



DVB-T

Matt Holiday, KØDVB

BCARES — Summer 2018



Why Digital?

- 1 Weak-signal performance
- 2 Picture quality
- 3 Higher resolution



Digital ATV works better in our environment

Remember Analog?



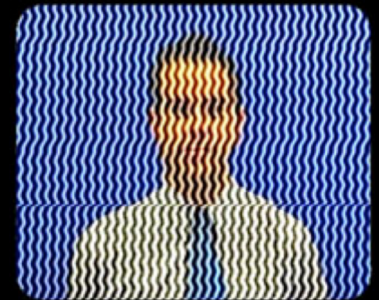
Ghosting



Noise



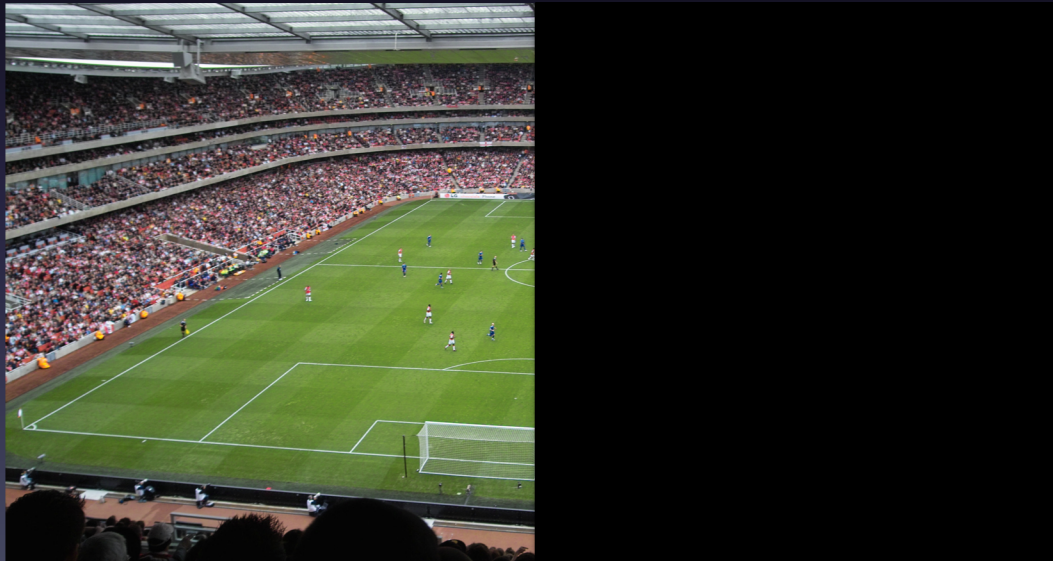
Electrical
Interference



Transmitter
Interference

Errors in Digital TV

In theory, digital TV is either P5 or P0



Is This P5 or P0?

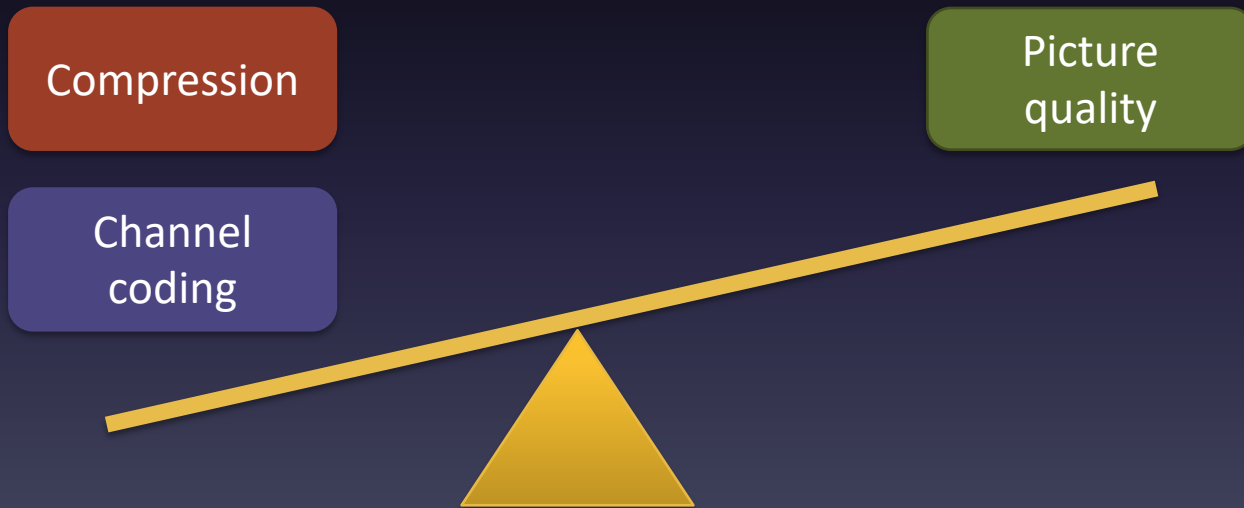
 sport
živě

SWIS

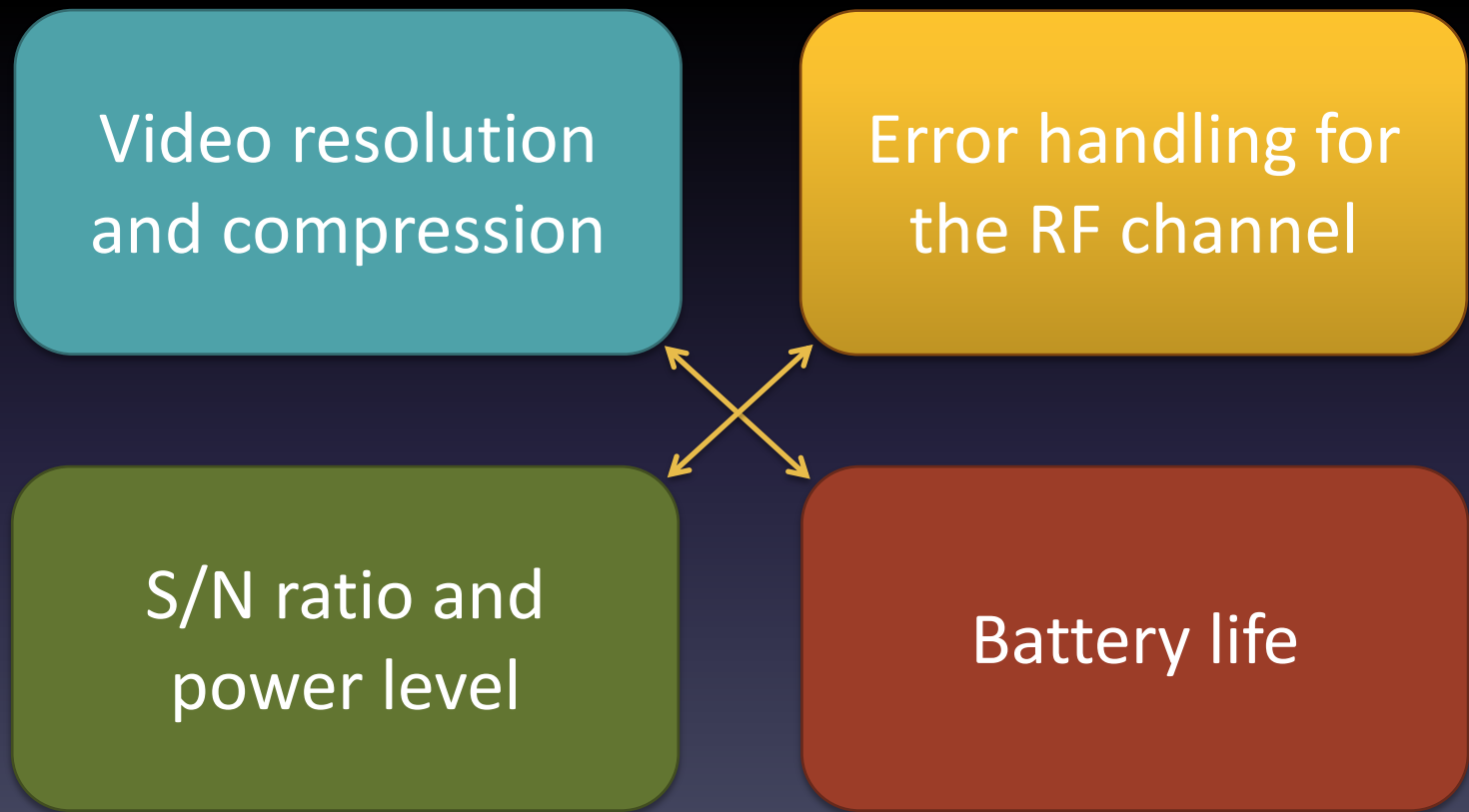


Why Do We Care?

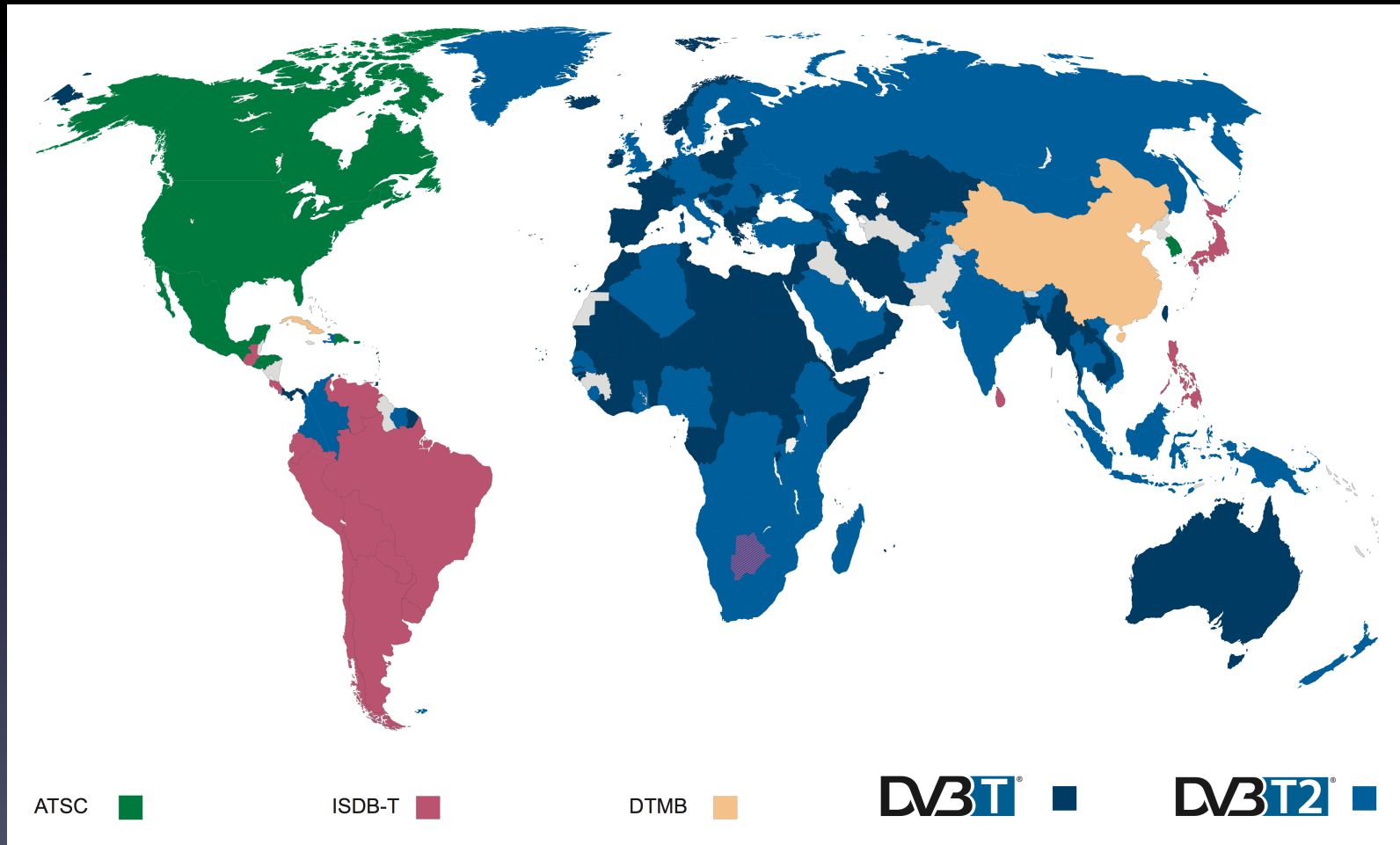
DTV engineering choices impact picture quality



We Have Key Tradeoffs



Digital TV Standards



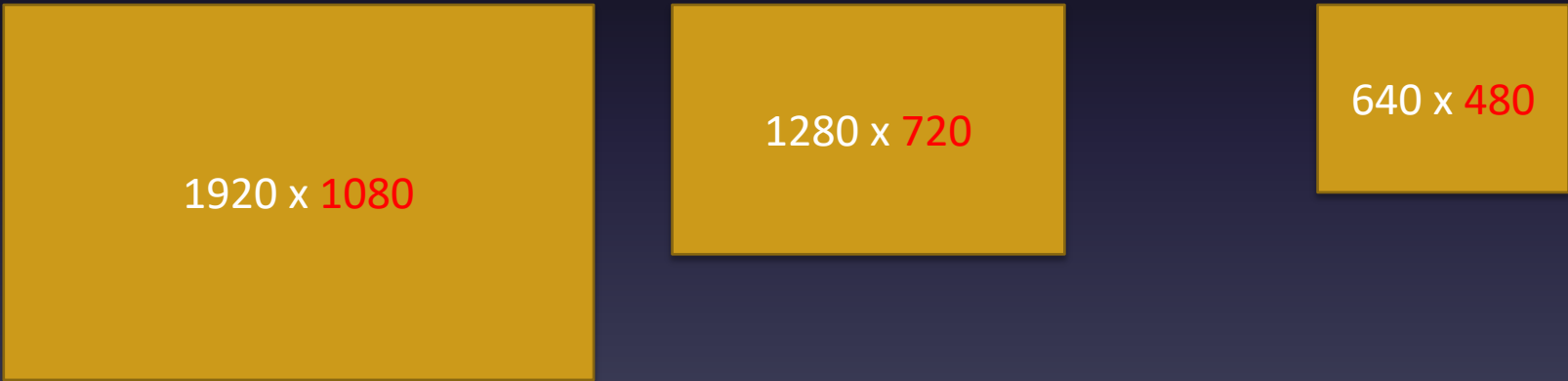
Why Use DVB-T?

- 1 Weak-signal performance
- 2 Multipath performance
- 3 Configurability [is that a word?]

