DTV ATSC 8-VSB Standard Review

April 20, 2001

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Sarnoff Corporation

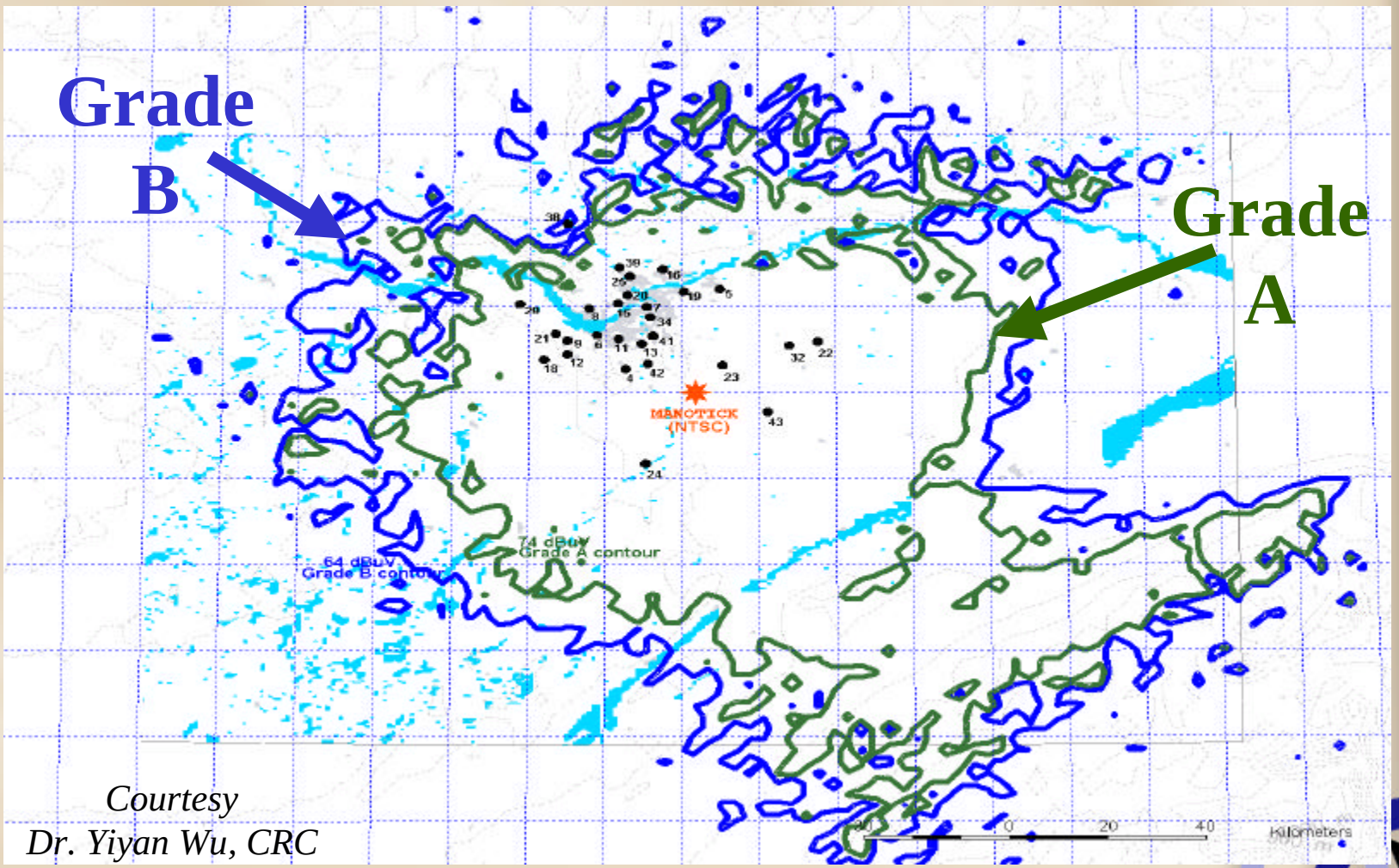
Outline

- Original Requirements
- What the RF channel can support
- ATSC Channel Coding
- 8-VSB Scorecard
- New Requirements
- The future

Original Requirements

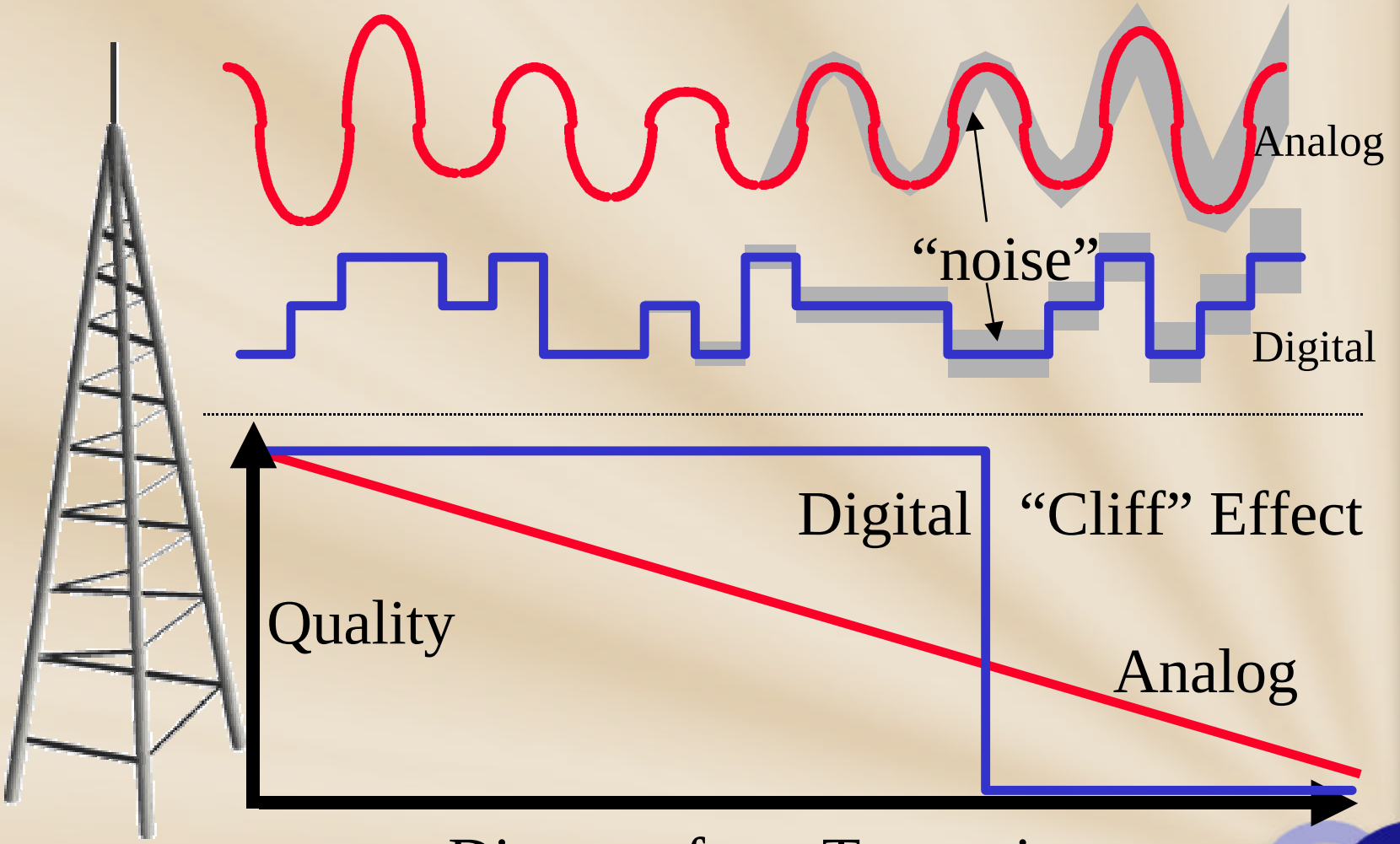
- Must replicate NTSC Grade B service area
- Must support HDTV programming
- Must work in the presence of
  - thermal (white) and impulse noise
  - co-channel and adjacent channel interference
- Reception must be highly reliable for fixed receivers using suitable antennas

