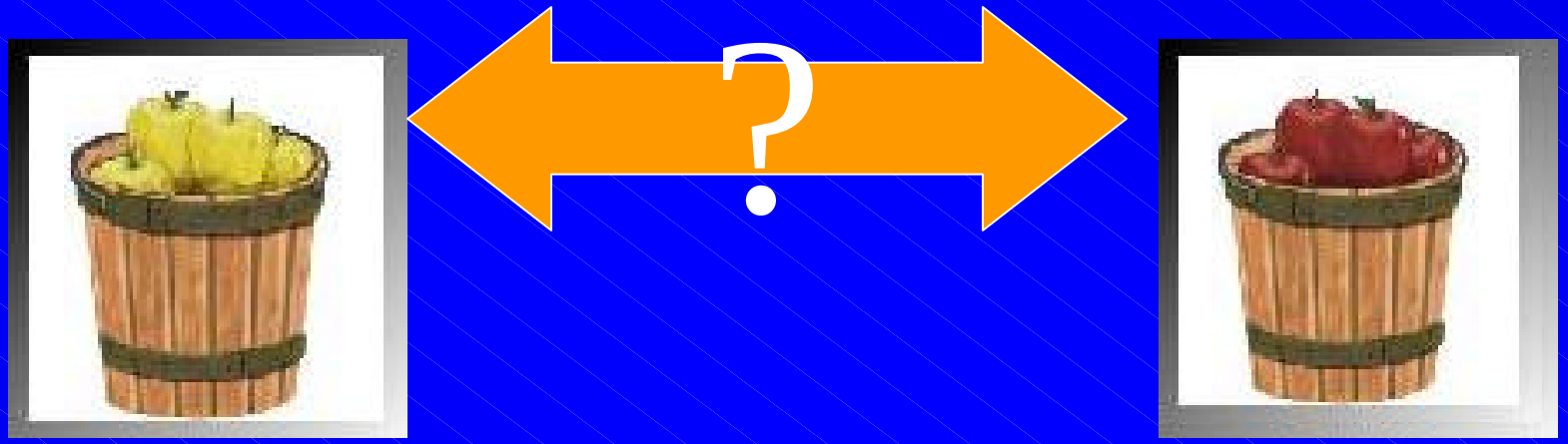
Receive Antennas Used (Cont'd)

- Portable
  - Washington (UHF)
    - Half wave dipole
  - Cleveland (VHF)
    - Megawave set top antenna

Typical Testing Method

- Start with 8VSB
  - Orient antenna for best reception
  - Record measurements
  - Measure margin by adding noise
  - Rotate antenna to find maximum angular range of reception
- Switch transmitters to COFDM (at same average power level) and repeat

Apples to Apples Comparison



COFDM	
Modulation:	64QAM
FFT:	8K
FEC:	3/4
Guard int.	1/16 (75 µsec)
Net data rate:	19.76 MB/s

VSB	
Modulation:	8VSB

Trellis FEC:	2/3
EQ range:	>40 µsec
Net data rate:	19.39 MB/s

Spectrum Analysis

- Determine impact of COFDM on coverage and interference characteristics of existing FCC Channel Assignment Plan
- Laboratory tests of 8VSB and COFDM receivers to obtain planning factors
- Coverage and interference analysis for 8VSB and COFDM using computer model

And now....

The RESULTS...

RESULTS

- **Laboratory**
  - **Selection of equipment for field testing**
  - **Input parameters for coverage and interference analysis (Planning Factors)**
- **Spectrum Analysis**
- **Field Test**

Laboratory Tests

- COFDM modulator/receiver testing
  - Contacted 12 different manufacturers to acquire COFDM 6 MHz equipment
  - Three manufacturers agreed to modify their equipment for US operation
  - Developed lab test plan. Established six different criteria for selecting the best modulator and receiver
  - Lab tests conducted at CRC in Canada

Laboratory Tests

- Two of the three different receivers tested had performance shortfalls that would have produced poor field results
  - One receiver was disqualified because of poor first adjacent channel rejection
  - The other was disqualified because of poor dynamic range capability for input signal

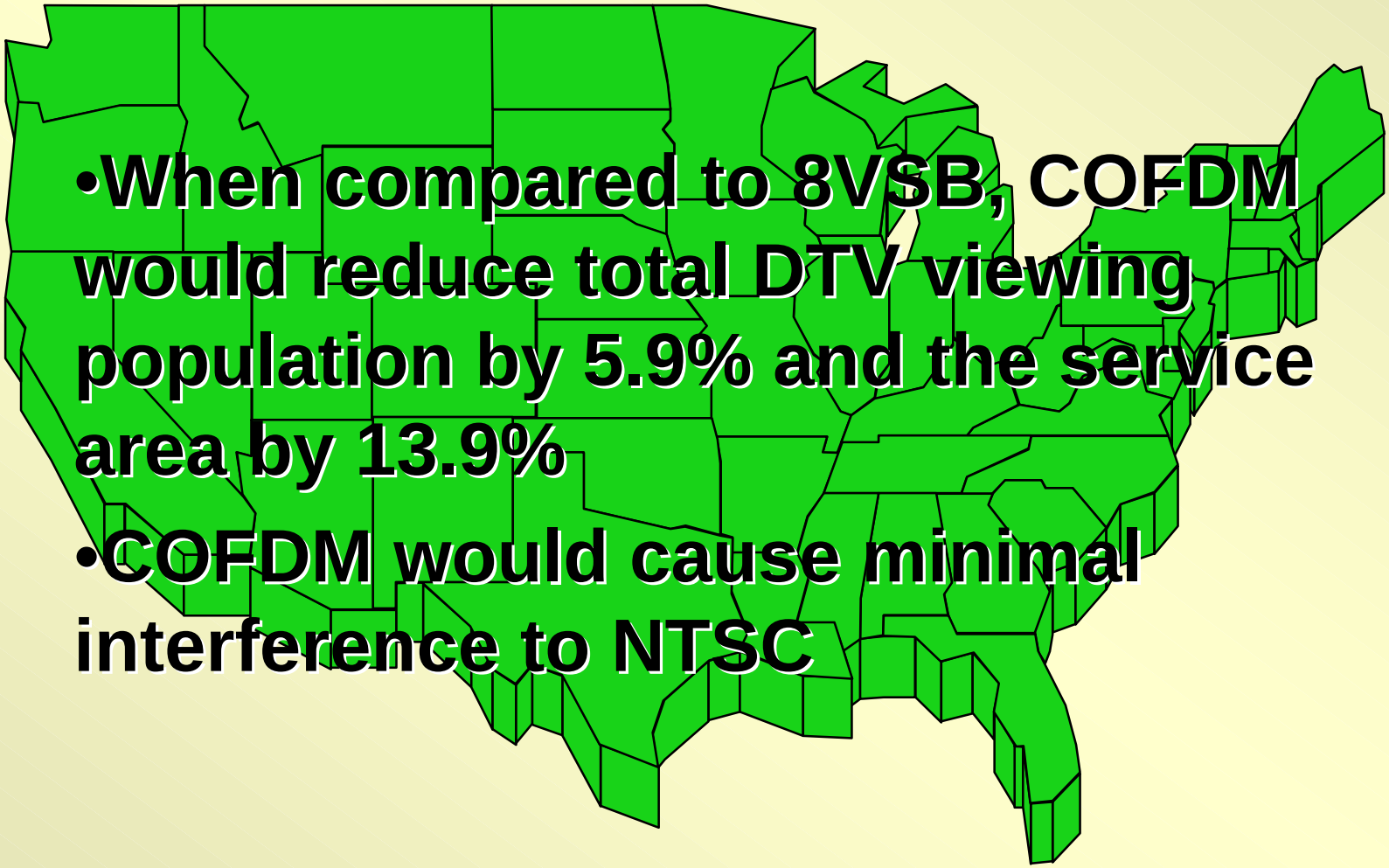
Laboratory Tests

- 8VSB receiver testing
  - Contacted 14 different manufacturers to acquire their latest product
  - Four manufacturers agreed to lend their equipment for testing
  - Developed lab test plan. Established six different criteria for selecting the best receiver
  - Lab tests conducted at ATTC in Alexandria, VA

Laboratory Tests

- Three out of the four receivers tested had limited performance in one or more of the six criteria established. However, these limitations were not serious enough to disqualify them for use in field measurement. The best performing receiver was ultimately selected for the field test program.

