Field Testing of ATSC 3.0 Physical Layer Technologies

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It Started here in Madison!

- October 2014
- Facilities of WKOW-TV
- Modes Tested
  - Fixed reception
  - Indoor reception
  - Mobile reception
- Middle of the night
  - WKOW; Kohl Center; Steel Garage; Marriott
  - *Were you with us??*

- Additional Tests in Cleveland – dedicated 24/7 channel
  - May and July 2015

October 22, 2014…..

WKOW-TV Facilities

Field Testing at Night

October 22, 2014…..

Indoor Tests

Kohl Center

October 22, 2014…..

Indoor
Reception in
Steel Garage

Ultra HD (4K)
at Marriott

5 Key Features of ATSC 3.0

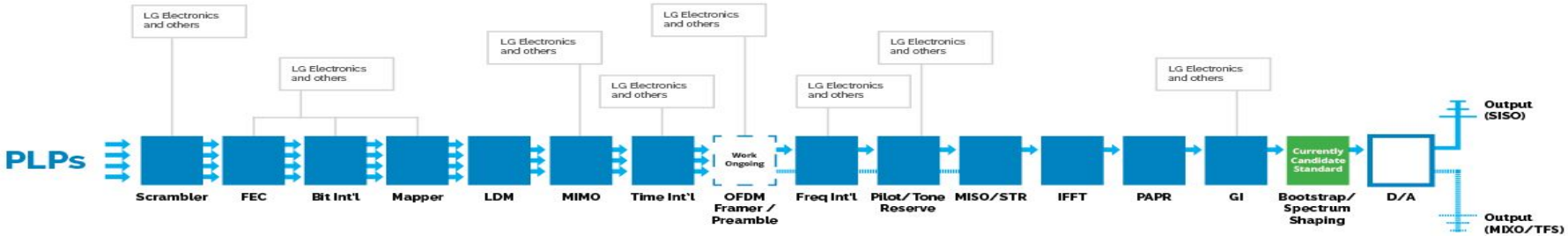
- Robust Mobile Reception
- Ultra HD TV Transmission
- IP Transport
- Advanced Emergency Alerting
- Immersive Audio

America's TV viewers will benefit from ATSC 3.0, as broadcast television integrate new capabilities and features into the receivers of the future.

Physical Layer – as Field Tested

- OFDM – Based
  - LDPC inner coding
  - Code rates 5/15 to 13/15
  - GI = 30 to 240 uS (60 uS & 120 uS tested)
- “Futureproofing”
  - Preamble Signaling
  - FEF (Future Extension Frames)
  - Carries TS, IP or GS (Generic Stream) packets

Much of LG/Zenith/GatesAir Technology Included in ATSC 3.0 Physical Layer Candidate Standard