DVB-T works better in our environment

HDTV Resolution

HDTV is defined by lines of *vertical* resolution



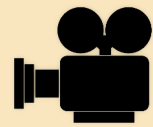
1920 x 1080

1280 x 720

640 x 480

Elements of Digital TV

Source Coding



Quantization

Compression

Packetization

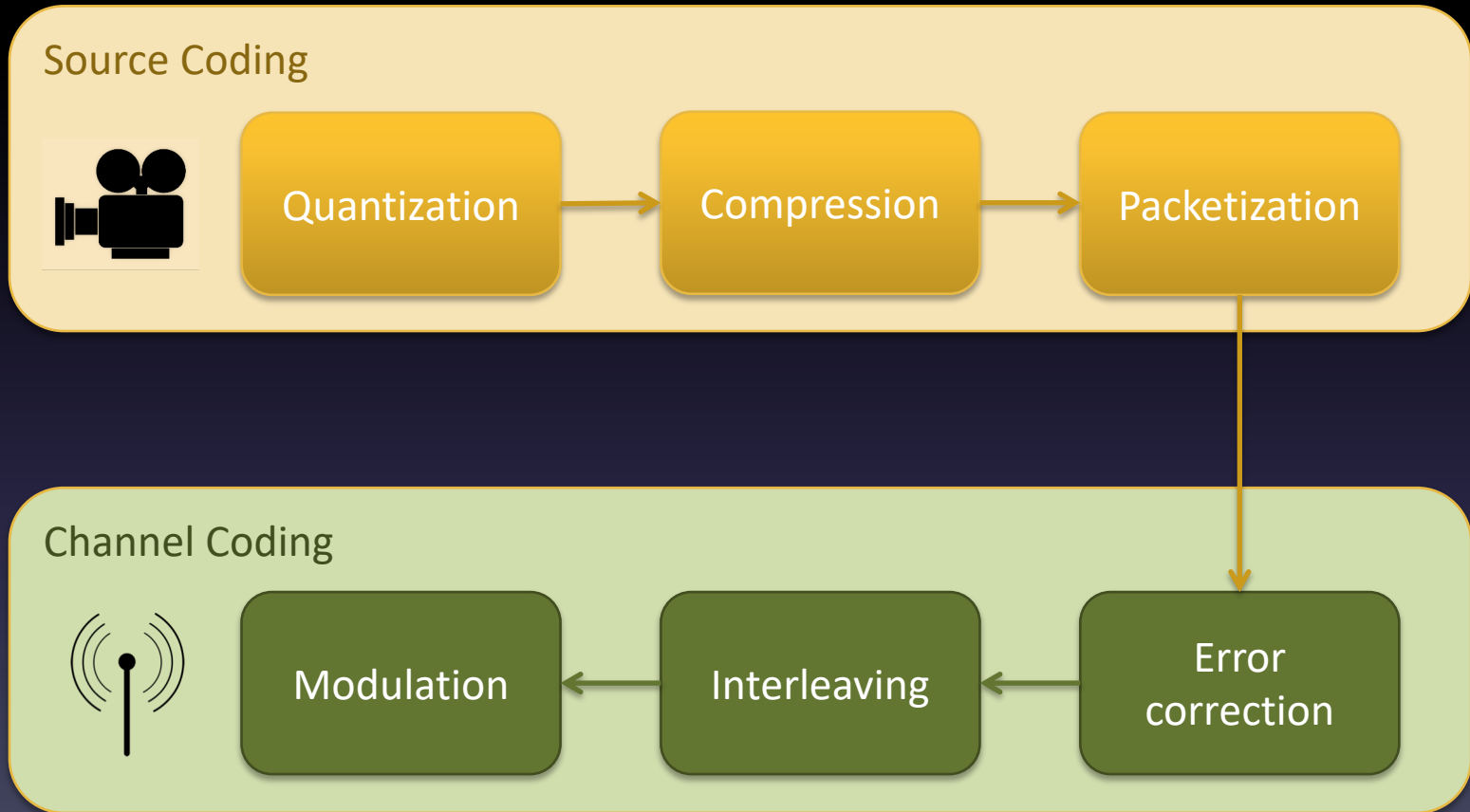
Channel Coding



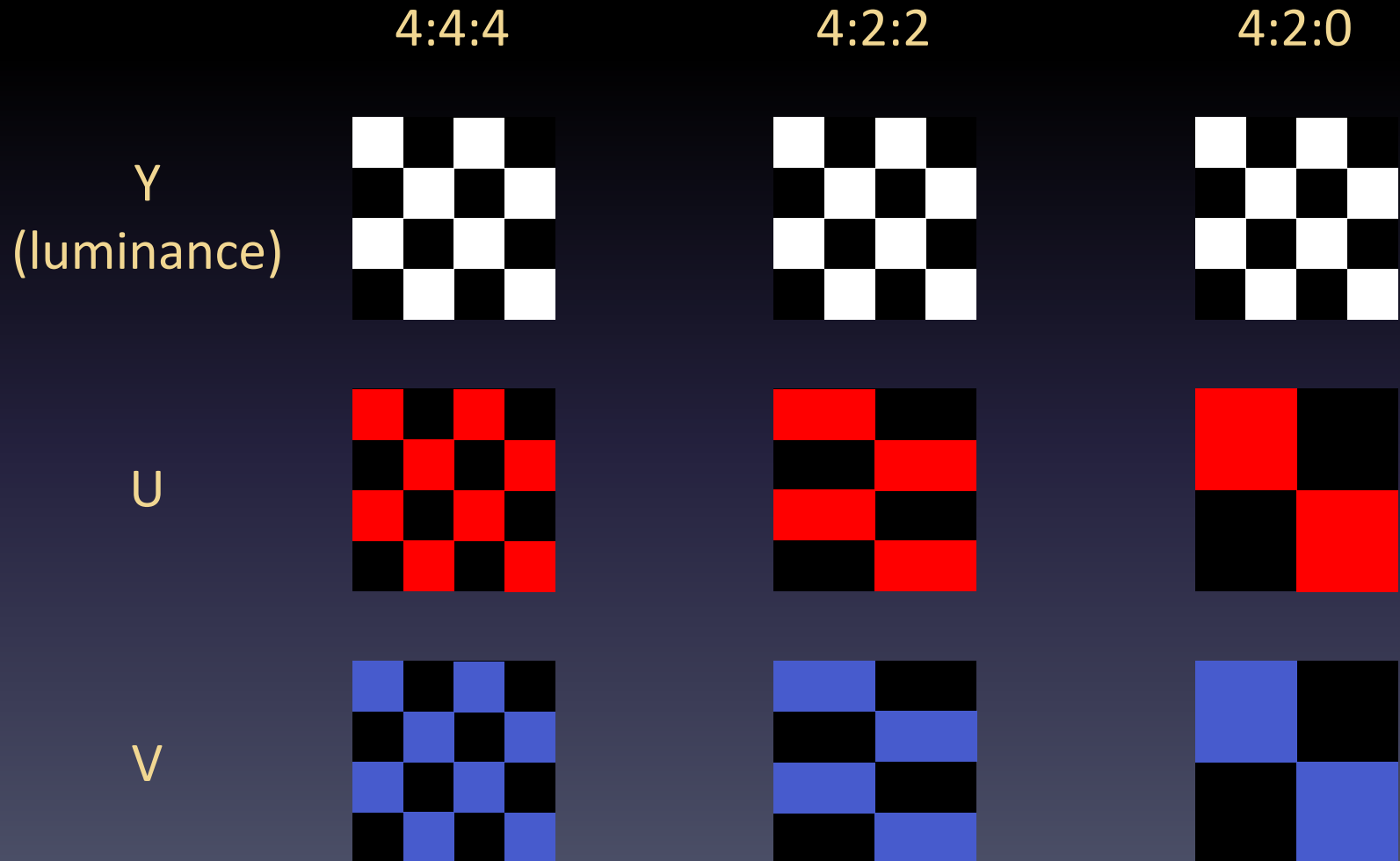
Modulation

Interleaving

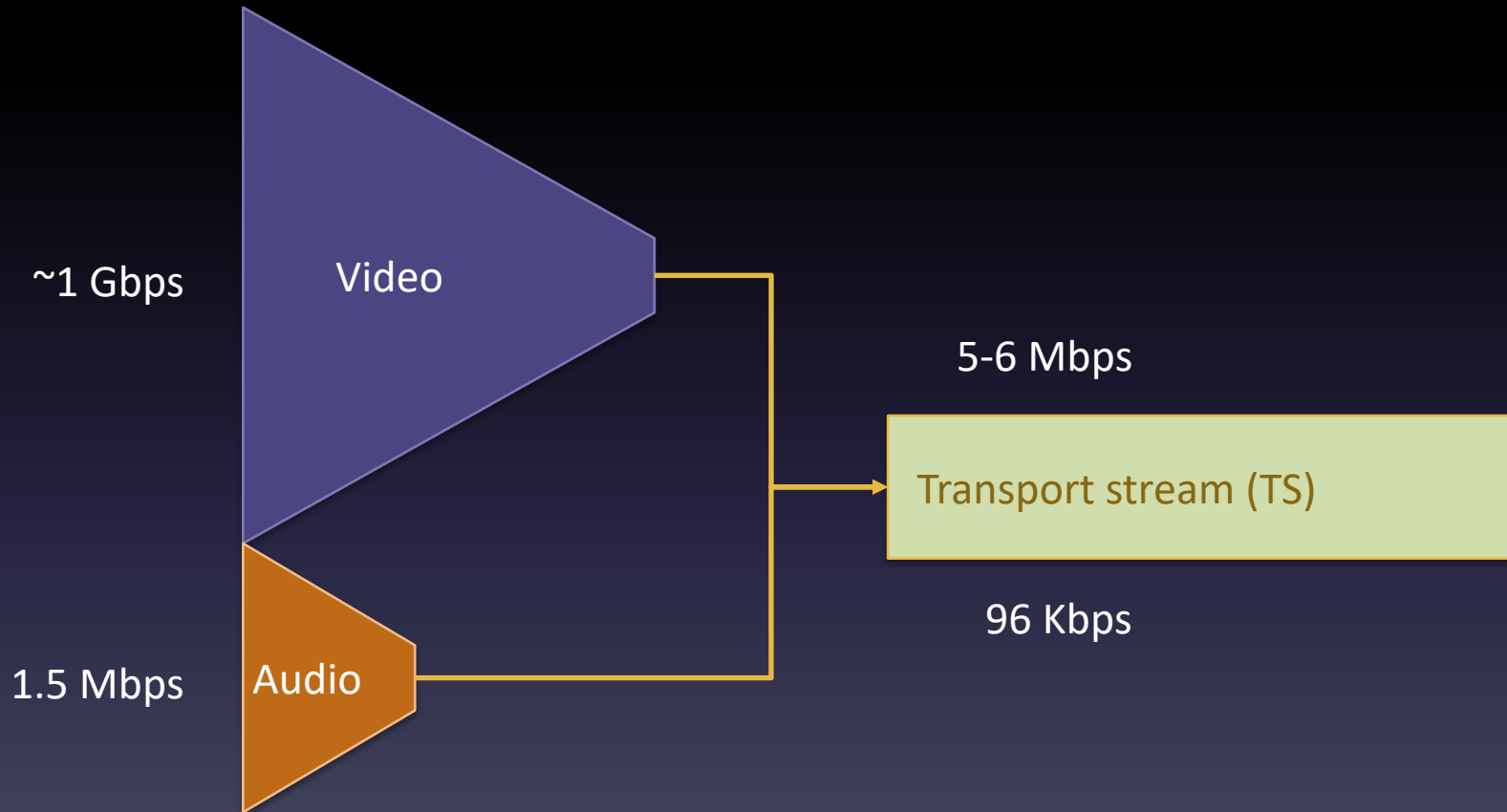
Error
correction



Quantization



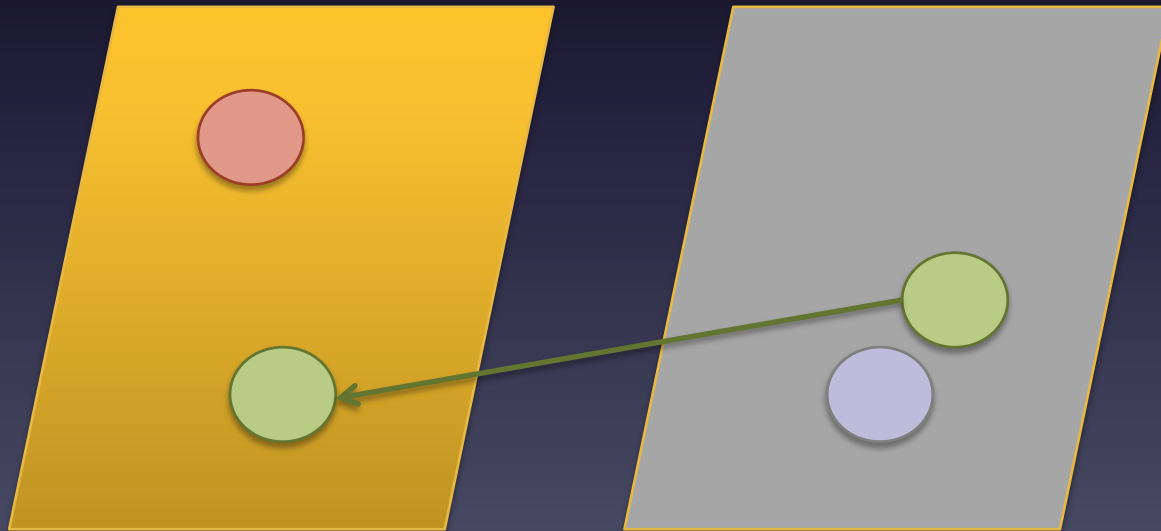
MPEG-2 Source Coding



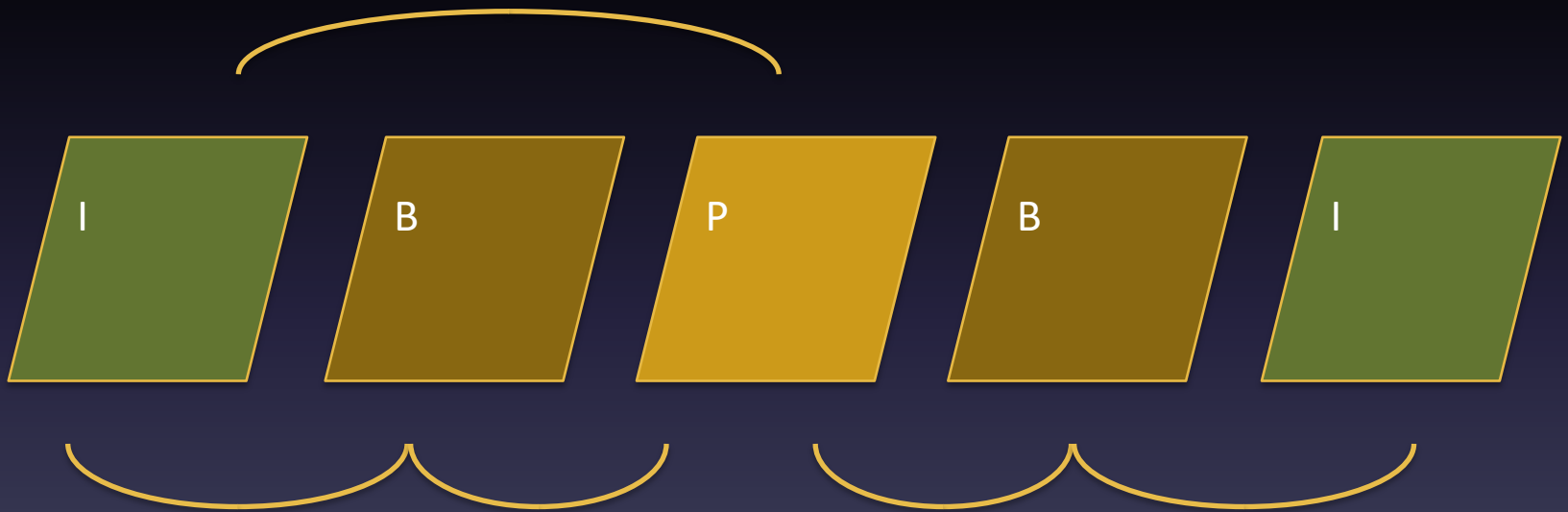
Lossy Video Compression

JPEG-like compression

Motion prediction — not all frames are whole



MPEG-2 Frame Types



Goal: Avoid Frame Drops

Compared to frame drops, compression doesn't really matter as much

So the focus should be on correct error handling for the given RF environment

And Now a Little Theory

We're going to talk about errors occur in data transmission

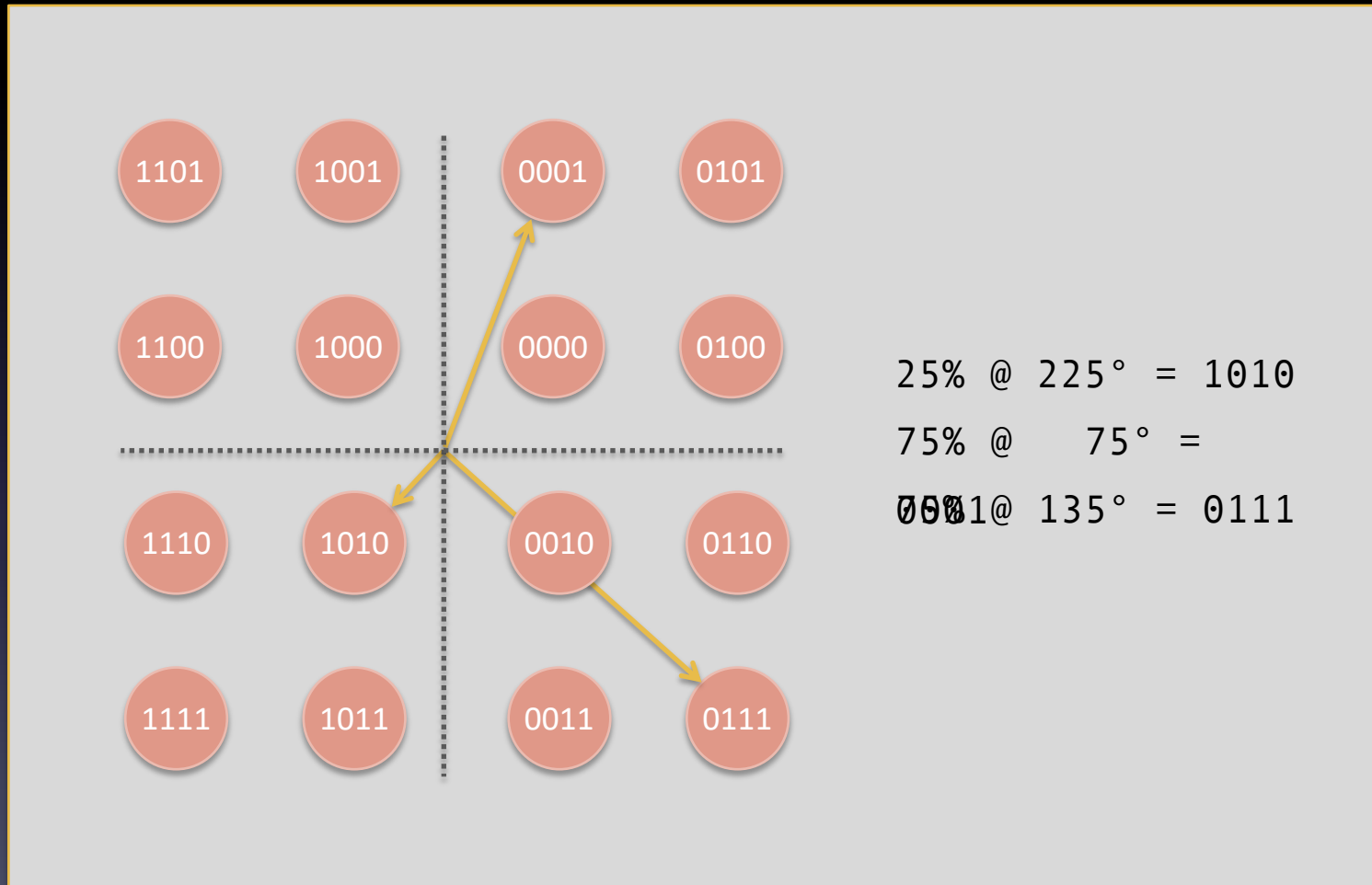
And how this relates to modulation and the signal-to-noise ration of our environment