Service Areas

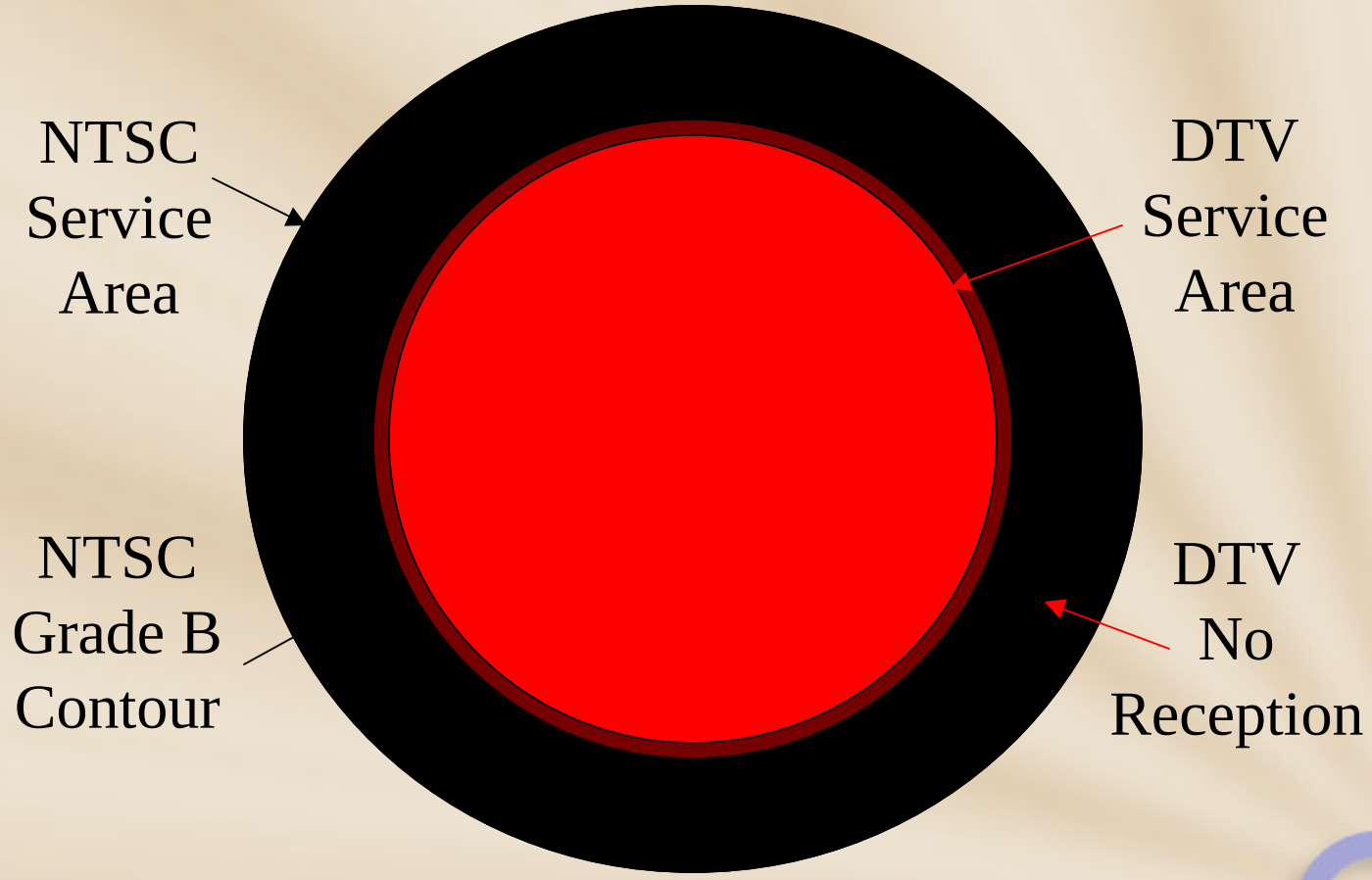


Courtesy
Dr. Yiyan Wu, CRC

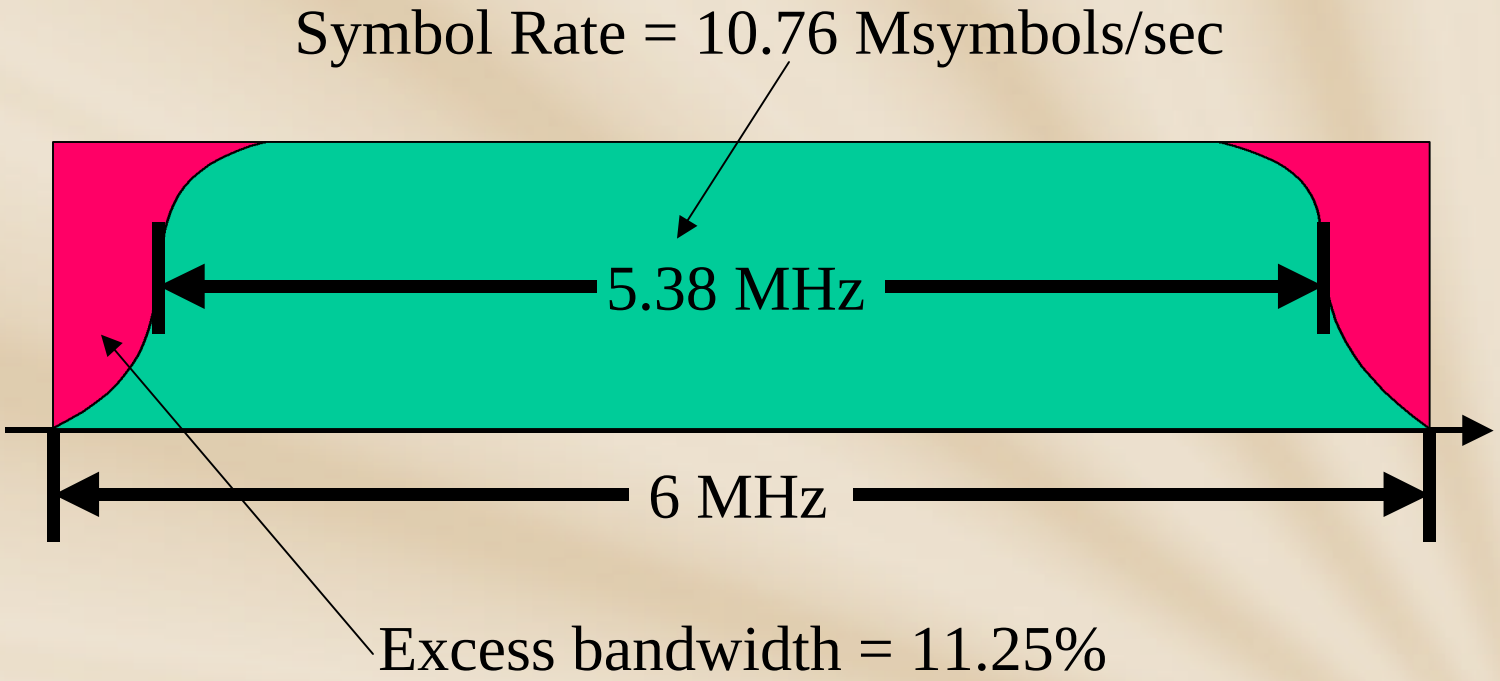
The Cliff Effect



Service Quality

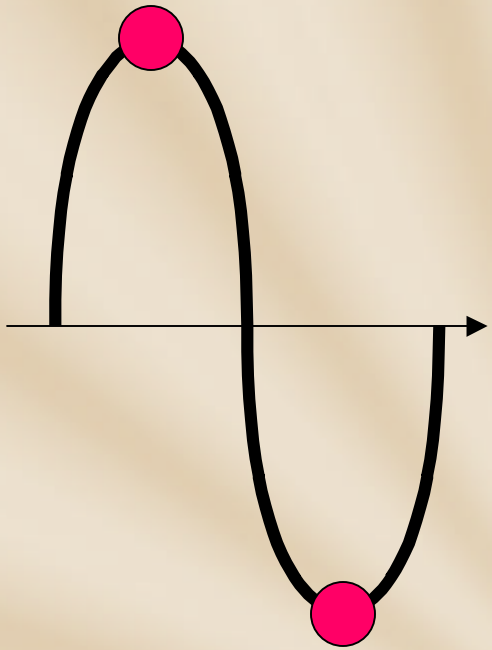


The RF Channel



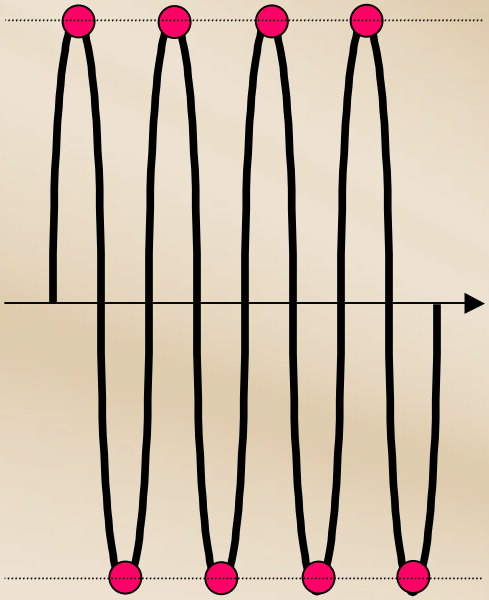
What's A Symbol?

- An independent amplitude event that can carry information
- VSB modulation has a *bandwidth efficiency* of 2 symbols/cycle.