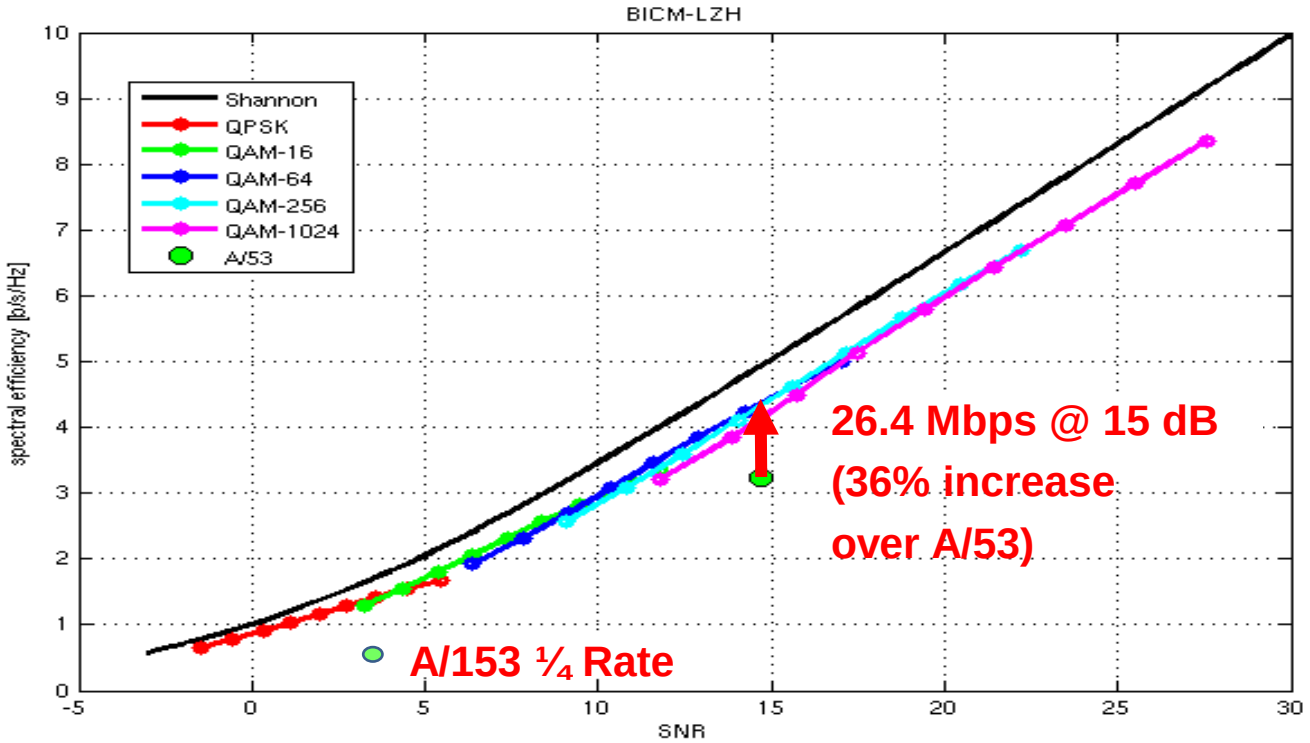
Green element: first Physical Layer Candidate Standard

Blue elements: second Physical Layer Candidate Standard

System Highlights

- OFDM Modulation
- LDPC coding
- 36% capacity increase over ATSC 1.0
- HEVC coding for video
- Multiple Data Pipes

Spectrum Efficiency vs. SNR



32k-FFT, GI-1/160, P128_2

FUTURECAST Features

- Multiple Pipes with Varying Robustness
- Hierarchical signaling structure
- FIC for fast channel change
- EAC Emergency Alert Channel
- Frame Repetition Unit (FRU) for robust signaling
  - Hierarchical Frame structure adopted in ATSC 3.0 Candidate Standard as Frames and Subframes with multiple Physical Layer Pipes (PLPs)

Simulations; then Hardware

- Simulations identified inconsistencies
  Corrected before hardware built
- FPGA Modulator
- FPGA Receivers
  - Identified Sensitivity Implementation loss (> 1 dB)
  - Hardware modified prior to field testing