Quadrature Amplitude Modulation

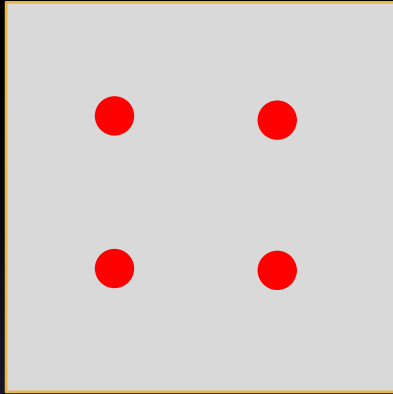
Multiple bits per symbol

Modulation	States	Bits / symbol
QPSK	4	2
16-QAM	16	4
64-QAM	64	6

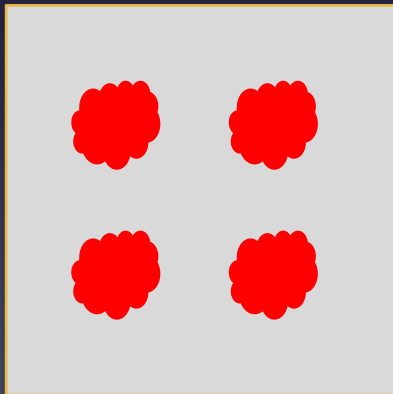
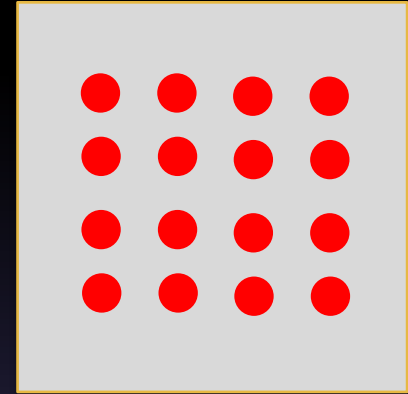
Amplitude + Phase = Symbol



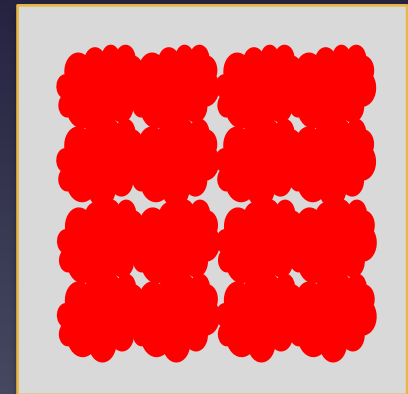
QAM Constellation



With low noise

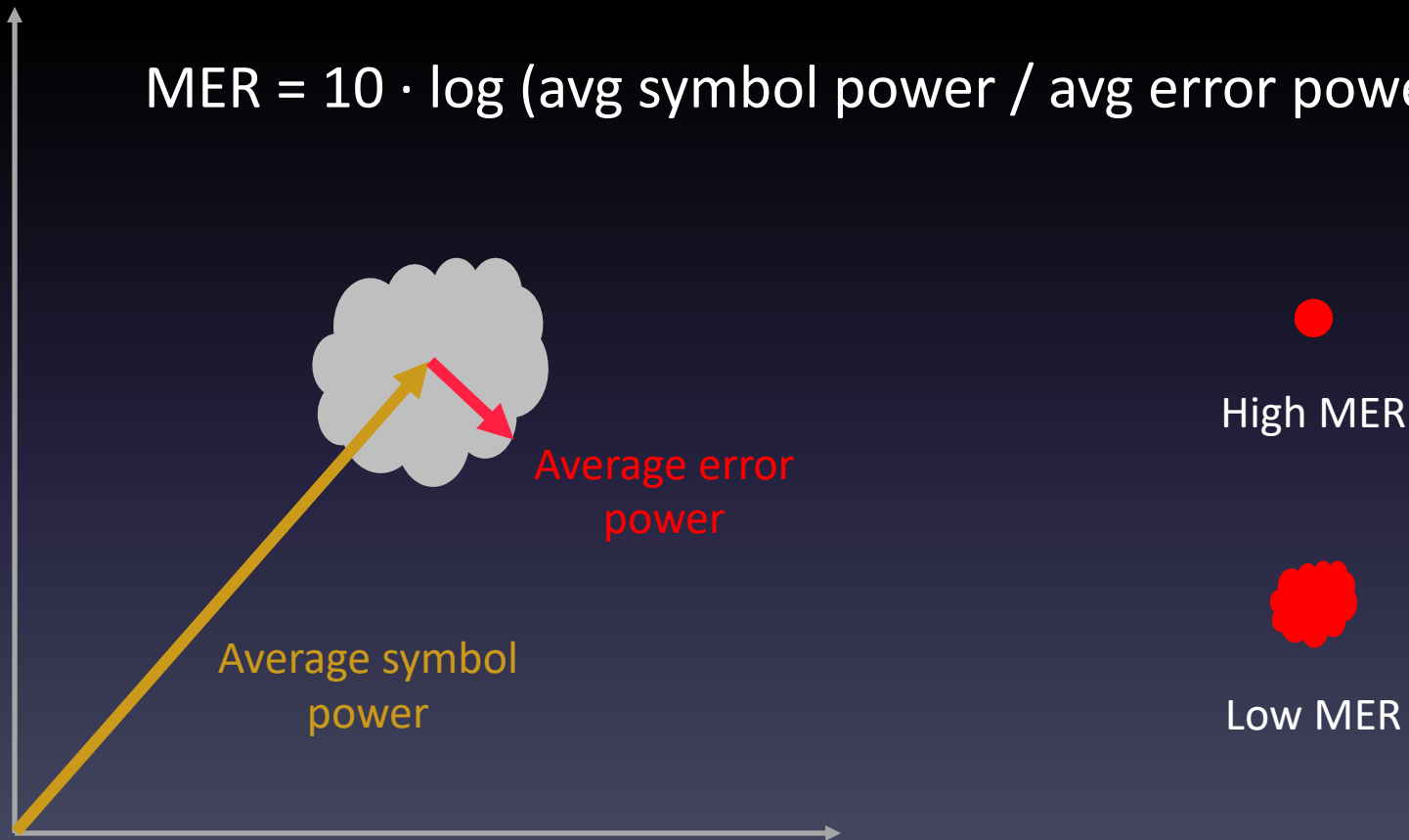


Too much noise?



Modulation Error Ratio (MER)

$$\text{MER} = 10 \cdot \log (\text{avg symbol power} / \text{avg error power})$$



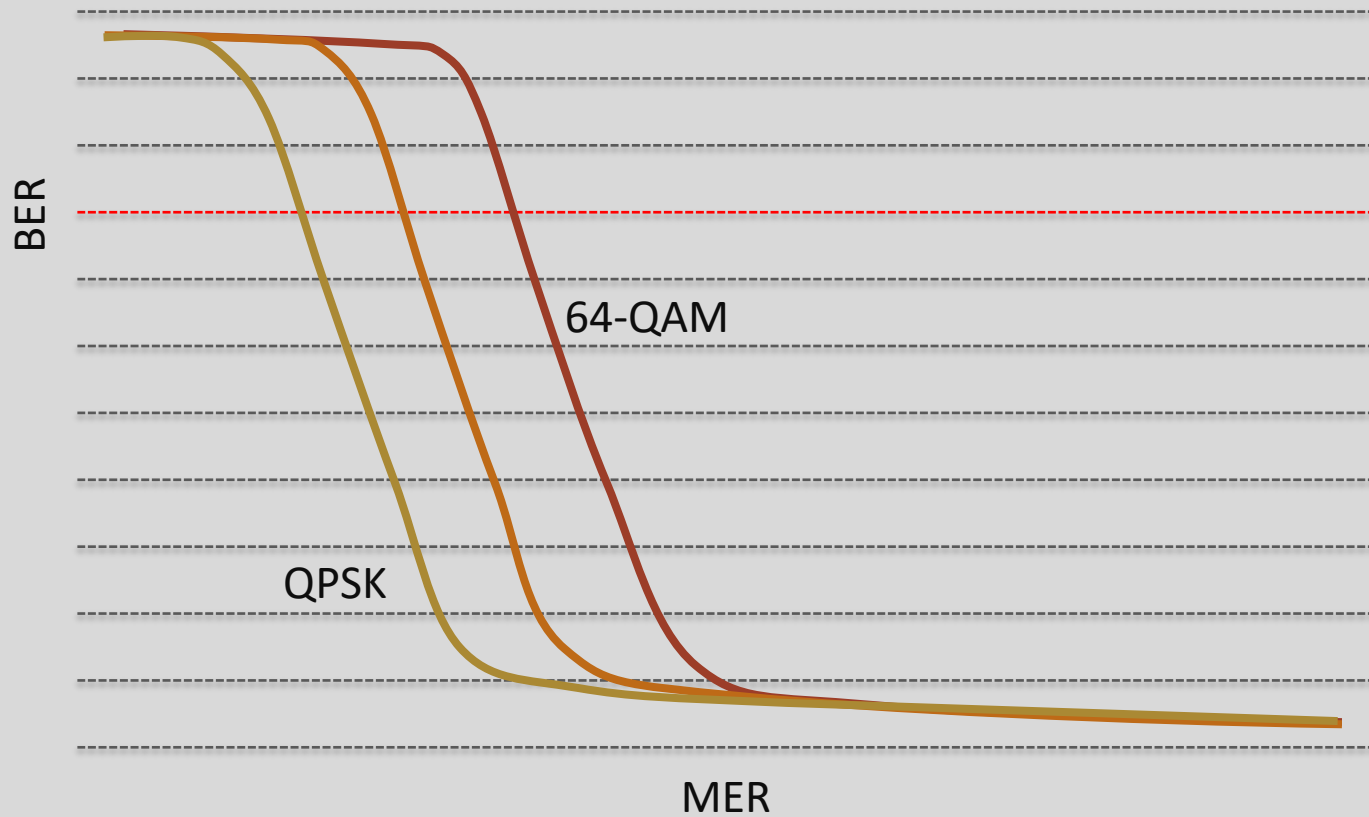
Bit Error Rate (BER)

The fraction of bits that are interpreted wrongly

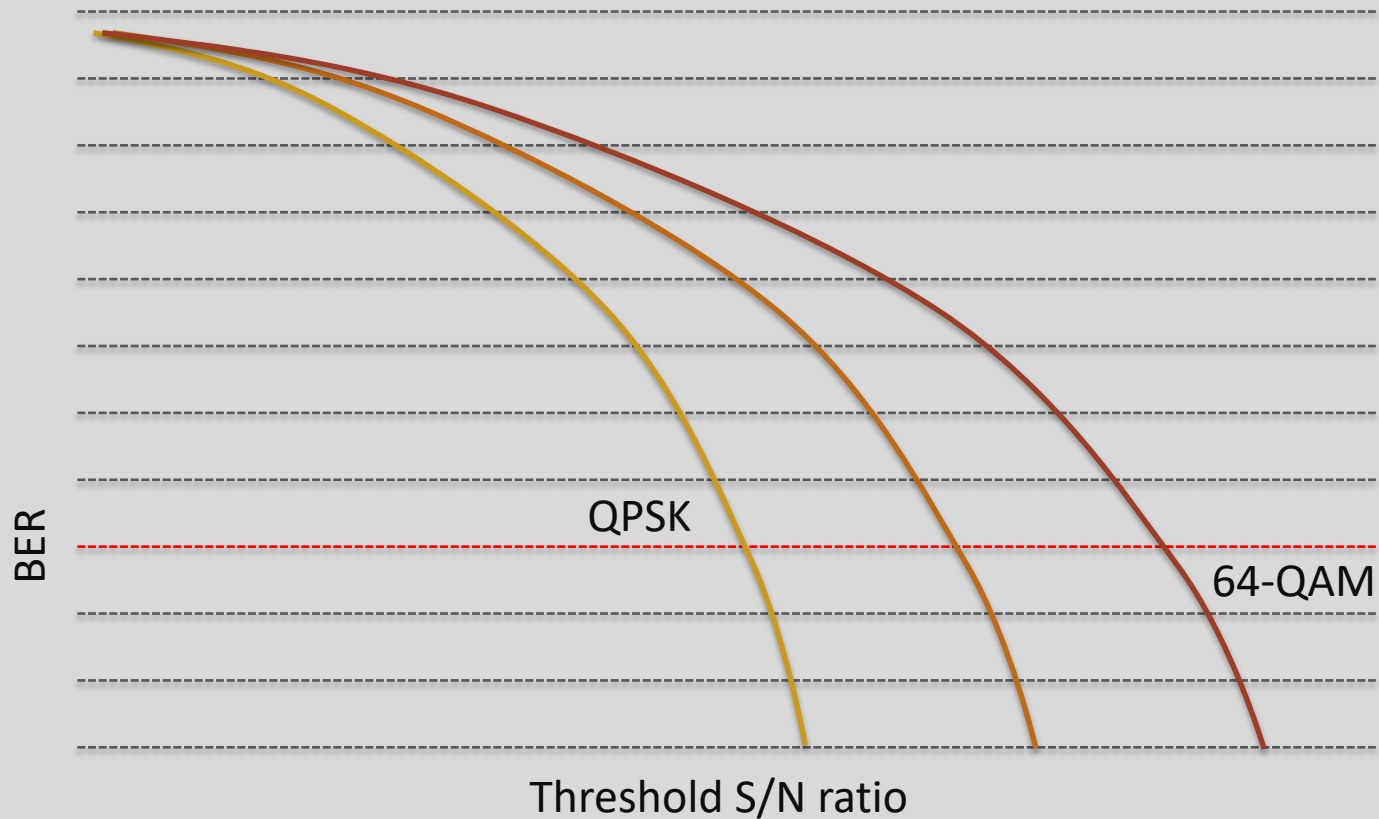
A BER of $2 \cdot 10^{-4}$ means 2 bad bits per 10,000

