ATSC
Mobile DTV *TRANSMISSION SYSTEM*
Overview

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Agenda

- **Mobile / Handheld DTV Overview**
- **M/H System History**
- **M/H DTV Introduction**
- **ATSC Terrestrial Transmission System Overview**
- **ATSC M/H Transmission System Details**
- **M/H Field Testing Summary**
- **Broadcaster Recommendations**
- **Closing Thoughts …**

MOBILE / HANDHELD DTV OVERVIEW

ATSC M/H System
Background

- **After fixed terrestrial broadcasting became established, broadcasters wanted to expand services**

- **More system *flexibility* (2000)**
  - **Repeater capability** **(translators, on-channel repeaters, & SFN)**
  - **Mobile & handheld (M/H) capability** **(improved robustness to increased propagation severity)**

- **Same RF spectrum usage, transmit powers, & interference protection**

- **But with *backwards* compatibility to protect:**
  - **Legacy consumer receiver investments**
  - **Legacy broadcaster equipment investments**
  - **Spectral allocations**

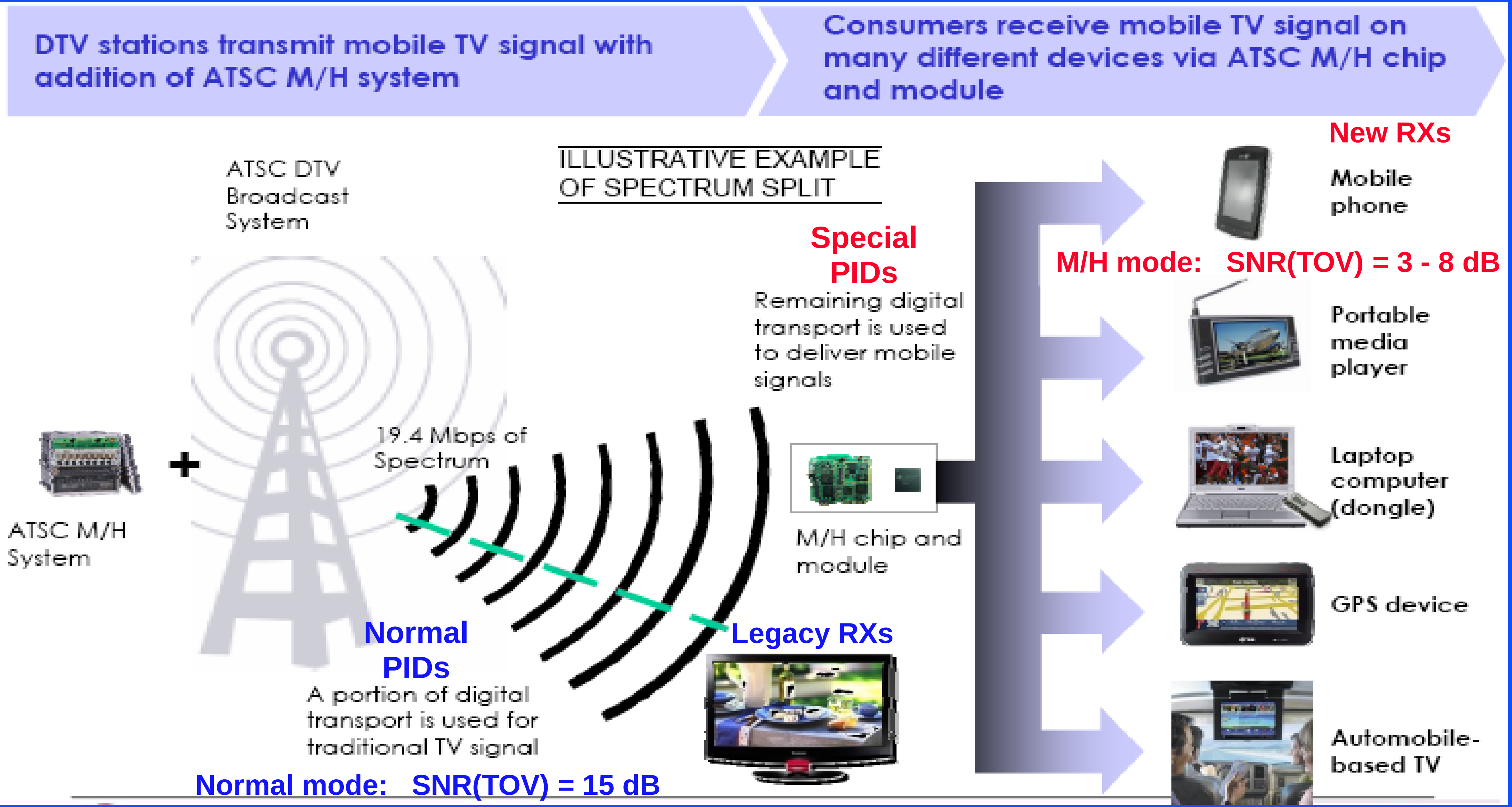
ATSC M/H System

Benefits

- **Broadcast streaming is alternative to Internet & mobile telephony**
  - “One-to-many” architecture with no network congestion
  - No outside providers or data plan consumption charges
  - High quality live, *local* television
  - *Free* & *reliable* propagation path
    - Especially in time of emergency or catastrophe (hurricanes, tornadoes, earthquakes, …)
    - M-EAS standard now available (Mobile Emergency Alert System)
- **TV “on the go” everywhere**
  - Triple play: HDTV, SD, & Mobile
  - Potential for *free* mobile television as well as *pay* services, as desired
  - Consumer viewing habits available via service & audience measurement
  - No need for: WiFi, Internet, cellular phone service, or data plans

ATSC M/H System

Applications



 Backwards compatibility: Legacy DTV sets read M/H PIDs & *gracefully* discard M/H packets

M/H SYSTEM HISTORY

ATSC M/H System

Brief History

3 years

- ATSC M/H standardization process begins: October 2006
- ATSC Request for Proposals: May 2007
- Open Mobile Video Coalition (OMVC) created: 2007
- OMVC feasibility (IDOV) field experiments & market study: 2008
- ATSC Candidate Standard: November 25, 2008
- FCC full-power analog station turn-off (10-year Transition): June 12, 2009
- Finalize ATSC M/H Standard (A/153, Parts 1-8): October 15, 2009
- FCC announces conversion of TV spectrum to broadband: Oct 2009
- FCC announces National Broadband Plan (NBP): March 2010
- Mobile Content Venture & Mobile 500 Alliance both created: 2010
- ATSC Mobile EAS (M-EAS) standard (A/153, Part 10): Spring 2012
- 133 * broadcast stations transmitting M/H in 49 markets: September 2013

4 months

* 24 more stations announced M/H service "coming soon" for a total of 157 in 51 markets

ATSC M/H System

OMVC Mission

- Open Mobile Video Coalition (OMVC)
  - Created in 2007 by broadcast groups & stations
  - Desired a *single* industry standard
- Goals
  - Field Test Proposed Physical Layer Systems: IDOV (Independent Demonstration of Viability)
  - Work with ATSC: M/H Standards
  - Consumer trials & service evaluations: Focus Groups
  - Funded & performed system testing: Various Layers
    - RF Layer Performance & System Configuration Testing
    - Development of RF Propagation Modeling
  - Advocate M/H to: Carriers, Consumers, & Device Manufacturers
- NAB taking leadership role in continuing implementation
  - OMVC integrated into NAB December, 2012

ATSC M/H System

Handheld & Mobile Groups

- **Mobile Content Venture (Dyle TV)**
  - Created in April 2010
  - Represent 12 major broadcast groups
  - Covers ≈55% of population
  - Dyle Service with encryption keys, even for *free* service (allows feedback on viewer choices)
- **Mobile 500 Alliance (MyDTV)**
  - Created in December 2010
  - 46 broadcasting members, represent 420 stations (4 public)
  - Represent >24 broadcast companies (own >346 commercial TV stations)
  - Covers > 90% of TV households
- **Mobile**
  - Perhaps merge or join forces in late 2013 (May 2013 @ ATSC meeting)

M/H
DTV
INTRODUCTION

ATSC M/H System

General M/H Features

- **Dual stream system**
  - **In-band M/H service uses *portion* of 19.392 Mbps 8-VSB data payload**
- **Improved methods for mobile/handheld data reception**
  - **Forward Error Correction** (increased sensitivity & immunity to burst noise; data thresholds @ 3- 8 dB)
    - Stronger Reed-Solomon
    - Additional & longer interleaving for better time diversity (1 sec RS Frame, Block Interleaving)
    - Serial Concatenated Convolutional Coding (SCCC) & Turbo decoding (½-rate & ¼-rate)
  - **8-level training signals** (faster *synchronization & multipath* mitigation; > 100 mph)
    - Additional reference signals with higher repetition rate
- **Data efficient**
  - ***Scalable* coding for reception robustness versus payload data rate tradeoff**
  - **Each RF channel capable of 8 mobile streams @ 630 kbps for each stream**
- **Burst data transmission**
  - **Rx power cycling**
  - **Battery life extension**

ATSC M/H System

General M/H Features (cont)

- Efficient video (MPEG-4) & audio (HE AAC) coding schemes
  - High <u>quality</u> or large <u>quantity</u> *live* or *non-real-time* programs
- IP-based mobile payload
  - Supports stream & non-real-time file delivery
  - Enables cross-media compatibility
- System *optionally* supports service features
  - Viewer identification (advertising information)
  - Access control
  - Paid service offerings
- Easy integration into ATSC broadcast systems
  - No constraints on PSIP
  - No changes or additions to STL (single SMPTE 310M STL capability)

ATSC M/H System

Backwards Compatibility with Standard 8-VSB

- Same Tx hardware infrastructure (encoder / mux & exciter < $150k startup cost)
- Identical signal format:
  - MPEG data transport stream headers (encapsulate IP datagrams)
  - Equi-probable 8-VSB data levels
  - Same data frame structure & synchronization (segments, sync, pilot, FEC)
  - Legacy PSIP carriage utilized
- Legacy receiver error correction capability
- Audio decoder buffer constraints
- *Indistinguishable* emitted RF spectral characteristics (same ERP & interference)
- FCC Considerations:
  - *Same* broadcast RF channel assignment
  - No additional FCC authorization required (still need to transmit 1 free SD program)

ATSC M/H System

Backwards Compatibility with Standard 8-VSB (cont)

- **Standard (*legacy*) ATSC 8-VSB receivers**
  - **Special M/H PIDs are read & packets *gracefully discarded***
  - **Identical error correction capability**
  - **Same TOV performance** (SNR ≈ 15 dB @ threshold)

- **Special (*new*) receivers with additional capability**
  - **Special M/H packets are known & robustly decoded** (TPC signaling)
  - **Allows indoor, portable, pedestrian, & mobile reception**
  - **Provides larger coverage area** (SNR ≈ 3 - 8 dB @ threshold, depending on coding)

ATSC *DIGITAL* TERRESTRIAL TRANSMISSION SYSTEM OVERVIEW

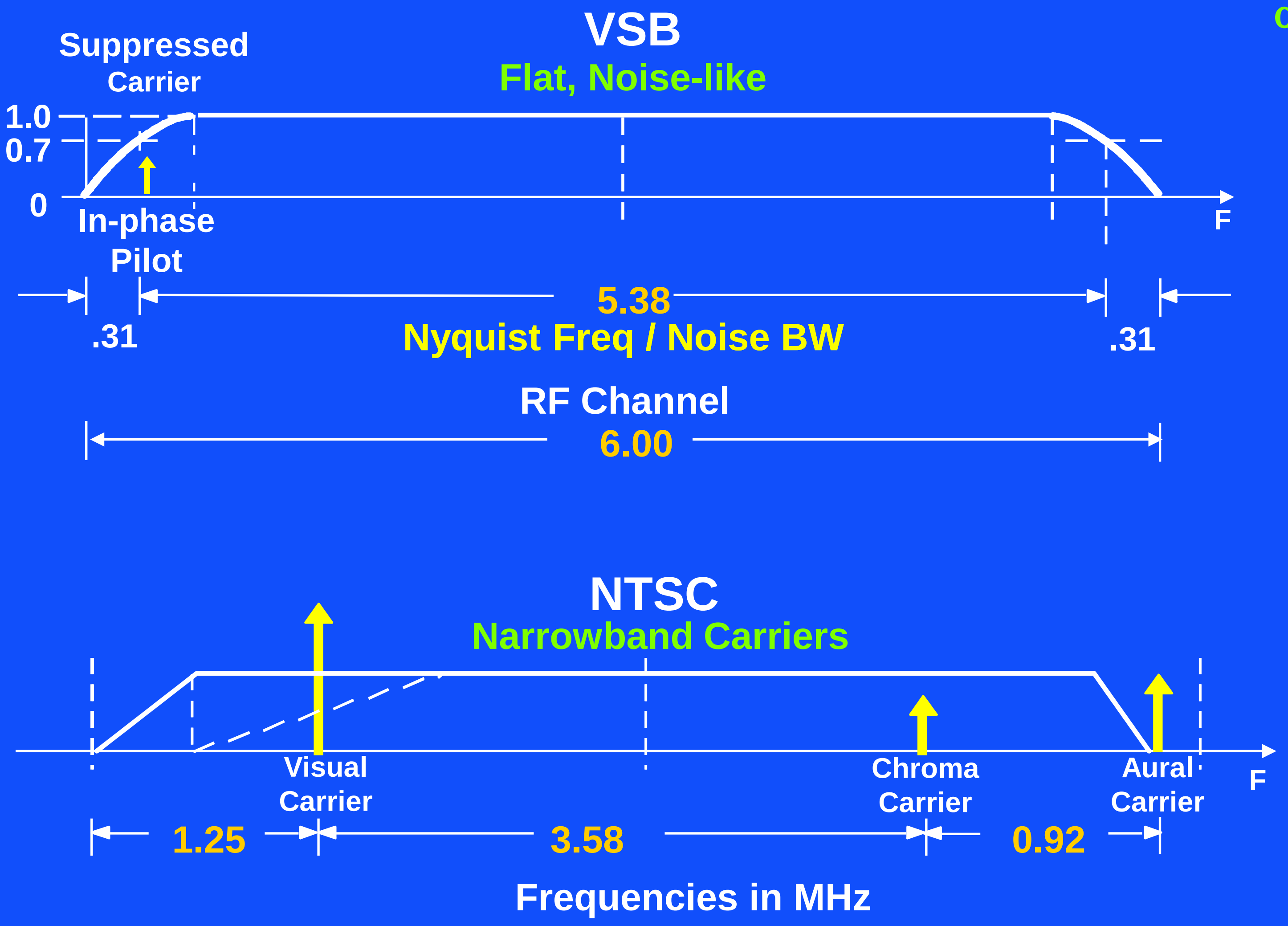
(with paranthetical comments …)