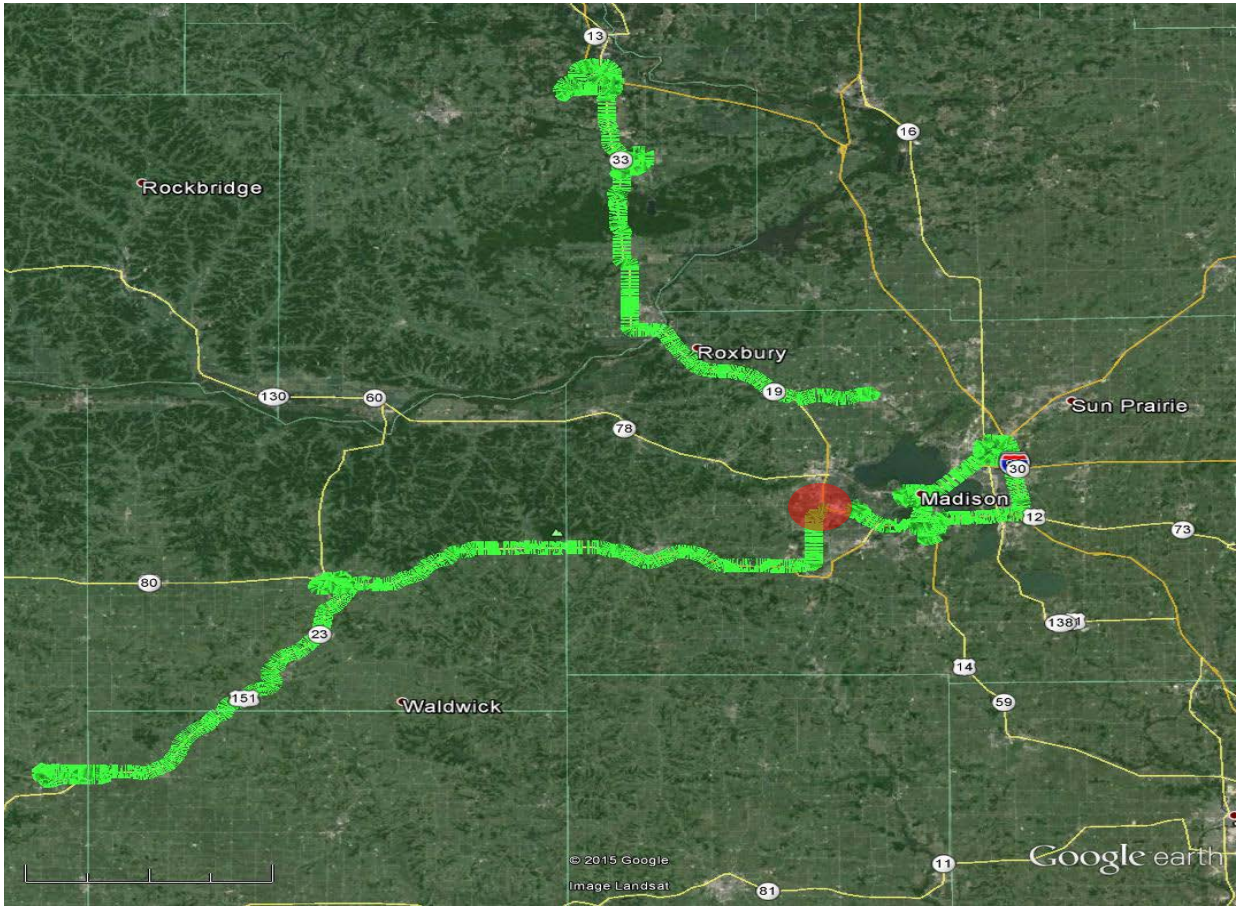
Three Transmission Modes

- DP0 High Capacity Mode
  - 36% higher than VSB
- DP1 Similar Threshold to ATSC M/H ¼ Rate
  - 2 ½ times the data capacity of M/H
- DP2 Very Robust Deep Penetration