As MER goes down, BER goes up

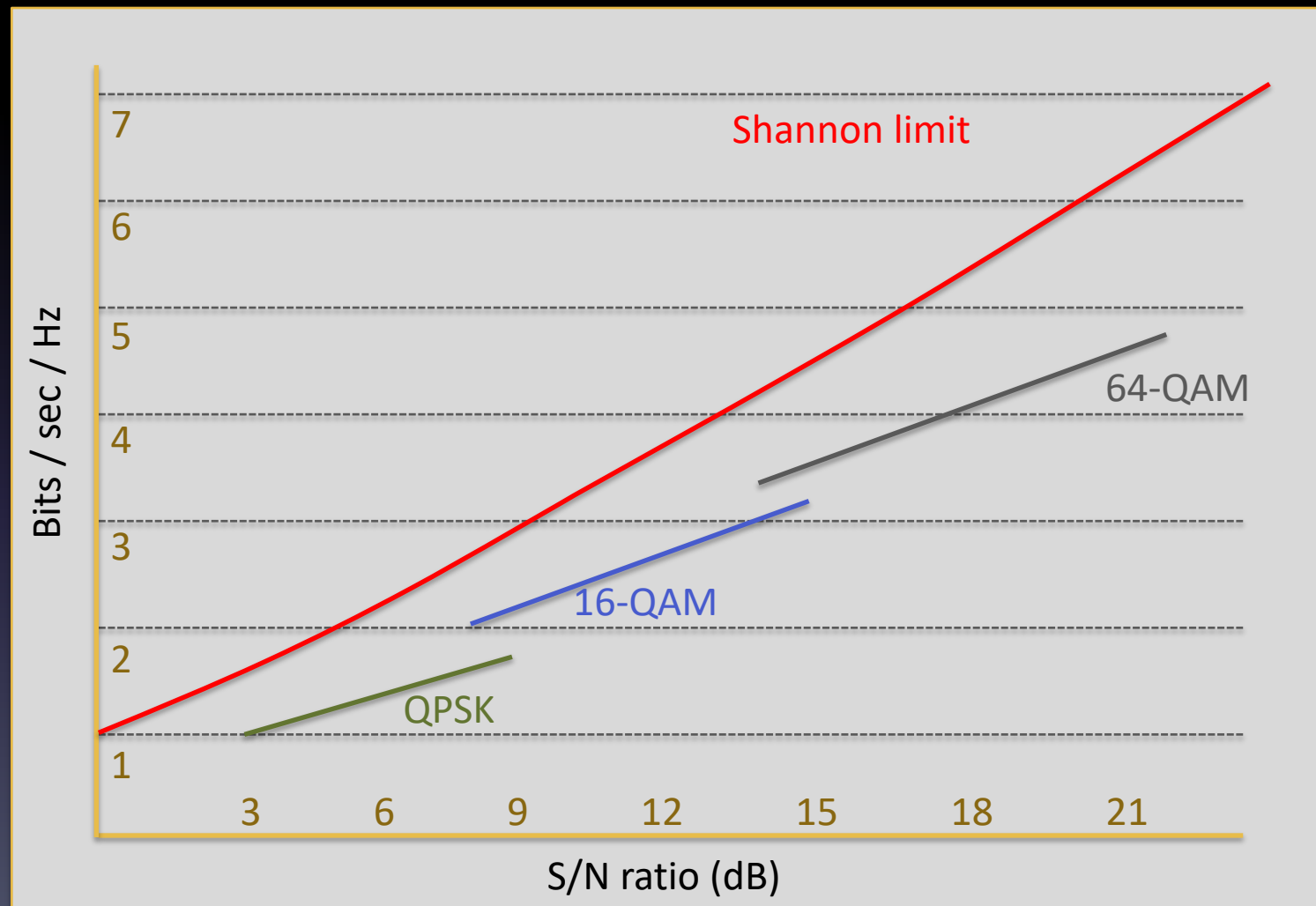
MER vs BER



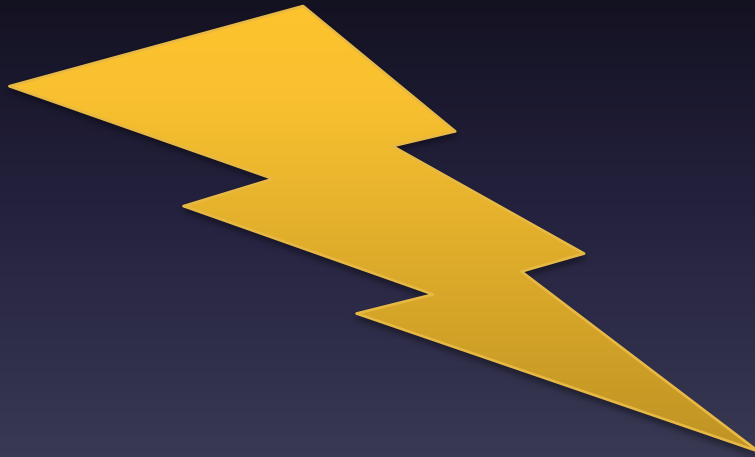
Modulation vs BER



Gaussian Spectral Efficiency



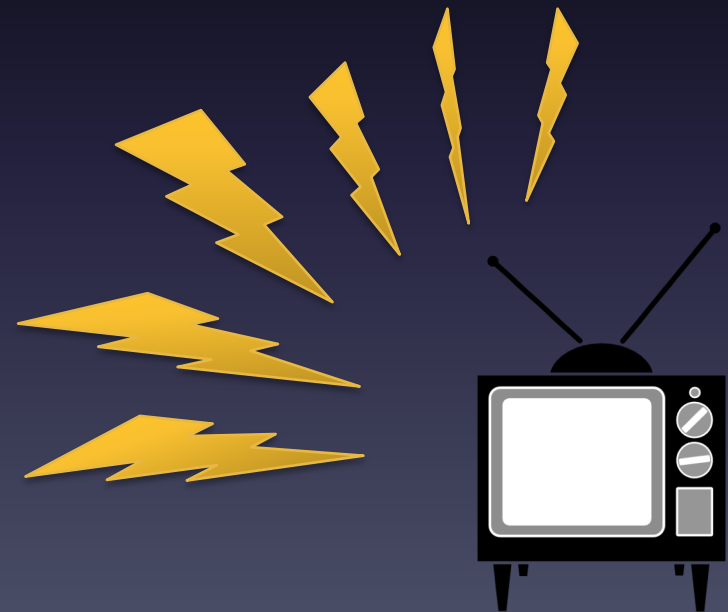
Gaussian Channels



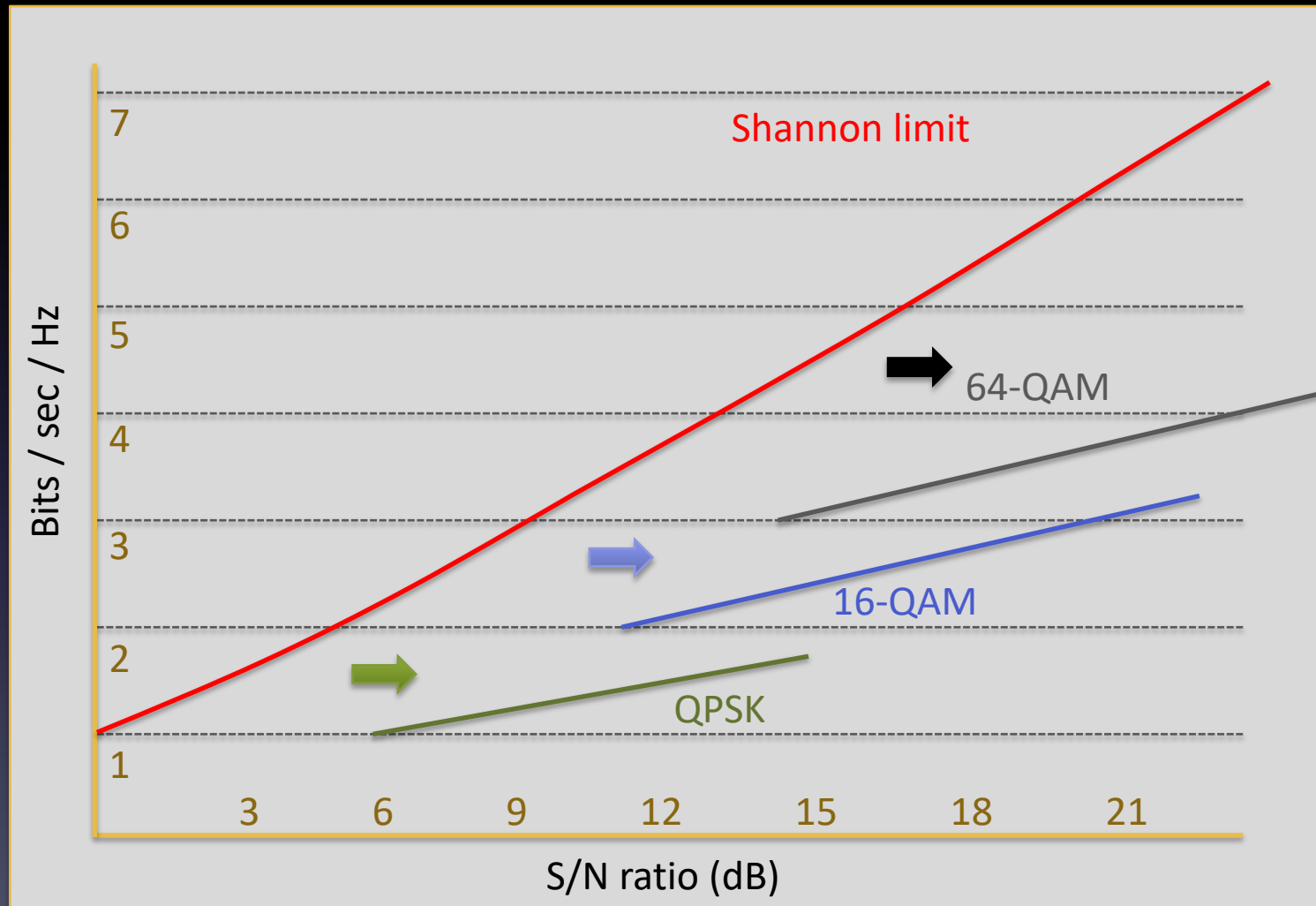
Rician Channels



Rayleigh Channels



Rayleigh Spectral Efficiency



Forward Error Correction

We can't resend the data from the transmitter

Instead, we add error correction to the data sent forward, so the receiver can fix the mistakes

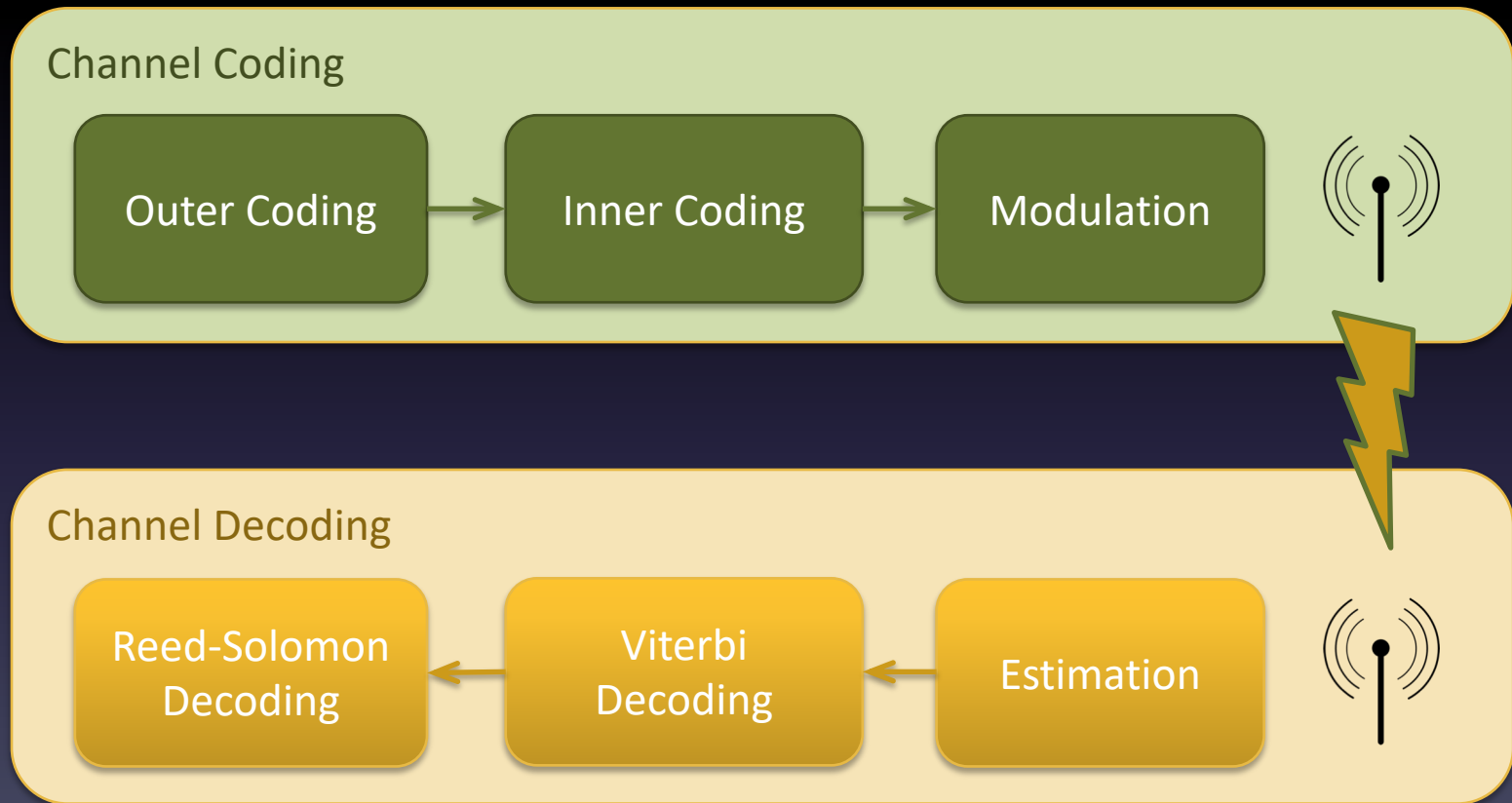
Why Did We Do All That?

In part 2, we'll use this knowledge to engineer DVB-T transmissions for no frame drops

Our goal will be to hit a target BER during the decoding process

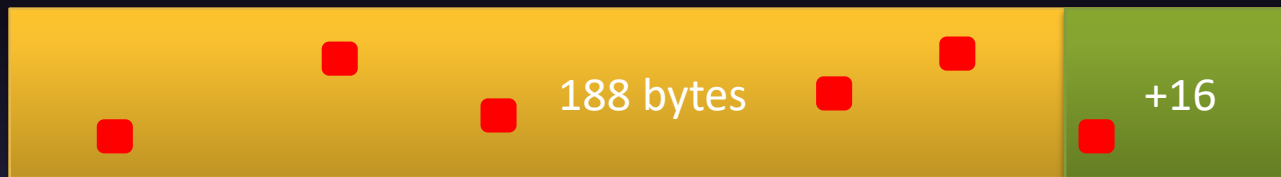


Transmission and Reception



Outer Channel Coding

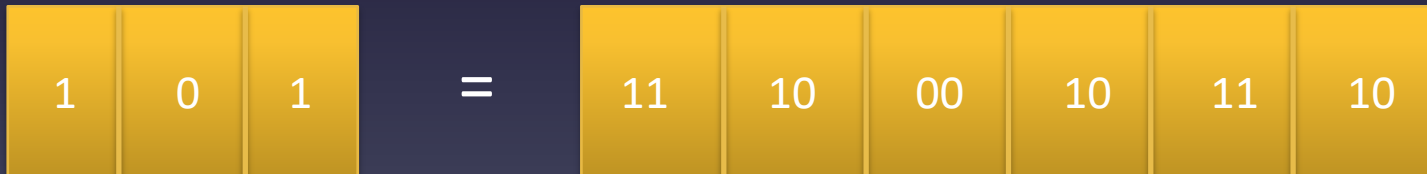
Reed-Solomon block code + byte interleaving



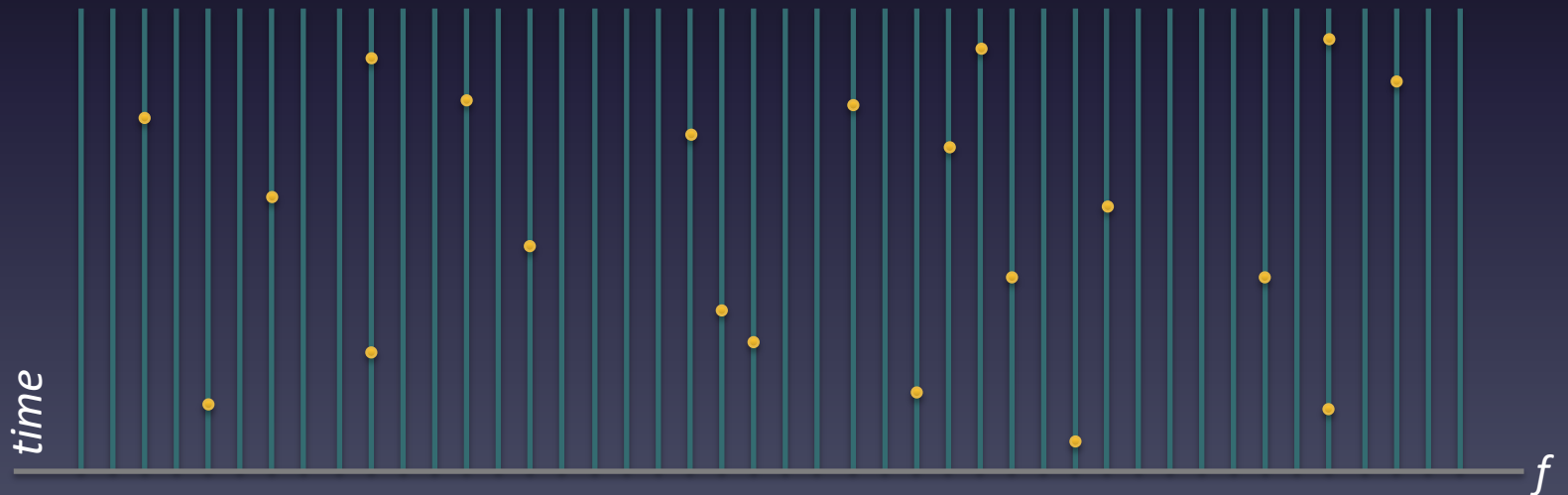
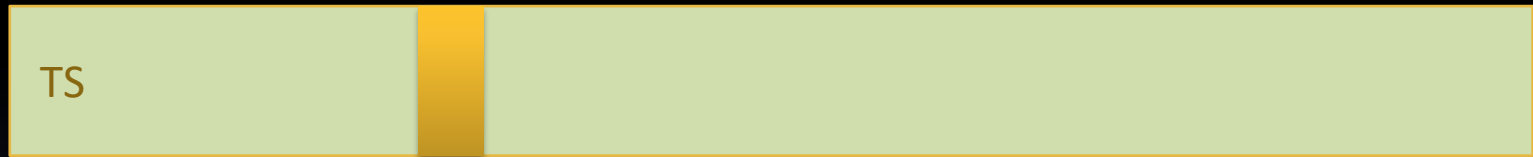
Inner Channel Coding