ATSC Legacy Transmission System Overview

VSB & NTSC Spectra Comparison

More Efficient *Low* Average Power

(7-12 dB lower)



More Efficient RF *Bandwidth*

(19.4 Mbps)

Less Efficient *High* Peak Power

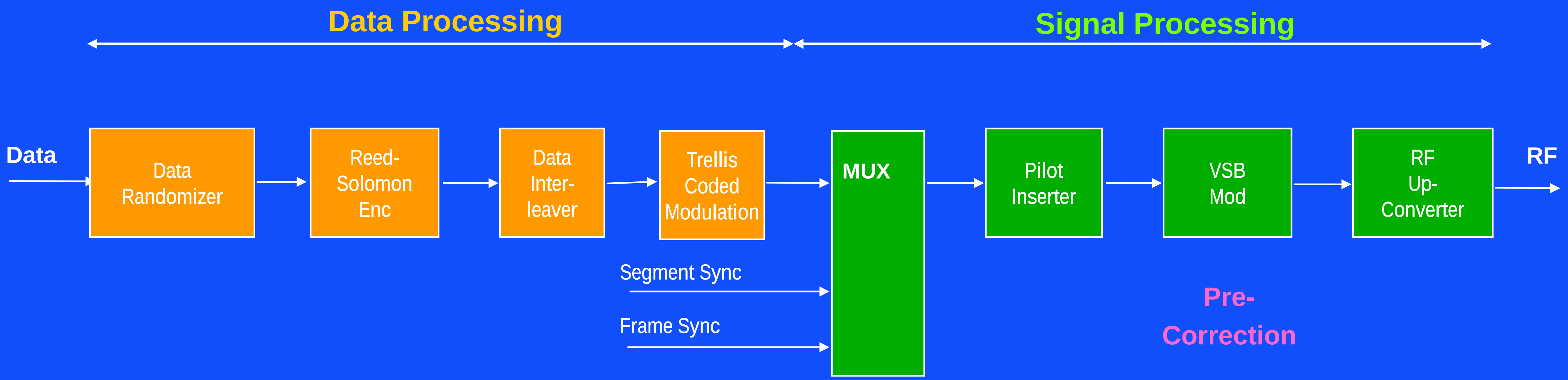
Less Efficient RF *Bandwidth*

Remember that NTSC & ATSC transmitted signals are *both* analog in nature

Adding M/H capability to legacy ATSC signal has *identical* RF spectral characteristics

ATSC Legacy Transmission System Overview

8-VSB *Transmitter* Block Diagram



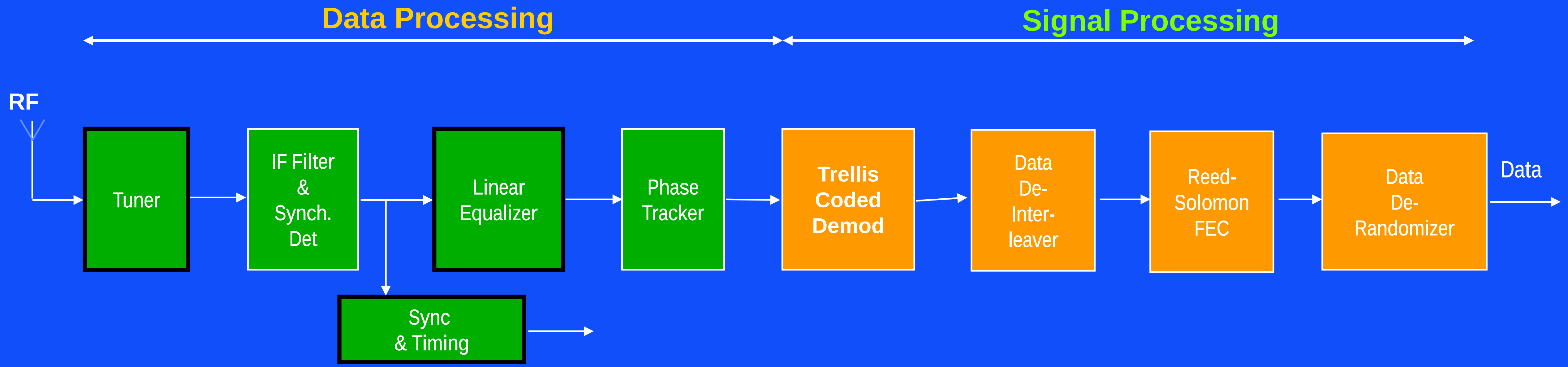
Randomization
& Error Coding
(Structured Sequences)

Critical Filtering
& Modulation
(Waveform Coding)

Signal processing blocks affect transmitted signal *quality*

ATSC Legacy Transmission System Overview

8-VSB *Receiver* Block Diagram



Critical Filtering
& De-Modulation
(Waveform Coding)

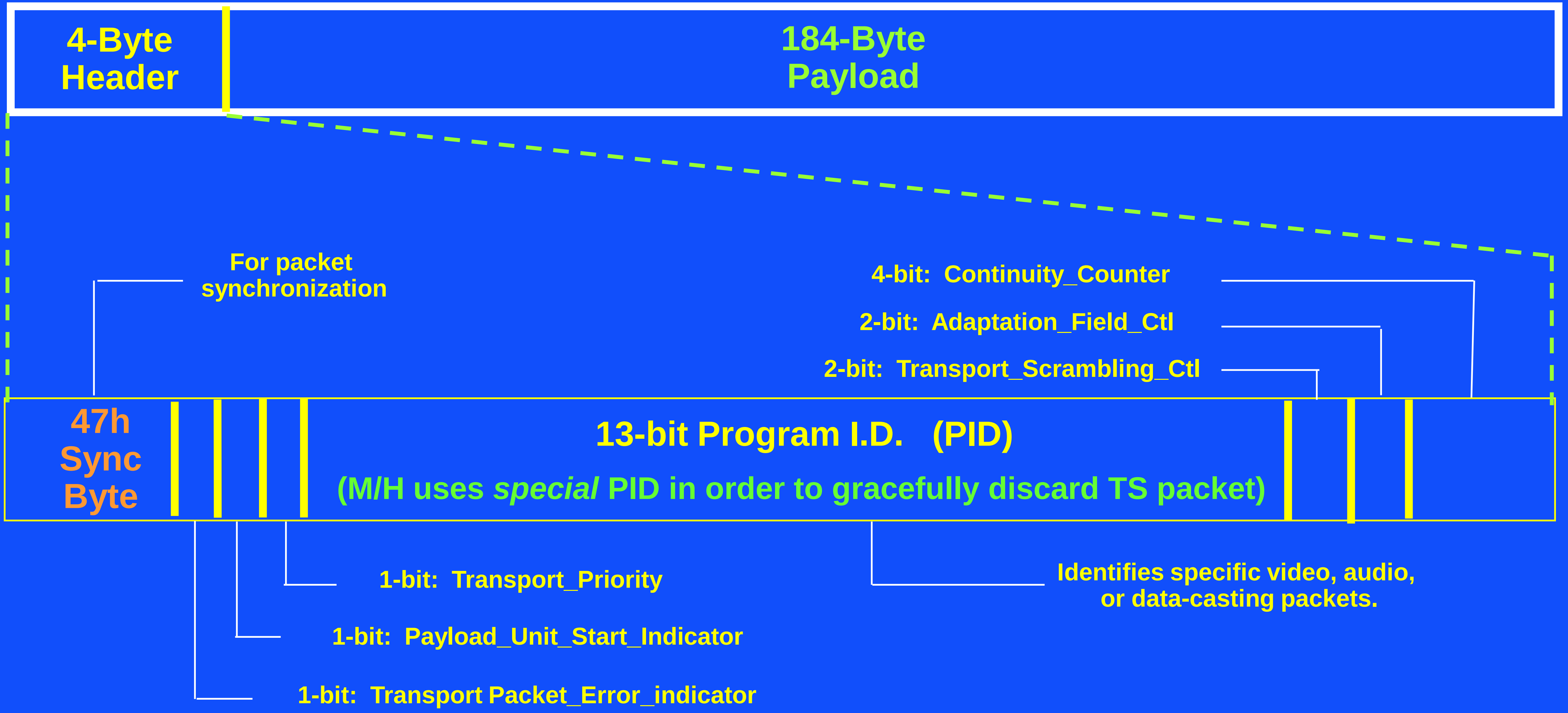
Error Correction
& De-Randomization
(Structured Sequences)

Signal processing blocks affect Rx performance improvements

See ATSC standard: A/53E

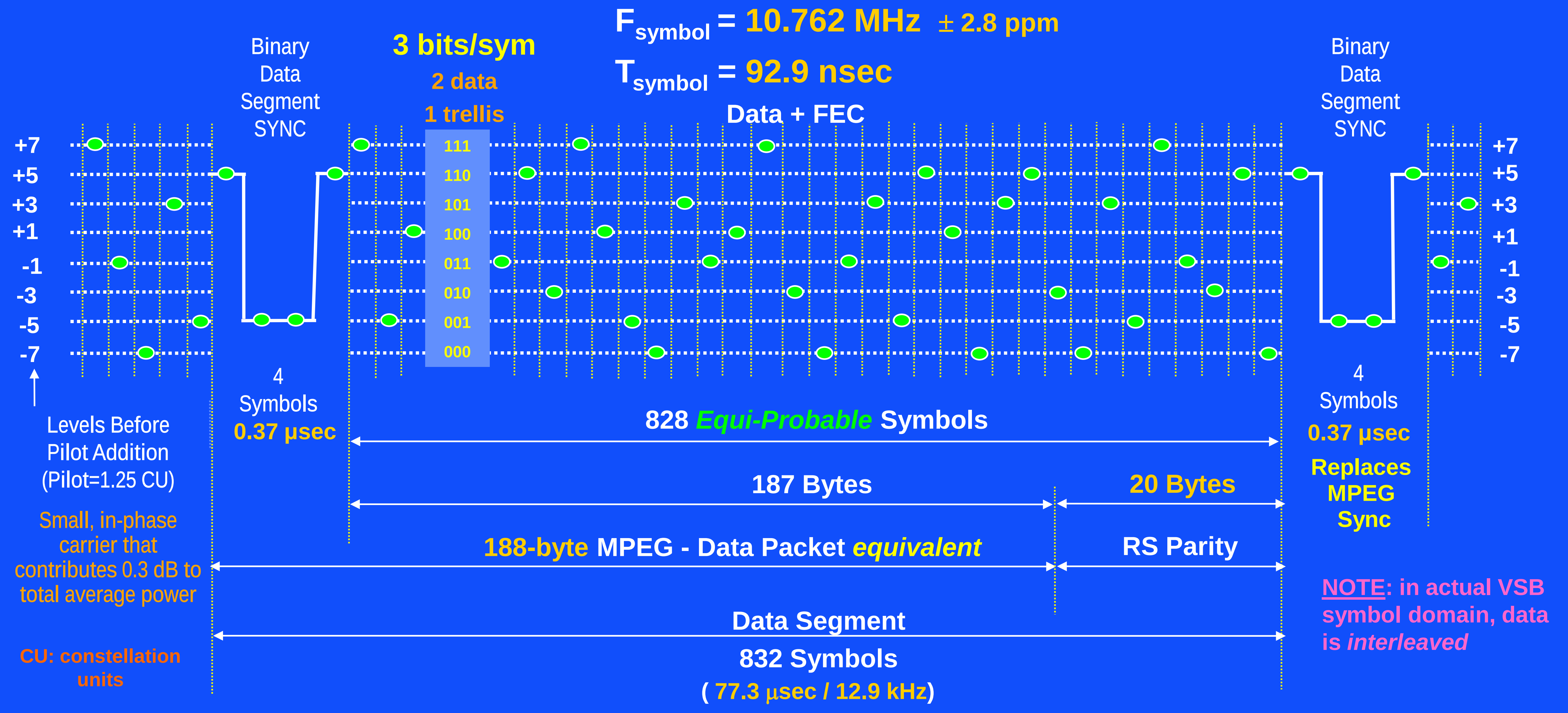
ATSC Legacy Transmission System Overview

MPEG Transport Packets: *Fixed* Length (188-byte)