Spectrum Analysis



- When compared to 8VSB, COFDM would reduce total DTV viewing population by 5.9% and the service area by 13.9%
- COFDM would cause minimal interference to NTSC

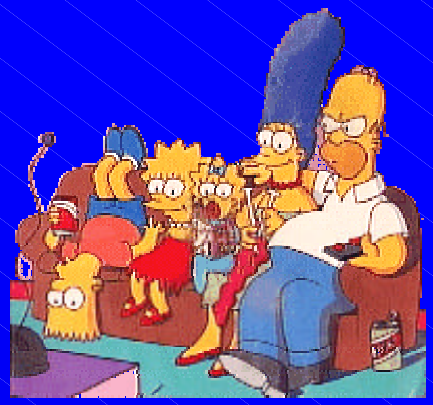
Spectrum Analysis

Additional DTV Interference in percent of service area	Percentage of Stations affected by converting to COFDM	
	By Population (%)	By Area (%)
Decreased Interference	0.5	0.1
0 - 5 %	38.0	0.4
5 –10%	31.6	4.2
10 – 15%	11.6	70.5
15 – 20%	8.9	23.1
20 – 25%	2.4	1.0
25 – 30 %	1.2	0.3
30 – 35 %	0.5	0
> 35%	0.3	0.3

Standard 30 foot outdoor antenna

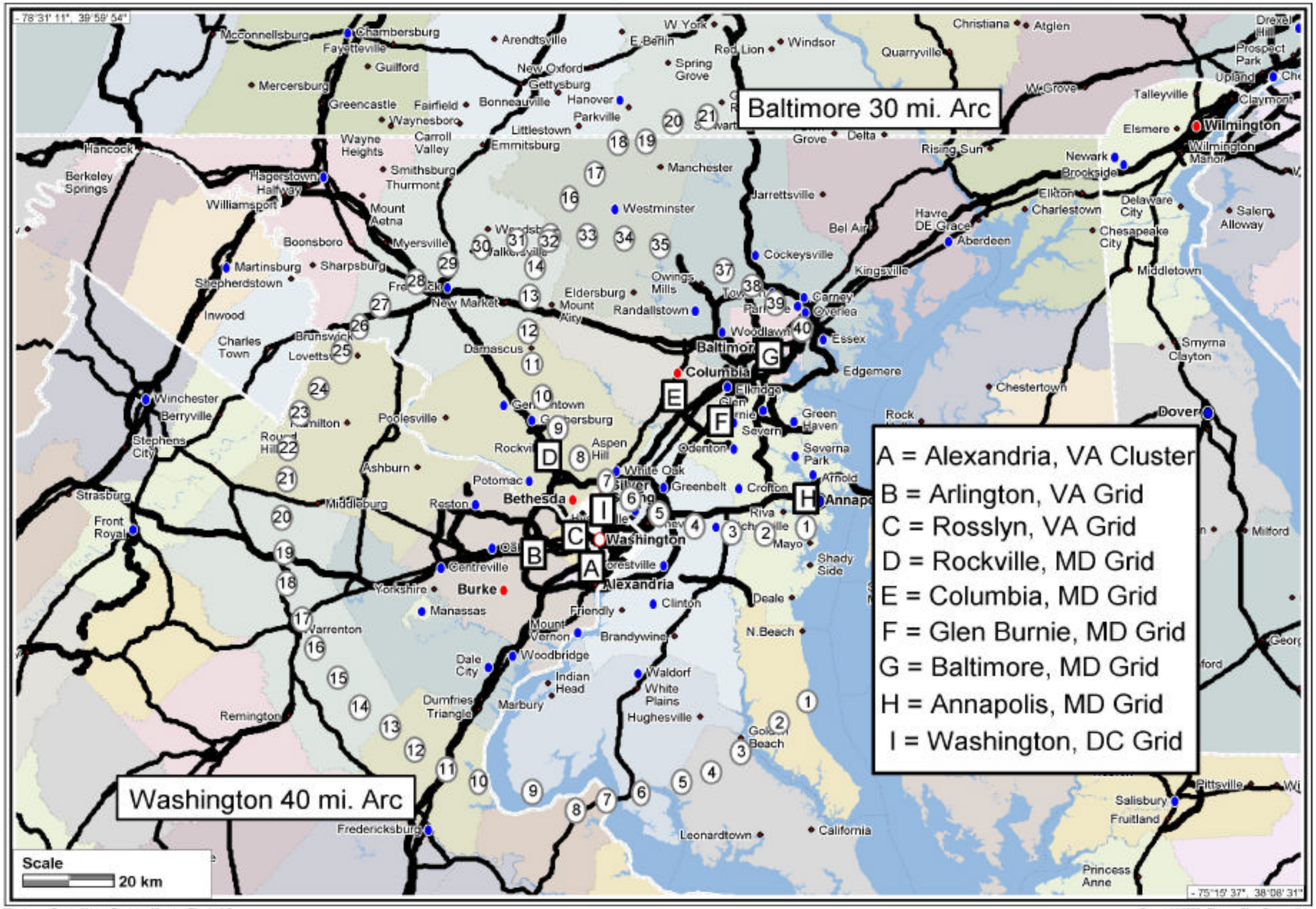
Washington/Baltimore Results (UHF)

6 foot outdoor antenna (Portable reception)



Indoor antenna

Washington Test Sites



Outdoor Reception Findings

- ***At 30 feet***, **8VSB was successfully received at a greater percentage of sites than COFDM on all four stations. 8VSB performed better up to the farthest distances measured (55 miles)**
- ***At 6 feet,*** **COFDM was successfully received at a greater percentage of sites than COFDM for close-in sites. At greater distances performance was very close**
- **In the "ease of reception" testing (antenna pointing sensitivity), COFDM outperformed 8VSB at 6 feet**

Figure 4: Reception Statistics by Station (30 Ft)

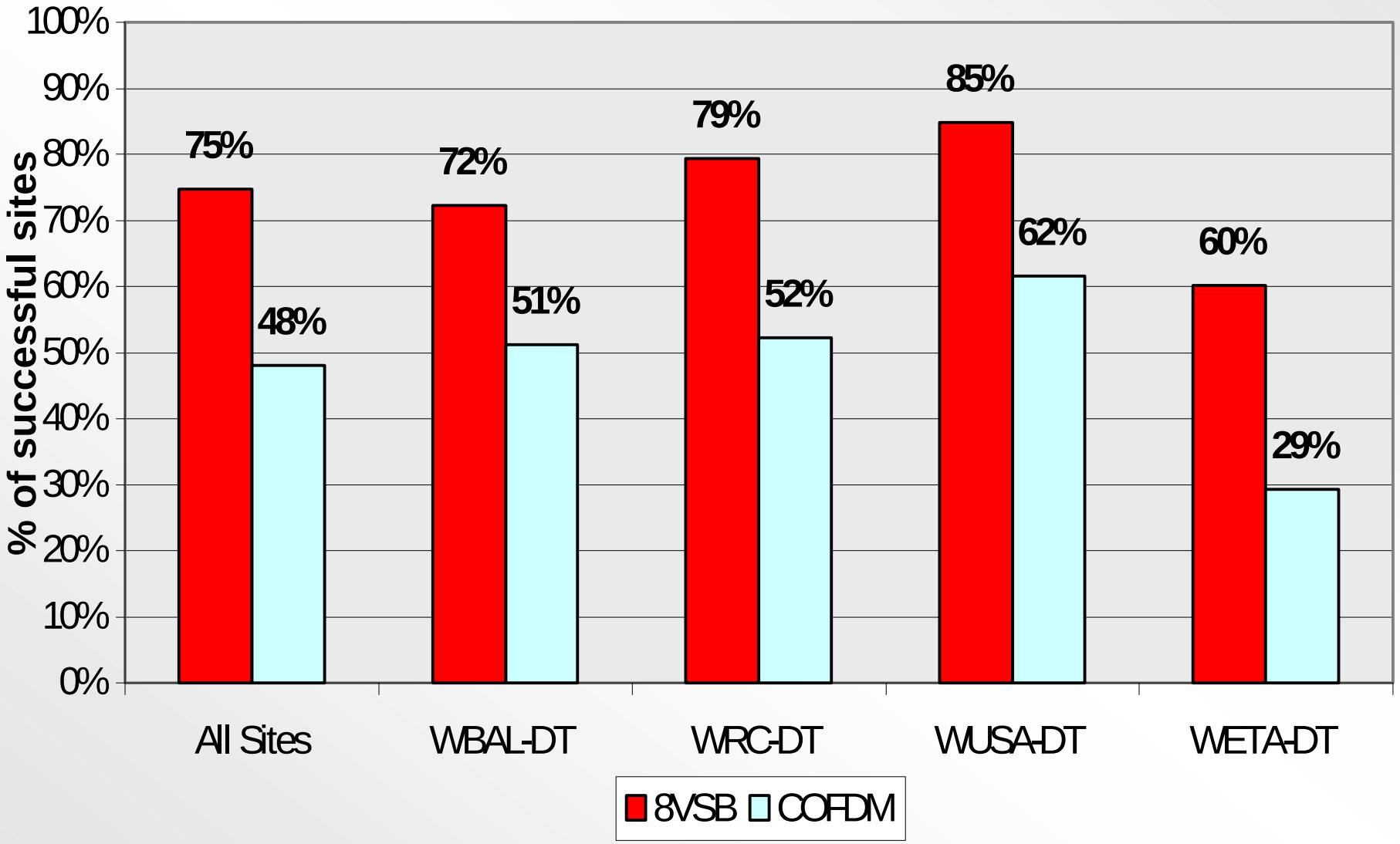


Figure 5: Reception Statistics by Station (6 Ft)