Convolution code + symbol interleaving

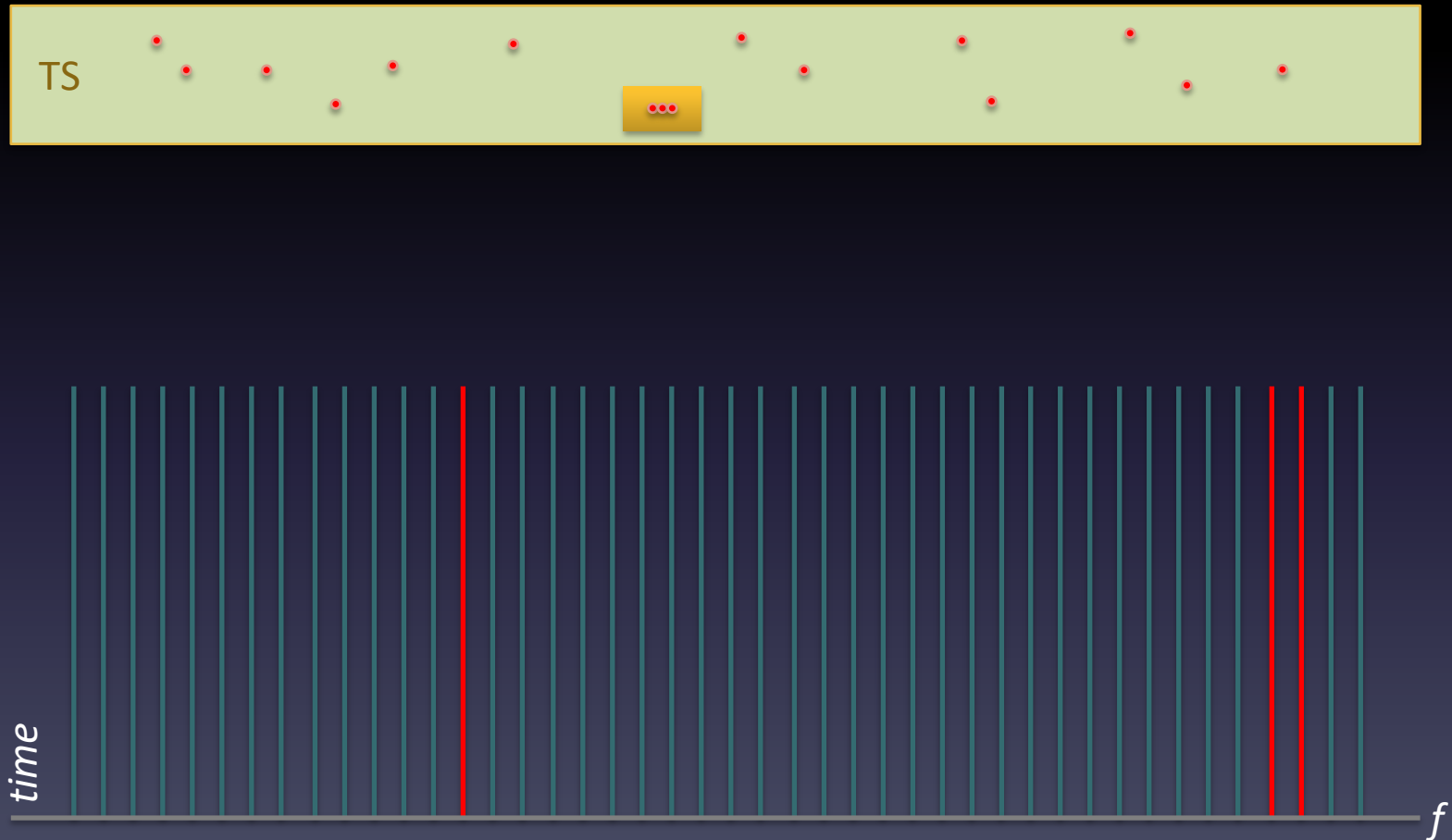
- $1/2, 2/3, 3/4, 5/6, 7/8$
- Content bits / encoded bits



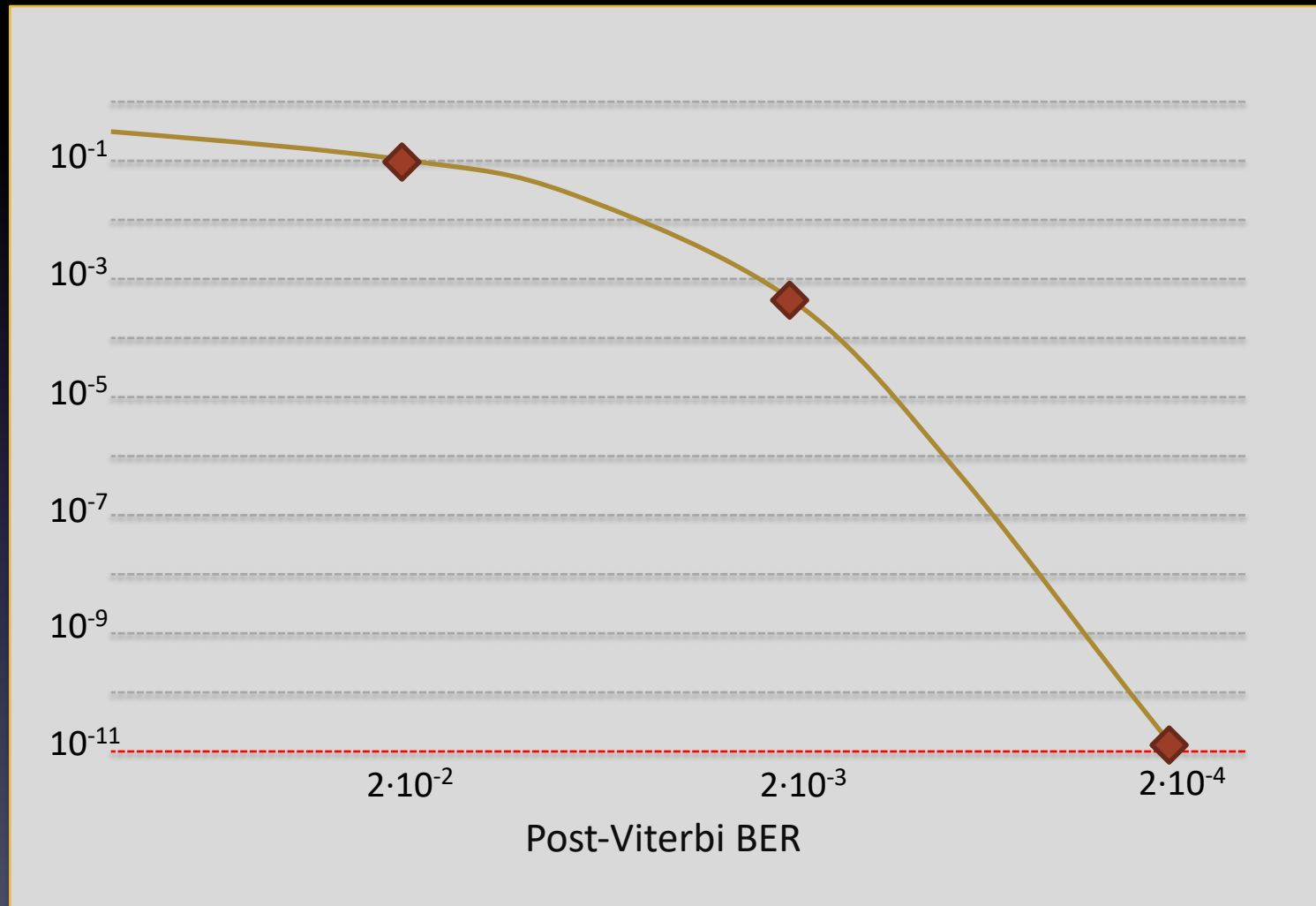
Interleaving onto Carriers



Effects of Channel Fading



BER After Reed-Solomon



Post-Viterbi BER Goal

$$2 \cdot 10^{-4}$$

This level ensures almost no frame drops occur

So What Can We Change?

Code rate (FEC / convolution code)

Amplification

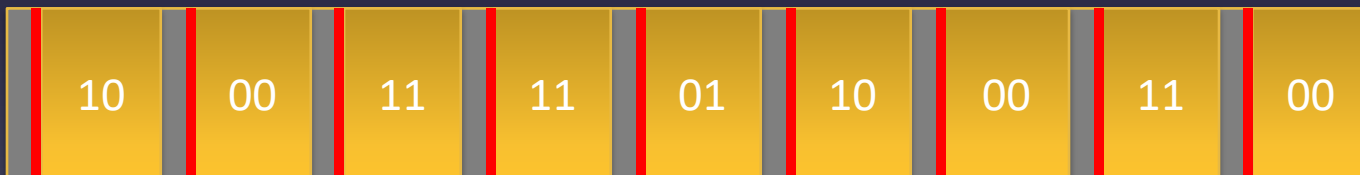
Guard interval

Location — change the environment

Guard Interval

Protects against high-powered echoes

- $1/4$, $1/8$, $1/16$, $1/32$
- Fraction of symbol width



Guard Interval vs Distance

We only need a guard interval for long and *relatively* strong echoes

Unless we're doing DX transmissions, we don't really need much guard interval at all

Original Net Data Rate (Mbps)

Modulation	Code Rate	Guard 1/4	Guard 1/8	Guard 1/16	Guard 1/32
QPSK	1 / 2	3.73	4.15	4.39	4.52
	2 / 3	4.97	5.53	5.85	6.03
	3 / 4	5.60	6.22	6.59	6.79
	5 / 6	6.22	6.91	7.32	7.54
	7 / 8	6.53	7.26	7.68	7.92
16-QAM	1 / 2	7.46	8.29	8.78	9.05
	2 / 3	9.95	11.05	11.71	12.06
	3 / 4	11.20	12.44	13.17	13.57
	5 / 6	12.44	13.82	14.63	15.08
	7 / 8	13.06	14.51	15.37	15.83
64-QAM	1 / 2	11.20	12.44	13.17	13.57
	2 / 3	14.92	16.59	17.56	18.10
	3 / 4	16.80	18.66	19.76	20.36
	5 / 6	18.66	20.73	21.96	22.62
	7 / 8	19.59	21.77	23.05	23.75

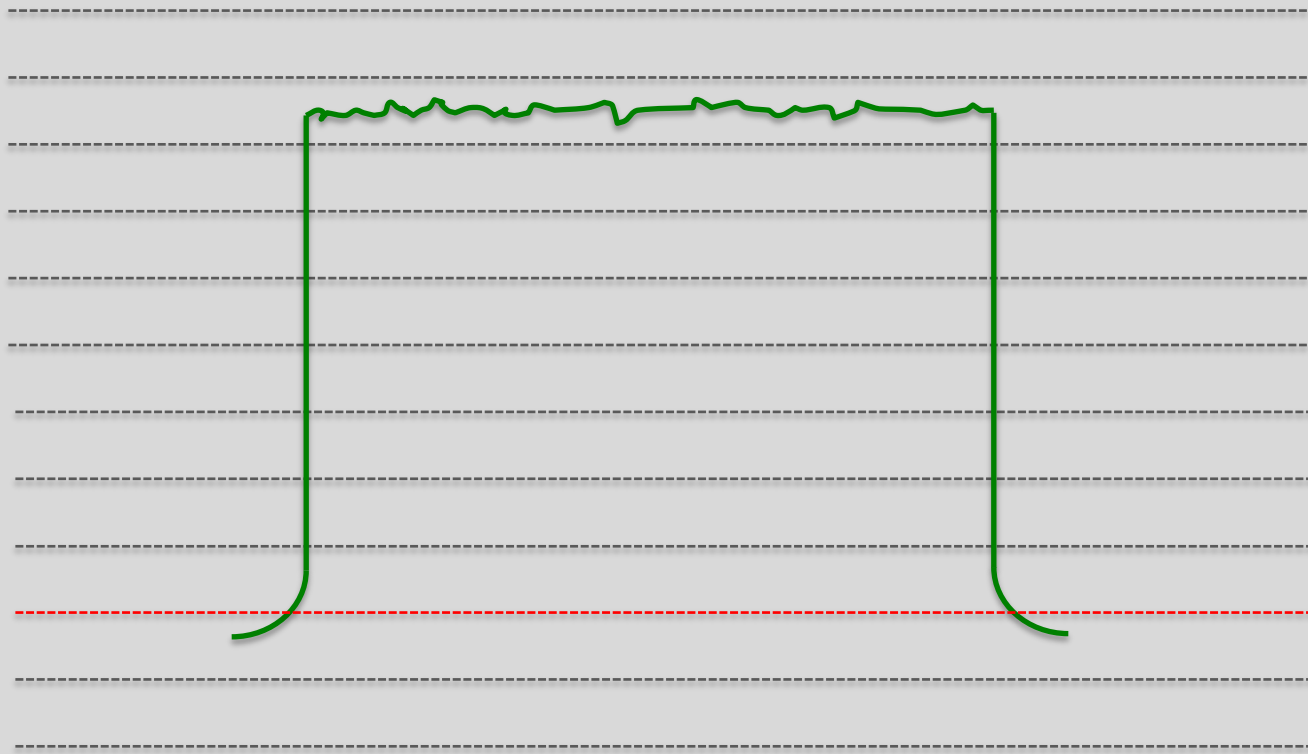
Threshold S/N Ratio (dB)

Modulation	Code Rate	Gaussian	Rician	Rayleigh
QPSK	1 / 2	3.1	3.6	5.4
	2 / 3	4.9	5.7	8.4
	3 / 4	5.9	6.8	10.7
	5 / 6	6.9	8.0	13.1
	7 / 8	7.7	8.7	16.3
16-QAM	1 / 2	8.8	9.6	11.2
	2 / 3	11.1	11.6	14.2
	3 / 4	12.5	13.0	16.7
	5 / 6	13.5	14.4	19.3
	7 / 8	13.9	15.0	22.8
64-QAM	1 / 2	14.4	14.7	16.0
	2 / 3	16.5	17.1	19.3
	3 / 4	18.0	18.6	21.7
	5 / 6	19.3	20.0	25.3
	7 / 8	20.1	21.0	27.9

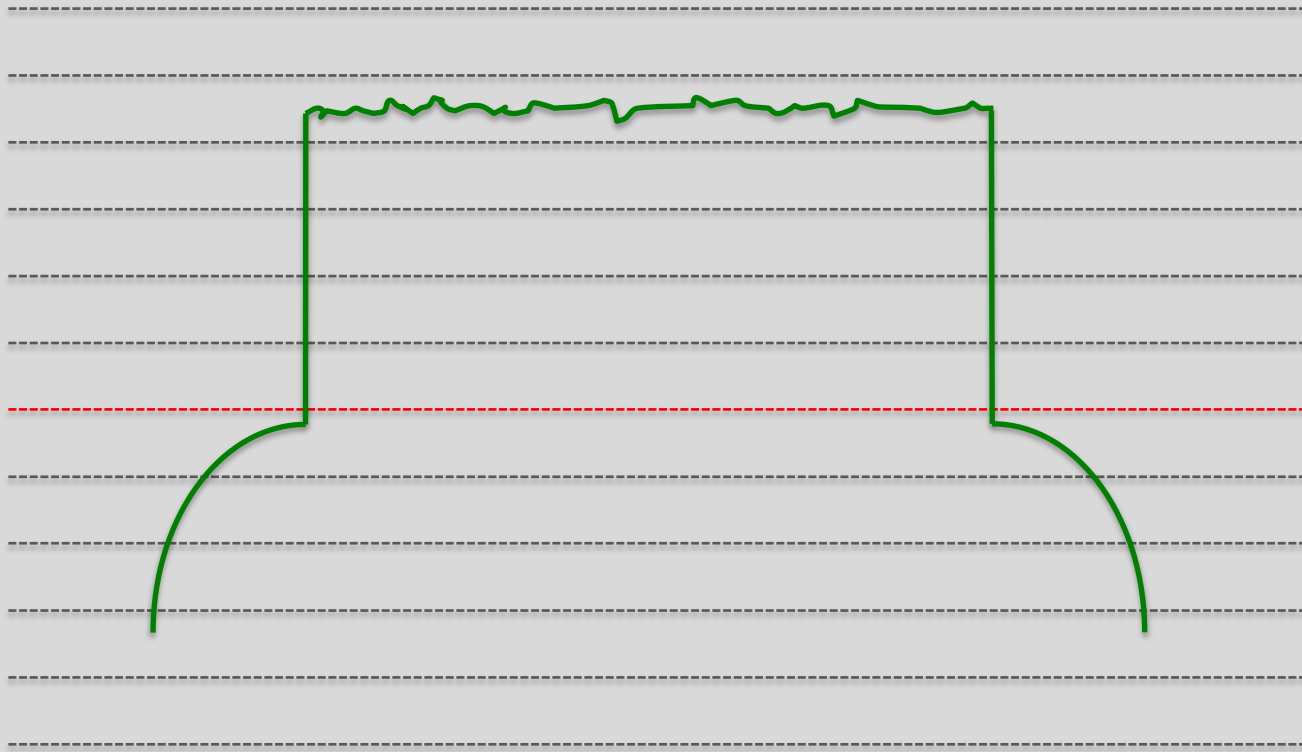
New Net Data Rate (Mbps)

Modulation	Code Rate	Guard 1/4	Guard 1/8	Guard 1/16	Guard 1/32
QPSK	1 / 2	3.73	4.15	4.39	4.52
	2 / 3	4.97	5.53	5.85	6.03
	3 / 4	5.60	6.22	6.59	6.79
	5 / 6	6.22	6.91	7.32	7.54
	7 / 8	6.53	7.26	7.68	7.92
16-QAM	1 / 2	7.46	8.29	8.78	9.05
	2 / 3	9.95	11.05	11.71	12.06
	3 / 4	11.20	12.44	13.17	13.57
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64-QAM	1 / 2	11.20	12.44	13.17	13.57
	2 / 3	14.92	16.59	17.56	18.10
	3 / 4	16.80	18.66	19.76	20.36
	5 / 6	18.66	20.73	21.96	22.62
	7 / 8	19.59	21.77	23.05	23.75