ATSC Legacy Transmission System Overview

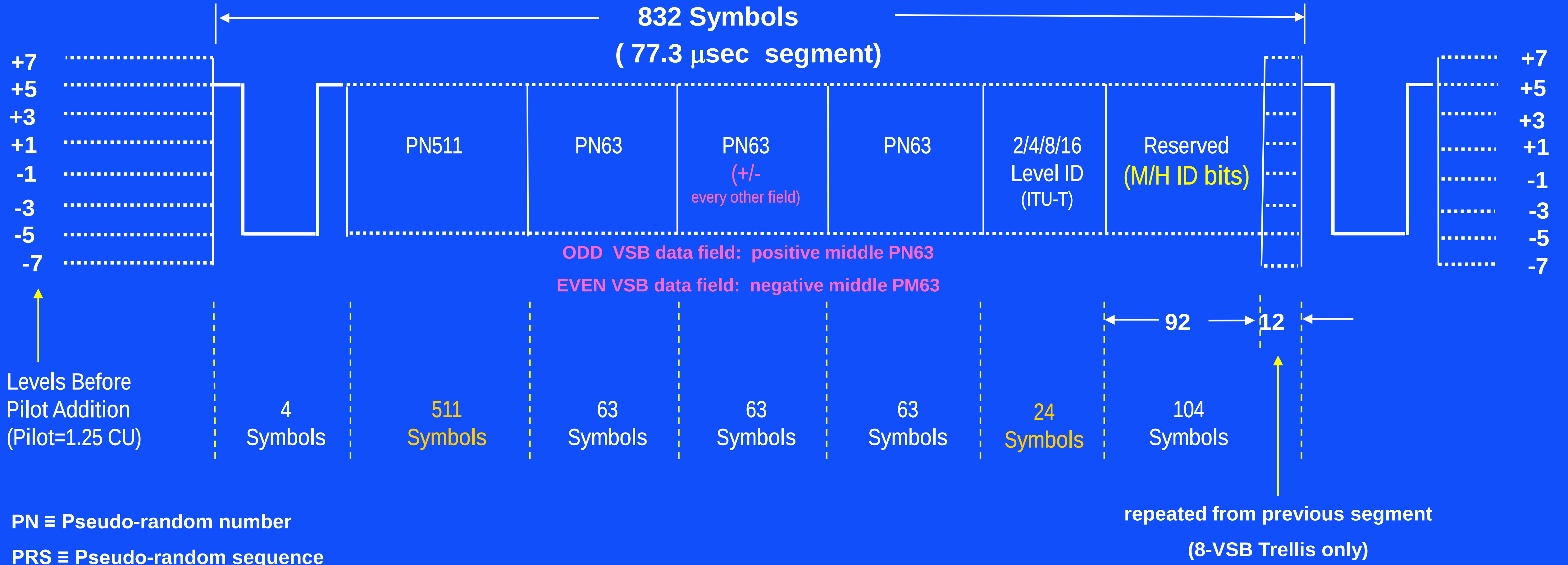
8-VSB *Baseband* Data Segment Format



Raw **data rate = 32.287 Mbps or 21.524 Mbps;** ***Net*** **data rate = 19.393 Mbps**

ATSC Legacy Transmission System Overview

8-VSB *Baseband* Data Frame Sync Format



PN ≡ Pseudo-random number

PRS ≡ Pseudo-random sequence

Repetition period / rate = 24.2 msec / 41.3 Hz

(every 313 segments)

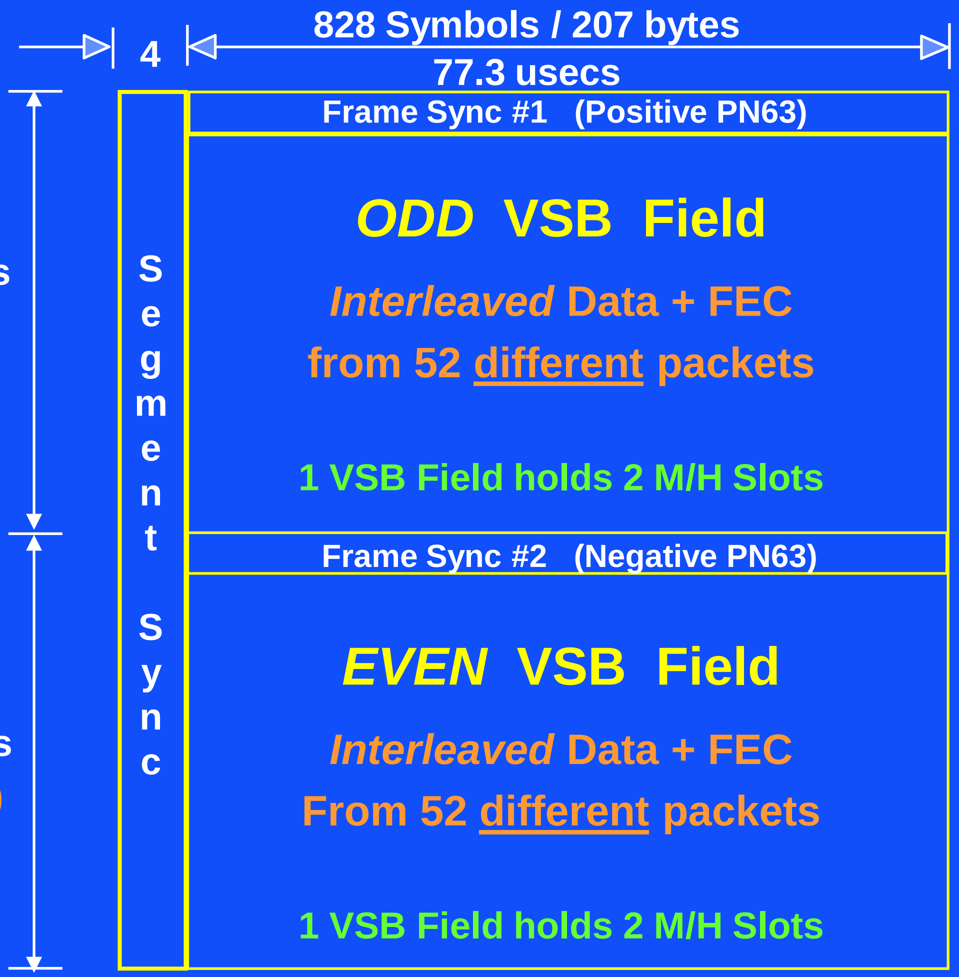
ATSC Legacy Transmission System Overview

8-VSB Data (Frame Timing Structure)

Each segment carries *equivalent* of 1 TS packet, but from 52 different packets

Interleaving causes segments to contain data from *multiple* TS packets

Each VSB frame has *identical* structure



Even & odd VSB data fields determined by middle PN63 within field sync

Binary Segment syncs added in lieu of 47h MPEG TP syncs

Binary Frame syncs added at start of each data field

VSB *symbol domain* *after* convolutional data byte interleaving

Overall Data Efficiency = (188/208) x (312/313) = 90%

(Adding M/H technology does *NOT* change VSB data frame structure)

ATSC Legacy Transmission System Overview

8-VSB System Characteristics

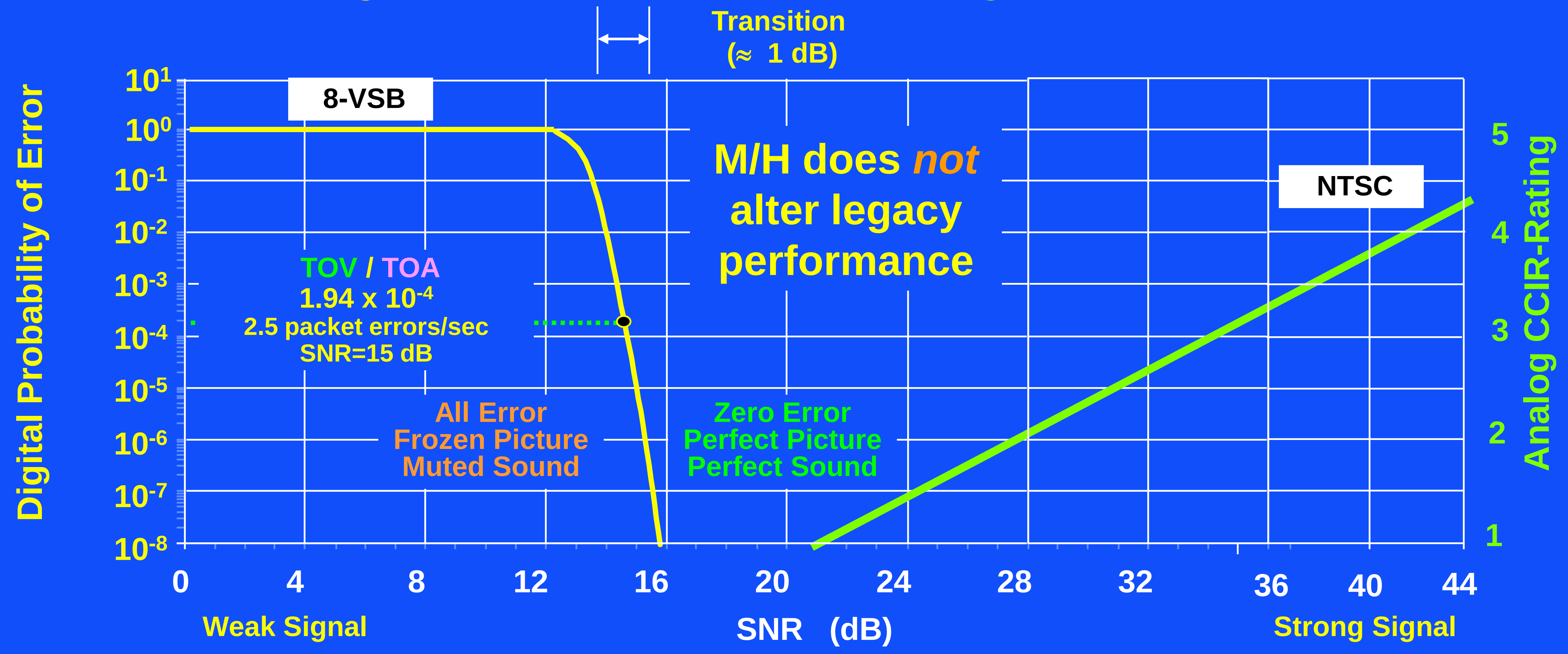
Parameters	8T-VSB	Units
Channel BW	6.0	MHz
Excess BW	11.5	%
Symbol Rate	10.762	MHz
Symbol Period	92.9	nsec
BW Efficiency	3	bits/symbol
Trellis-Coding Rate	2/3	-----
Net data rate	2	bits/symbol
Reed-Solomon FEC	t=10 (207, 187)	-----
Segment Length (including sync)	832	symbols
Segment Sync duration	4	symbols
Frame Sync duty cycle	1/313	-----
Payload Data rate	19.4	Mbps
Spectral Efficiency	≈ 4	bits/Hz
Power Increase from Pilot	0.3	dB
Peak/Ave Power Ratio	6.3	dB (@ 99.9%)
SNR @ Error Threshold	15.0	dB
Burst Noise Threshold	193	μsec

 M/H does NOT alter values for legacy signal; M/H receivers have different *payload* & *SNR* (thr)

ATSC Legacy Transmission System Overview

Probability of Error versus SNR

Digital "*Cliff Effect*" & Analog "*Gradual Effect*"

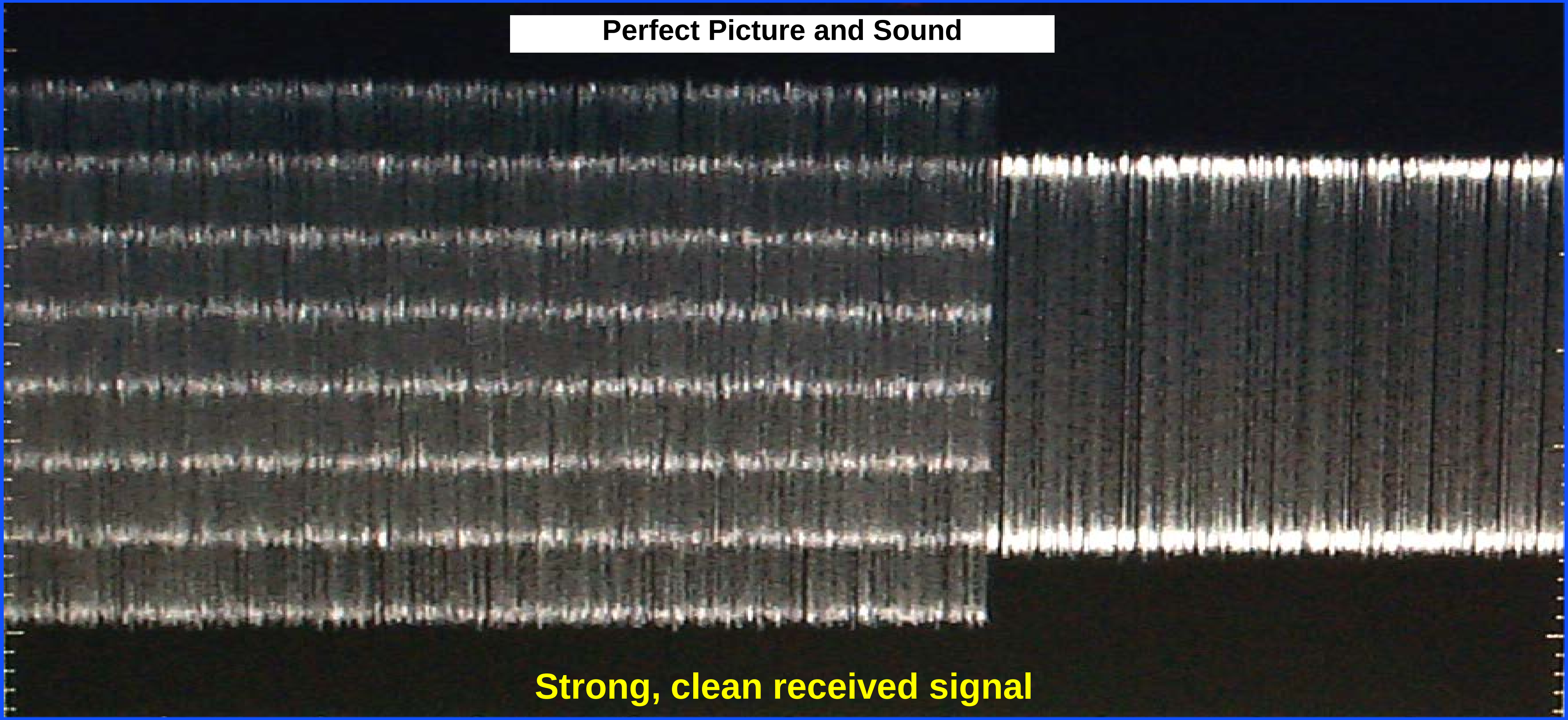


"Digital Cliff Effect: Don't *fear* it … just *respect* it !!!"