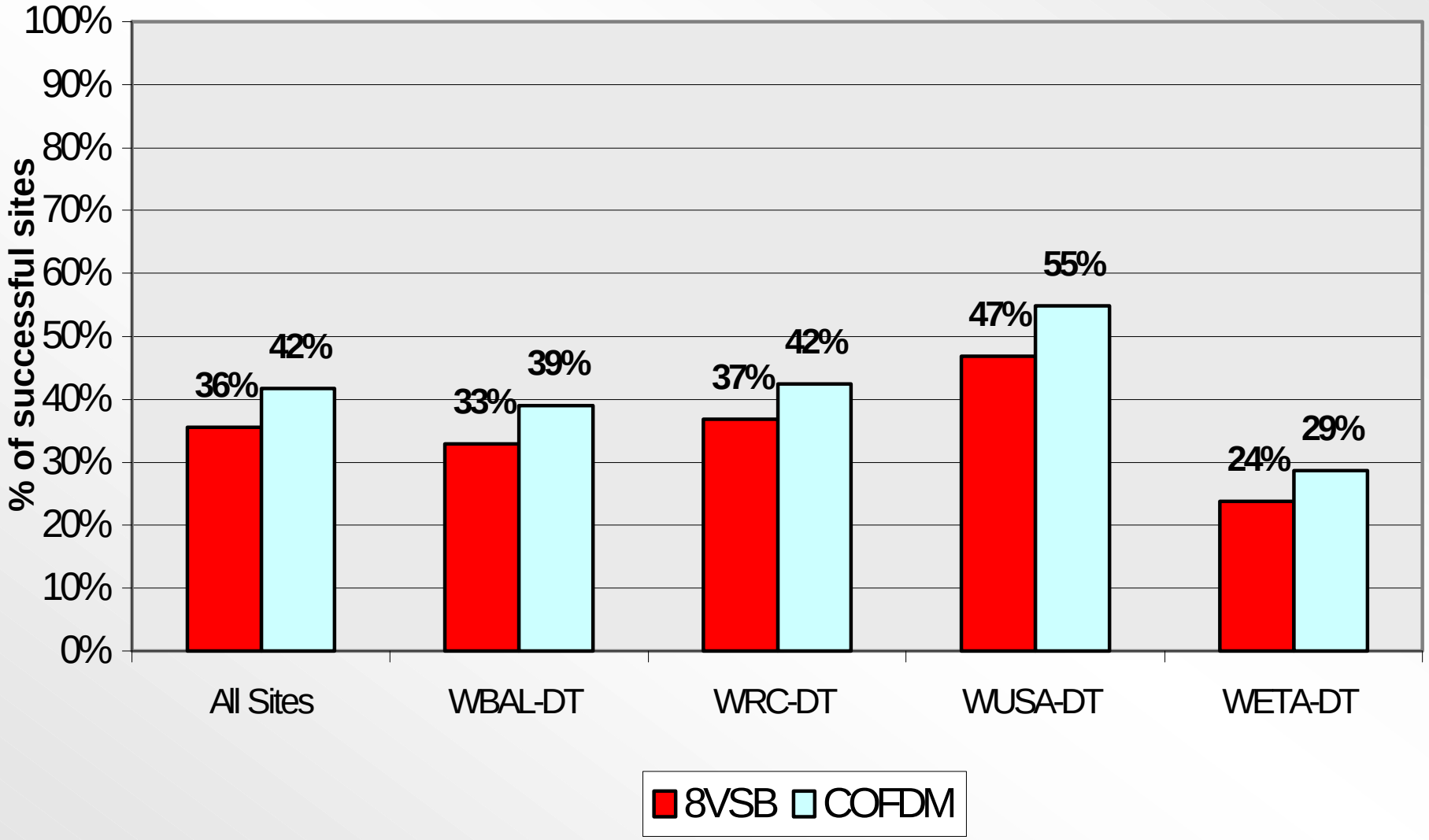


Figure 16: WRC-DT Reception Statistics vs. Distance (30 Ft)