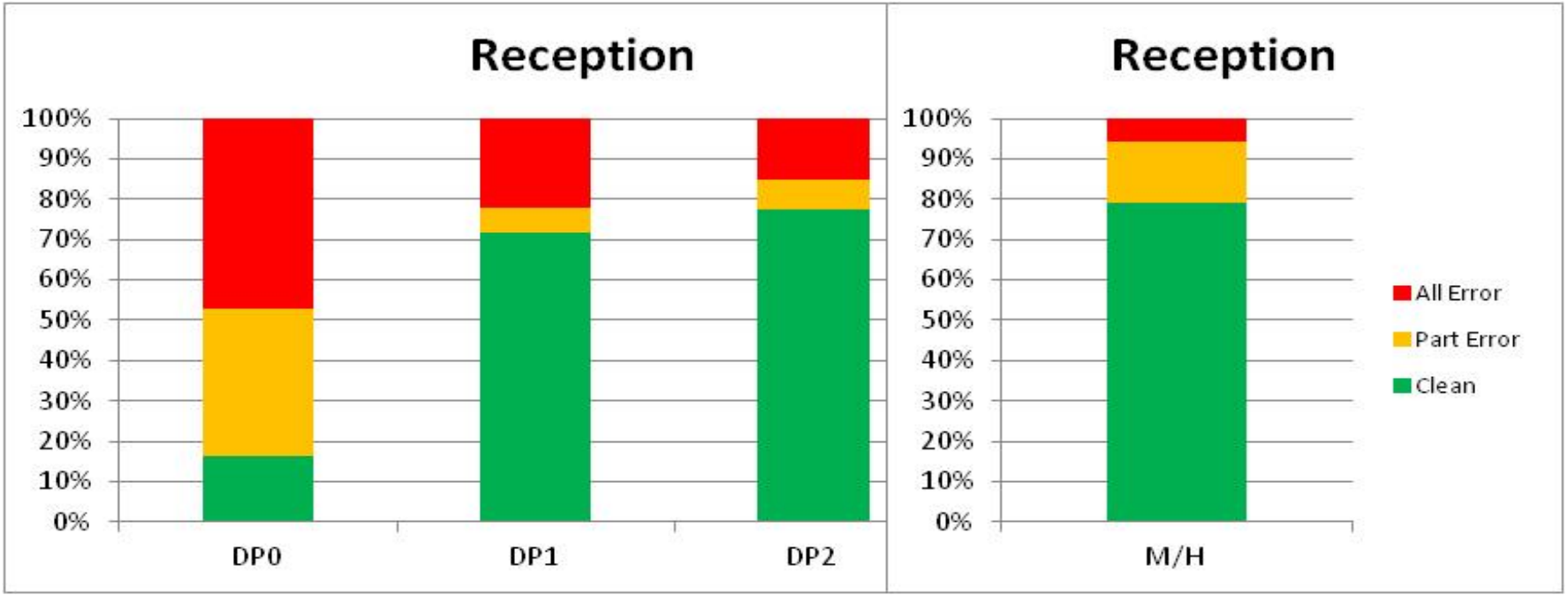
Mobile Reception in Madison

- Mobile Routes
  - 53 miles Southwest
  - 40 miles Northwest (past ridge)
  - Downtown
- Over 16,500 data points for each mode
- DP0 *mobile* performance was poor (expected)
- M/H and DP1 performance was similar

Madison Mobile Routes



Madison Reception - 2014



Errors over-reported

System Improvements Based on Madison Tests

- Error reporting issue identified
- DP2 performance enhanced with improved preamble

Transmitter Availability

- Madison
  - 1:00 AM to 4:00 AM in place of regular programming
- Cleveland
  - 24/7 access to spare transmitter tied up in channel allocation freeze

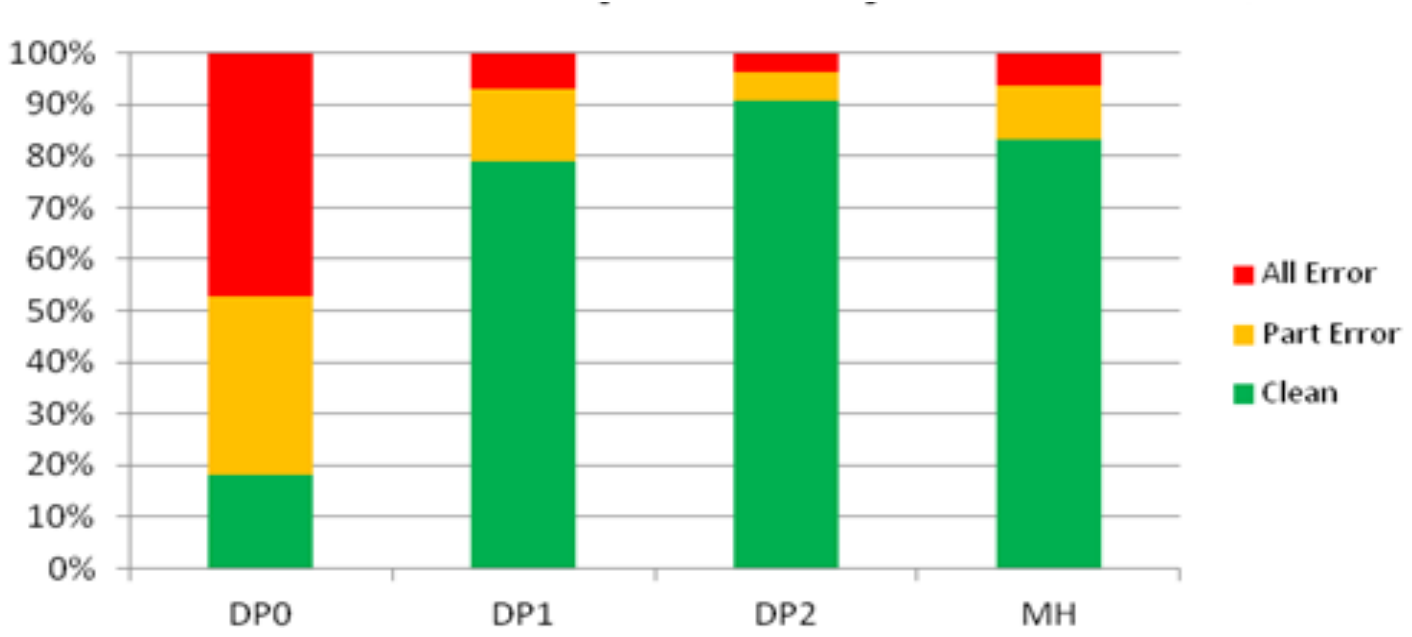
- Mobile routes measured VSB/MDTV in one direction and FUTURECAST in the return direction