TOV = Threshold Of *Visible* errors; TOA = Threshold Of *Audible* errors

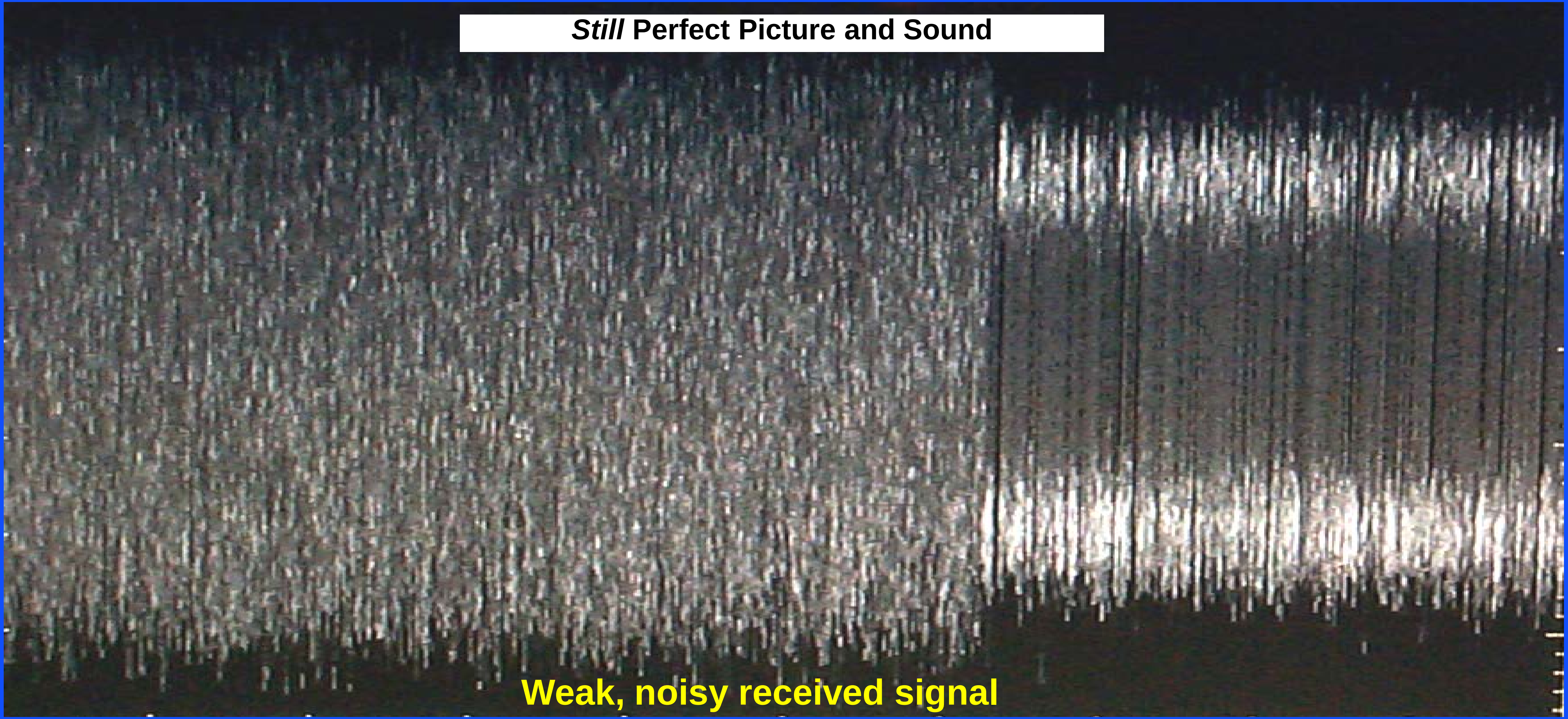
ATSC Legacy Transmission System Overview

8-VSB Symbol Output @ 35 dB SNR



ATSC Legacy Transmission System Overview

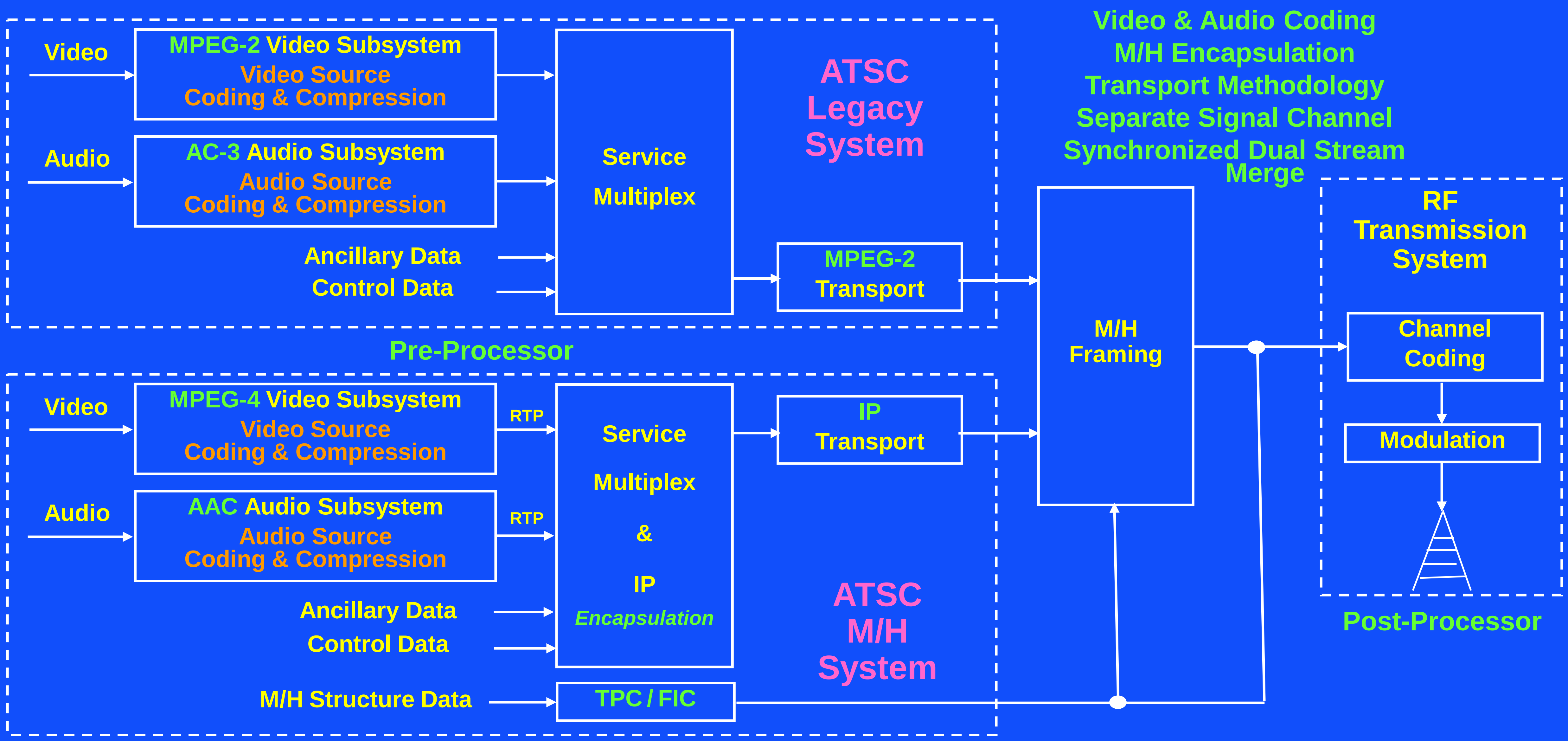
8-VSB Symbol Output @ 15⁺ dB SNR



ATSC M/H TRANSMISSION SYSTEM DETAILS

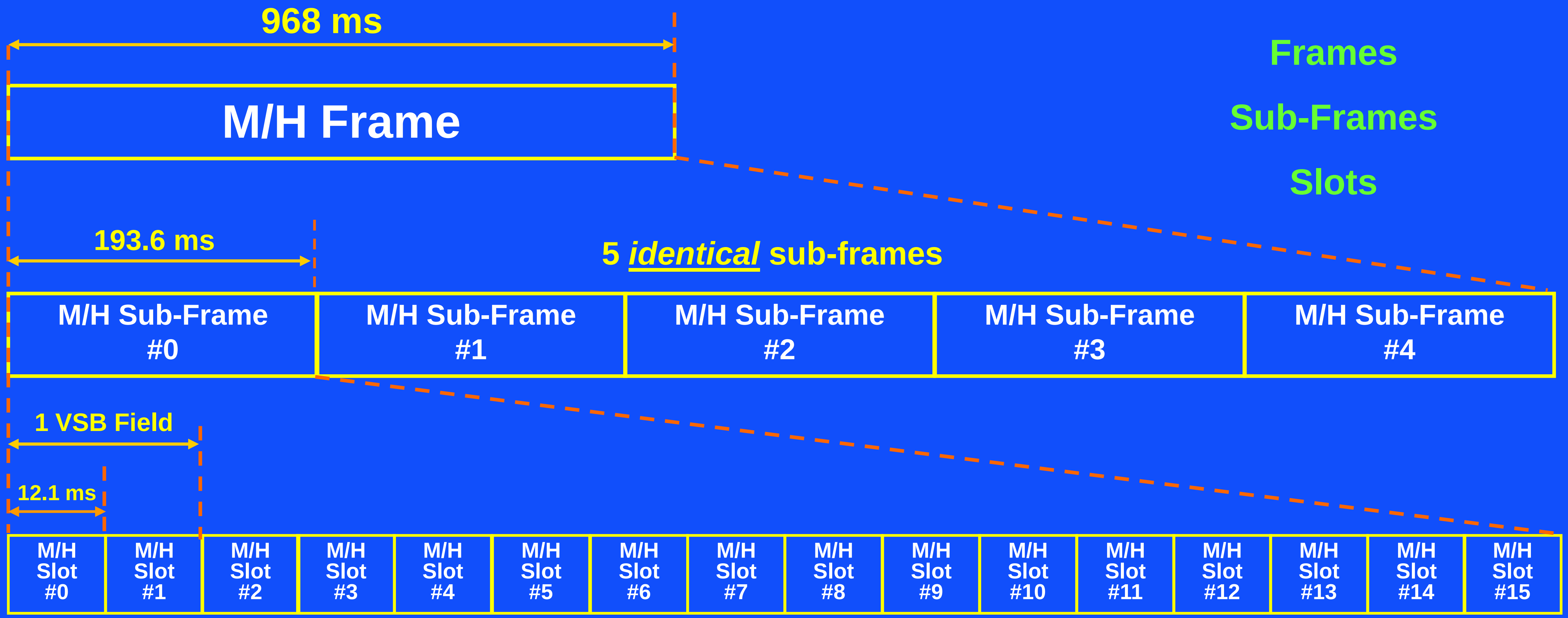
ATSC M/H System

Enhanced ATSC Broadcast *System* Block Diagram (Dual Channel)



ATSC M/H System

M/H Data (M/H Frame Timing Structure)



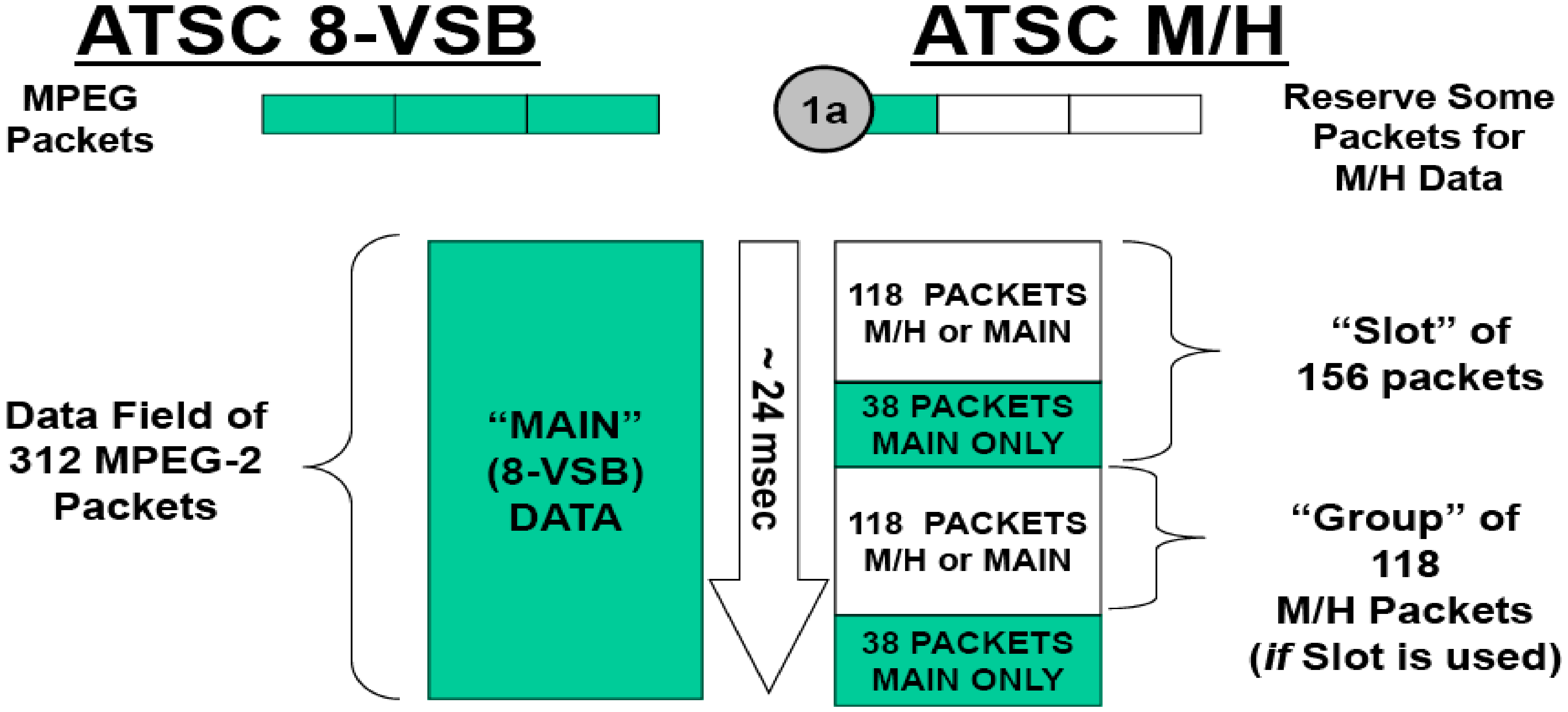
1 M/H Frame = 5 M/H Sub-Frames = 80 M/H Slots = 40 8-VSB Data Fields

Adding M/H technology does *NOT* change VSB data frame structure

Note: 2 Slots fit within one 8-VSB Data *Field* (312 data packets)