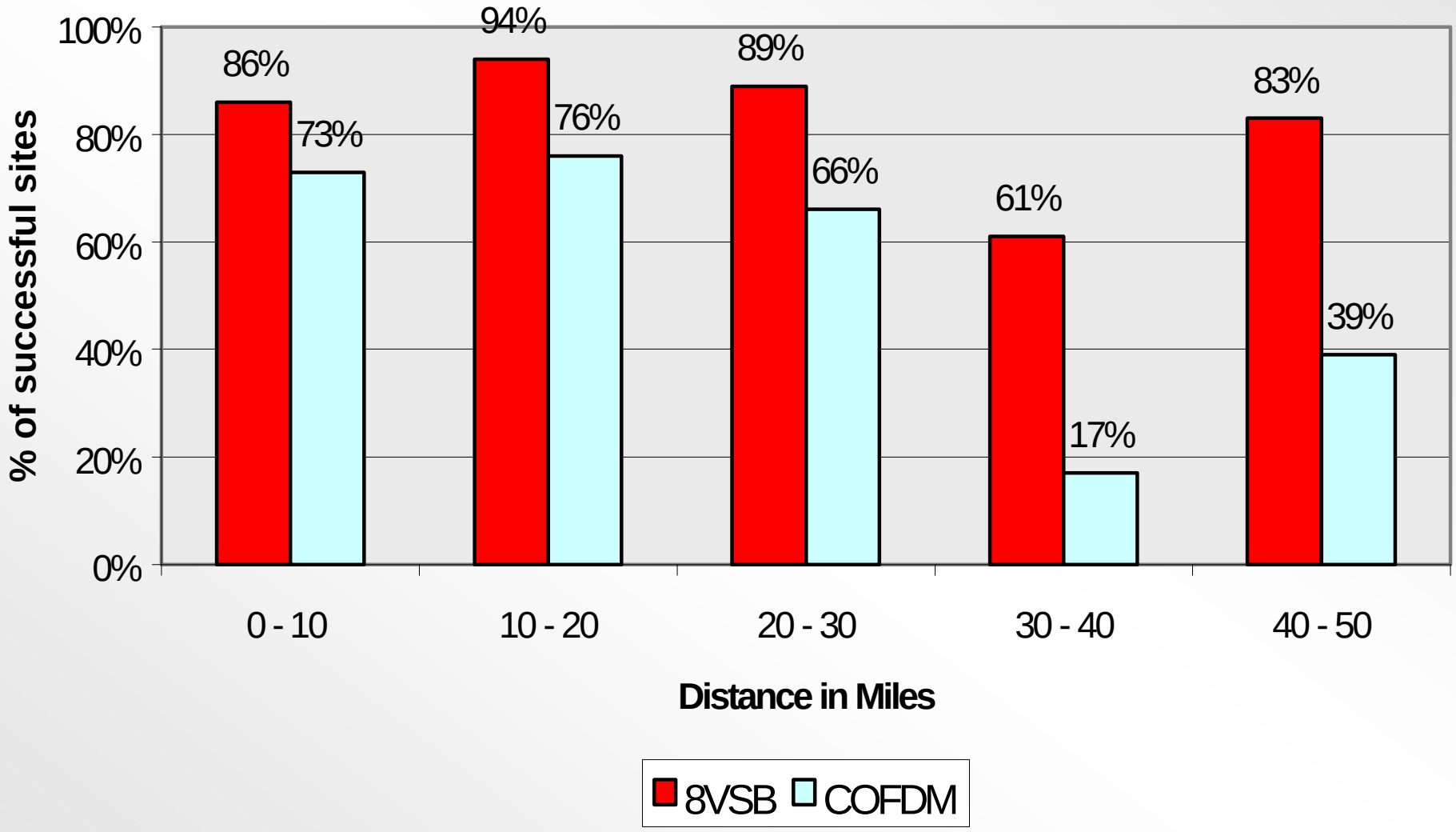
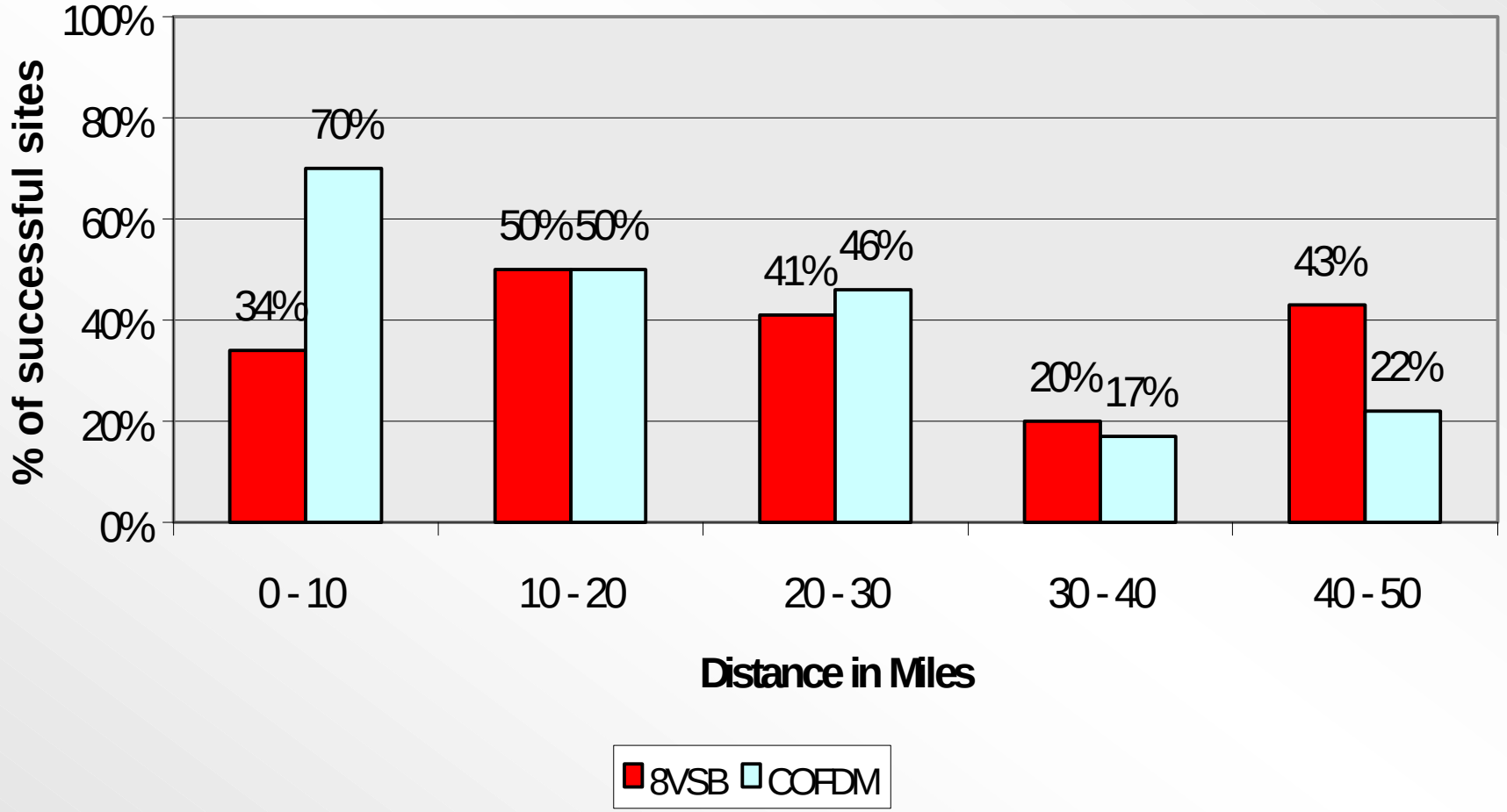
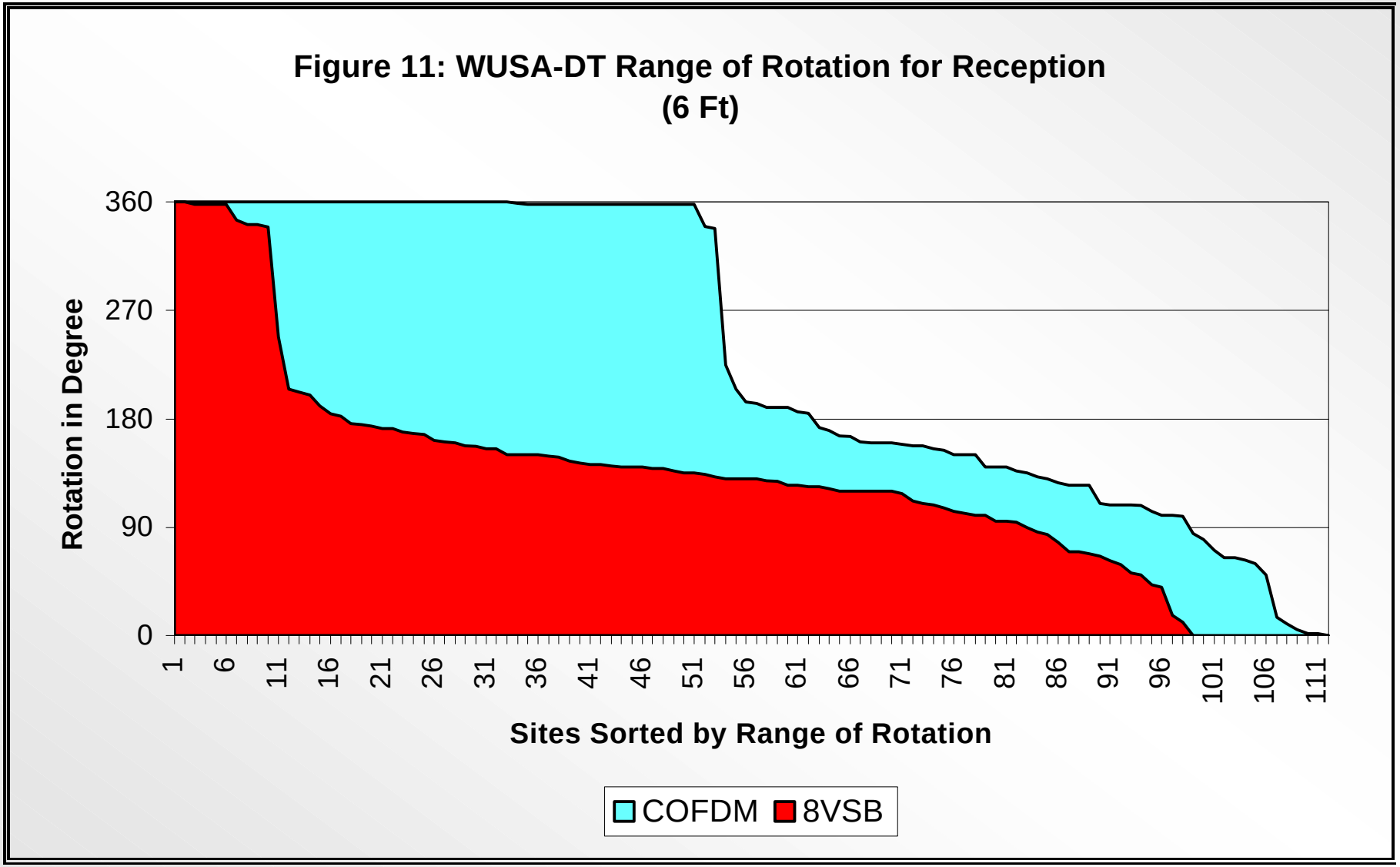
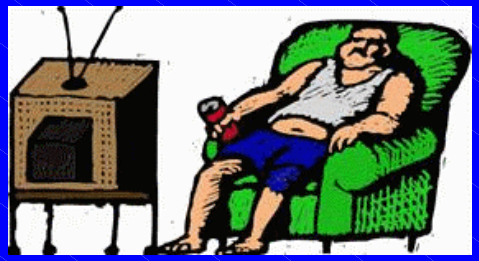


Figure 17: WRC-DT Reception Statistics vs. Distance (6 Ft)



Ease of Reception





Indoor Reception Findings

- The percentage of successful reception was similar for 8VSB and COFDM. This was true for both indoor antennas (Bowtie & Silver Sensor). Successful reception was achieved at only about 30% of sites, which is disappointing.