Mobile Reception in Cleveland

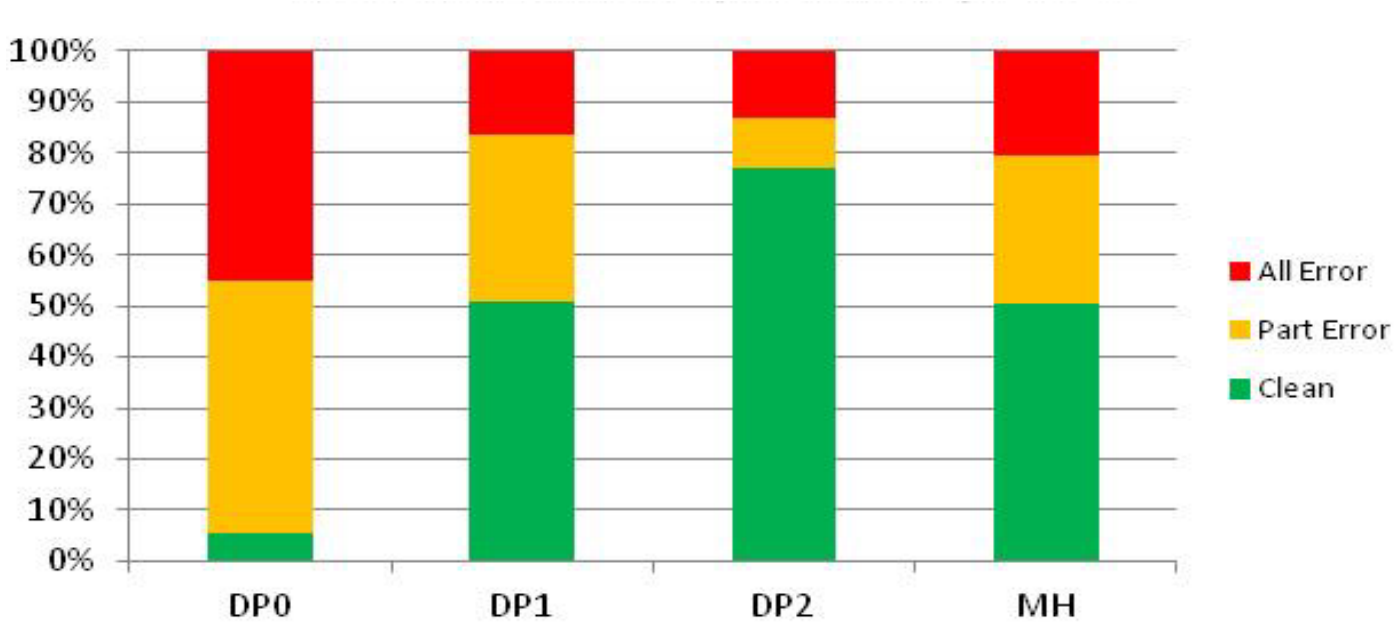
- Mobile Routes
  - 50 miles Southwest
  - 40 miles East
  - 25 miles South
  - Downtown
  - Southern Edge of Reception
- Over 18,000 data points for each mode
- DP2 Performance Improvement Verification