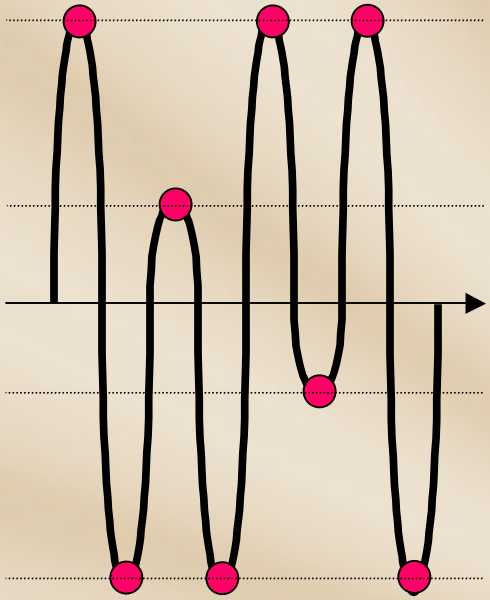
Symbols and Bits

1 bit/symbol



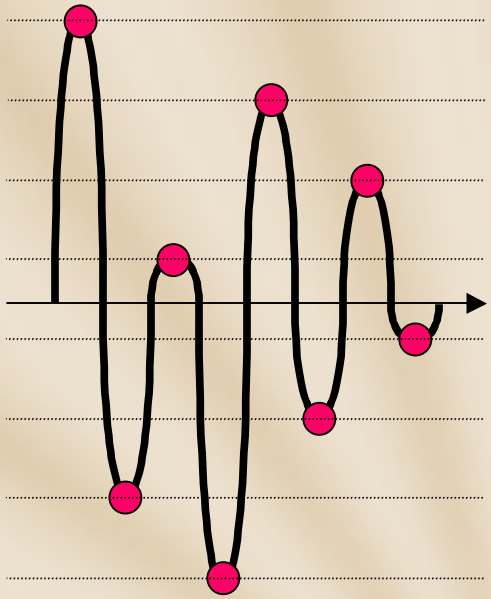
10.76 Mb/s

2 bits/symbol



21.52 Mb/s

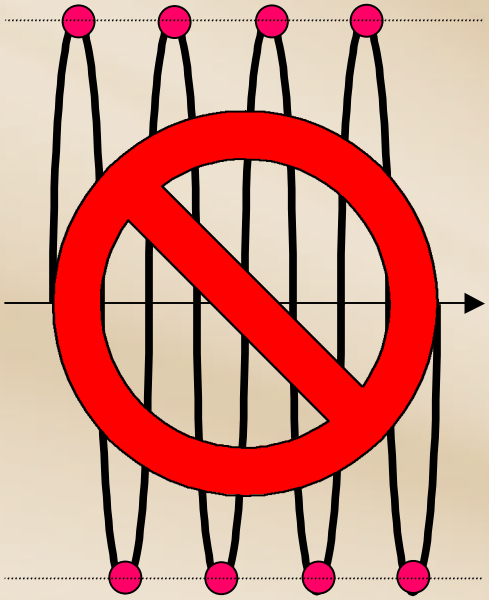
3 bits/symbol



32.28 Mb/s

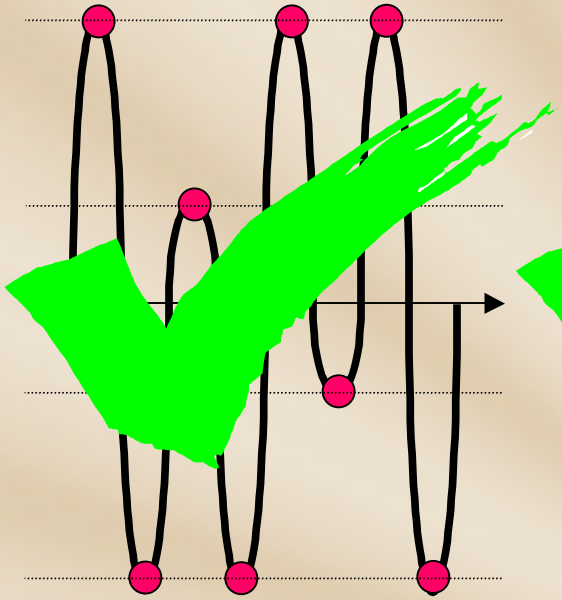
Bit Rate and HDTV

1 bit/symbol



10.76 Mb/s

2 bits/symbol



21.52 Mb/s

3 bits/symbol

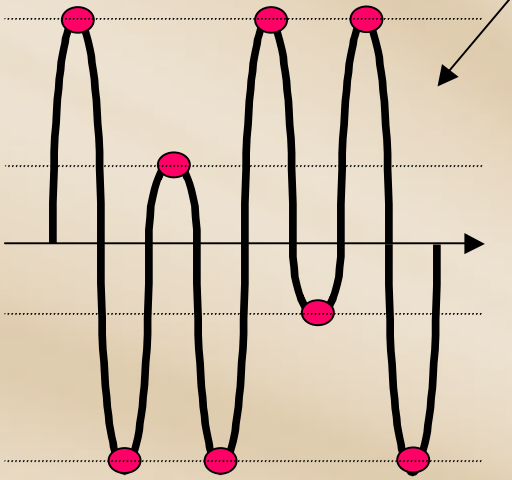
32.28 Mb/s

C/N Threshold

4-VSB

2 bits/symbol

Without Trellis Coding



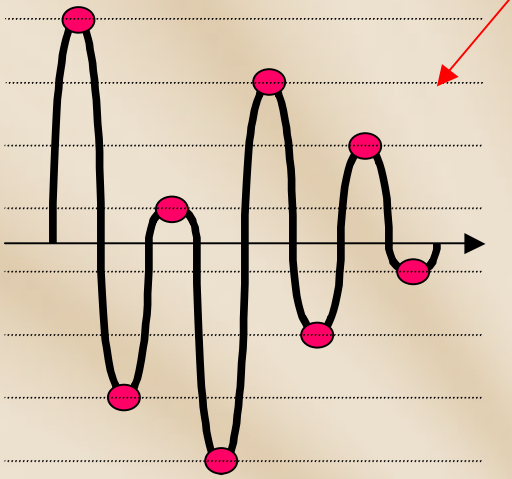
21.52 Mb/s

C/N = 16.1 dB

8T-VSB

3 bits/symbol

With Trellis Coding

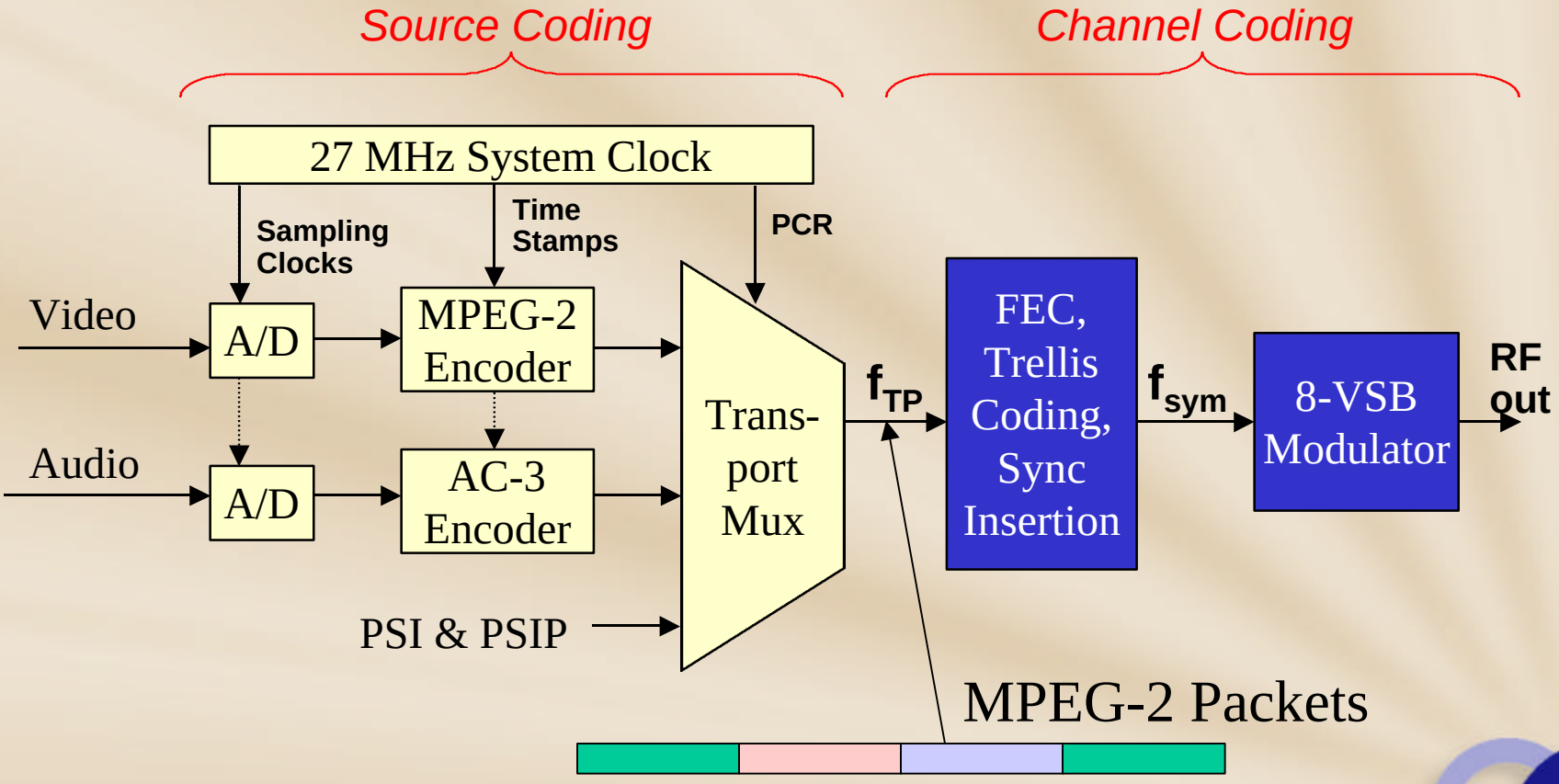


32.28 Mb/s

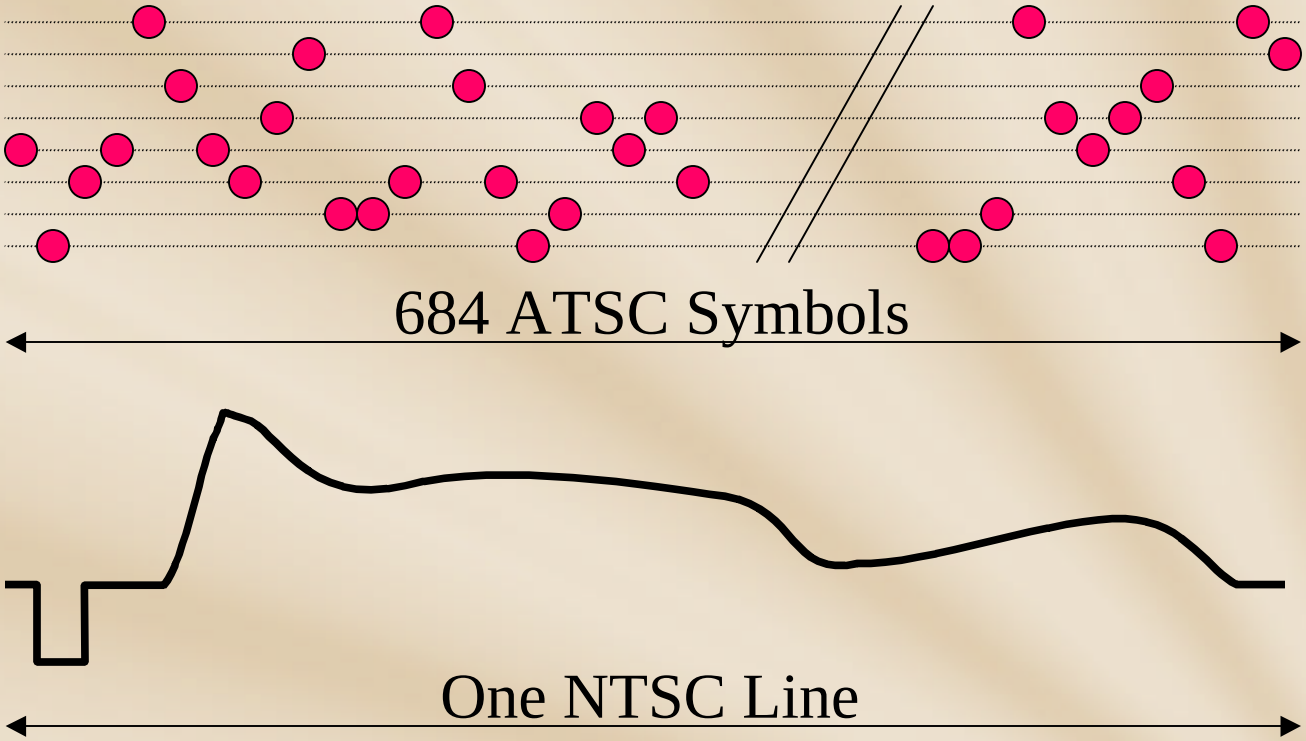
C/N = 15 dB

Trellis coding extends reception threshold

Source and Channel Coding



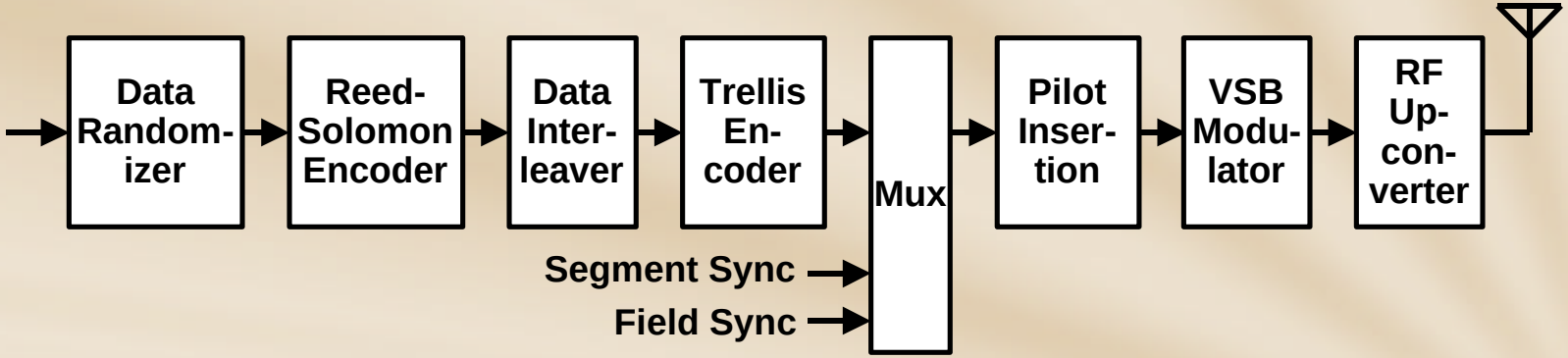
Related Rates



- Eases the ability to reject NTSC interference

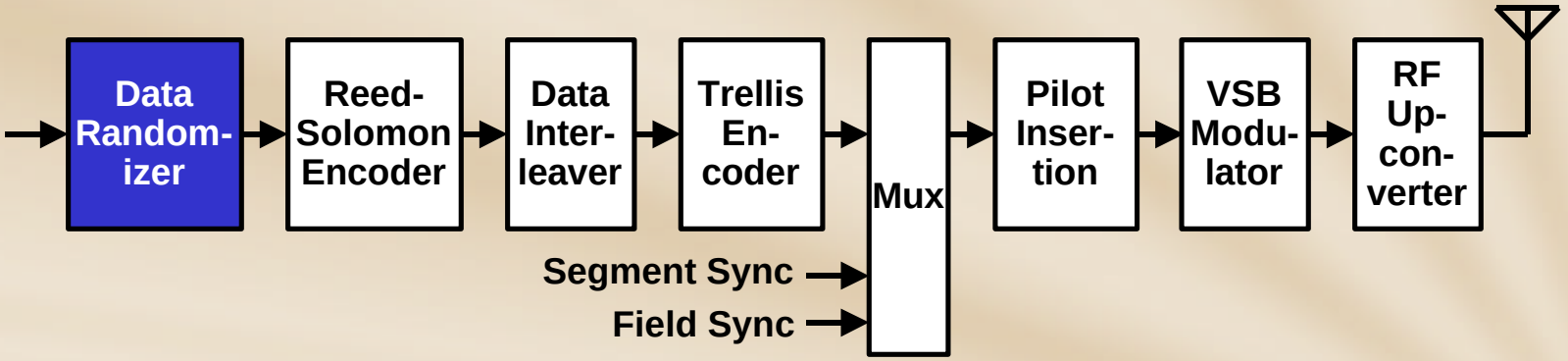
ATSC Channel Coding

- Two Vestigial Sideband (VSB) Modulation Modes
  - 8-VSB (Terrestrial)
  - 16-VSB (Cable - not used in practice)
- 8-VSB is focus of this talk

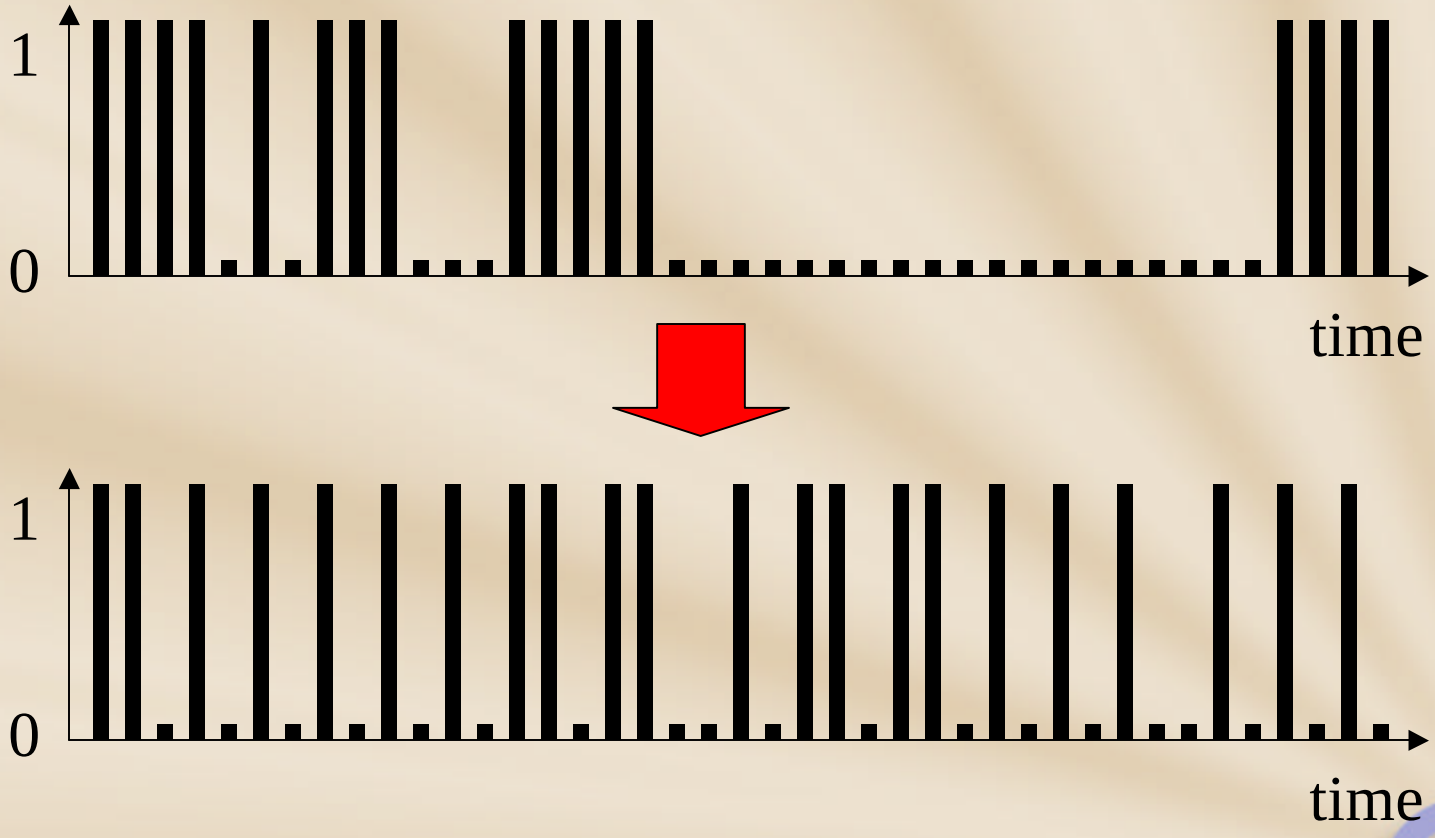


Data Randomizer

- Randomizes data payload within a Transport Packet
- Flattens RF spectrum, even when no signal is present