Figure 23: Reception Statistics for Indoor Sites by Station Using a Bowtie Antenna (Indoor)

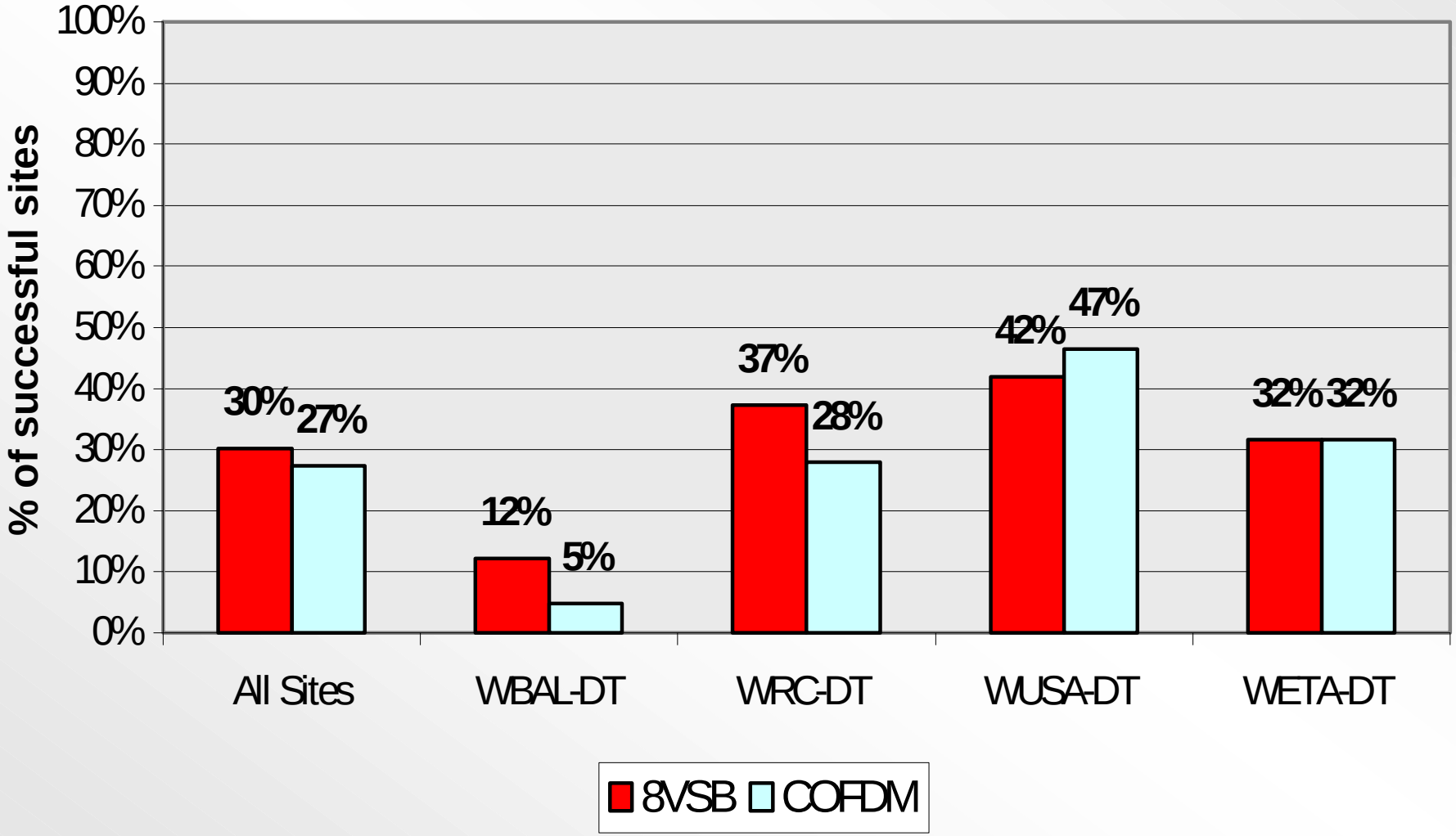
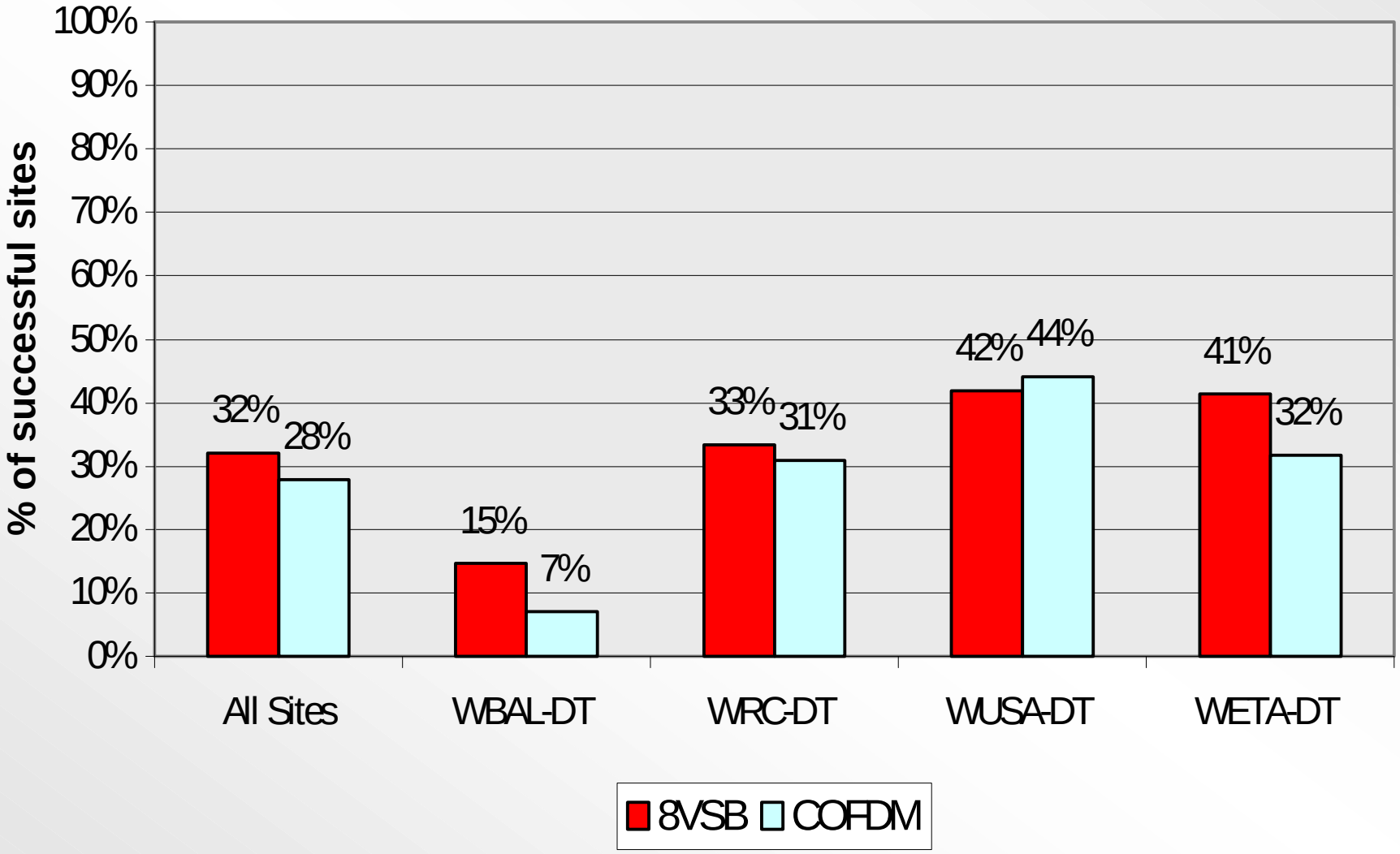
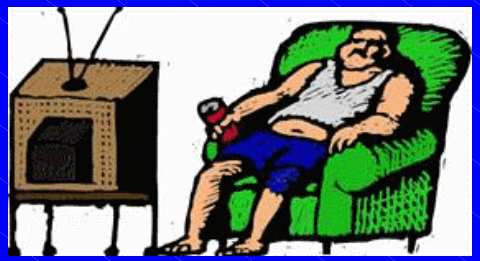