DVB-T Signal



After Amplification



Amplification Settings

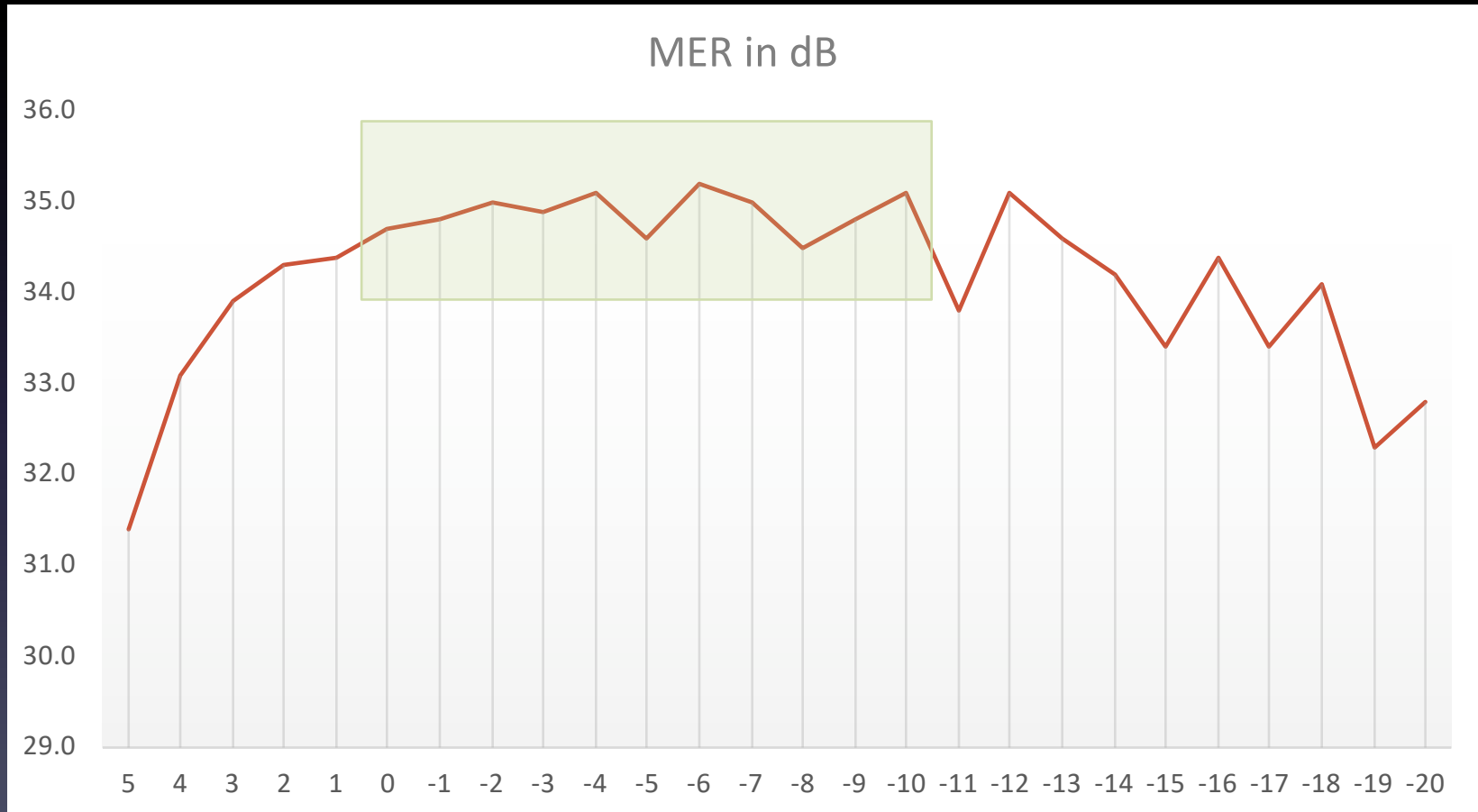
We want 30+ dB to the noise shoulder

So we attenuate modulator output by 15 dB *

Amplifier output

Low	25 dBm	300 mw
Medium	30 dBm	1 watt
High	35 dBm	3 watts

Modulator Calibration



Current Draw vs Power

Camera	0.4 amps
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Modulator	0.4 amps
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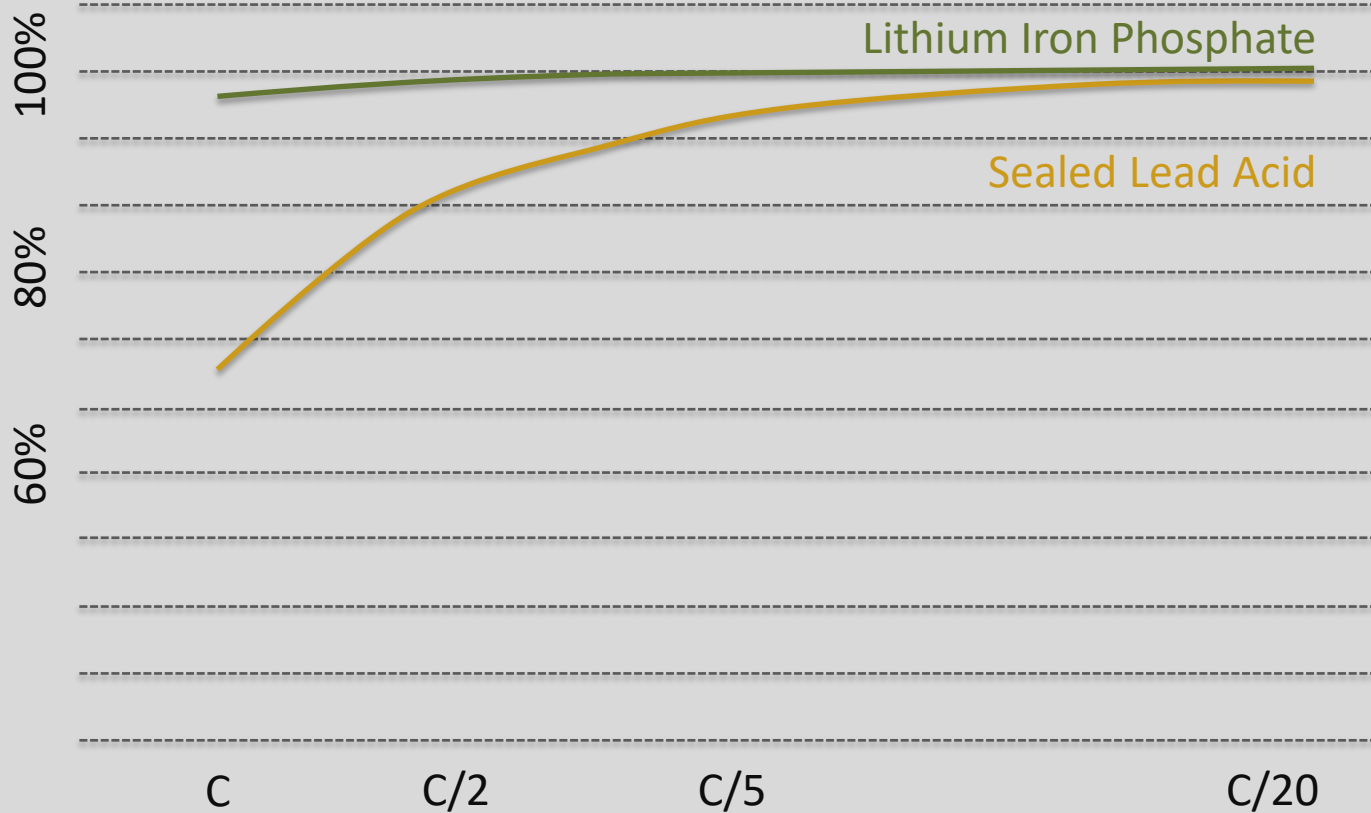
Amplifier		
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Low	0.6 amps	1.4 amps
-----	----------	----------

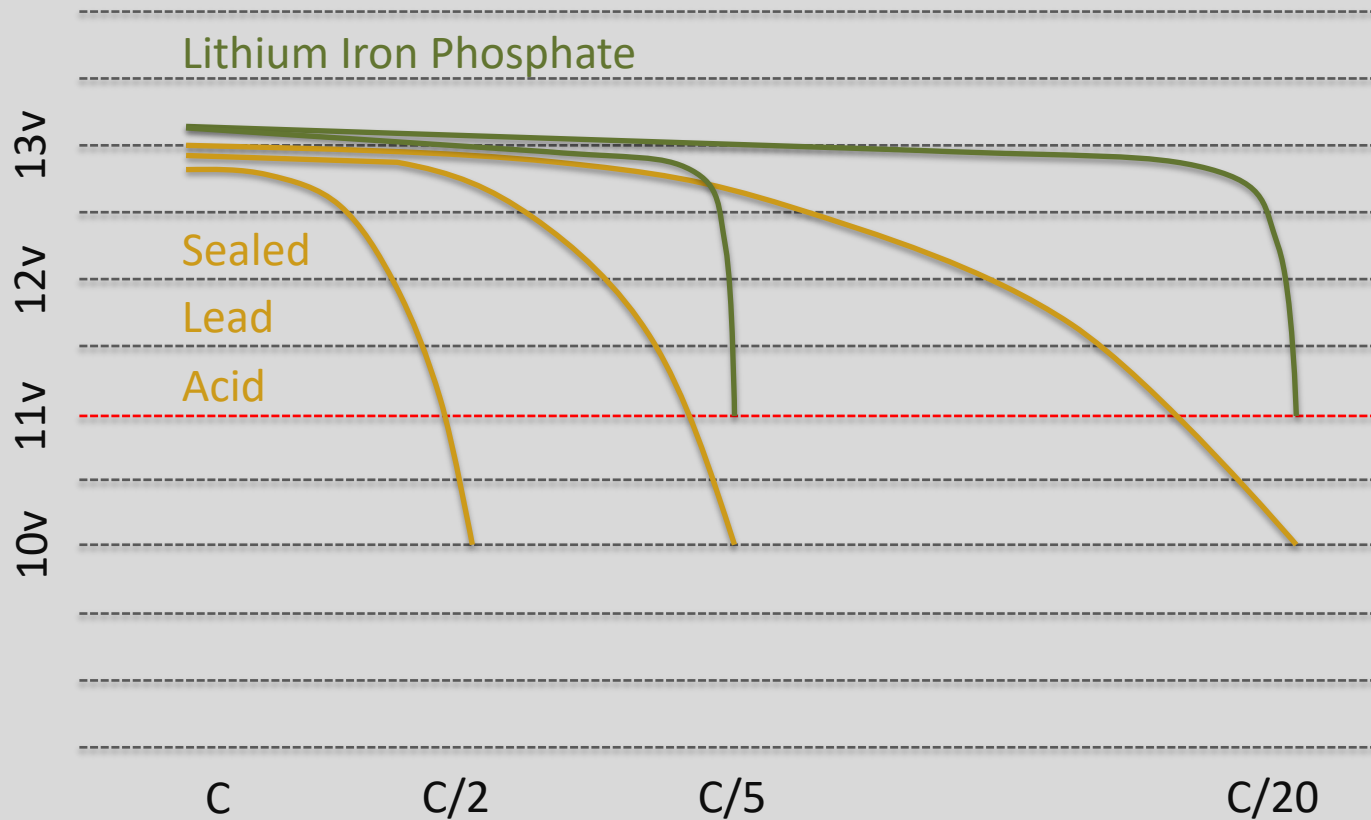
Medium	1.0 amps	1.8 amps
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High	3.0 amps	3.8 amps
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Battery Capacity



Battery Voltage



Battery Choices for DVB-T

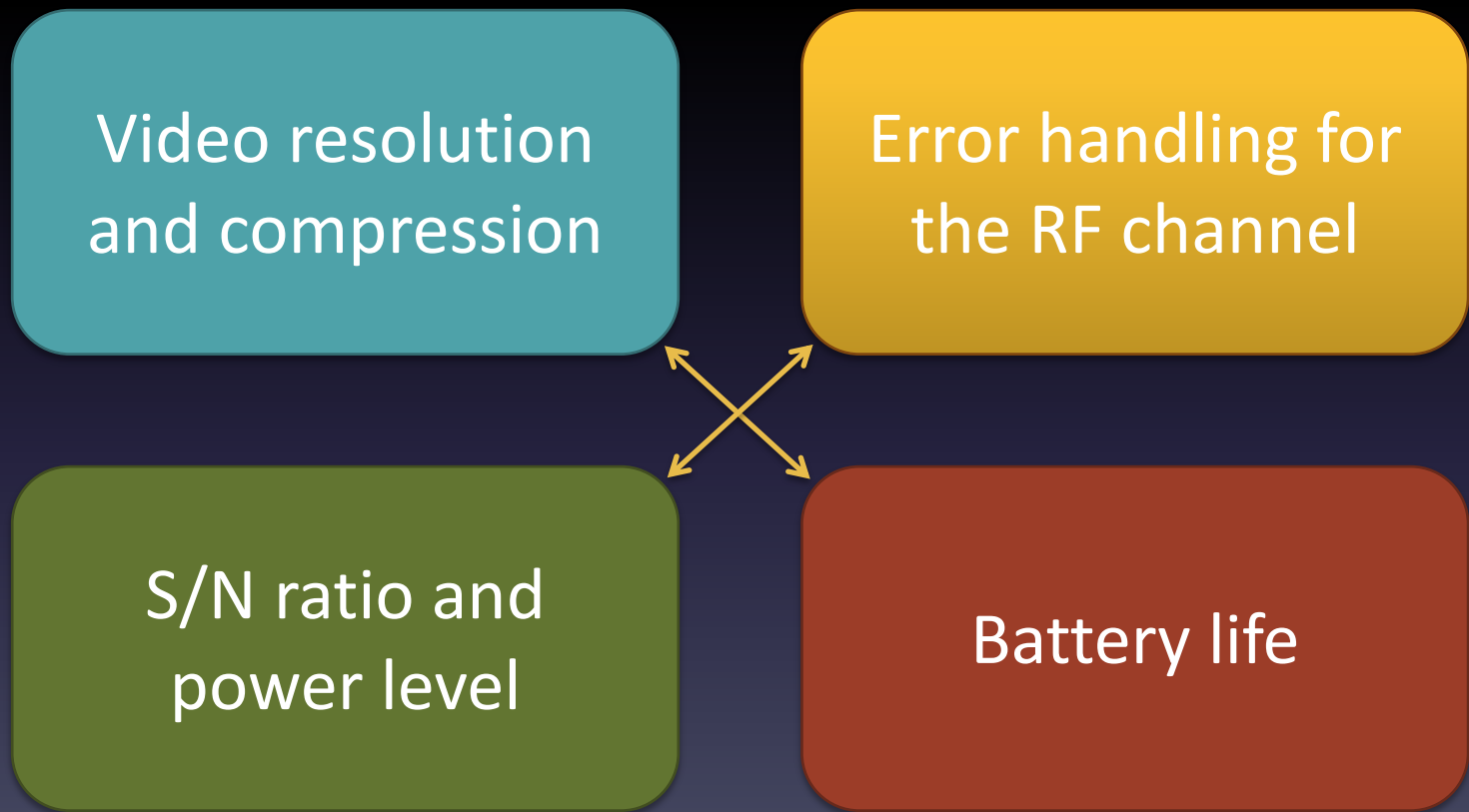
7.5 Ah SLA batteries

- Last about 60-90 minutes on high
- May degrade amplifier output before that

LFP batteries

- About 4 times the energy density per pound
- About 5 times the cost per amp hour

Revisit the Key Tradeoffs



Typical Parameters

Thursday ATV nets

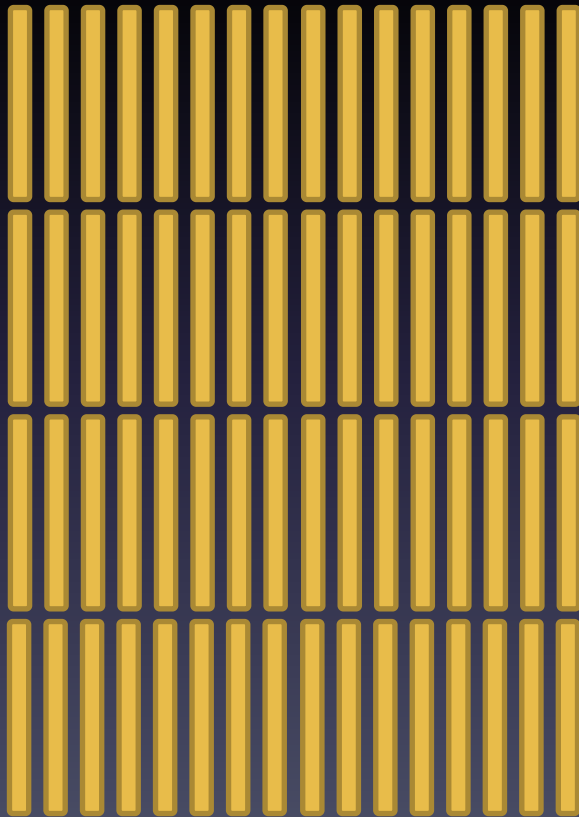
- QPSK, 5/6 coding rate, 1/16 guard interval
- 6.0+ Mbps data rate, 1080p