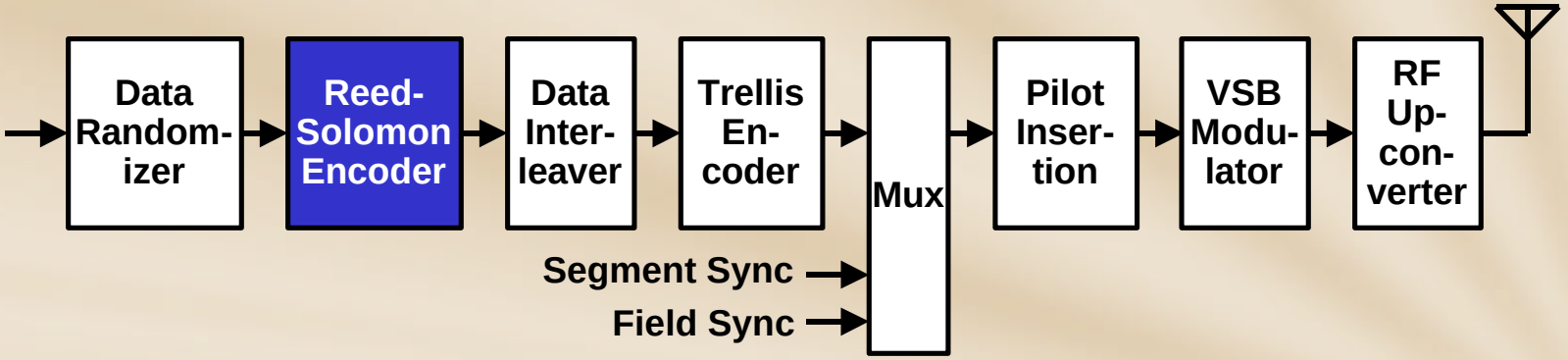


Data Randomizer

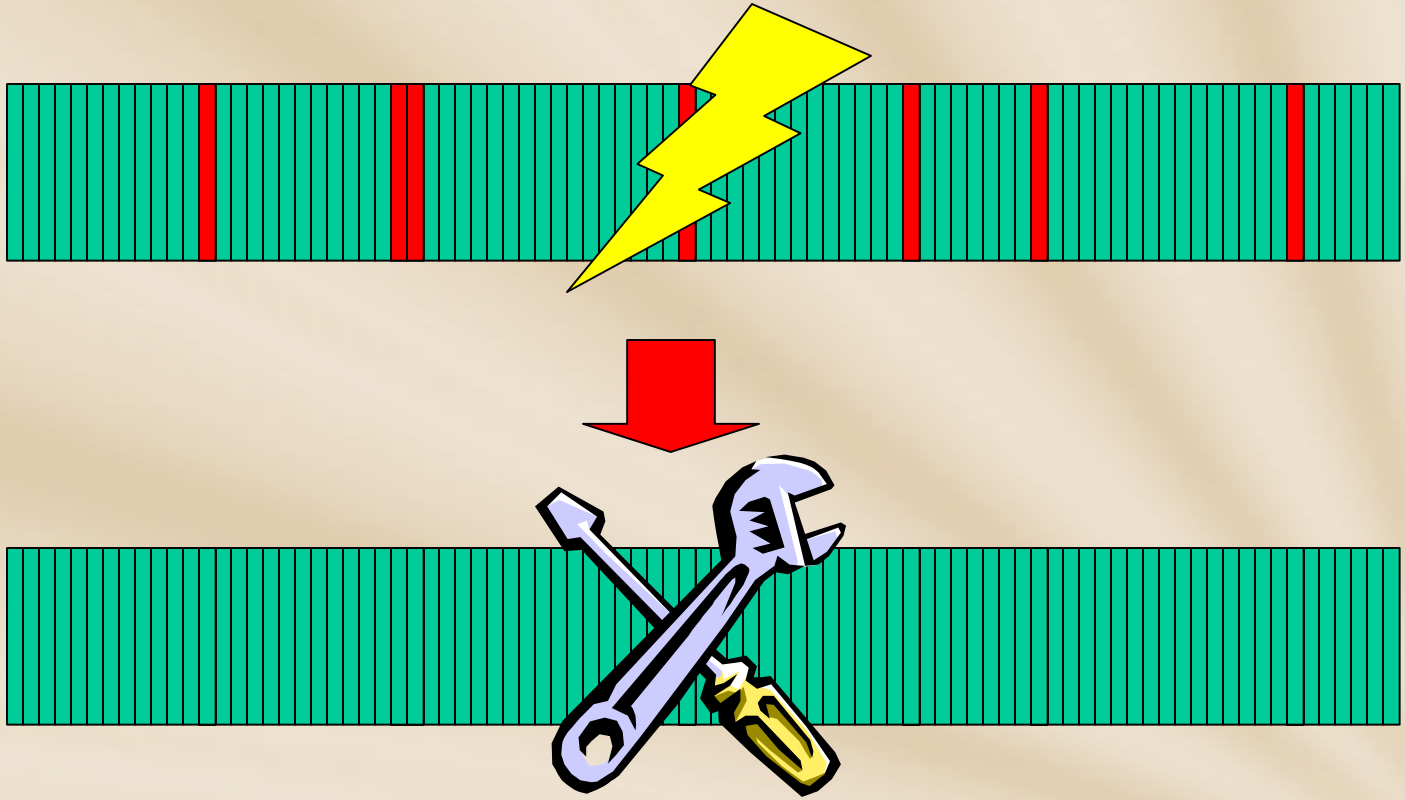


Reed-Solomon Encoding

- A type of Forward Error Correction (FEC) coding
- Appends 20 parity bytes to every 188-byte Transport Packet
- Can correct up to 10 byte errors/packet

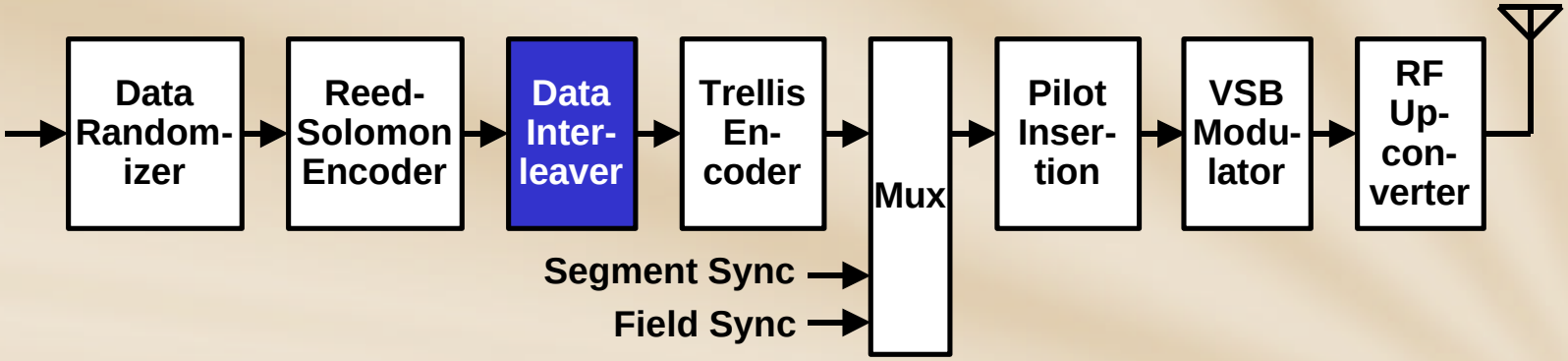


Reed-Solomon Encoding



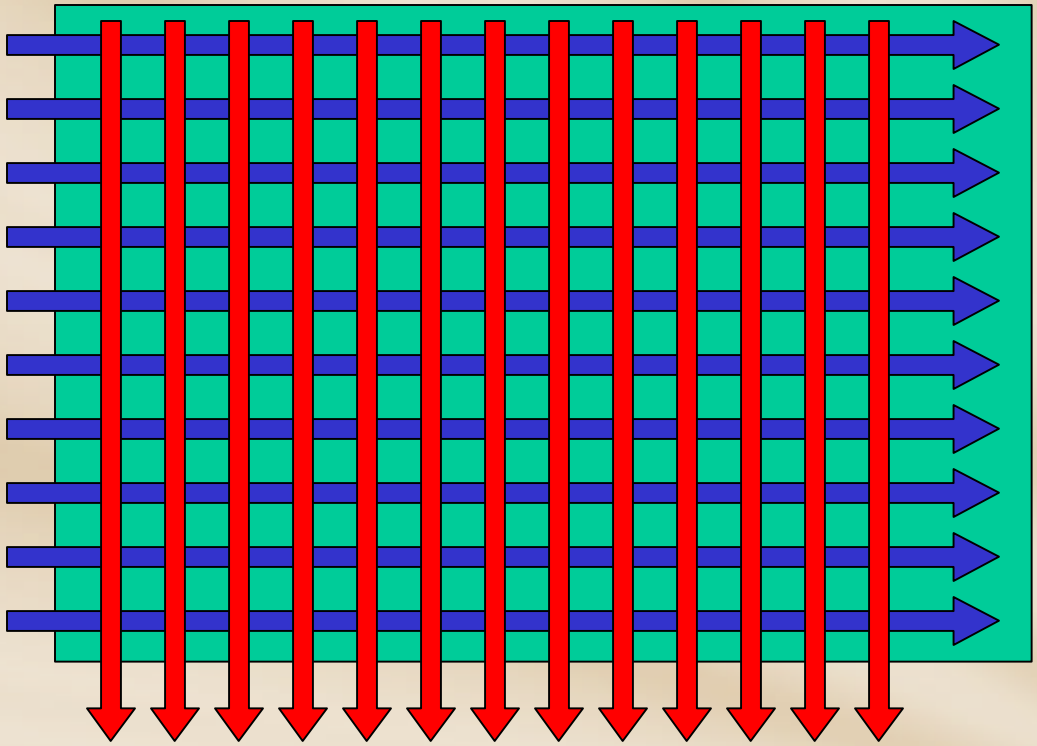
Data Interleaver

- Shuffles bytes among 52 data segments (data segment = transport packet + FEC)
- Spreads burst errors out over time
- Increases efficiency of FEC



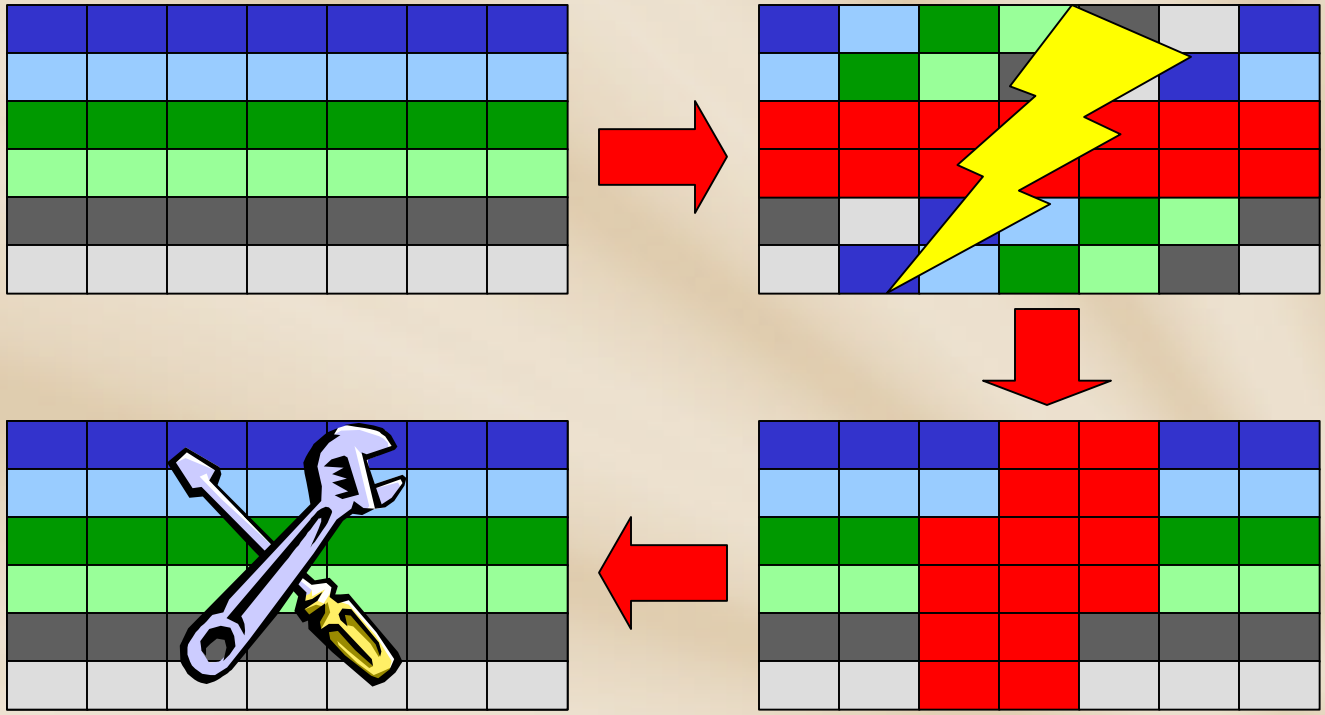
Data Interleaver

Read in
by rows.