Figure 22: Reception Statistics for Indoor Sites by Station Using the Silver Sensor (Indoor)



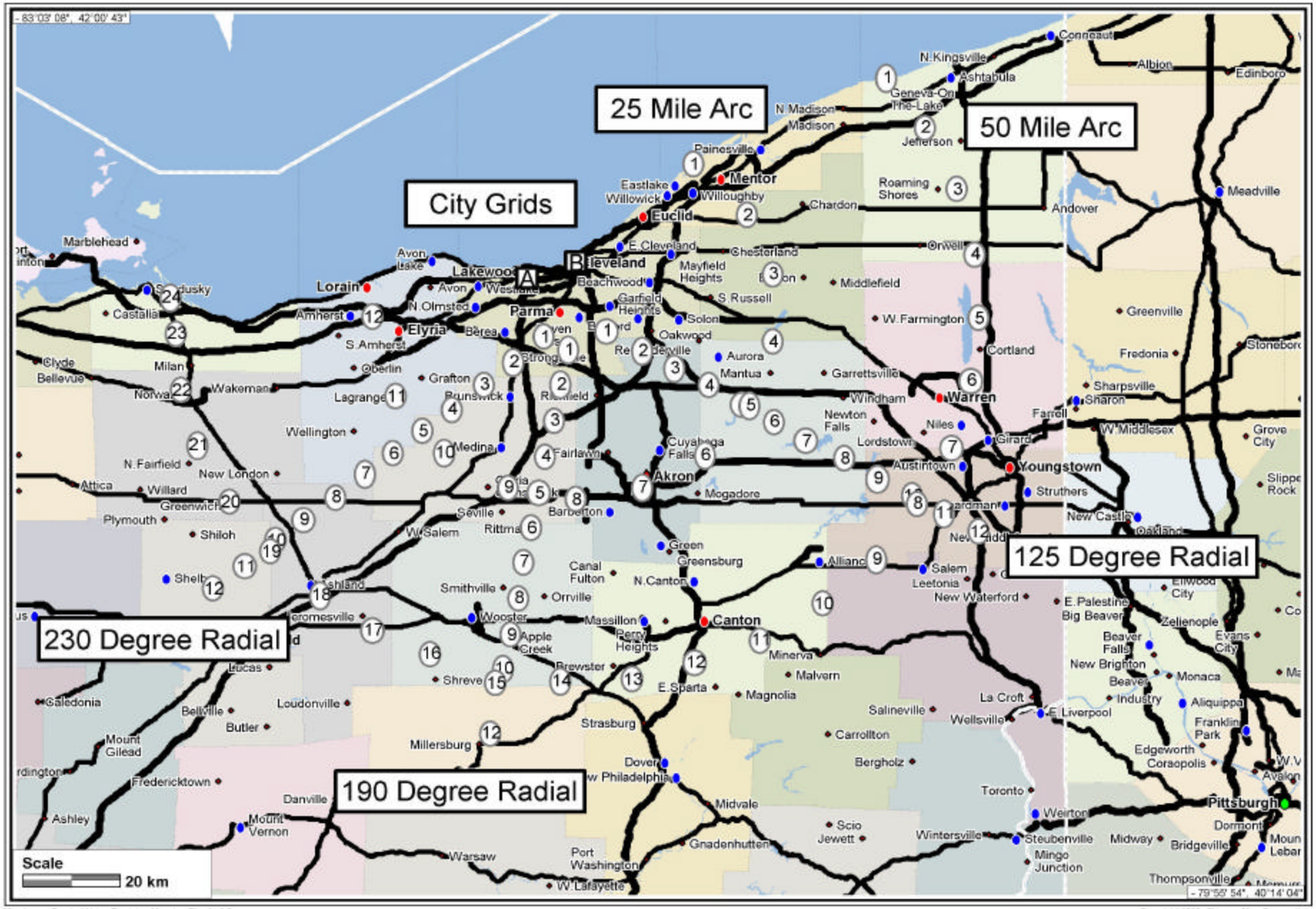
Cleveland Results (Low VHF)



6 foot outdoor antenna
(Portable reception)

Standard 30 foot outdoor antenna

Cleveland Test Sites



Outdoor Reception Findings

- *At 30 feet*, 8VSB was successfully received at a greater percentage of sites than was COFDM. 8VSB performed better than COFDM away from the transmitter. COFDM performed better closer to the transmitter
- For sites that had acceptable NTSC picture quality, 8VSB was successful 92% of the time while COFDM was successful 78% of the time
- *At 6 feet*, 8VSB was successfully received at twice as many sites as COFDM. However, 8VSB achieved a 28% success rate which is disappointing

Figure 25: Reception Statistics for WKYC (30 Ft)