Cleveland Mobile Routes

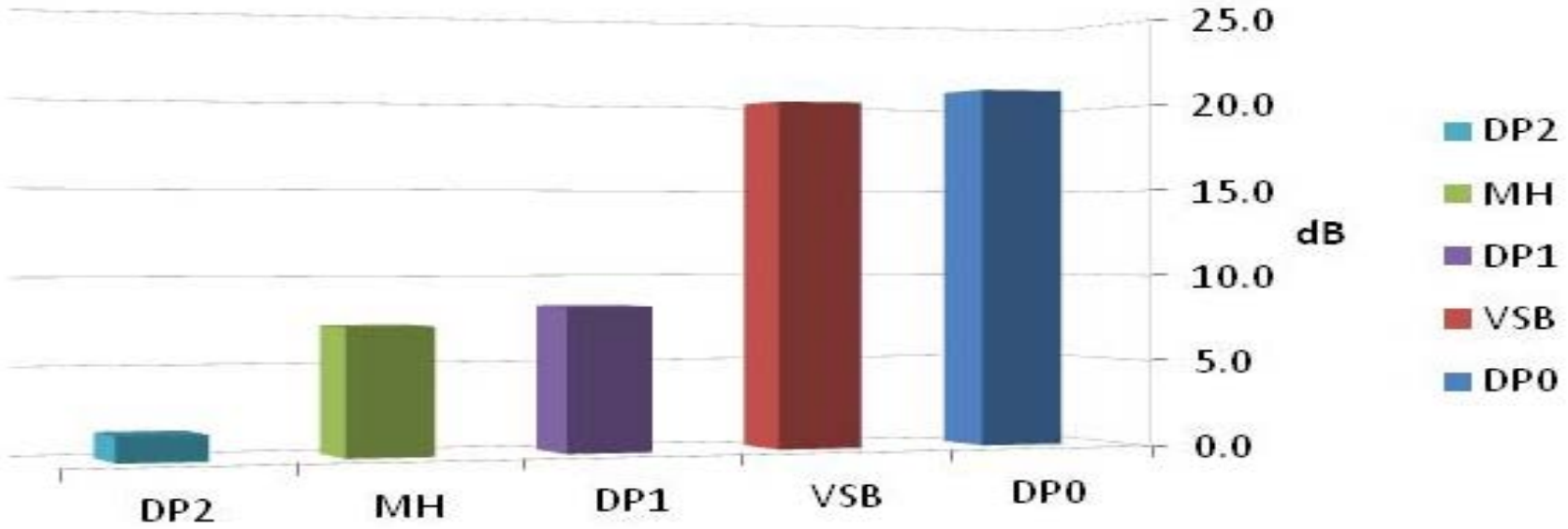
Cleveland Reception – Radials (May)



Cleveland Reception – Fringe (July)