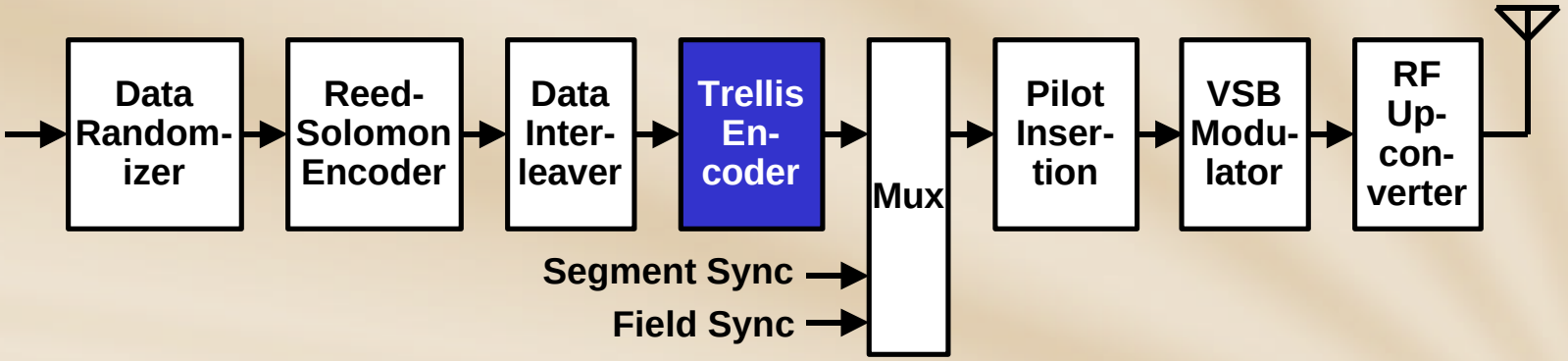
Write out by columns.

Data Interleaver

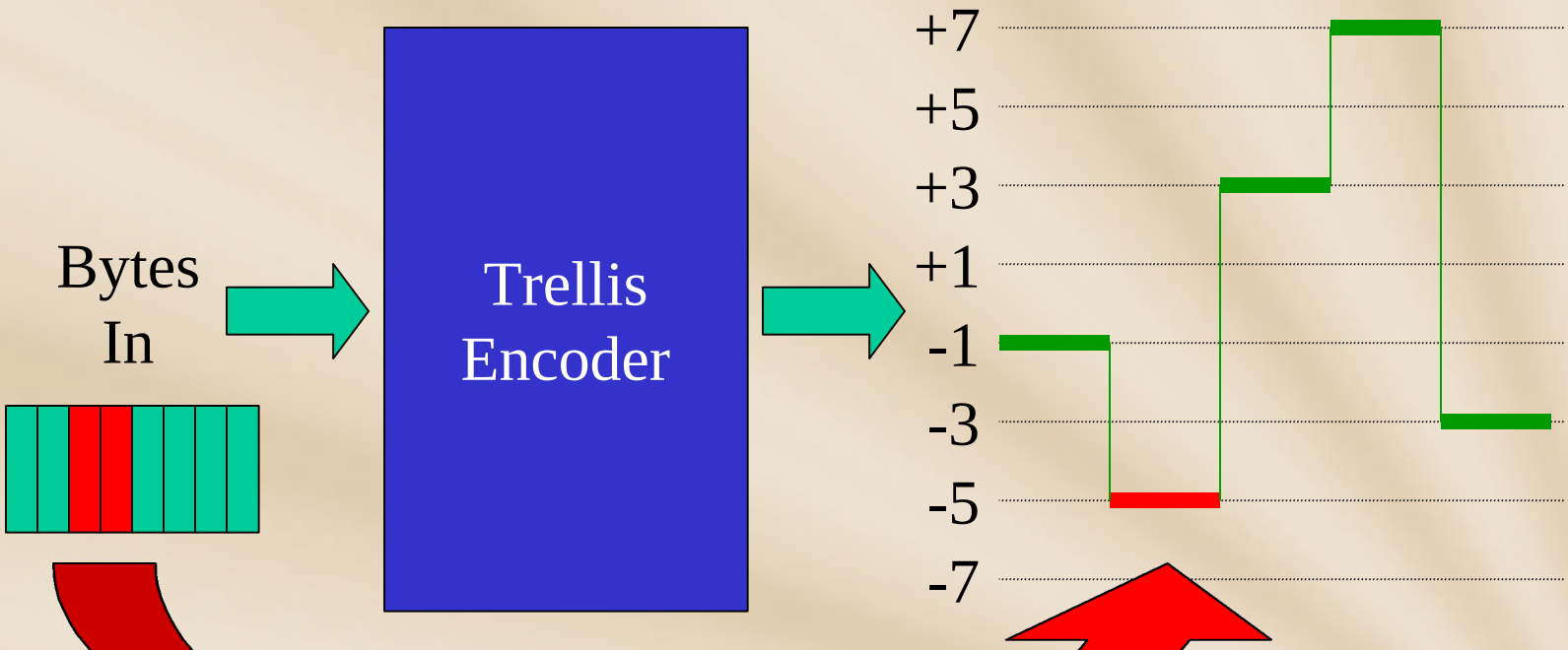


Trellis Encoder

- Another layer of error correction coding
- Extends reception threshold
- Adds an extra bit to each pair of bits (2/3 rate)
- Every 3 bits mapped to 8 distinct levels at output

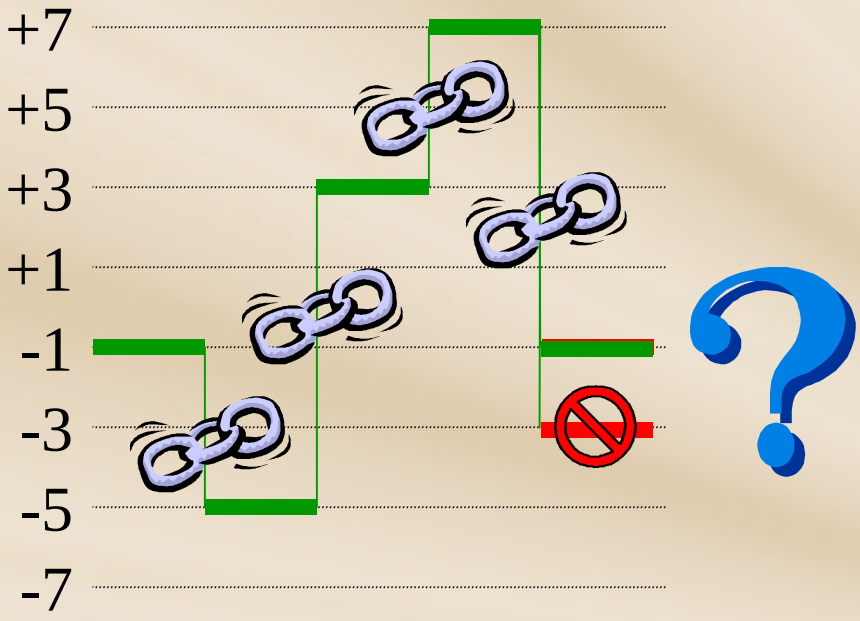


Trellis Encoder



Trellis Encoder

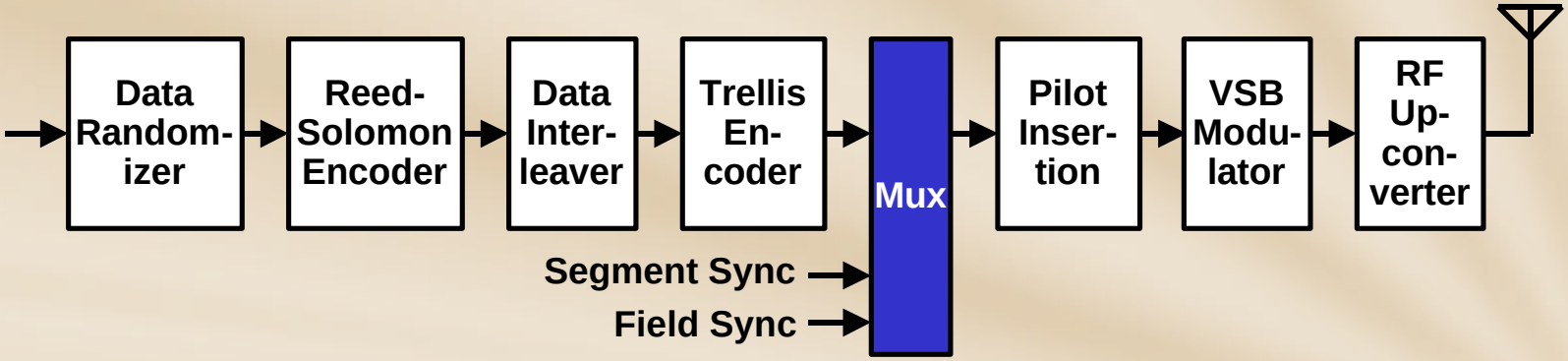
Forces dependency
between symbols



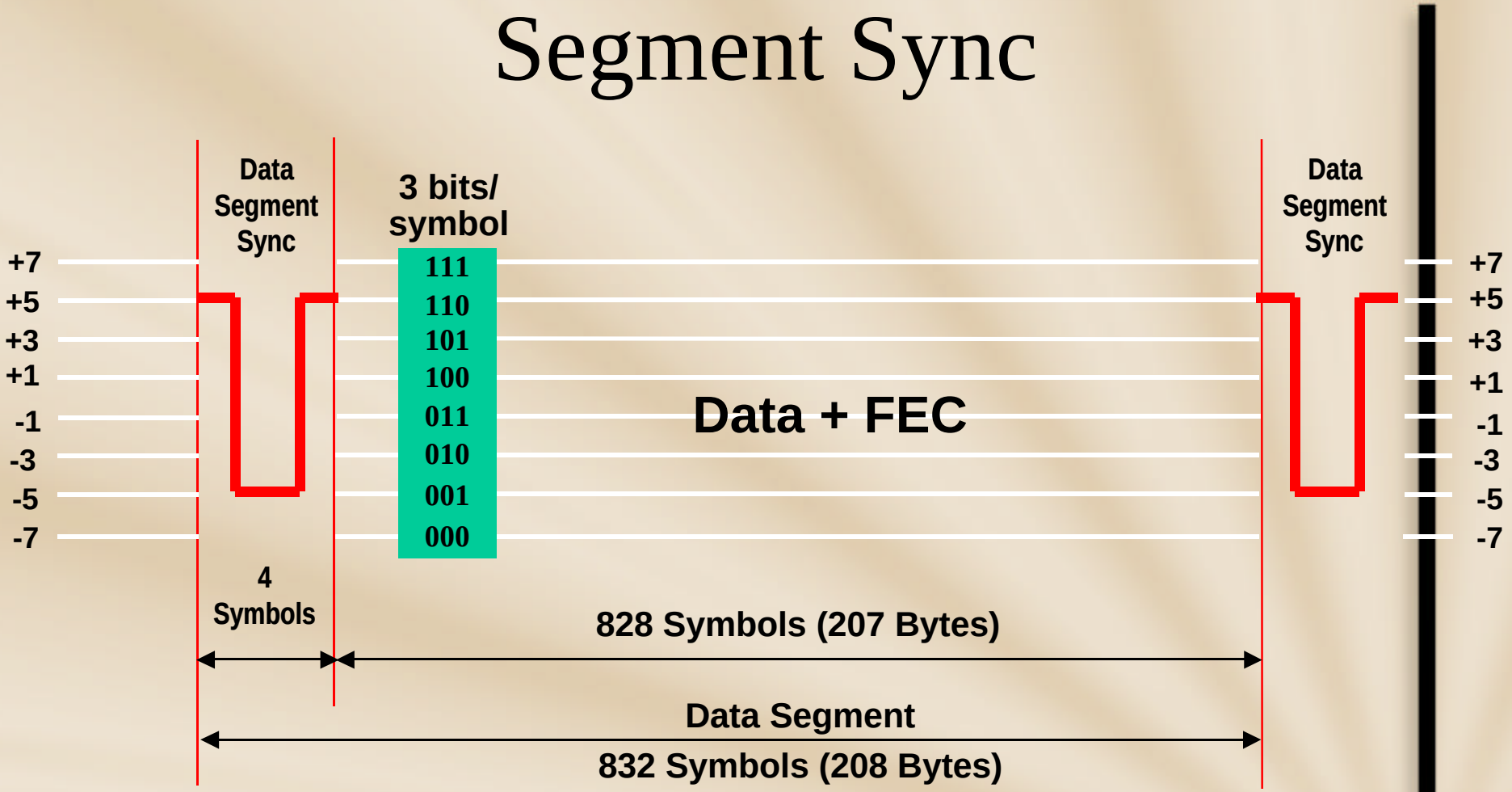
Trellis decoder checks each symbol against past history to determine which values are allowed

Data & Sync Mux

- Syncs are 2-level patterns that can be recovered at SNR's as low as 0 dB.
- 4-symbol Segment Sync replaces Transport Sync byte
- Field Sync contains training signals