ATSC M/H System

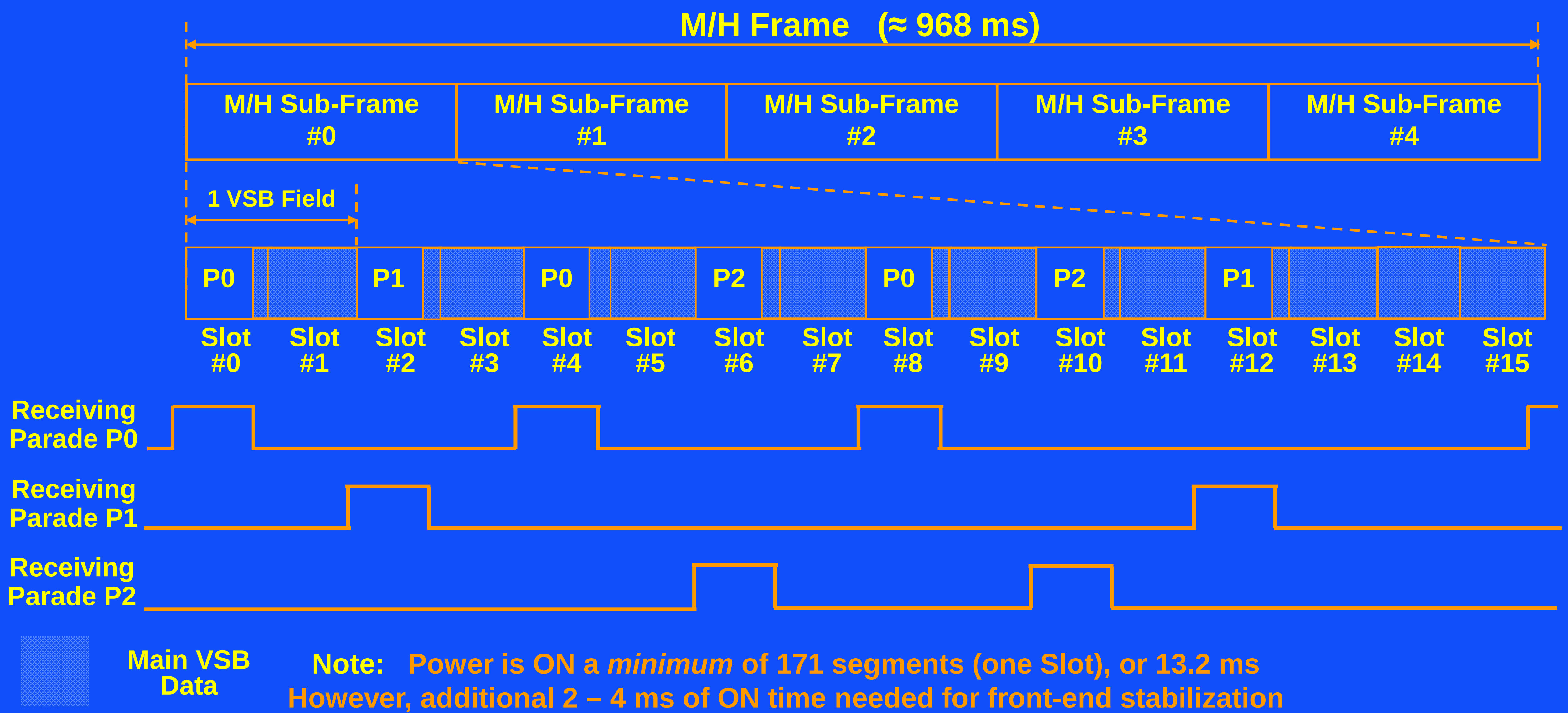
M/H Data (VSB Frame Timing Structure)



Each Slot has a section for Main packets & one for M/H packets
Each Slot may or may not contain M/H data
Each Slot carries 156 data packets (156 Main or 118 M/H + 38 Main)
2 M/H Slots transmitted per 8-VSB Data Field
M/H Frame *offset* from VSB field Sync by 37 packets

ATSC M/H System

M/H Data (Parade of Groups with Power Saving)



Note: Power is ON a *minimum* of 171 segments (one Slot), or 13.2 ms
However, additional 2 – 4 ms of ON time needed for front-end stabilization
Burst transmission allows *battery conservation*

ATSC M/H System

Quick M/H Data Calculation for *Maximum* M/H Data Usage

If *all* of the Slots were filled with M/H data packets,
Maximum amount of data *taken from* 8-VSB would be:

$$F_{M/H\ DATA}\ (max) = (118/156) * 19.392659\ Mbps$$

$$F_{M/H\ DATA}\ (max) = 14.66806\ Mbps$$

(M/H payload data + FEC + training signals)

If *all* of the Slots were filled with M/H data packets,
Maximum amount of data left *for* 8-VSB would be:

$$F_{VSB\ DATA}\ (max) = (38/156) * 19.392659\ Mbps$$

$$F_{VSB\ DATA}\ (max) = 4.723853\ Mbps$$

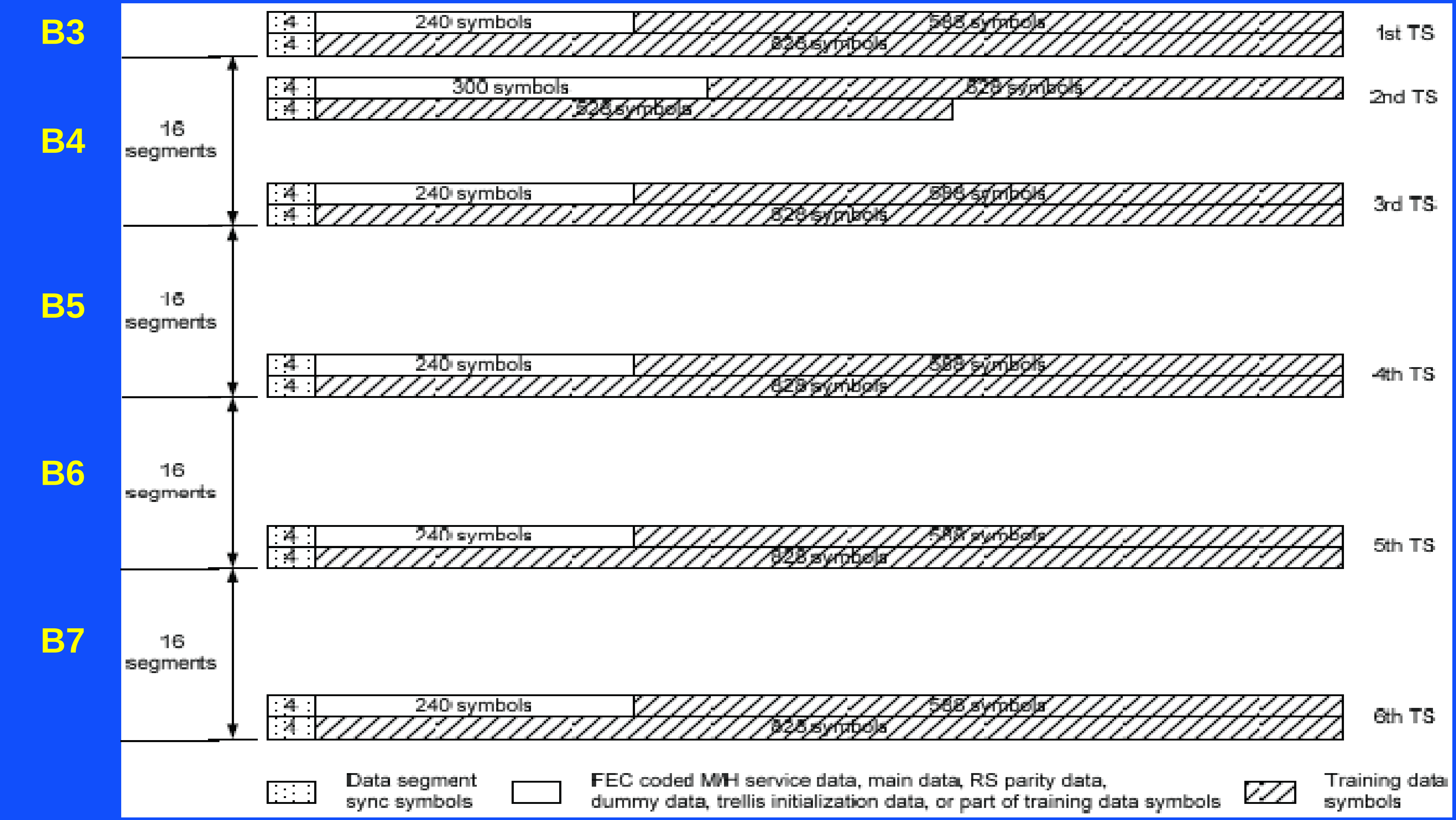
(VSB payload data)

NOTE: NoG can be max value of 8 for one Ensemble, but 2 Ensembles can have total NoG of 16
However, FCC *requires* broadcasters to transmit at least 1 free SD program

ATSC M/H System

M/H Data (6 Reference Training Signals)

Blocks



Long & regularly-spaced training signals in *each* M/H Group

6 known *8-level* training signals provide best *direct* channel estimation

1 short training signal further protects signaling data

Training signals help with M/H synchronization

Appear like normal 8-level data to legacy receivers

Training signals in *every* M/H Group within VSB symbol domain

ATSC M/H System

M/H Data (TPC & FIC Robust Signaling)

Training Signal TS1 at end of Block B3 immediately preceding signaling data

1st segment of M/H Block B4 → 207 bytes

2nd segment of M/H Block B4 → 69 bytes

Training Signal TS2 in Block B4 immediately following signaling data

TPC & FIC transmitted in *every* M/H Group & heavily coded for extra robust transmission

Transmission Control Parameters (TPC) uses 72 bytes:

10 *payload* bytes @ ¼-rate trellis coding = 40 bytes

8 RS parity bytes @ ¼-rate trellis coding = 32 bytes

Caries definition of specific transmission parameters for each Parade in an M/H Frame

&

Fast Information Channel (FIC) signaling data uses 204 bytes:

37 *payload* bytes @ ¼-rate trellis coding = 148

14 RS parity bytes @ ¼-rate trellis coding = 56 bytes

Carries cross-layer Ensemble & service binding info for fast M/H service acquisition

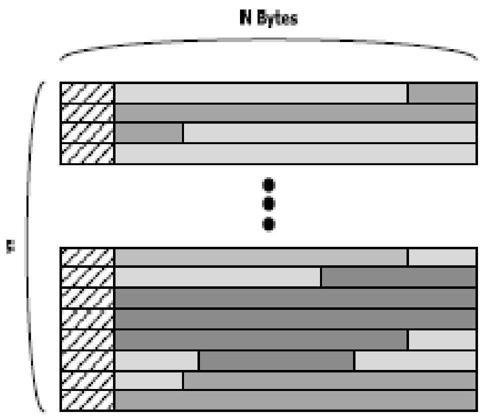
***Total* # of Signaling Bytes per Group: 72 + 204 = 276**

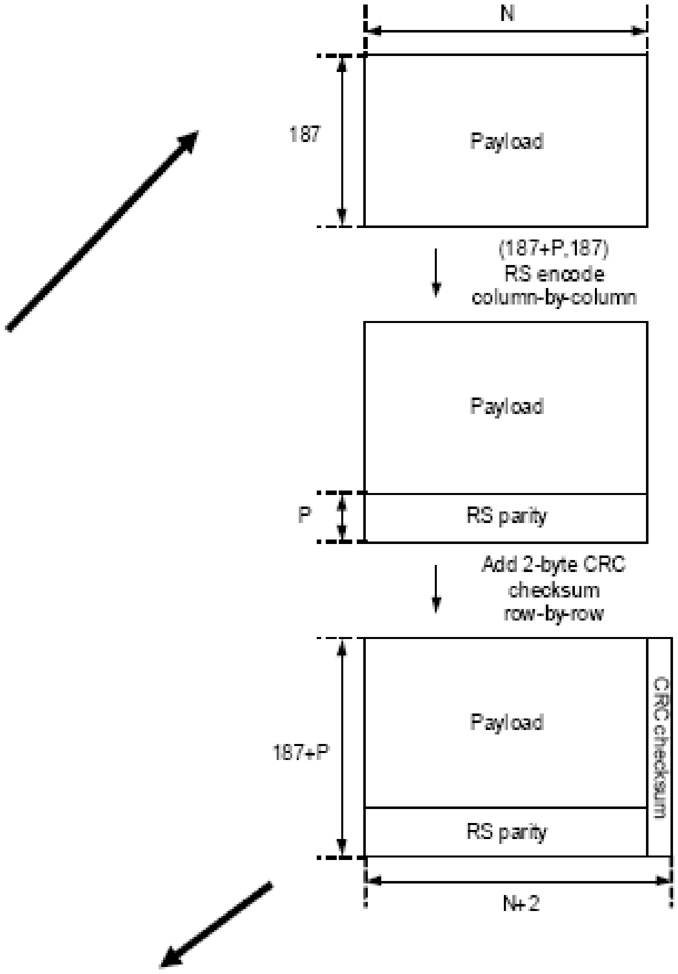
ATSC M/H System

M/H Data (Ensembles & RS Frame Data Packing)

"RS Frame" contains all data in one Parade (for 968 msec)

187 Rows of Bytes





Payload data
N Columns
by 187 rows

Add RS Bytes to Columns
P = 24, 36, or 48

Add Two CRC Bytes per Row

Pack left to right and top to bottom with M/H header and IP packets – wrap as necessary

(Then add legacy 8-VSB headers and RS bytes)