Typical CU parameters

- QPSK, 3/4 coding rate, 1/32 guard interval
- 5.6 Mbps data rate, 720p

Carrier Modes

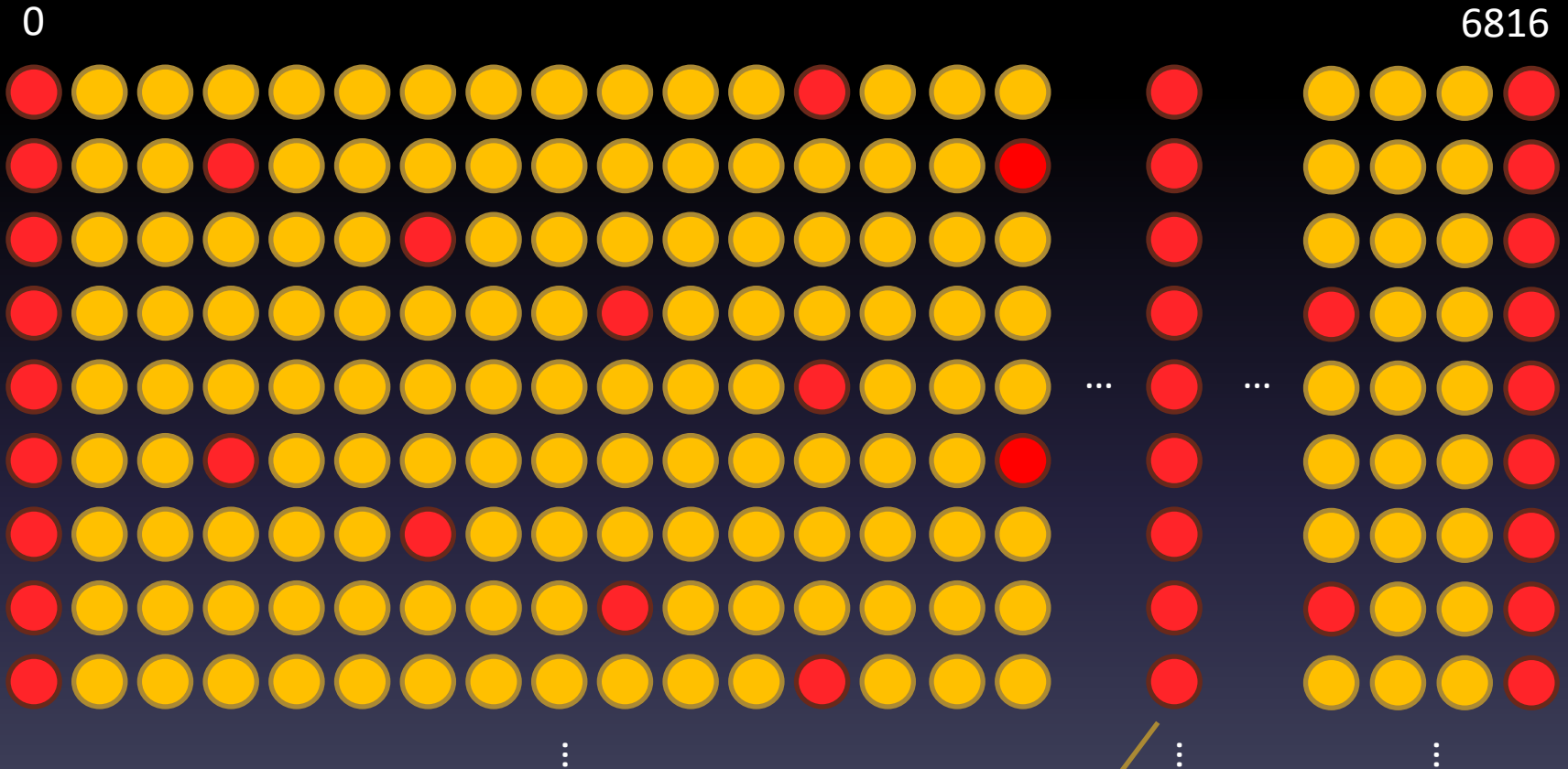
8K



2K



Pilots



Continual pilots and
TPS carriers every so often

Alternative Performance Goals

60 seconds of “error free” video

Requires 1.3 dB less SNR than $2 \cdot 10^{-4}$ BER goal

ATSC vs DVB-T

Only one carrier & pilot
modulation (8ASK, 3 bits/symbol)
coding rate (2/3)
standard bit rate (19.4 Mbps)

But it's cheaper! *

* Well, the set-top boxes are cheaper ...

Can We See the Numbers?

Using the Hi-Des receiver as a test tool

Using a commercial DVB-T test tool

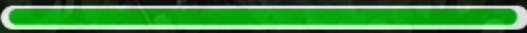
Yellow Button Screen

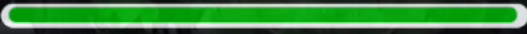
Frequency: 423000

Bandwidth: 6M

TPS Lock: Yes

MPEG2 Lock: Yes

Signal Quality:  100 %

Signal Strength:  100 %

Constellation: QPSK

High Code Rate: 2/3

Guard Interval: 1/32

TransmissionMode: 8K

Yellow Button Overlay

PAT version: 0

-11 dBm

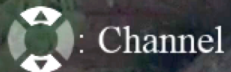
K0DVB-TV

23 dB



Green Button Screen

Demod FW Version:
Demod Tuner ID:
Frequency: 423000 Transmission Mode: 8K
Bandwidth: 6M Frequency Offset: 0
TPS Lock: Yes Signal Quality: 100
MPEG2 Lock: Yes Signal Strength: 100
RSD Abort Count: 0 Signal Strength dBm: -11
Post VTB BER: 0.00e+00 SNR: 22
Constellation: QPSK RSSI: 113
High Code Rate: 2/3
Guard Interval: 1/32



: Channel



: Page



: Exit

READ

DEMOM

Reg: 0 x

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--

Val: 0 x

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: R/W



: D/T



: Reg

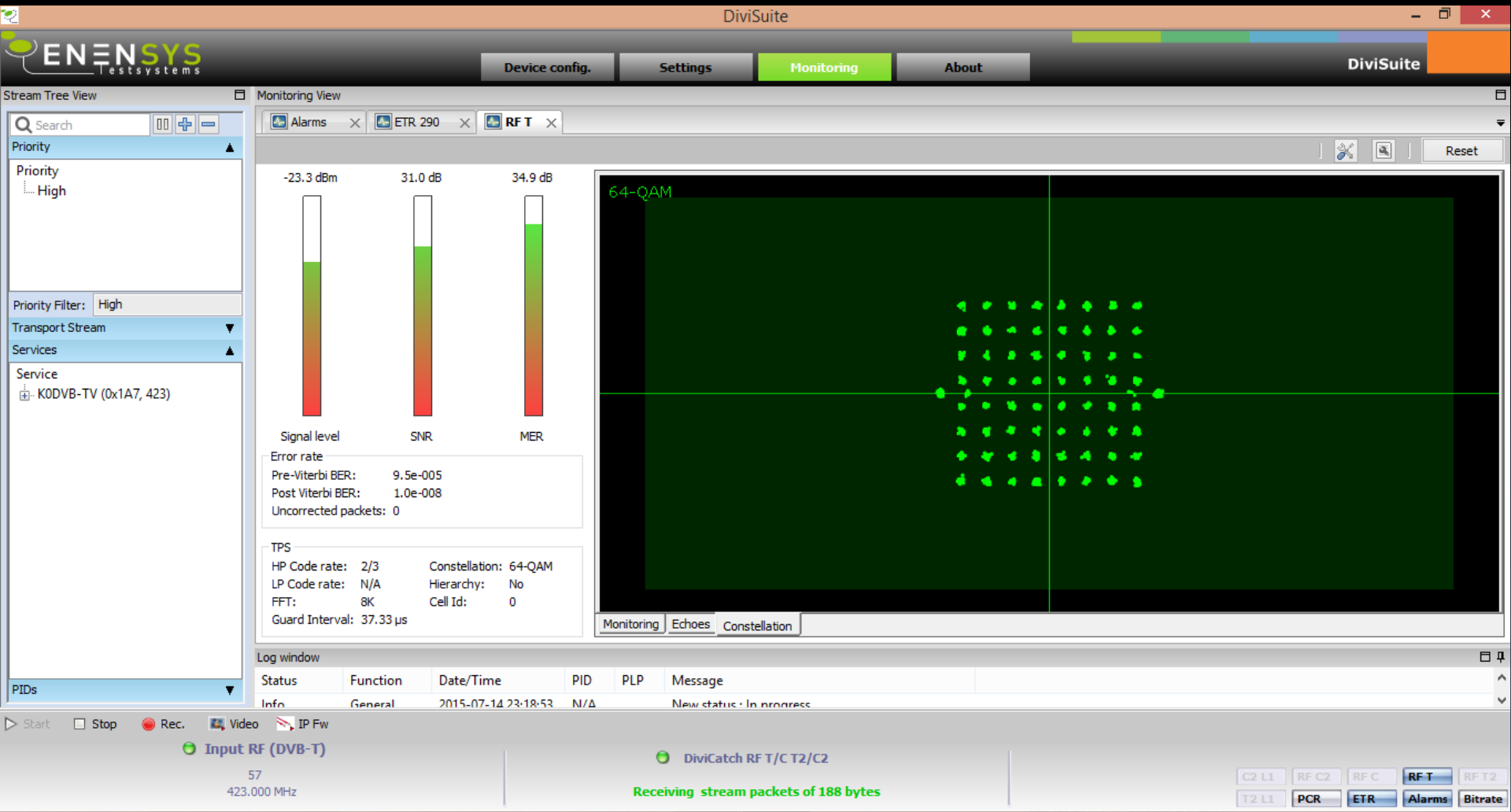


: Val



: Run

Commercial Test Tools



Good: Without Preamp

DiviSuite

Device config. Settings **Monitoring** About

Stream Tree View

Search

Priority

Priority Filter: High

Transport Stream

Table

- PAT (TSId 423, s0)
- PMT (progId 423, s0)
- NIT_actual (NetworkId 423, s0)
- SDT_actual (TSId 423, s0)
- EIT_actual (ServiceId 423, s0)

Services

PIDs

Monitoring View

Bitrate Alarms RF T ETR 290 PCR

Signal level: -79.1 dBm

SNR: 20.1 dB

MER: 19.3 dB

Error rate

Pre-Viterbi BER: 3.3e-005

Post Viterbi BER: 7.0e-007

Uncorrected packets: 0

TPS

HP Code rate: 5/6

LP Code rate: N/A

FFT: 8K

Guard Interval: 74.67 μ s

Constellation: QPSK

Hierarchy: No

Cell Id: 0

Monitoring Echoes Constellation

Log window

Status	Function	Date/Time	PID	PLP	Message
Info	General	2015-07-30 15:01:33	N/A		New status : In progress
Info	General	2015-07-30 15:01:18	N/A		New status : Device opened

Start Stop Rec. Video IP Fw

Input RF (DVB-T)

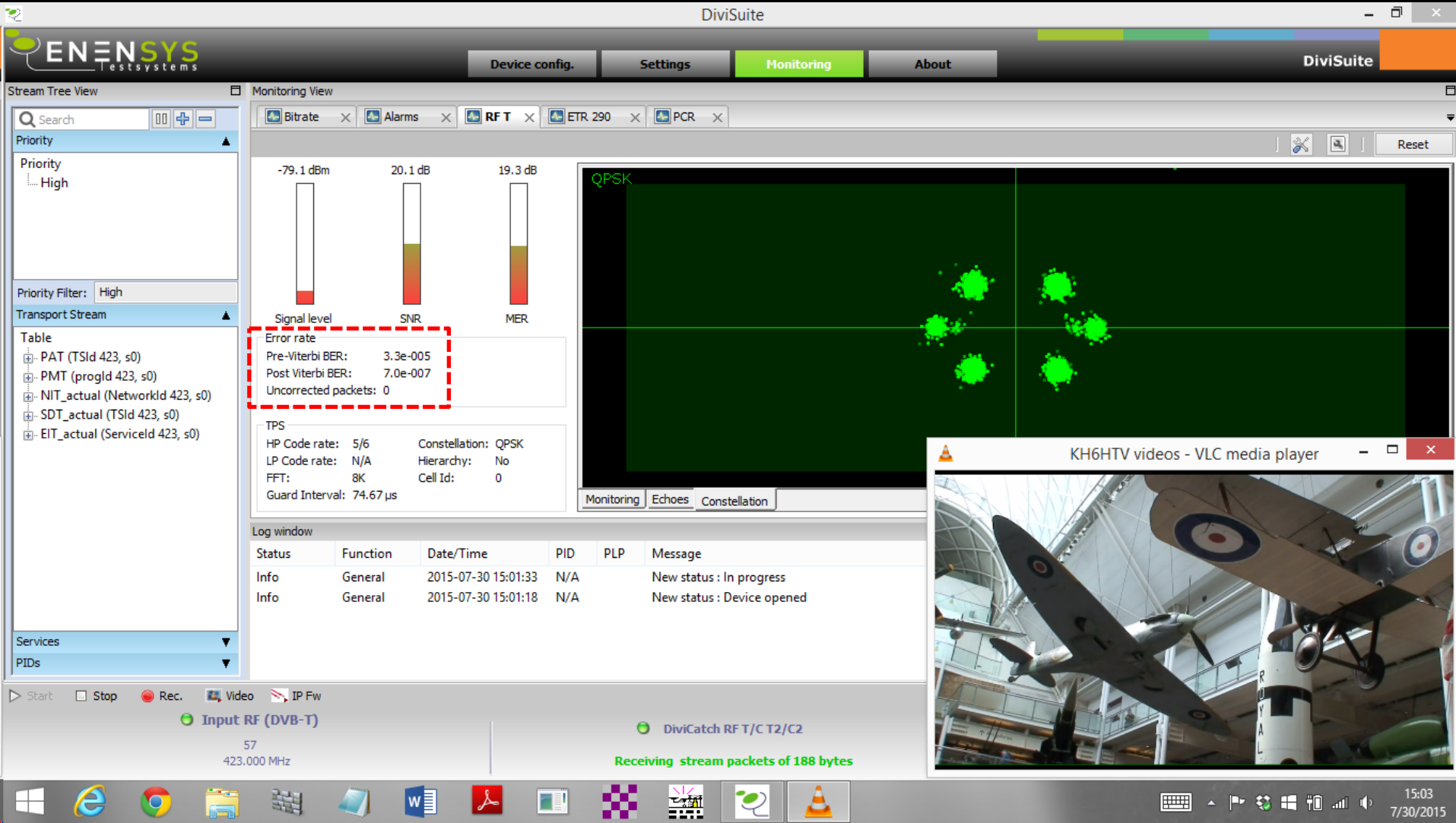
57

423.000 MHz

DiviCatch RF T/C T2/C2

Receiving stream packets of 188 bytes

KH6HTV videos - VLC media player



Better: With Preamp

The screenshot displays the DiviSuite software interface, which is used for monitoring and analyzing digital video broadcasts. The interface is divided into several sections:

- Top Bar:** Contains the ENESYS Testsystems logo and navigation tabs for Device config., Settings, Monitoring (active), and About.
- Stream Tree View:** Located on the left, it shows a hierarchy of streams. The 'Transport Stream' section is expanded, listing several streams: PAT (TSId 423, s0), PMT (progId 423, s0), NIT_actual (NetworkId 423, s0), SDT_actual (TSId 423, s0), and EIT_actual (ServiceId 423, s0).
- Monitoring View:** The main area on the right, which is further divided into sub-sections:
 - RF T:** Displays three vertical bar charts for Signal level (-58.6 dBm), SNR (22.6 dB), and MER (20.9 dB). Below these charts, a red dashed box highlights the 'Error rate' section, which includes: Pre-Viterbi BER: 2.4e-005, Post Viterbi BER: 1.0e-008, and Uncorrected packets: 0.
 - TPS:** Displays transmission parameters: HP Code rate: 5/6, LP Code rate: N/A, FFT: 8K, Guard Interval: 74.67 µs, Constellation: QPSK, Hierarchy: No, and Cell Id: 0.
 - Log window:** A table at the bottom of the Monitoring View showing system logs.
- Bottom Bar:** Contains status information: 'Input RF (DVB-T)' at 57 MHz and 423.000 MHz, and 'DiviCatch RF T/C T2/C2' receiving stream packets of 188 bytes.
- Taskbar:** The Windows taskbar at the bottom shows various application icons, including Internet Explorer, Google Chrome, and VLC media player.

In the bottom right corner, a small window titled 'KH6HTV videos - VLC media player' is visible, showing a video of a military aircraft.