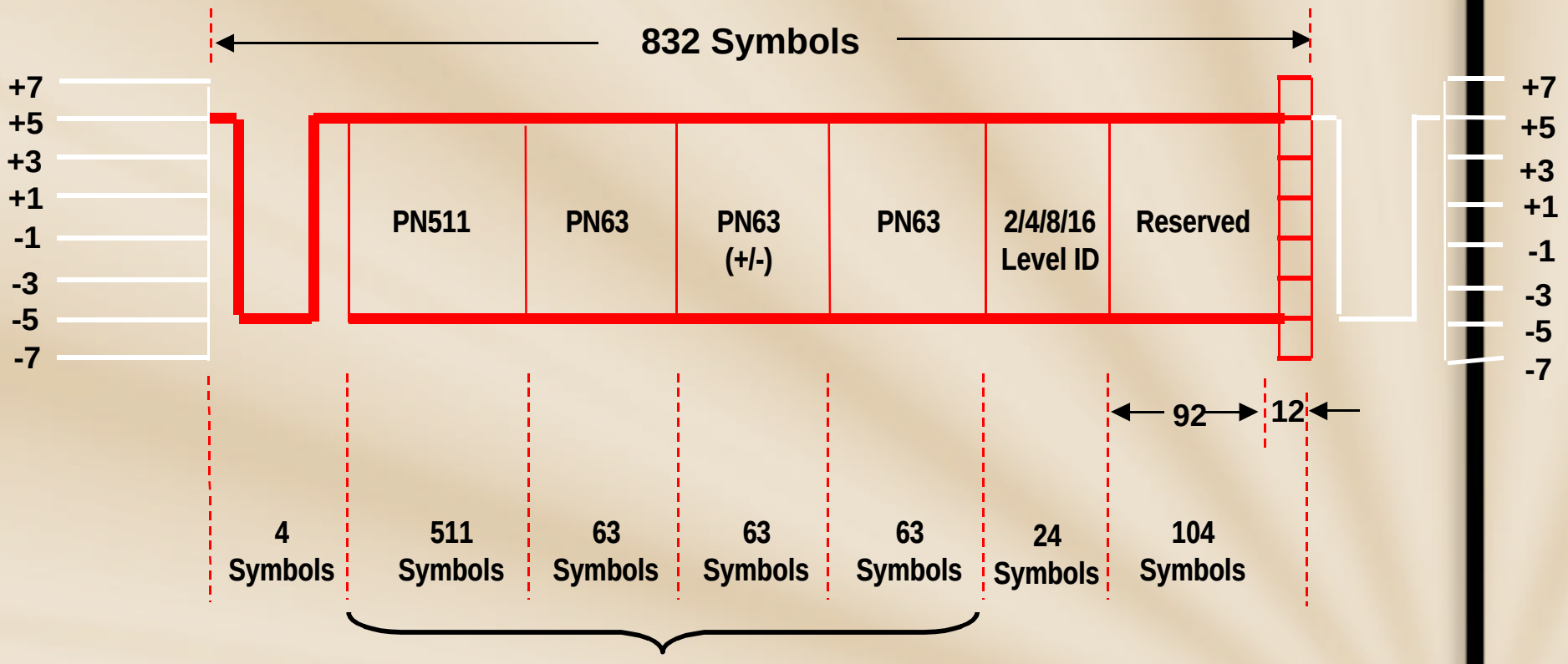


Segment Sync



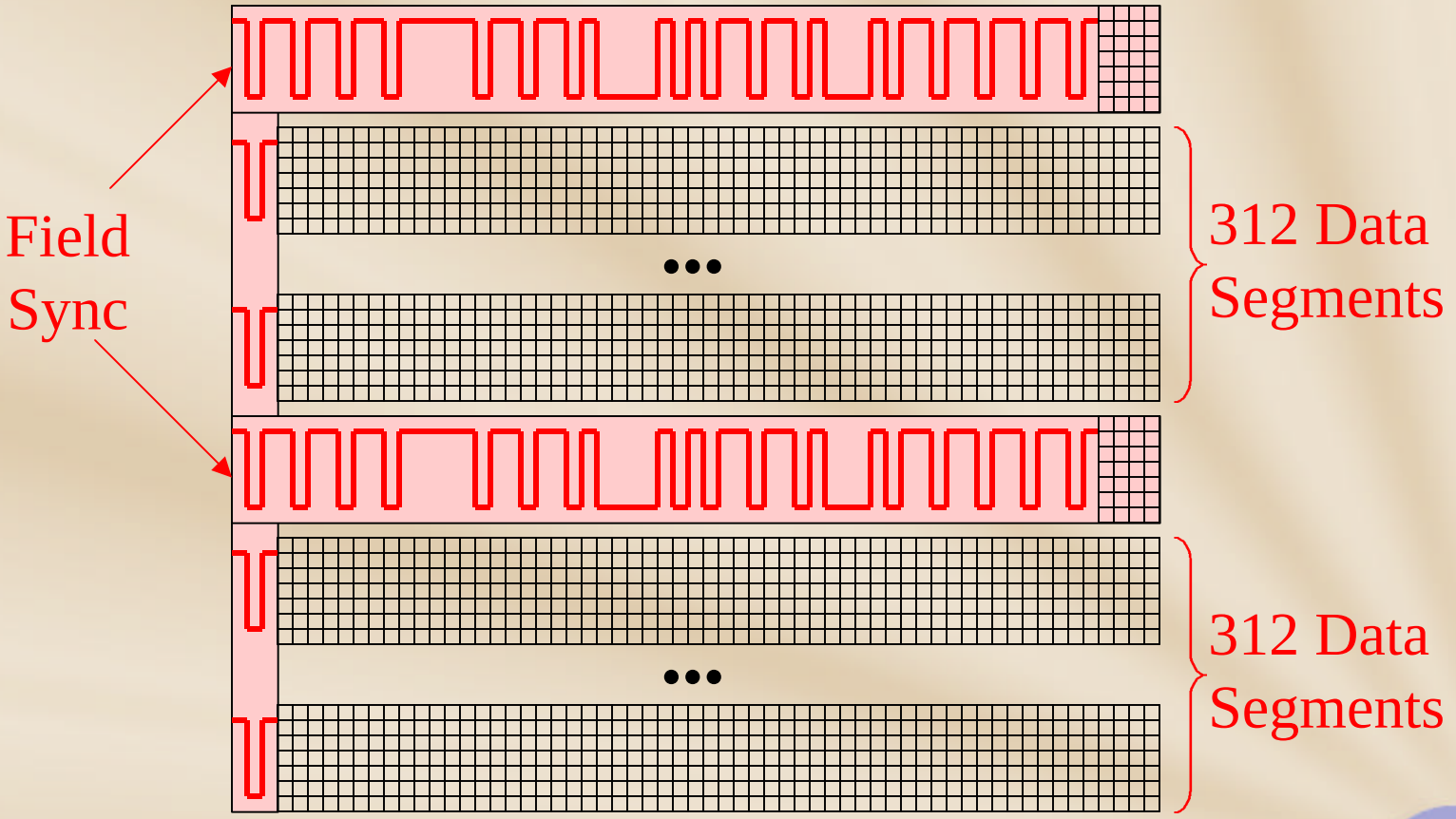
Courtesy
Gary Sgrignoli, Zenith

Field Sync



Courtesy
Gary Sgrignoli, Zenith

Data Frame


Segment Sync
Field Sync
312 Data Segments
312 Data Segments

The Transport Rate

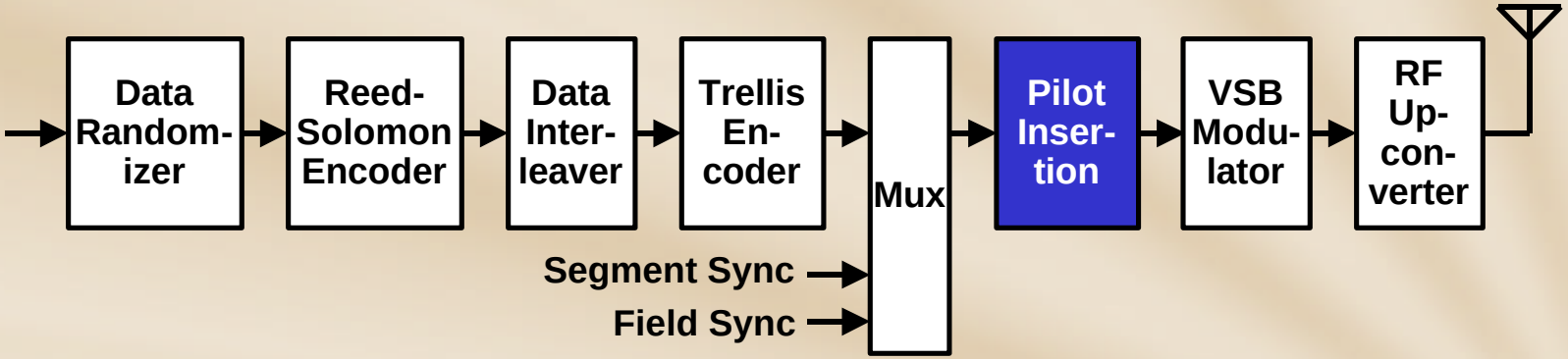
$$f_{transport} = 2 \cdot \left(\frac{188}{208}\right) \cdot \left(\frac{312}{313}\right) \cdot f_{symbol}$$

19.39 Mbits/sec

10.76 Msymbols/sec

Pilot Insertion

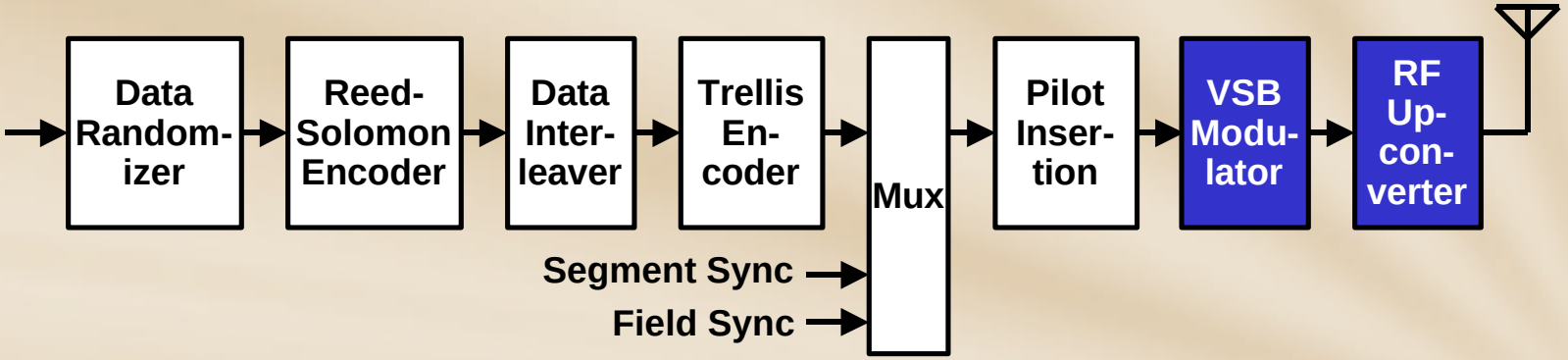
- Achieved by adding a 1.25 offset to the output levels
- Only adds about 0.3 dB to average power



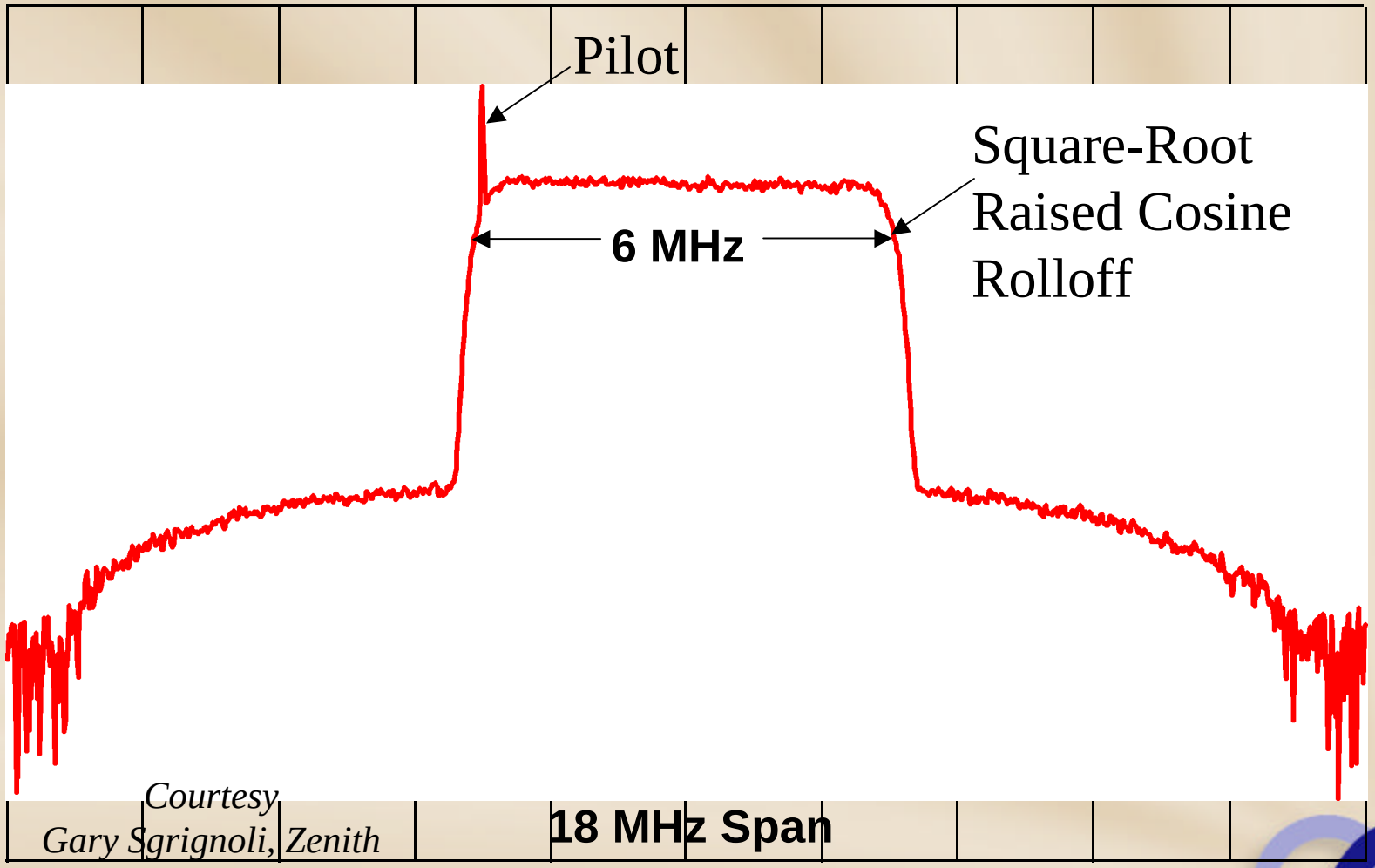
Pilot Insertion

VSB Modulator & RF Upconverter

- The 10.76 Msymbols/s, 8-level signal is suppressed-carrier modulated and lower sideband removed
- Resulting spectrum is flat, except for 620 kHz band edges having square-root raised cosine responses

