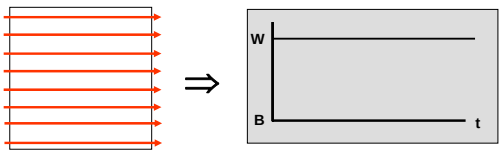
Sidebar: Video vs. Cinema

- 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

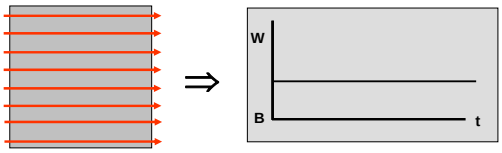
1-D Signal from Constant-Brightness Scene – White



White Scene

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

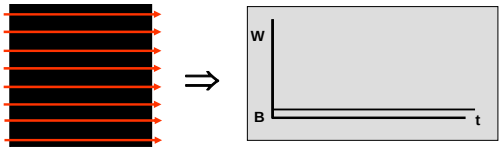
1-D Signal from Constant-Brightness Scene – Gray



Gray Scene

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

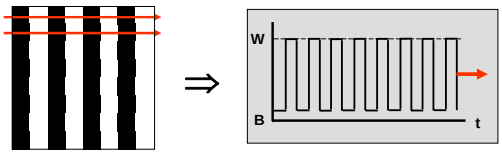
1-D Signal from Constant-Brightness Scene – Black



Black Scene

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

1-D Signal from Varying Scene



Varying Scene

Oscillating Signal
Temporal Frequency $\nu = \nu_{max}$

Signal "Bandwidth"

Bandwidth = Range of temporal frequencies ν ("nu") in transmitted signal

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

ν_{min} = 0 cycles per second (Hz)
ν_{max} = # of scanning spots ÷ 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 representation

How to Compute Bandwidth $\Delta\nu$

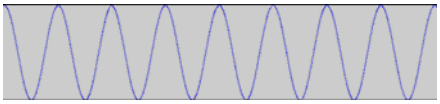
- Count Number of Pixels scanned and displayed per Second
  - = Number of pixels per line $\times$
  - Number of lines per frame $\times$
  - Number of frames per second
  - (= rows $\times$ columns $\times$ frames per sec.)
- Divide by 2
  - = Number of pixels per cycle at maximum

Why Divide by 2?

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

Pixel Pattern

Corresponding Waveform



Bandwidth of NTSC "Luminance" Signal

- "Black-and-White" Image
- Minimum Oscillation Frequency is:
  - 0 cycles per second = 0 Hz
- Maximum Oscillation Frequency is:
  - 525 spl × 525 lpf × 30 fps ÷ 2 spc (spots per cycle`)
  - = 4,134,375 Hz ≅ 4 MHz

"spl" = "spots per line" (number of pixels per scan line)
"lpf" = (scan) "lines per frame"
"fps" = frames per second
"spc" = "spots per cycle" (2 spots per cycle at maximum frequency ν)

What About Color Video?

- Color Image Made from 3 Monochrome Images (“channels”)
  - Red, Green, Blue
- Might Expect to Need 3 × B&W Bandwidth

$$\Delta\nu \cong 12 \text{ MHz}$$

- BUT: this assumes that the color images are completely independent (unrelated)!

Image Channels ARE NOT Independent!

RGB Channels Often Are Very Similar!

Red

Green

Blue

Sum