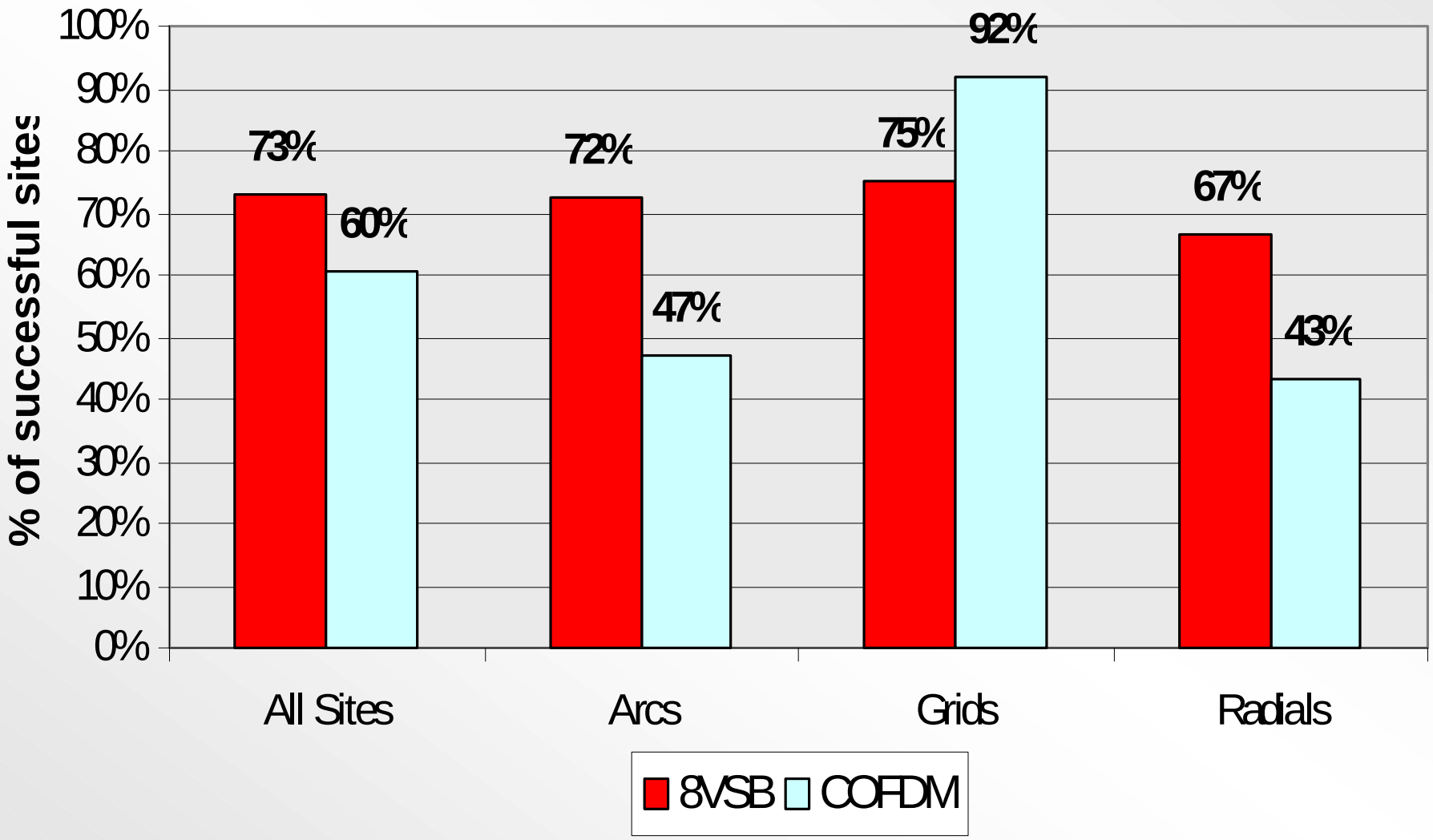
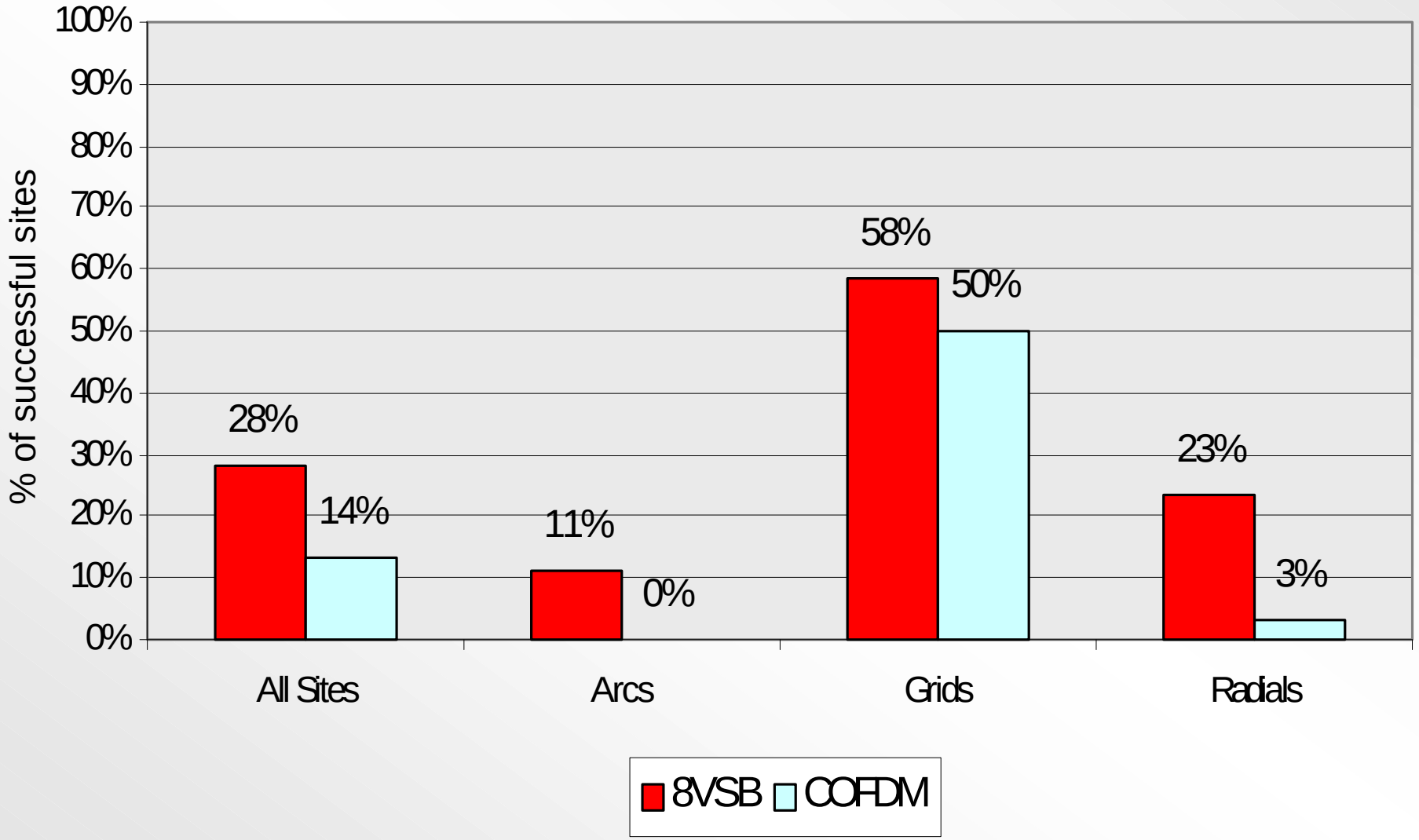
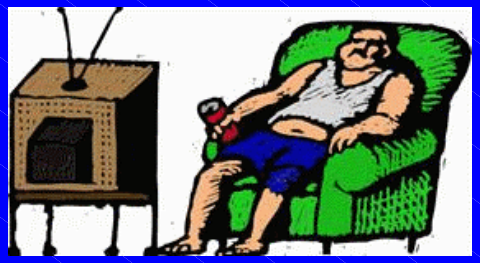


Figure 26: Reception Statistics for WKYC (6 Ft)



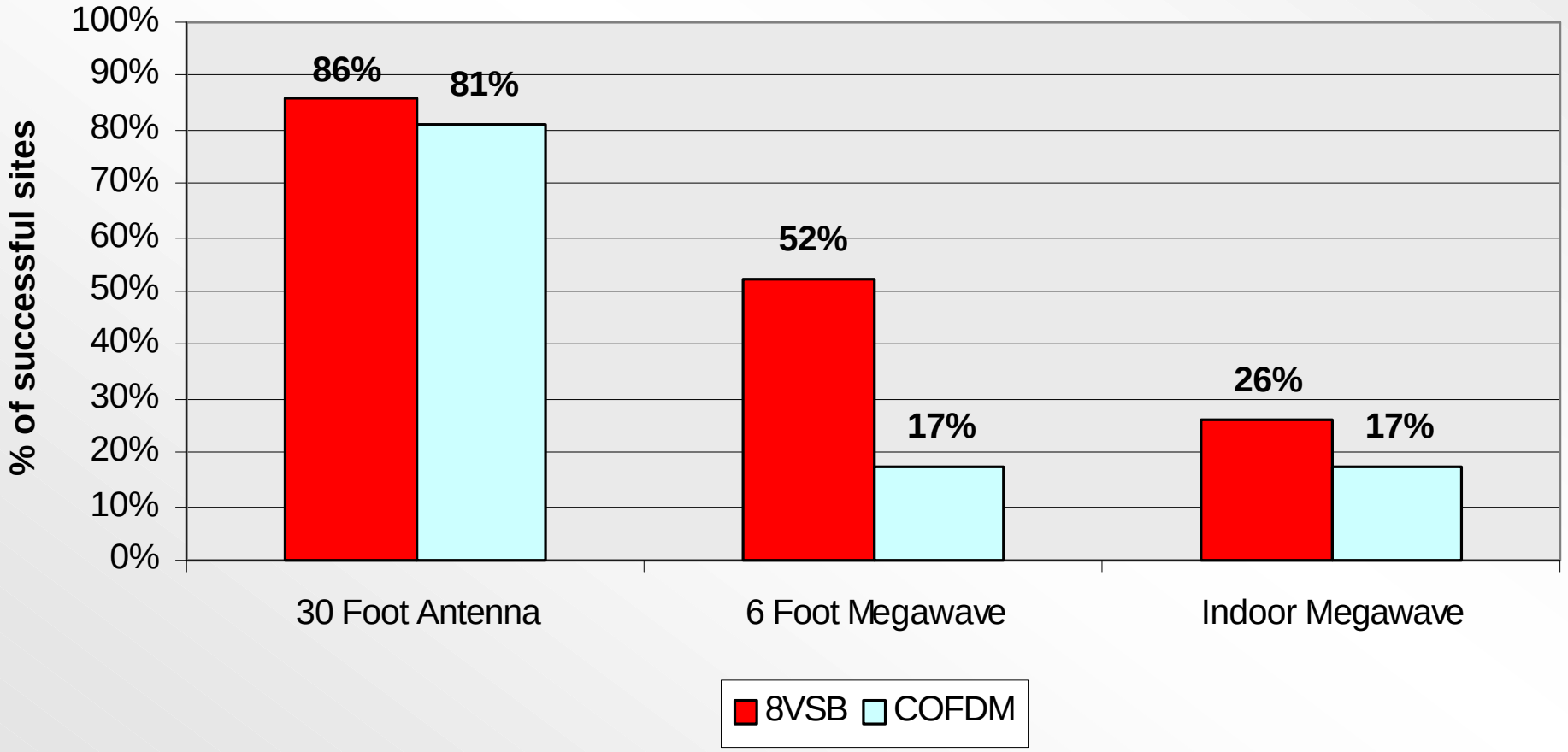


Indoor Reception Findings

- **Successful reception for 8VSB was 9 percentage points better than COFDM. However, even 8VSB achieved only a 26% success rate, which is disappointing.**