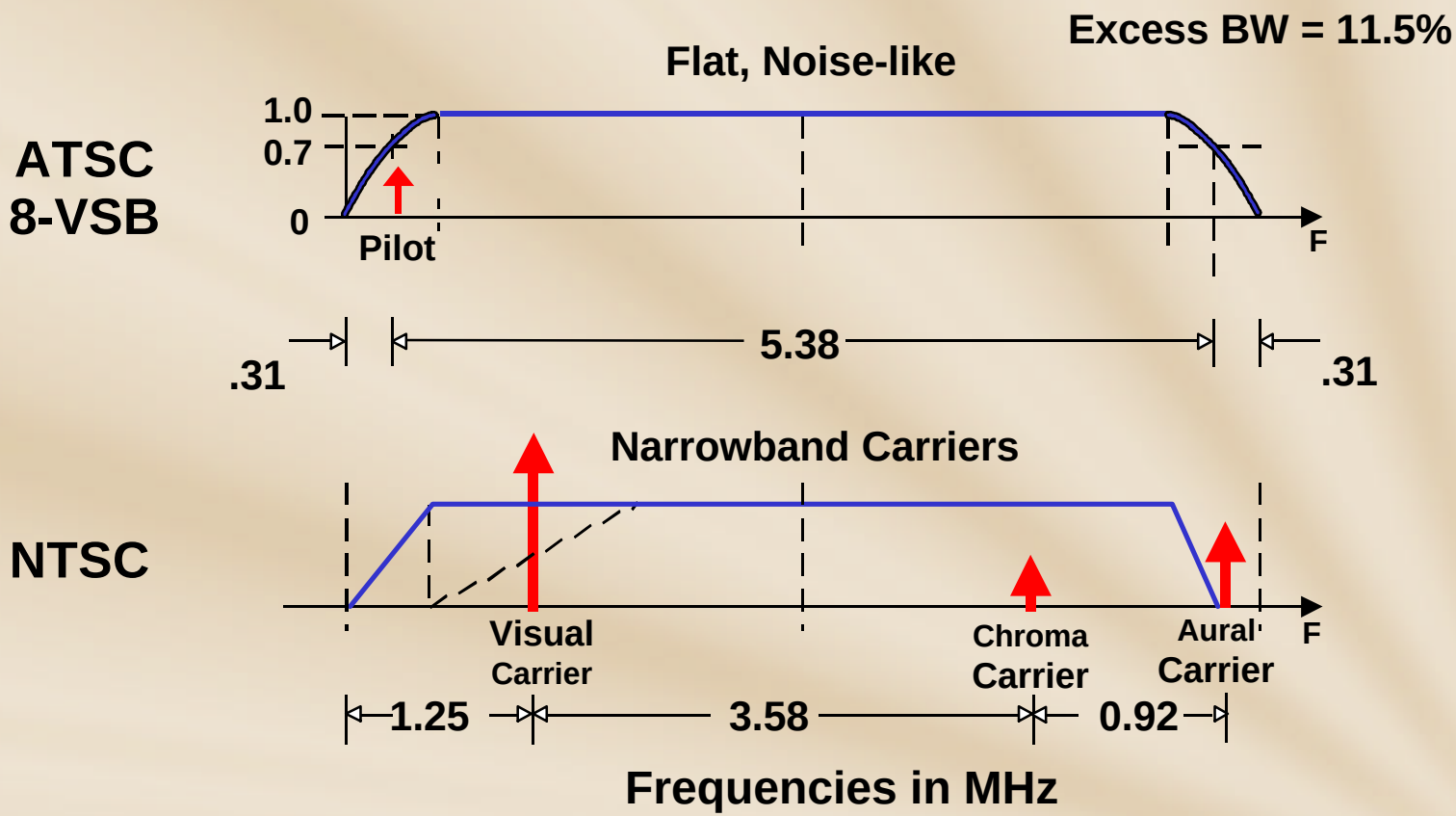


8-VSB RF Spectrum



Courtesy
Gary Sgrignoli, Zenith

NTSC vs ATSC RF Spectra



Courtesy
Gary Sgrignoli, Zenith

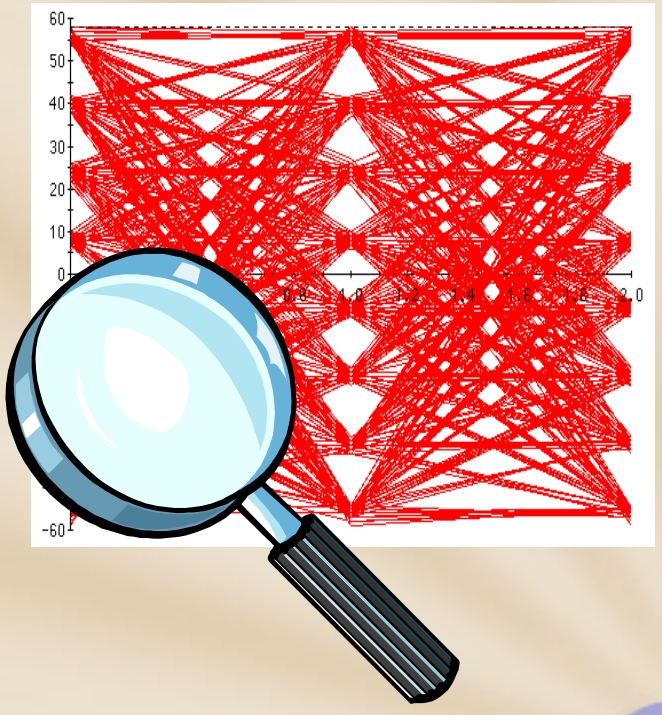
Transmitter Requirements

- High SNR
- High Linearity
- High Frequency Stability
- Low Phase Noise
- FCC Mask Compliance
- Some manufacturers pre-correct for linear and nonlinear distortions

8-VSB Analyzers

…a sampling based on Web search...

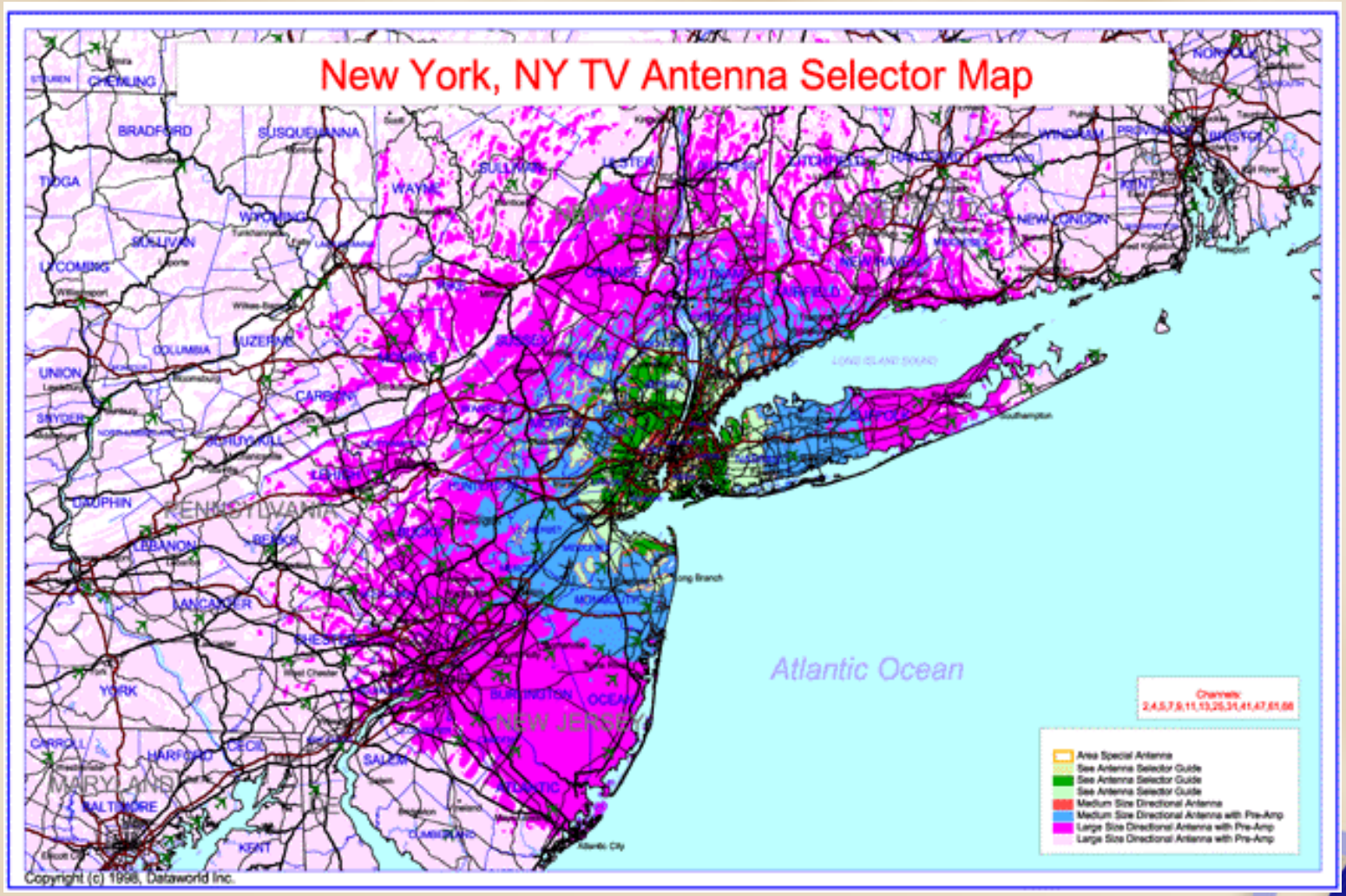
- Agilent Technologies
- Harris
- Leader Instruments
- Tektronix
- Triveni Digital
- Rohde & Schwarz
- Videotek