Ensemble is a collection of M/H services *encapsulated* into RS Frame

RS Frame is basic *time period* for very robust M/H data transmission

Each Ensemble is 2-dimensionally coded for robustness transmission

Each Ensemble can be coded for various levels of robustness

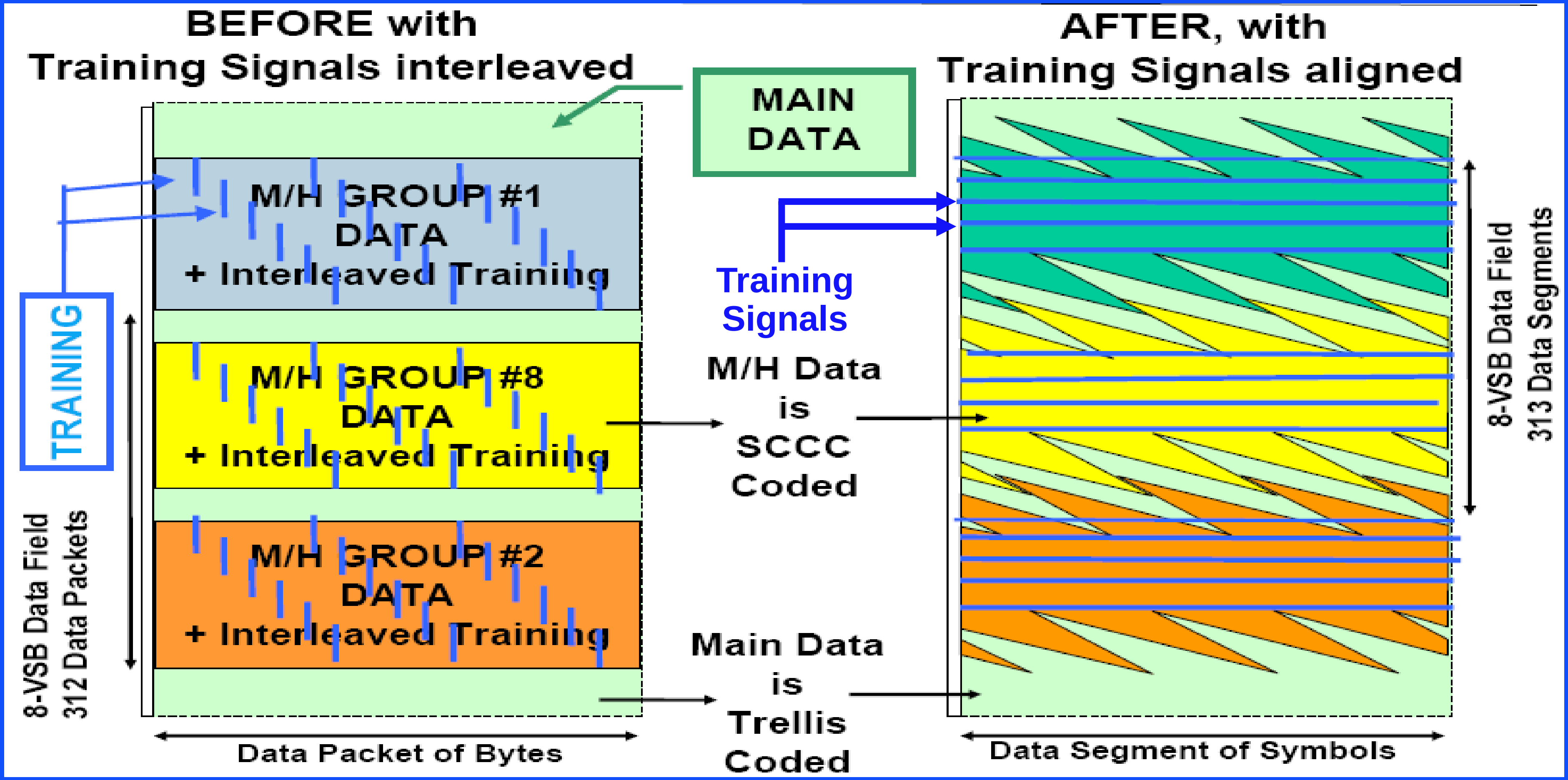
Each column coded with RS

Each row coded with CRC to mark errors for double error correction capability

Disperses data over 968 ms rather than just 4 msec for more *burst protection*

ATSC M/H System

M/H Data (Effects of Convolutional Byte Interleaving)



TP Packets Domain

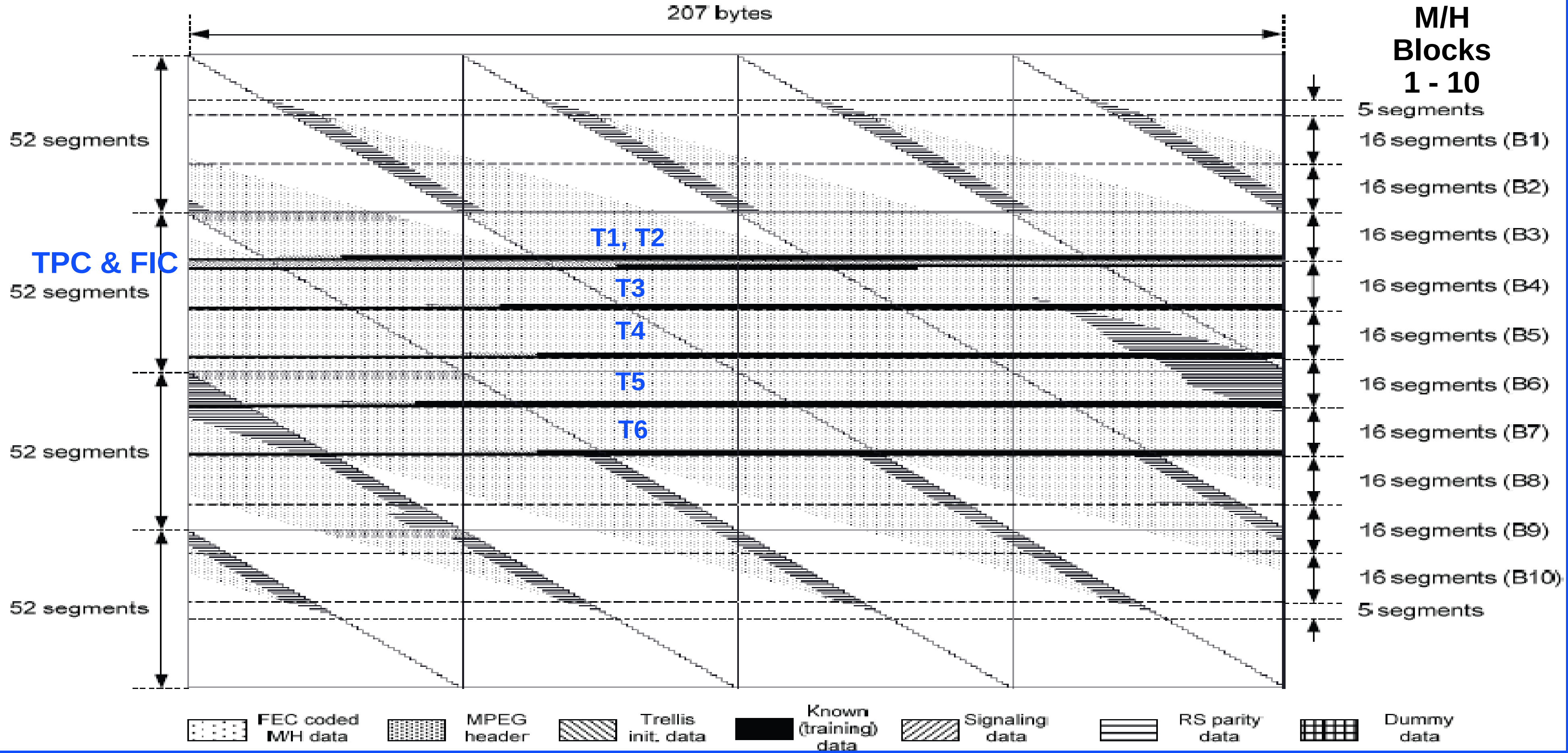
VSB Symbol Domain

M/H Groups can be dispersed over 170 data segments (118 + 52)

There are regions with: 1) only VSB data, 2) only M/H data, & 3) both

ATSC M/H System

M/H Data (*Separate* Blocks B1 – B10)



118 M/H packets
+
52 packet dispersion
=
170 VSB segments

which equals

10 * 16-segment *Blocks*
+
10 extra segments

(5 before & 5 after)

Note 6 TRAINING signals !!!

M/H Block = 16 contiguous post-interleaved segments (*only* in VSB symbol domain)

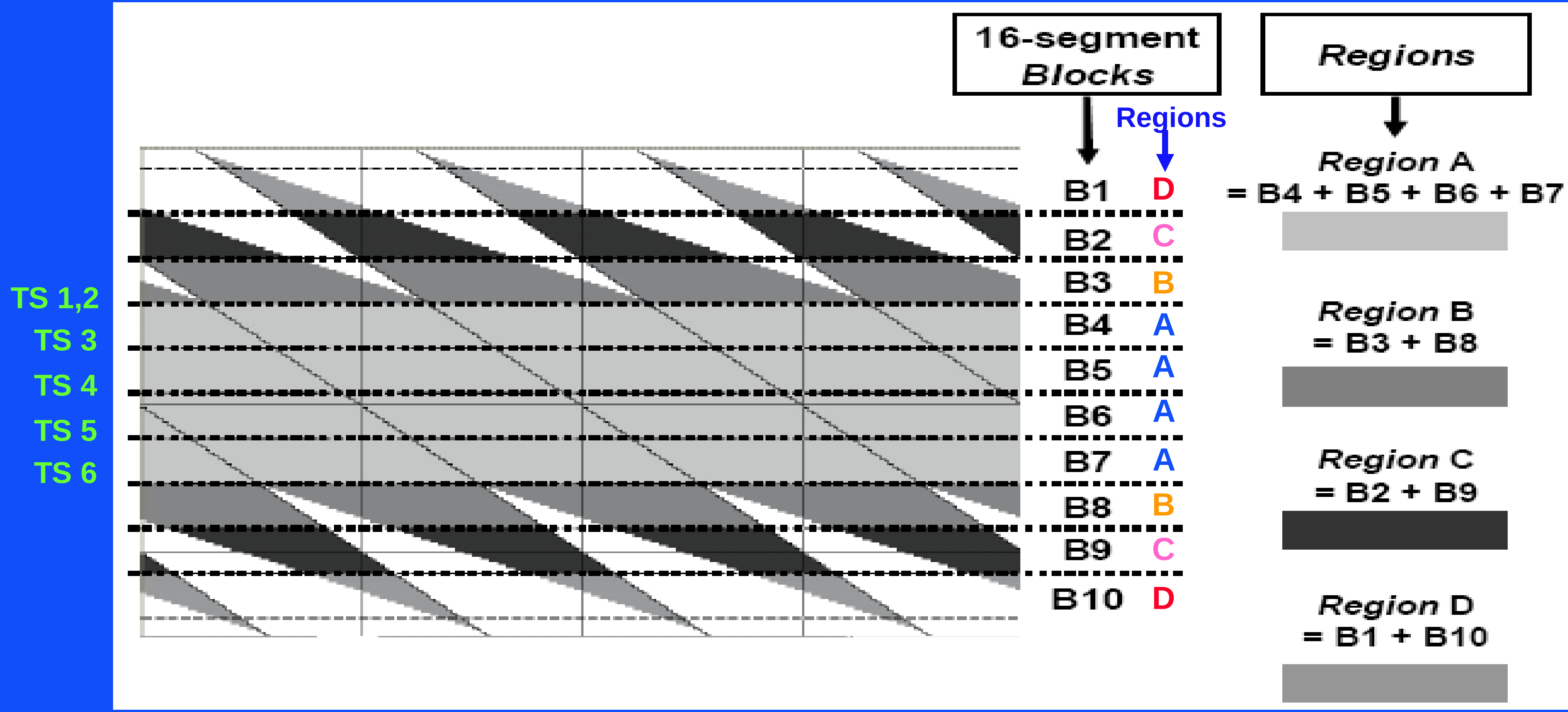
M/H Blocks either have *all* M/H data or *mixture* of M/H data & legacy VSB data

5 segments at beginning & end have legacy RS parity bytes; *not* part of M/H Blocks

VSB symbol domain (*after* convolutional data byte interleaving)

ATSC M/H System

M/H Data (Regions)



Regions = different data capacity; depends on presence of training signals, signaling data, or legacy data

Regions = different robustness; depends on relative position to training signals

ATSC M/H System

M/H Data Calculation (Legacy VSB Data Rate Loss)

- **Main Data Rate Loss (MDRL)**
  - **MDRL = [118/156] * [NoG/16] * [1/PRC] * 19.392658 Mbps** (simple algebraic formula)
    - [118/156] is # of M/H data packets to total packets in a Group
    - [NoG/16] is # of Groups used out of 16 Slots per Sub-Frame
    - PRC is Parade Repetition Cycle (Parade repeated every PRC Frames)
    - Constant value 19.392658 Mbps is VSB data bit rate (in kbps)
- **Comments**
  - MDRL describes loss of legacy 8-VSB data rate (max NoG=8)
  - No compensation for padding bytes required
  - Minimum data rate loss is when NoG = 1 & PRC = 7
  - Maximum data rate loss is when TNoG = 16 & PRC = 1

NOTE: NoG can be max value of 8 for one Ensemble, but 2 Ensembles can have *total* NoG of 16

ATSC M/H System

M/H Data Calculation (M/H Payload Data Rate)

- **Payload Data Rate (PDR)**
  - **PDR = {[N*187] / [5*16*156*188* PRC]} * 19.392658 Mbps** (simple algebraic formula)
    - N is # of data columns & 187 is # data rows in RS Frame
    - 5*16 is # of Slots in M/H Frame (5 Sub-Frames*16 Slots)
    - 156 is # of *possible* data packets in a Slot
    - 188 is # of payload data bytes per data packet
    - PRC is Parade Repetition Cycle (Parade repeated every PRC Frames)
    - Constant value 19.392658 Mbps is VSB payload bit rate (in kbps)
- **Comments**
  - PDR describes M/H data rate (for one Ensemble, max NoG=8)
  - Includes padding bytes & M/H Transport Header bytes
  - Minimum data rate is when NoG = 1 & PRC = 7
  - Maximum data rate loss is when TNoG = 16 & PRC = 1

 NOTE: NoG can be max value of 8 for 1 Ensemble, but 2 or more Ensembles can have *total* NoG of 16