Status	Function	Date/Time	PID	PLP	Message
Info	General	2015-07-30 15:01:33	N/A		New status : In progress
Info	General	2015-07-30 15:01:18	N/A		New status : Device opened

Really Bad Signals

DiviSuite

ENESYS Testsystems

Device config. Settings **Monitoring** About

Stream Tree View

Search

Priority

Priority Filter: High

Transport Stream

Table

- PAT (TSId 423, s0)
- PMT (progId 423, s0)
- NIT_actual (NetworkId 423, s0)
- SDT_actual (TSId 423, s0)
- EIT_actual (ServiceId 423, s0)

Services

PIDs

Start Stop Rec. Video IP Fw

Input RF (DVB-T)

57
423.000 MHz

Monitoring View

Bitrate Alarms ETR 290 PCR RFT

-86.0 dBm 5.8 dB 4.3 dB

Signal level SNR MER

Error rate

Pre-Viterbi BER: 3.3e-002

Post Viterbi BER: 2.2e-004

Uncorrected packets: 0

TPS

HP Code rate: 2/3 Constellation: QPSK

LP Code rate: N/A Hierarchy: No

FFT: 8K Cell Id: 0

Guard Interval: 37.33 μ s

Log window

Status	Function	Date/Time
Info	General	2015-07-16 15:22

QPSK

KH6HTV videos - VLC media player

Media Playback Audio Video Subtitle Tools View Help

15:57
7/16/2015

Echo Estimation

DiviSuite

ENESYS Testsystems

Device config. Settings **Monitoring** About

Stream Tree View

Search

Priority

Priority Filter: High

Transport Stream

Services

Service

NOVE (0x38D, 909)

Monitoring View

Bitrate Alarms RF T ETR 290 PCR

Signal level: -67.2 dBm

SNR: 13.4 dB

MER: 13.6 dB

Error rate

Pre-Viterbi BER: 5.8e-004

Post Viterbi BER: 3.6e-005

Uncorrected packets: 0

TPS

HP Code rate: 5/6

LP Code rate: N/A

FFT: 8K

Guard Interval: 74.67 µs

Constellation: QPSK

Hierarchy: No

Cell Id: 0

Monitoring Echoes Constellation

Value (dB)

Delay (µs)

	1	2	3	4	5	6	7	8
Value (dB)	-11.10	-40.50	-41.80	-42.60	-42.70	-43.00	-43.20	-43.30
Delay (µs)	1.55	-147.78	-1.55	-144.67	-192.89	-20.22	-31.11	-110.44

Log window

Status	Function	Date/Time	PID	PLP	Message
Info	General	2015-08-06 16:28:10	N/A		New status : In progress
Info	General	2015-08-06 16:27:56	N/A		New status : Stopped
Info	General	2015-08-06 15:59:13	N/A		New status : In progress
Info	General	2015-08-06 15:56:12	N/A		New status : Stopped
Info	General	2015-08-06 15:29:13	N/A		New status : In progress

Start Stop Rec. Video IP Fw

Input RF (DVB-T)

75a

909.000 MHz

DiviCatch RF T/C T2/C2

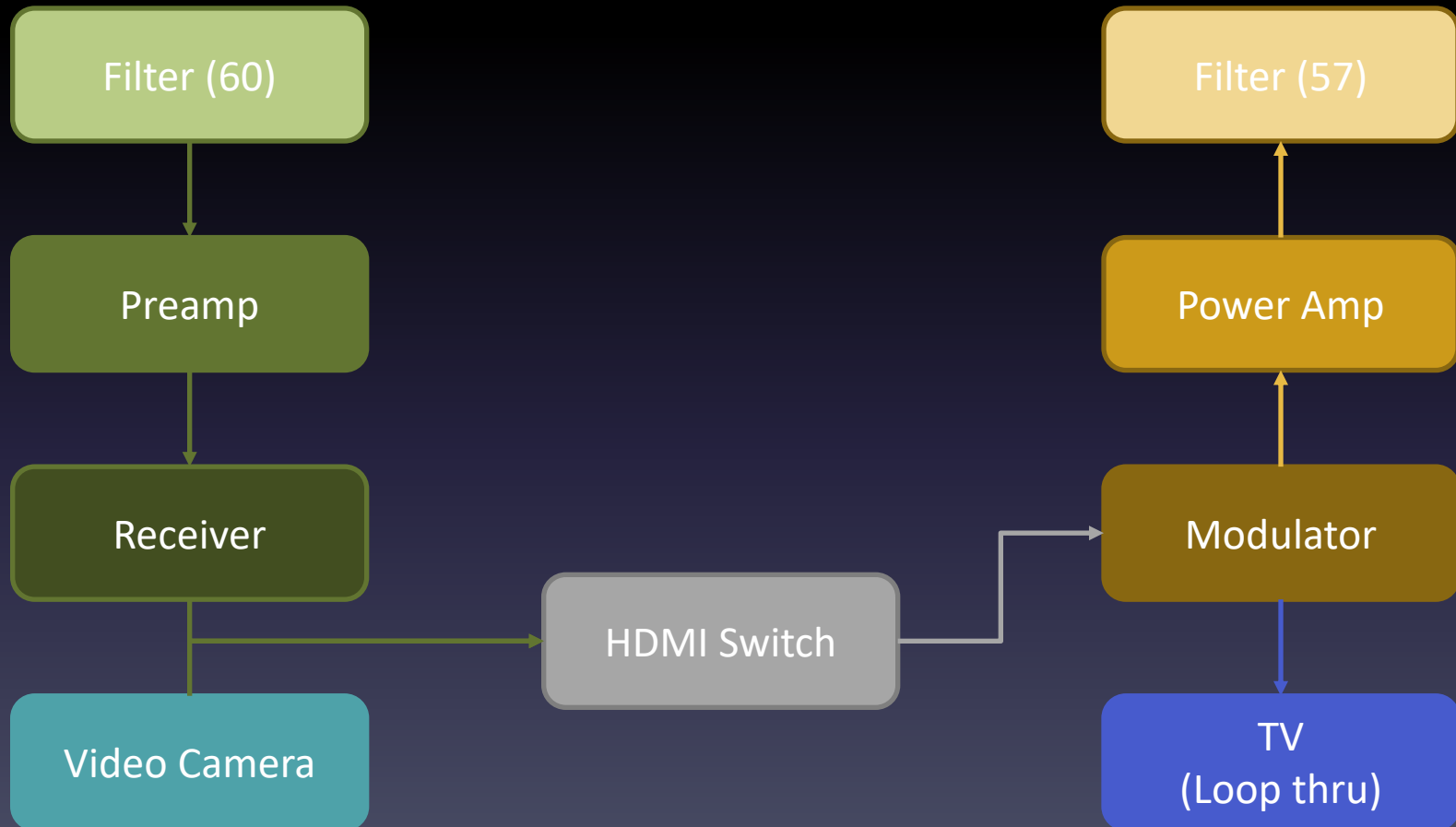
Receiving stream packets of 188 bytes

C2 L1 RF C2 RF C RF T RF T2

T2 L1 PCR ETR Alarms Bitrate

16:31 8/6/2015

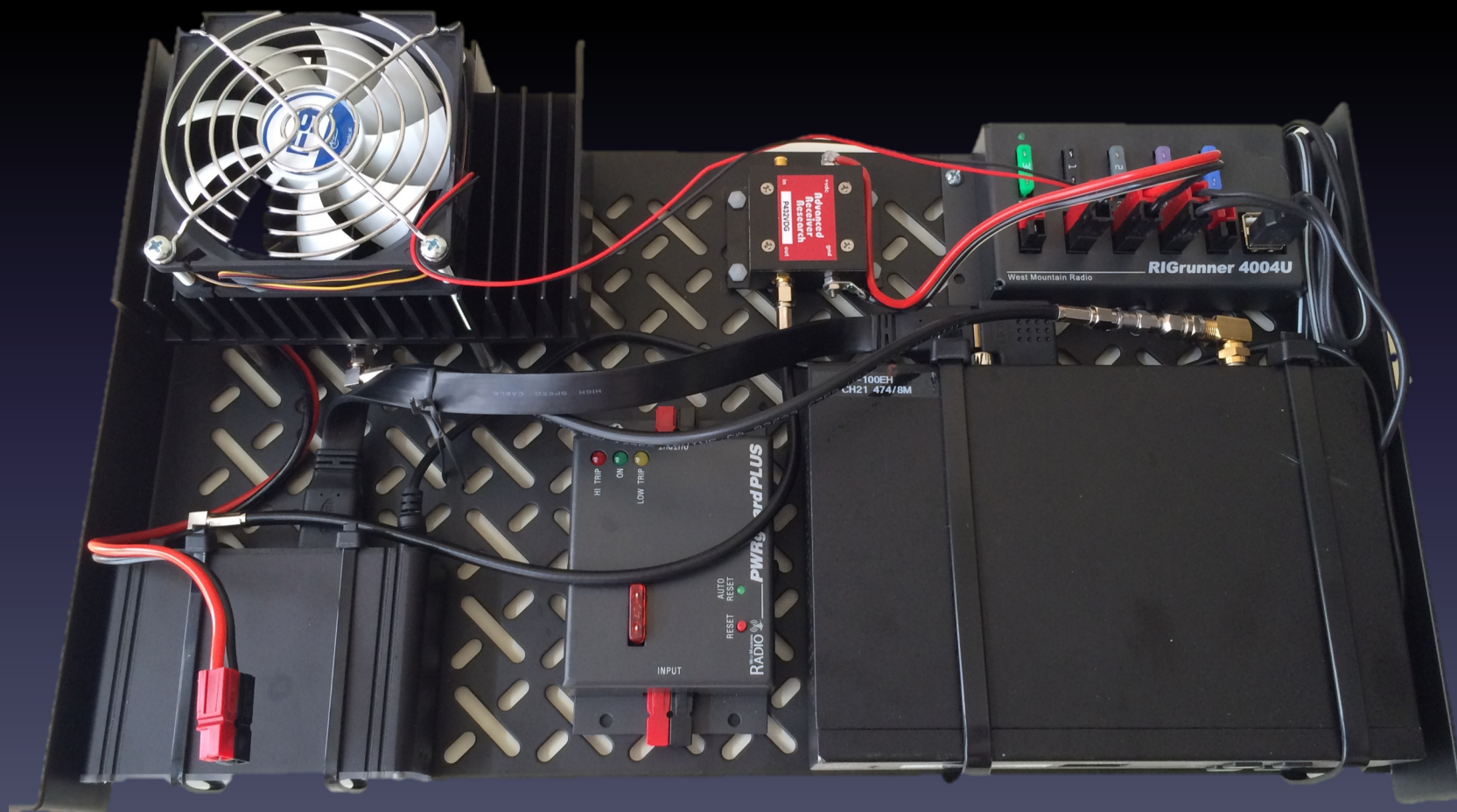
Portable Repeater



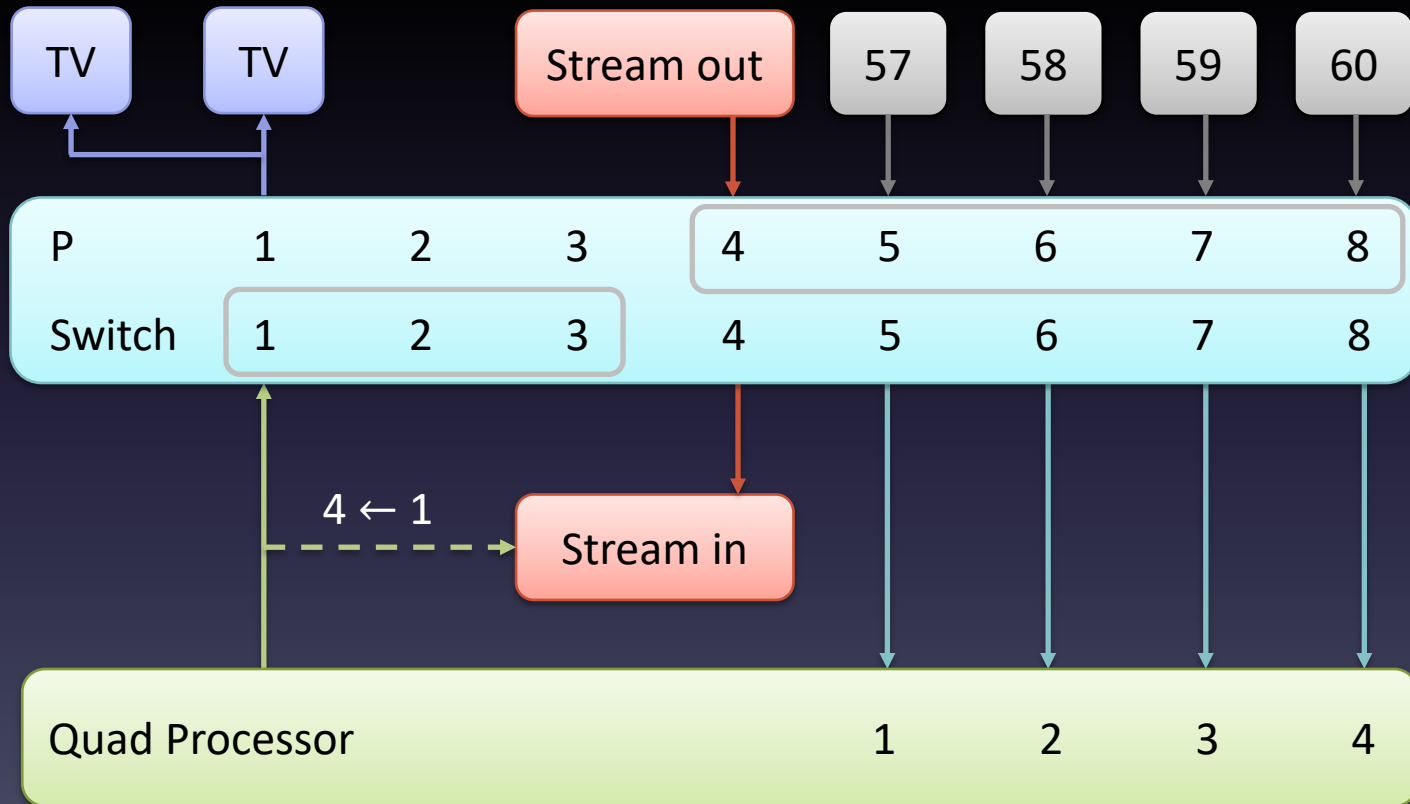
Portable Repeater



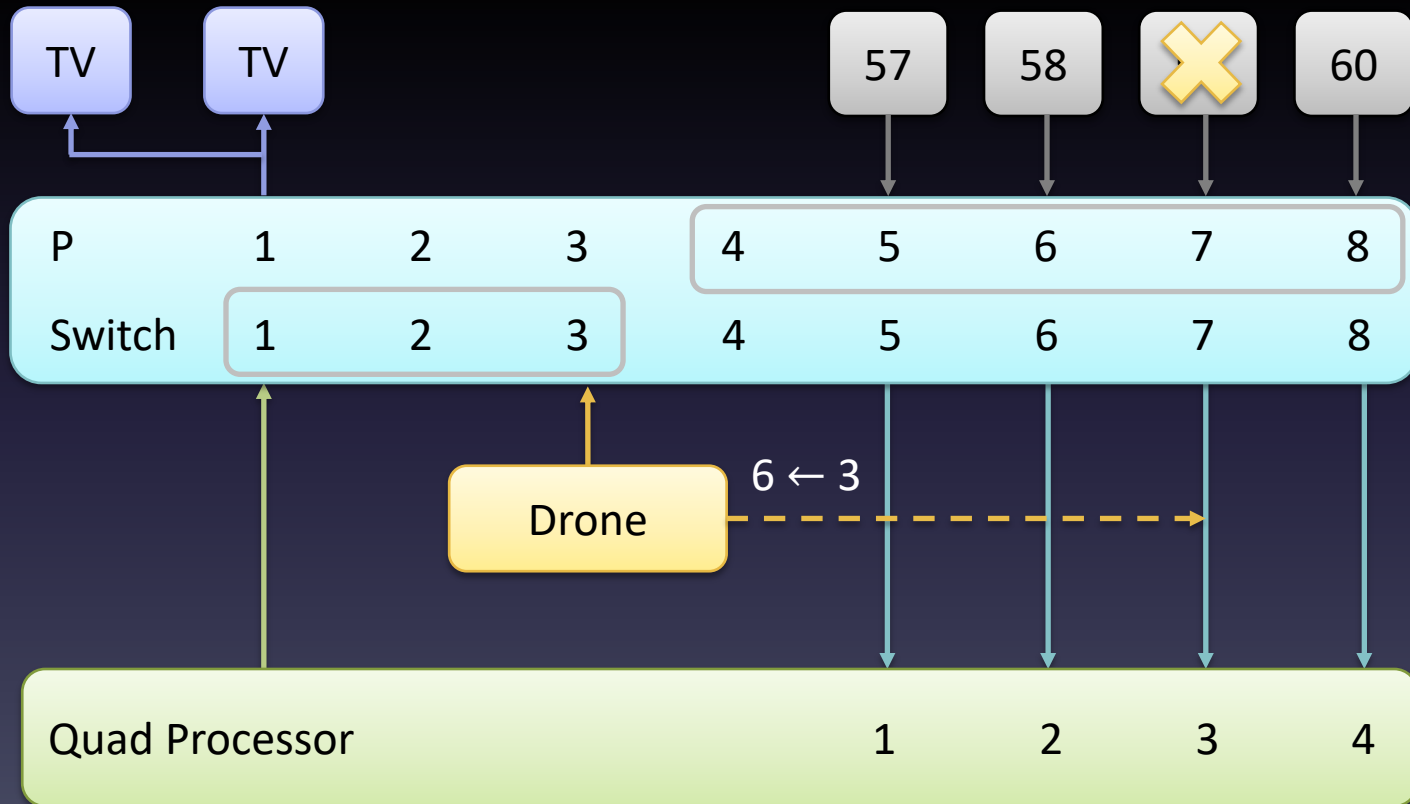
Portable Repeater



Portable Quad Box



Portable Quad Box



Portable Quad Box



Future Directions

900 MHz operation — success so far

Mobile to base or mobile through a repeater

DX operation, particularly from the hills

Show & Tell

Test tool

Portable repeater

Portable quad box

Thanks

KH6HTV Jim Andrews

NØYE Don Nelson

KIØHG Dave Sharpe

KØLRS Mark Huff

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