Indoor Reception Statistics

Figure 38: Reception for WKYC-DT for Indoor Sites (30FT/ 6 FT/ Indoor)



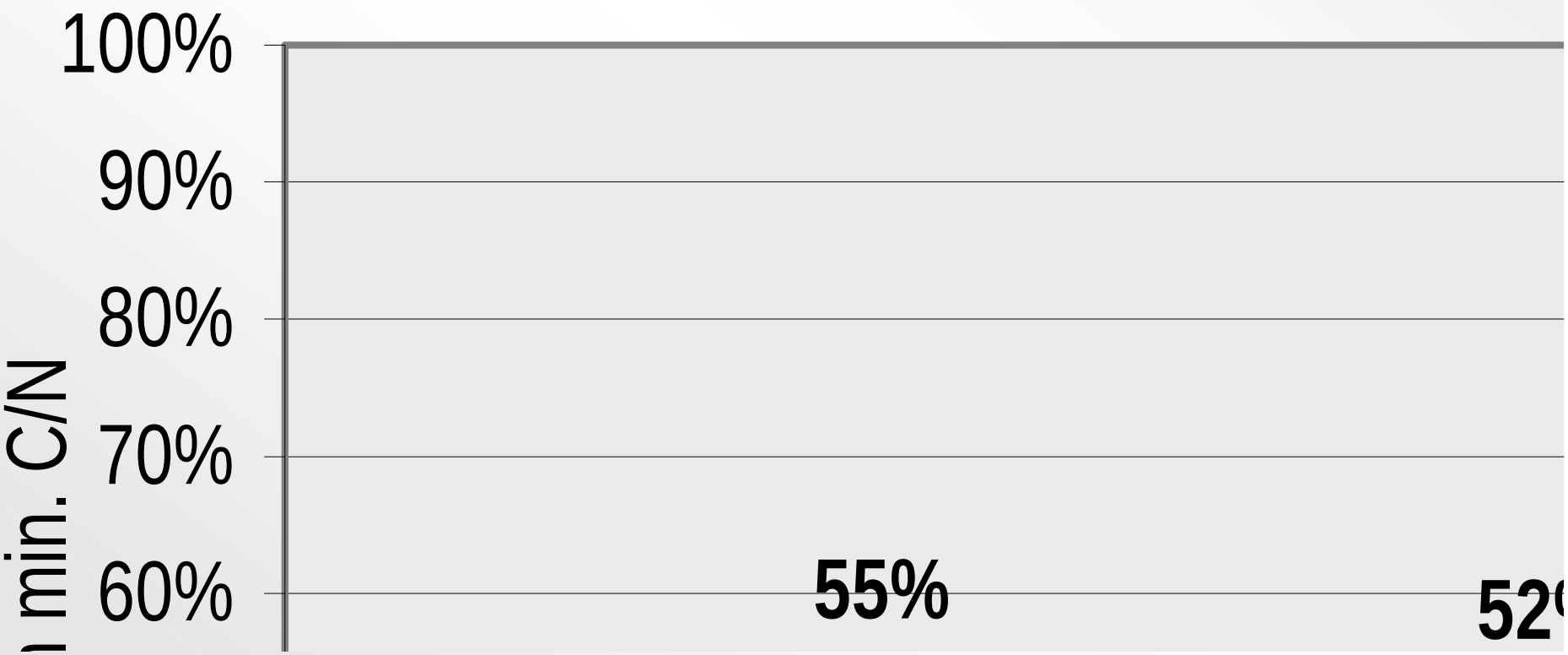
Other Findings

- **Data confirmed the theoretical Carrier-to-Noise (C/N) performance difference of about a 4 dB advantage of 8VSB over COFDM**
- **Both technologies had areas where their performance characteristics could be improved. The performance deficiencies of both systems accounted for some of the failures observed in the field**

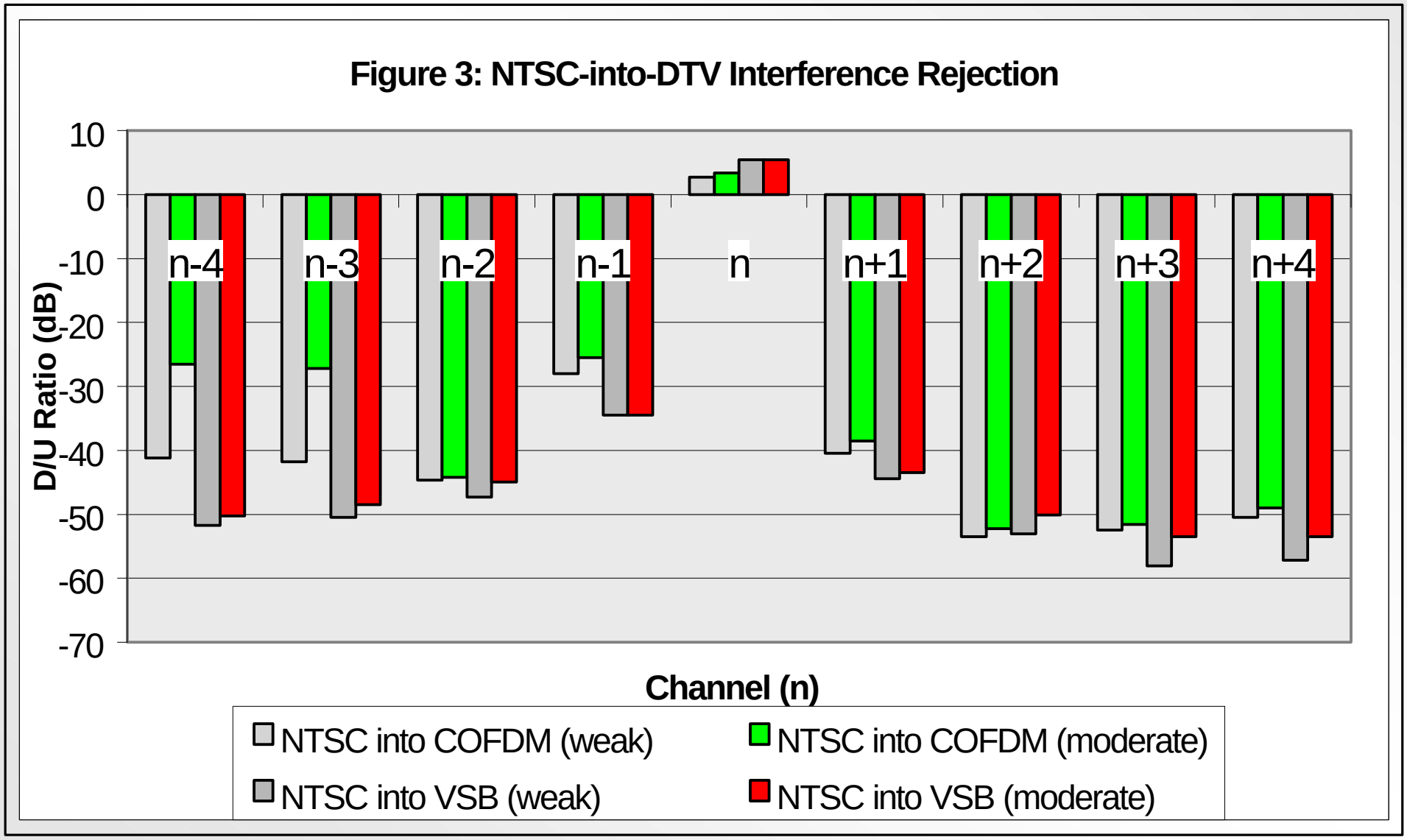
Failure Analysis

- Inadequate signal Level
- Noise (natural and manmade)
- Interfering RF signals
- Multipath impairments (static and dynamic)
- Receiver characteristics

Figure 2: Failed Sites that did not and Gri



COFDM Receiver Performance



Conclusions

- 8VSB is suitable for a broadcast service when a 30 foot outdoor antenna is used for reception
- Results are less optimistic for outdoor reception at 6 feet for both systems
- Neither systems exhibited the level of reliability required for an indoor broadcast service
- Given the level of failures at moderate and weak signal levels at low VHF, the data suggests the planning factors used by the FCC to predict low VHF service are inadequate

Acknowledgements

ABC, CBS, WRC, PBS, WETA, NAB, Gannett, Sinclair, PTV, Sencore, Harris, Tandberg, Thomcast, Pioneer, Rohde & Schwarz, Toshiba, NEC, CRC, Zenith, ATTC, Thomson, Potomac Instruments, BT, Nokia, VSB & COFDM Technical Group members