ATSC M/H System

Possible M/H Data Modes: 102 Total

SCCC Outer Code:
½ or ¼

RS Frame Mode:
Single or Dual

SCCC Block Mode:
10 separate or 5 pairs

RS Parity:
P = 24, 36, or 48 bytes

Regions				RS Frame	SCCC Block	RS Parity	# of
(A)	(B)	(C)	(D)	Mode	Mode	Bytes	Modes
½	½	½	½	Single, Dual	Separate, Paired *	24, 36, 48	9
½	½	½	¼	Single, Dual	Separate	24, 36, 48	6
½	½	¼	½	Single, Dual	Separate	24, 36, 48	6
½	½	¼	¼	Single, Dual	Separate	24, 36, 48	6
½	¼	½	½	Single, Dual	Separate	24, 36, 48	6
½	¼	½	¼	Single, Dual	Separate	24, 36, 48	6
½	¼	¼	½	Single, Dual	Separate	24, 36, 48	6
½	¼	¼	¼	Single, Dual	Separate	24, 36, 48	6
¼	½	½	½	Single, Dual	Separate	24, 36, 48	6
¼	½	½	¼	Single, Dual	Separate	24, 36, 48	6
¼	½	¼	½	Single, Dual	Separate	24, 36, 48	6
¼	½	¼	¼	Single, Dual	Separate	24, 36, 48	6
¼	¼	½	½	Single, Dual	Separate	24, 36, 48	6
¼	¼	½	¼	Single, Dual	Separate	24, 36, 48	6
¼	¼	¼	½	Single, Dual	Separate	24, 36, 48	6
¼	¼	¼	¼	Single, Dual	Separate, Paired *	24, 36, 48	9

102 total possible data modes, but *not* all of them are useful

Early days of development, 2 most commonly used modes:

(¼, ¼, ¼, ¼) P48 Paired

(½, ¼, ¼, ½) P48 Separate

Reception can vary depending on:

Signal strength
Multipath

Note: * Paired SCCC Blocks only used with all-½-rate, all-¼-rate, & Single RS Frames

ATSC M/H System

Specific M/H Data Mode Considerations & Tradeoffs

Mode Opt (#)	Regions (A) (*)	(B) (*)	(C) (*)	(D) (*)	RS Frame Mode (Single/Dual)	SCCC Block Mode (Separate/Paired)	RS Parity Bytes (#)	Data Efficiency (%)	Payload Data Rate (kbps)
1	½	½	½	½	Single	Paired	48	34.1	312.2
2	½	½	¼	¼	Single	Separate	48	30.5	279.8
3	½	¼	¼	¼	Single	Separate	24	29.2	267.4
4	½	½	X	X	Dual	Separate	48	27.0	247.3
5	½	¼	¼	¼	Single	Separate	48	26.1	239.6
6	¼	¼	¼	¼	Single	Paired	24	18.9	173.1
7	¼	¼	¼	¼	Single	Paired	48	16.9	154.6
8	¼	¼	X	X	Dual	Separate	48	13.3	122.1

Note: NoG=1; MDRL = 917 kbps; Options 5 & 7 are most commonly tested & demonstrated

Remember that this payload data rate is for NoG = 1

Can increase by factor of 8

Opt 1 *highest* data rate, but *least* robust; Opt 8 *lowest* data rate, but *most* robust

Opt 2 has 16.8% *higher* data rate than Opt 5, but only slightly *less* coverage

Opt 3 has 11.6% *higher* data rate than Opt 5, but only moderately *less* coverage

Opt 6 has 12.0% *higher* data rate than Opt 7, but only slightly *less* coverage

Opt 4 has 3.2% *higher* data rate than Opt 5, but only slightly *more* coverage

Opt 8 has 21.0% *lower* data rate than Opt 7, but much *better* coverage, plus secondary RS Frame data available for less robust applications

ATSC Mobile System

M/H Data (General DTV Spectrum Allocation)

FCC requires 1 NTSC quality free-to-air service

M/H service can be free-to-air, subscription-based, or both

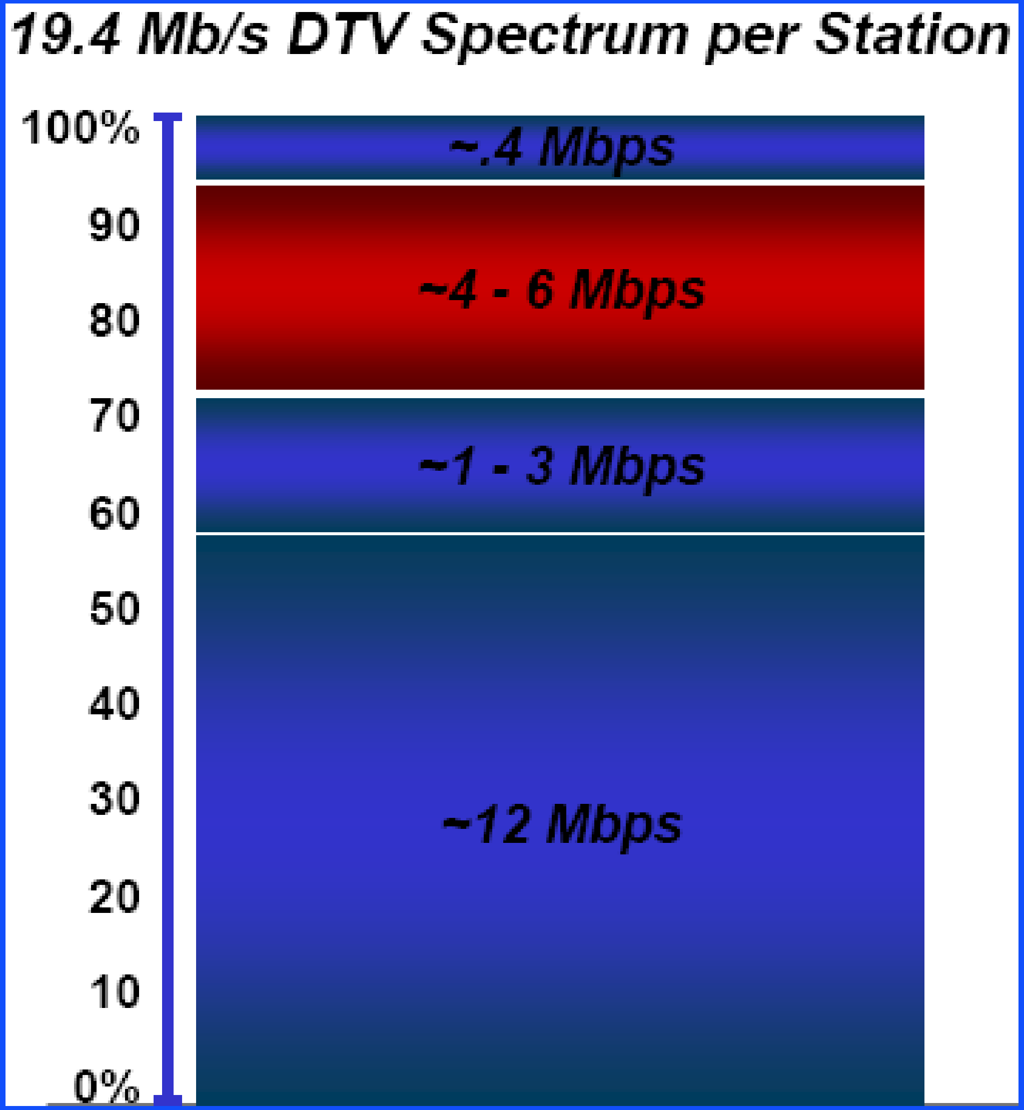
Auto backseat video or driver audio
Pedestrian handheld data

ATSC program guide (PSIP) ≈ 0.5 Mbps

Typical SD service in MPEG-2 ≈ 3-4 Mbps

Typical HD service in MPEG-2 ≈ 9 – 14 Mbps

M/H mobile CHs scalable in quantity & robustness, ≈ 2 Mbps per Ensemble



PSIP Services

2 – 3 Mobile Video Services

Additional SD Multicasts

HD Primary Network Feed

Example: Network or Network Affiliate DTV Station

ATSC Mobile System

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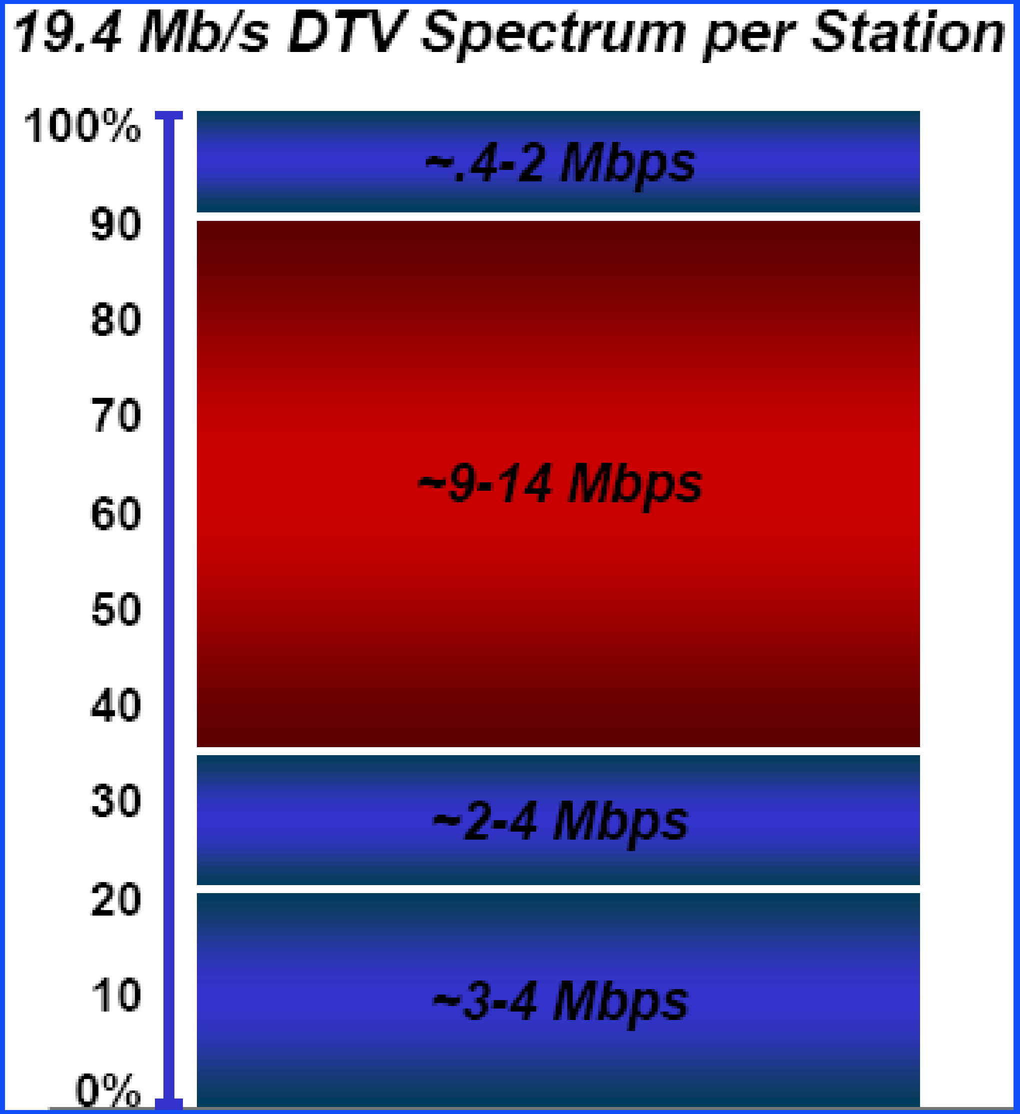


PSIP & Ancillary Data Service

4 – 8 Mobile Video Services

Additional SD Multicasts

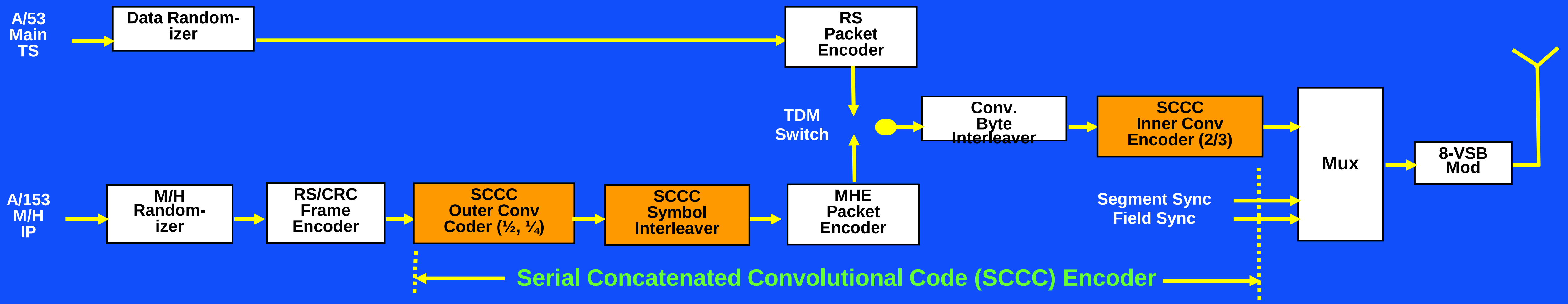
SD Primary feed

Example: Independent DTV Station

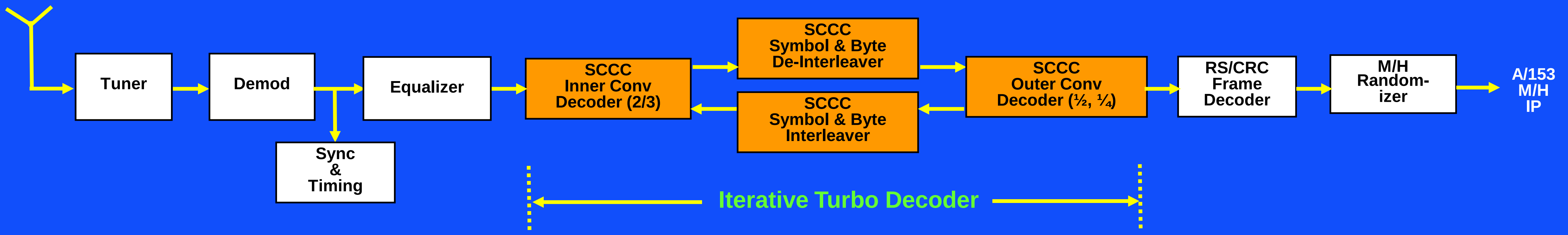
ATSC Transmission System *Enhancements*

Simplified M/H Transmitter & Receiver

M/H Transmitter



M/H Receiver



Note: A/153 M/H Standard only dictates transmitter output *signal* requirements; M/H receiver manufacturers are free to implement compatible receivers in their own manner.