Fixed Reception Threshold



Fixed Reception Comparison

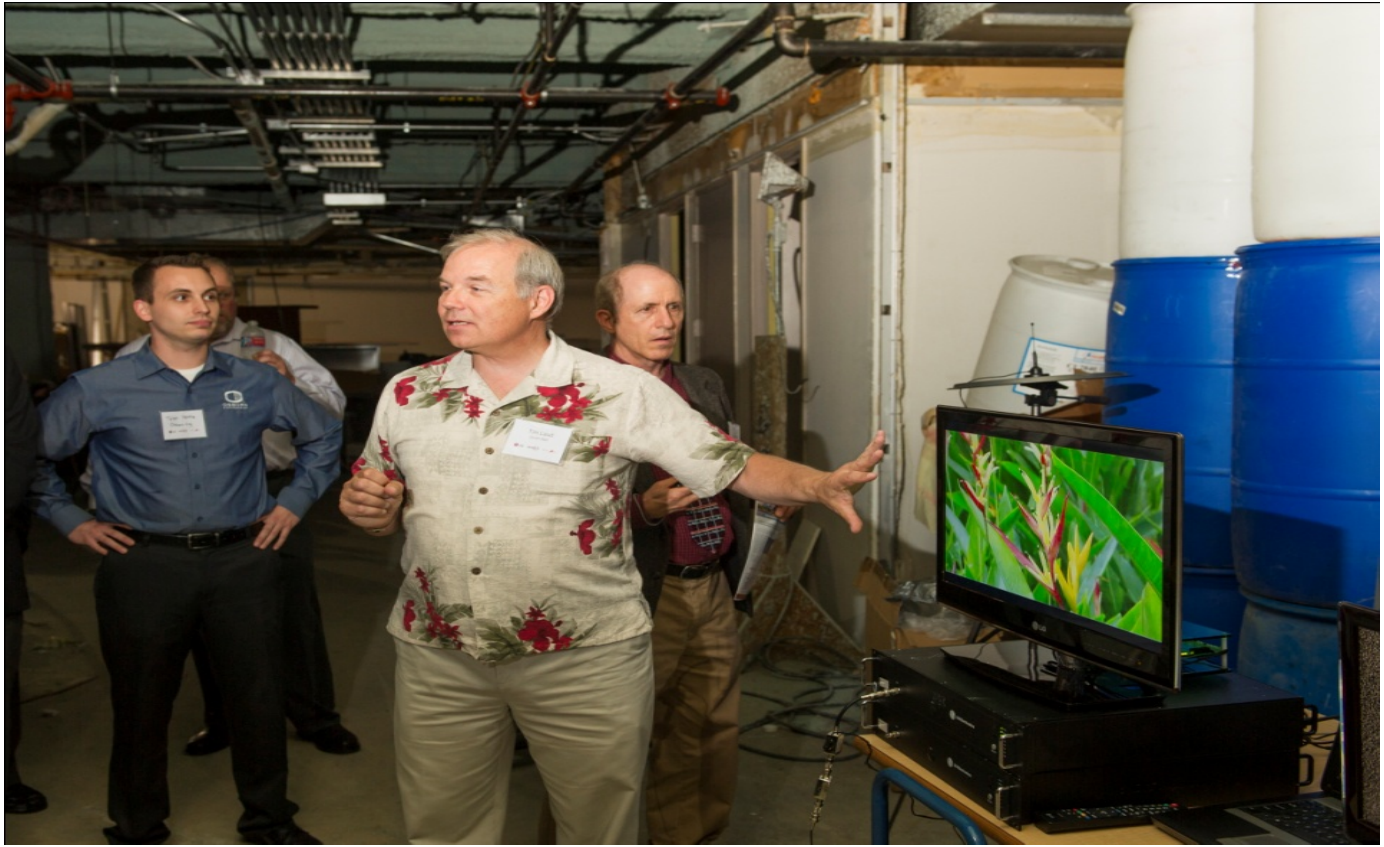
- DP0 & VSB have similar thresholds and similar performance
- DP1 & MH at similar thresholds have similar performance
- Channel Impairment loss has greater impact at higher thresholds

Basement Reception in Cleveland

- DP2 Reception where no TV signal has gone before

- Cell phone operation “iffy”

Basement Reception



Field Test Summary

- FPGA implementations provided extremely helpful data capture of key performance values
- Three simultaneous transmission modes
  - DP0: Similar threshold to VSB with improved capacity
  - DP1: Similar threshold to M/H ¼-rate with 2 ½ x efficiency (in bits/Hz)
  - DP2: Deeper indoor penetration than M/H
- RF recordings captured to assist in further lab development

Conclusion

- FUTURECAST hardware tests verify performance of technologies for ATSC 3.0, and have helped discover areas for refinement
- Increased capacity over VSB (ATSC 1.0) at similar thresholds is confirmed
- Much lower thresholds than ATSC 1.0 are possible
- Direct comparison to ATSC 1.0 demonstrates that performance is primarily dependent on white noise threshold – no unforeseen problems with new modulation / coding

Conclusion (2)

- FUTURECAST Tests Demonstrate Benefits of ATSC 3.0 Technologies
- Greatly improved bit-rate capacity for the same threshold as today's ATSC system
- Same coverage area for the same threshold
- Usable thresholds below existing M/H performance
- More mode flexibility
  - Improved indoor reception
  - Mobile modes
  - Handheld modes
- ATSC 3.0 should exhibit performance and benefits comparable to FUTURECAST

Thank You
and
Q & A