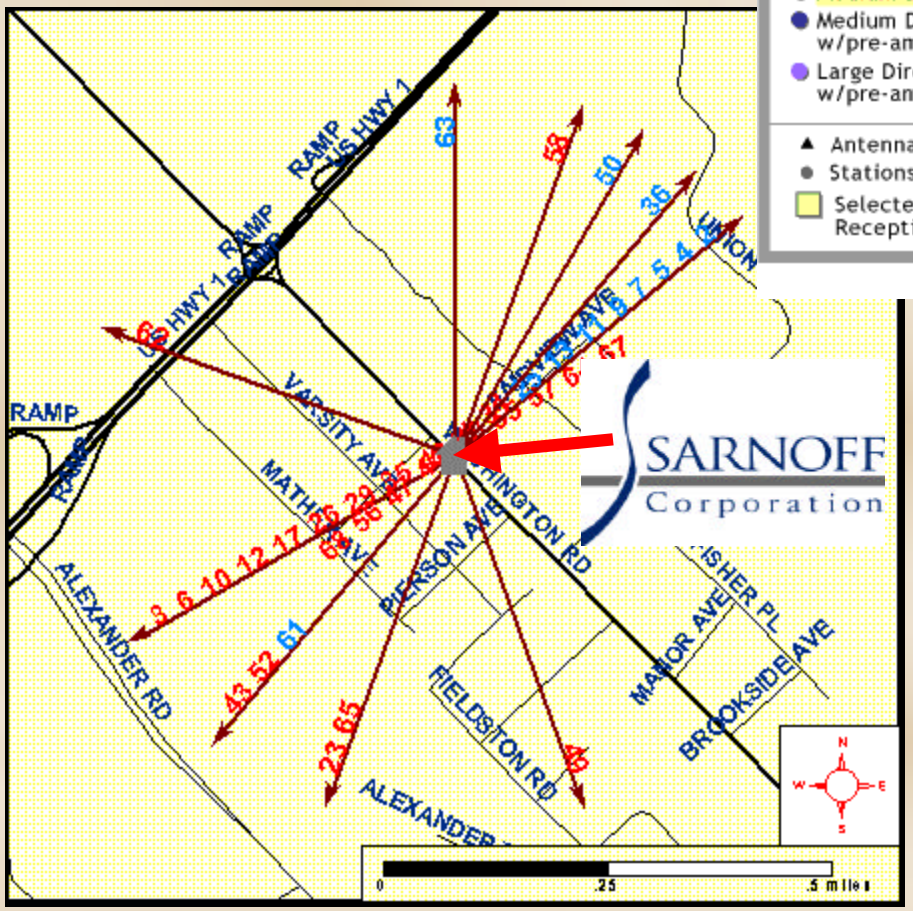
Reception Issues

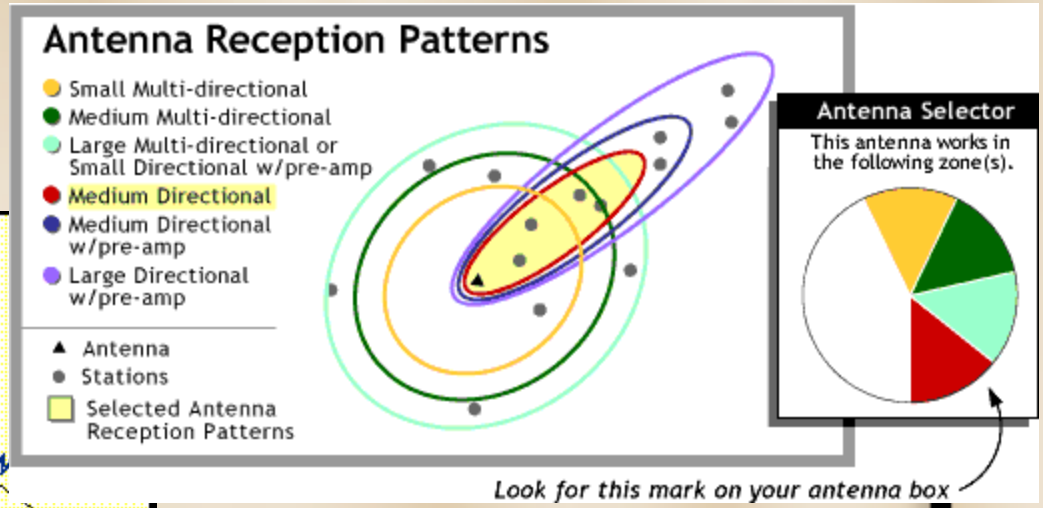
- Antenna gain and location
  - Directional antennas a must in certain areas
  - Indoor reception introduces 10-25 dB loss
- Noise figure
  - FCC planning uses 10 dB
- Adjacent and co-channel rejection
- Multipath requires adaptive equalization

Antenna Maps



antennaweb.org



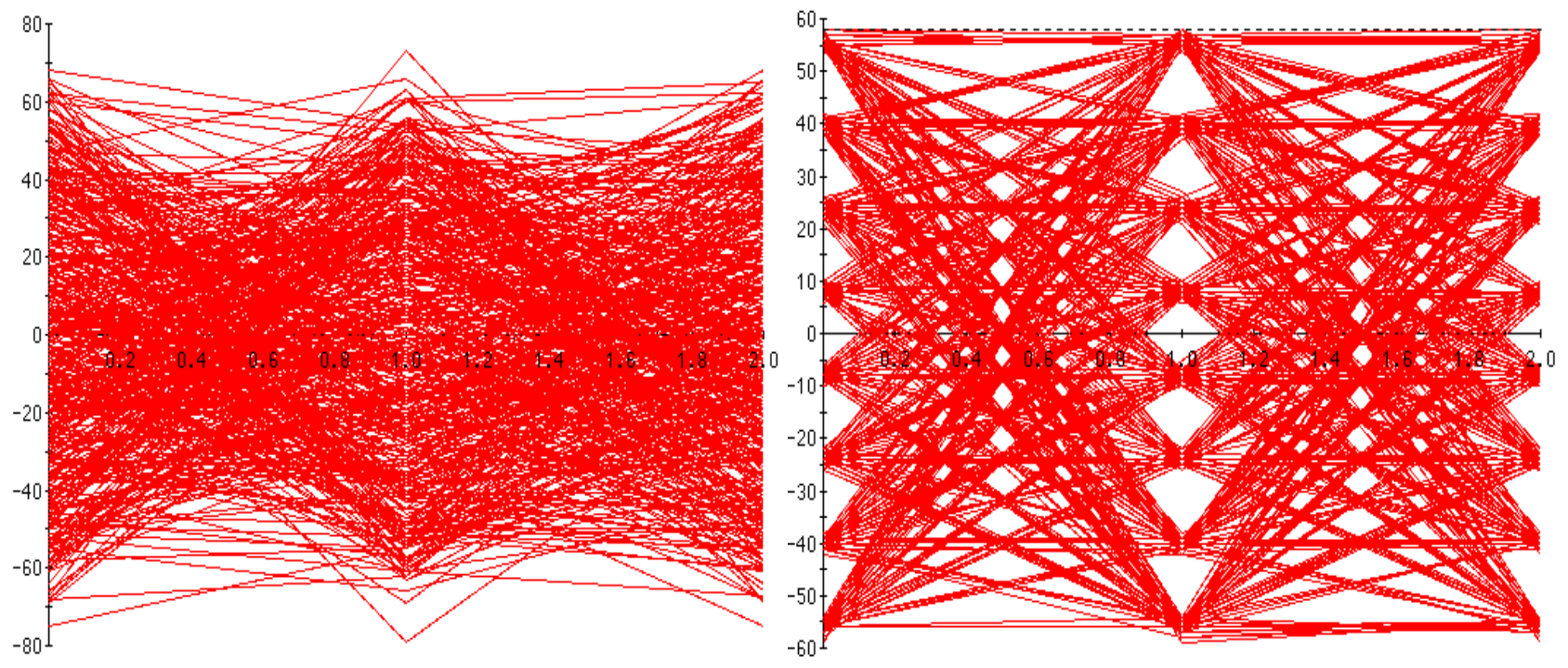


Enter location, select channel...

…out pops antenna needed to receive that channel

Adaptive Equalization

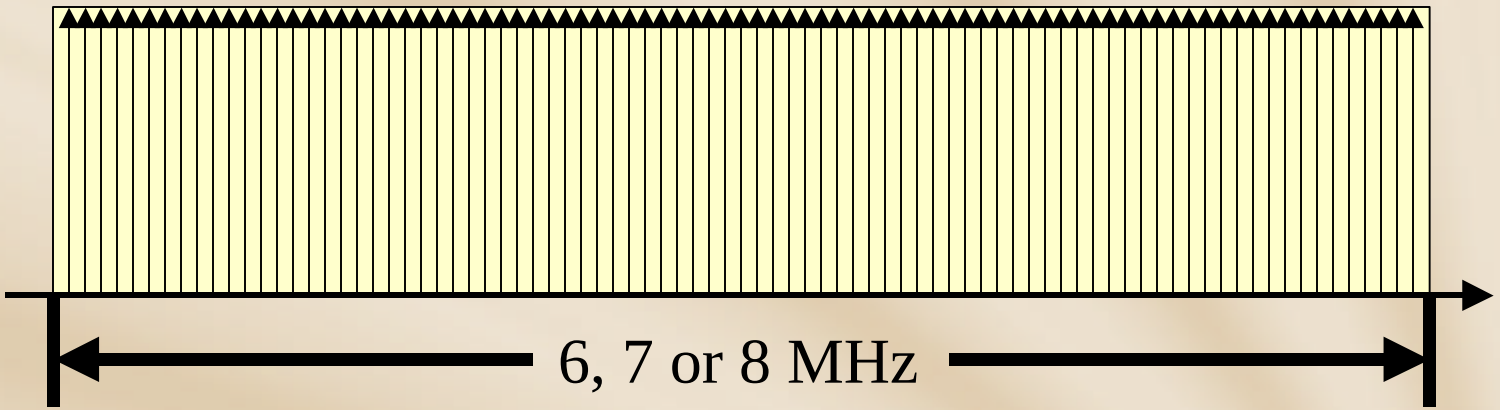
35 µs Static Multipath



256-Tap Equalizer (ATSC Baseline)

An Advanced Equalizer

COFDM



Thousands of carriers, each carrying a low data-rate digital signal containing temporal guard band intervals.

8-VSB vs COFDM

Parameters	8-VSB	COFDM
Peak-to-Average ratio	+	
C/N	+	
Multipath distortion -Weak -Strong -Dynamic	+ 	 + ++
Spectrum Efficiency	**MFN**	**SFN**

Courtesy
Dr. Yiyan Wu, CRC

8-VSB vs COFDM

Parameters	8-VSB	COFDM
HDTV	+	~+
Mobile	-	++
Phase Noise	+	
IntCo-Ch interference		
-DTV into NTSC	+	
-NTSC into DTV	~=	~=
-DTV into DTV	+	

Courtesy
Dr. Yiyan Wu, CRC

8-VSB: Ain't Broke

…but could be better...

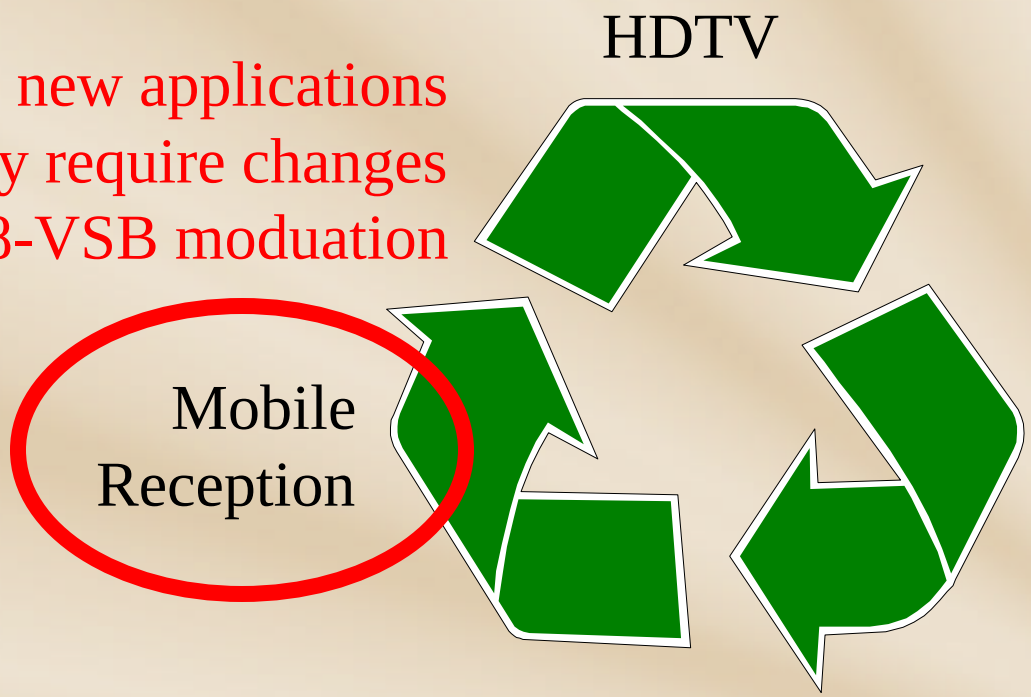
- NAB/MSTV reaffirmed support for 8-VSB based on field tests
- FCC also reconfirmed 8-VSB for ATSC transmission
- ...but poor indoor reception and inability to meet new service requirements are forcing a second look

Some New Requirements

- Portable Reception
- Pedestrian Reception
- Mobile Reception
- Multi-Mode Operation
- On-Channel Repeaters

DTV Tradeoffs

Some new applications may require changes to 8-VSB moduation



Courtesy Dr. Yiyan Wu, CRC

The Future

- Receiver technology will continue to improve, but some new services may require transmission enhancements
- ATSC has issued an RFP for potential revisions
  - Preference given to *compatible* 8-VSB enhancements

T3/S9 Work Plan

- T3/S9 = ATSC Specialist Group on RF Transmission
- Milestones
  - Responses to RFP due — April 2, 2001
  - Selection of technology — September 14, 2001
  - Field tests begin — November 14, 2001
  - Review of field tests — January 15, 2002
  - New standard or revision — January 31, 2002

Conclusions

- 8-VSB has largely met original performance goals
- NAB/MSTV and FCC have all reaffirmed this
- New requirements may force a revision to the standard
- Work is in progress…stay tuned!

Acknowledgements

- Gary Sgrignoli (Zenith)
- Dr. Yiyan Wu (CRC)