ATSC Mobile System

M/H Data (RF Performance Lab Results)

	8-VSB (A/53)	M/H (A/153) ½-Rate (Regions A & B)	M/H (A/153) ½-Rate	M/H (A/153) Mixed Rate	M/H (A/153) ¼-Rate
Required SNR (dB)	15	7.4	7.9	7.3	3.4
Doppler Rate (Hz) ≈ = max mph with complex Echoes (TU-6)	≈ 10 (depends on Rx)	150	80 *	140	180

Additional FEC provides lower SNR error threshold

Additional training signals provide faster dynamic multipath tracking

* **Note: 60 Hz *sometimes* quoted as minimum adequate rate (DVB, others)**

M/H FIELD TESTING SUMMARY

ATSC Mobile System

Mobile Field Test Vehicle Example

MSW Mobile DTV Field Test Van with 5 kW generator

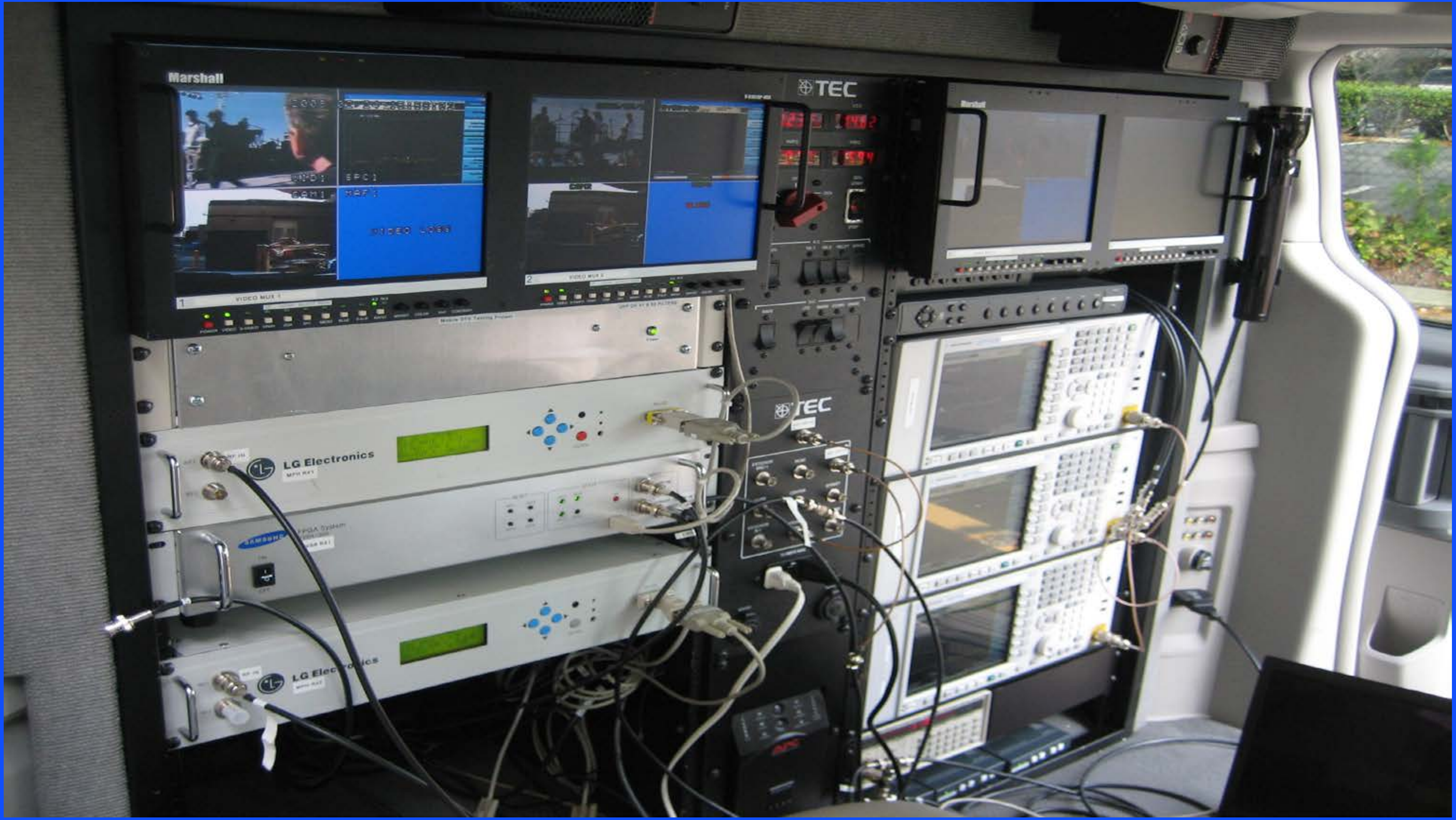
ATSC Mobile System

Mobile Field Test Vehicle Example

MSW Mobile DTV Field Test Van with easy access

ATSC Mobile System

Mobile Field Test Vehicle Example



MSW Mobile DTV Field Test Van with appropriate test equipment

ATSC Mobile System

OMVC Mobile Field Testing Data Set (2009 – 2010)

System Performance	Different Cities with Varying Terrain					
TYPE OF FIELD TEST	Atlanta	Seattle	San Francisco	Wash. DC 1, 2, 3	Dallas & Houston	TOTAL
Different Reception Conditions *(hrs)*	15	27	7	148		197
Pedestrian *(sites)*	351	321	101	910		1683
Various Coding Rates *(hrs)*	46	81	14			141
Multiple Ch. *(hrs)*	15	27		148		190
VHF Reception *(sites)*				12	19	31
UHF Reception *(sites)*				88	512	600
On-channel Repeater *(hrs)*				2160		2160
RF captures (#)				290	225	515
Production Devices *(sites)*				962		962

OMVC identified # of physical layer performance areas needing testing

Large sample size of field data from various U.S. cities for broadcaster confidence

ATSC Mobile System

Field Test Logistics Summary

- Non-optimum Tx conditions available during field tests, such as:
  - Tx Location
  - Tx ERP
  - Tx antenna HAGL
  - Tx polarization
- 1st & 2nd generation M/H receivers used during field tests
  - Still being optimized for sensitivity & multipath
  - Handheld antenna geometries and gains / losses still being improved
  - Data rate often optimized for small phone screen rather than larger tablet screen

ATSC Mobile System

Field Test Results Summary

- Signal strength is still *main* issue; multipath is a *secondary* issue
- Terrain effect on *mobile* reception
  - Most terrains, *outdoor* mobile antenna worked well within 30 miles
  - Very hilly terrains struggled with signal strength (repeaters would help)
- Pedestrian & indoor results
  - Phones with extendable antennas worked if S > -60 dBm (indoor or outdoor, moving or still)
- Code rates
  - ¼-rate (¼, ¼, ¼, ¼) code performed *slightly* better than mixed rate (½, ¼, ¼, ¼)
    - 3.5 - 4 dB better white noise threshold only translated to 3% - 5% more coverage
  - ½-rate (½, ½, ½, ½) code did *not* perform very well

ATSC Mobile System

Field Testing Results Summary (cont)

- **Multiple channel operation**
  - Performed well if Tx sites reasonably close as well as comparable ERP & HAGL
  - Pedestrian reception more challenging than mobile (need repeaters, better antennas, E-POL)
- **High-VHF operation**
  - Not enough data for statistical relevancy
  - Results were better for mobile than pedestrian (longer antennas & outdoors)

ATSC Mobile System

Field Testing Results Summary (cont)

- **On-channel repeater (OCR) operation**
  - **Improved both outdoor & especially indoor reception**
  - **DTS echoes were handled by mobile receivers** (*occasional* echo failures for > 70% amplitudes)
  - **Legacy 8-VSB receivers less robust to DTS echoes**
    - Sometimes had difficulty with > 40% DTS echoes
    - Performance varied significantly with make & model of DTV receiver
- **C-POL versus H-POL reception comparison**
  - **Mobile reception (λ/4 vertical whip) had significant improvement with C-POL** (≈10 dB)
  - **Outdoor pedestrian reception had slight improvement with C-POL** (≈4 dB)
  - **Indoor pedestrian reception had no improvement with C-POL** (≈0 dB due to de-polarization)

ATSC Mobile System

Field Testing Results Summary (cont)

- **RF Captures**
  - **Captures fed conductively into prototype Rx had thresholds between -78 & -84 dBm**
  - **Same signals fed into phone with internal antenna had 15 – 20 dB penalty**
  - **Most likely due to poor antenna efficiency & random orientation of antenna**
- **Prediction models**
  - **3 prediction modes: mobile, indoor pedestrian, outdoor pedestrian**
  - **Based on TIREM propagation model using empirical correction factors (from field testing)**
  - **Model uses following signal strength levels for predicting service at ¼-rate mode**
    - **82 dBμV/m for *indoor* pedestrian**
    - **72 dBμV/m for *outdoor* pedestrian**
    - **55 dBμV/m for *mobile*** **(fixed external antenna)**

BROADCASTER RECOMMENDATIONS

ATSC Mobile System

Recommendations for ATSC M/H Service Deployment

- **UHF service typically better than VHF service**
  - **Propagation better suited for building penetration**
  - **Spectrum noise level much lower at UHF, worse at VHF**
  - **Rx antenna performance degraded at VHF** (mobile better than handheld due to larger antenna)
  - **Low-VHF is *not* recommended**

- **Transmitter antenna located at *highest* elevation & *closest* to population**
  - **M/H highly dependent on “line-of-sight” to horizon**
  - **Change location or build new tower** (even community tower)
  - **Change from side-mounted to top-mounted antenna** (less pattern scalloping)
  - **Increase beam tilt** (more signal at close-in indoor sites without increasing interference)
  - **M/H service based on different planning factors than terrestrial DTV service**
    - **Rx antenna height: 4’ to 6’ AGL versus 30’ AGL**
    - **Rx antenna gain: -15 dBd to -3 dBd versus +10 dBd**

Remember current FCC freeze on minor TX changes

ATSC Mobile System

Recommendations for ATSC M/H Service Deployment

- **Use maximum authorized ERP with lower antenna gain & higher Tx power**
  - **Minimize close-in nulls & shadowed areas** **(minimize signal fading)**
  - **Goal is coverage saturation, *not* distance** **(maximum field strength important)**

- **Radiate highest quality signal**
  - **High SNR/MER** **(>30 dB, but overkill *not* needed)**
  - **Low-phase noise pilot carrier** **(ATSC recommendation or better)**
  - **FCC-compliant adjacent channel emissions** **(FCC mask)**
  - **In-spec symbol clock frequency & jitter** **(ATSC recommendation)**
  - **Do NOT throw away *any* packets** **(ATSC recommendation; e.g., ASI-to-SMPTE 310M converters)**

ATSC Mobile System

Recommendations for ATSC M/H Service Deployment

- **Include *both* horizontal & vertical polarization at Tx**
  - **M/H reception is *highly* dependent on vertically-polarized Rx antennas**
  - **Will provide more coverage with *both* H-POL & V-POL**
  - **Reduce time-varying signal *fades*** (also helps *terrestrial* reception)
  - **Simplify Rx antenna sensitivity for successful reception** (location & orientation)
- **Combine elliptically/circularly-polarized Tx antennas rather than use separate H & V antennas**
  - **Signal de-polarization can be expected, especially for handheld reception inside buildings**
  - **Separate Tx antennas may lose quadrature time phase relationship**

ATSC Mobile System

Recommendations for ATSC M/H Service Deployment

- **Consider use of DTx (distributed transmission) network**
  - **Single-frequency networks (SFN) or On-Channel Repeaters (OCR)**
  - **Multiple repeater sites in single frequency network can provide coverage in shadowed areas (terrain or man-made)**
  - **Provide larger coverage area for mobile viewer without resorting to channel changes to continue reception**
  - **Provide better coverage inside buildings**
  - **However, care must be taken to not degrade local *legacy* receiver reception**
- **Plan for system redundancy from beginning of M/H service**
  - **M/H is truly a wireless service**
  - **No CATV or satellite service will be carrying broadcaster's signals**

CLOSING THOUGHTS

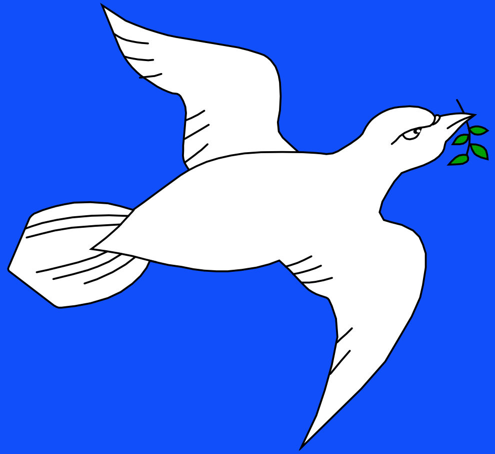
ATSC Mobile DTV

Summary

- **TV stations on-air**
  - Many stations on the air across country with M/H signal
  - $120k – $150k station equipment investment to transmit M/H
- **Broadcasters' one-to-many transmission model is key aspect**
  - Most efficient & reliable use of spectrum / bandwidth (no system traffic overloads)
  - No use of data plans
  - Reliable in crises (e.g., hurricanes, tornadoes, earthquakes, terrorism)
- **Two mobile broadcast groups exist, with *possible* future merger**
  - Mobile Content Venture (MCV) with "Dyle" branding
  - Mobile 500 Alliance with "MyDTV" branding
- **Consumer Devices**
  - Tablet (RCA), tablet/phone dongles (Elgato, Escort, Belkin), cellular phone (Samsung Galaxy)

Must overcome "chicken & egg" problem between broadcasters & consumer manufacturers

THANK YOU



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