Sidebar: Video vs. Cinema

- 30 Video frames per second
- 24 Cinema frames per second

How do you transmit movies over video since the frame rates don’t match?

- Repeat 1 cinema frame of every 4

1-D Signal from Constant-Brightness Scene – White

White Scene ⇒

"Constant" Signal, No Oscillation
Temporal Frequency \( \nu = \nu_{\text{min}} = 0 \)

1-D Signal from Constant-Brightness Scene – Gray

Gray Scene ⇒

"Constant" Signal, No Oscillation
Temporal Frequency \( \nu = \nu_{\text{min}} = 0 \)
1-D Signal from Constant-Brightness Scene – Black

- Black Scene
- "Constant" Signal, No Oscillation
- Temporal Frequency $\nu = \nu_{\text{max}} = 0$

1-D Signal from Varying Scene

- Varying Scene
- Oscillating Signal
- Temporal Frequency $\nu = \nu_{\text{max}}$

Signal “Bandwidth”

**Bandwidth** = Range of temporal frequencies $\nu$ ("nu") in transmitted signal

$\Delta \nu = \nu_{\text{max}} - \nu_{\text{min}}$ (Hz)

- $\nu_{\text{min}} = 0$ cycles per second (Hz)
- $\nu_{\text{max}} = \# \text{ of scanning spots} \div 2$ (spots per cycle)

(Need 2 “spots” (one each of black and white) to represent one cycle)

- Maximum "quantity" of data needed to transmit 1-D temporal signal representing
**How to Compute Bandwidth \( \Delta \nu \)**

- Count Number of Pixels scanned and displayed per Second
  - Number of pixels per line \( \times \)
  - Number of lines per frame \( \times \)
  - Number of frames per second
  
  \( (= \text{rows} \times \text{columns} \times \text{frames per sec.}) \)
- Divide by 2
  - Number of pixels per cycle at maximum

**Why Divide by 2?**

- Two pixels (one bright + one dark) can be represented by one cycle that oscillates at the maximum frequency

**Bandwidth of NTSC “Luminance” Signal**

- “Black-and-White” Image
- Minimum Oscillation Frequency is:
  
  \( 0 \text{ cycles per second} = 0 \text{ Hz} \)
- Maximum Oscillation Frequency is:
  
  \( 525 \text{ spi} \times 525 \text{ lpf} \times 30 \text{ fps} \div 2 \text{ spc} \) \( (\text{spots per cycle}^\prime) \)
  
  \( = 4,134,375 \text{ Hz} \approx 4 \text{ MHz} \)

**Notes:**

- \( \text{spi} \) = “spots per line” (number of pixels per scan line)
- \( \text{lpf} \) = (scan) “lines per frame”
- \( \text{fps} \) = frames per second
- \( \text{spc} \) = “spots per cycle” (2 spots per cycle at maximum frequency \( \nu \))
What About Color Video?

- Color Image Made from 3 Monochrome Images ("channels")
  - Red, Green, Blue
- Might Expect to Need $3 \times$ B&W Bandwidth
  \[ \Delta v \approx 12 \text{ MHz} \]
- BUT: this assumes that the color images are completely independent (unrelated)!

---

Image Channels ARE NOT Independent!

RGB Channels Often Are Very Similar!