- Transmits one of color difference signals on every other line; other alternates

- **Standards, from book:**

- Scanning parameters
- Horizontal timing
- Color matrix Equations

- **In composite system, luminance and chrominance are combined into**
- Frequency-interleaving scheme
- Allows transmitting them on a single channel
- Luminance signal transmitted on normal monochrome signal on cable
- Chrominance info placed on high-frequency subcarrier near top of channel bandwidth
- Can choose frequencies so that there is little interference between the signals
- Can have lower bandwidth of the chrominance signal without much loss of resolution, because the eyes are less sensitive to color edges than to brightness edges

- So, can transmit a color signal on same channel that used to be used to transmit black-and-white signal

- **NTSC**
- Composite luminance/chrominance system
- Had to be compatible with earlier monochrome system (1950's)
- Make luminence signal exactly the same as monochrome signal
- Luminance signal: Y
- Two chrominance signals are I and Q
- I = in-phase
- Q = quadrature
- Modulated on subcarrier signal, one at 0 degrees, one at 90 degrees (quadrature)
- Luminance can utilize the full 4.5 MHz bandwidth of TV channel
- I bandwidth is 1.5 MHz
- Q is 0.5 MHz

- **PAL and SECAM**
- PAL is Europe and Asia (except Japan)
- SECAM is France
- Differ from NTSC in way chrominance signals are encoded
- PAL uses complex process called Phase Alternating Line that allows chrominance signals to have 1.5 MHz bandwidth
- More tolerant of certain distortions in transmission than NTSC
- SECAM uses FM-modulated color subcarrier

- Filter those to creat R, G, B and create the three signals
- Complicated and expensive because of parallel data paths, need for synchronization
- Three-sensor cameras are used for highest-quality images

- **Consumer video camers use a less-expensive method**
- Single sensor cameras
- Filter system splits light into spots of colored light
- Appear side-by-disde on surface of sensor
- Need a very sensitive sensor to get the three separate component signals
- So, sometimes resolution suffers
- But, cheap and simple

- **Color TV: Composite**
- We described the three output signals as the red, green and blue components
- This corresponds to an RGB system
- Hard to distribute three signals in exact synchronism and relationship
- Most color TV systems do not handle RGB but rather
- Encode signals into composite format that can be distributed ona single cable
- Composite formats: NTSC, PAL, SECAM

- **All composite forms use Luminance/Chrominance principle**
- Color signal may be broken into two parts:

1. Luminance, the monochrome video signal that only controls brightness (luminence)
2. Chrominance, that contains coloring information

- Chrominance is further broken down into two signals, called color differences, because the tri-stimulus color system requires three independent signals for representation of all colors
- Luminance and chrominance are just one of many possible combinations of the three signals that could be used to transmit color information
- Start with RGB signals created in camera
- Generate luminance and chrominance using a linear matrix transformation

- Integrate several pixels to represent more color levels
- Hard to do on computer monitors since viewing distance is short

- **Resolution**
- Capability of an imagining system to produce fine detail in a picture
- Generally use the term to indicate the number of pixels across the width and height of a frame
- NTSC: 640x480

- **Color in Video**
- Make use of tri-stimulus theory of color reproduction
- Any color can be reproduced by mixing three primary colors

- **Grade school**
- Mix colors red, blue, yellow
- Technically, this is a subtractive color mixing
- Start with white paper, reflects all colors equally
- Apply paint that selectively absorbs/reflects
- So, blue paint is really "minus red" because it doesn't reflect any red light

- **Different system of primary colors for creating colors by mixing colored lights**
- Additive
- Then red, green, blue are primary colors
- Mix equal parts to get white

- **Video is an additive color system**
- Color CRT for display creates three light sources, mixed to reproduce an image
- Produced by three fluroescent phosphor codings on plate of CRT
-
- So, color camer produces three video signals to control three guns in a color CRT
- Conceptually simple way to do this: split light coming into video camera into three paths

- Generally describe displays by count of pixels across width and height
- Conventional television: 640x480 pixels
- In addition, have some overhead lines
- Video scanning system notation includes total number of lines including sync and blanking overhead : frame rate in hertz : indication of interlace (2:1) or progressive (1:1) scan
- So, NTSC is: 525/59.95/2:1 scanning
- PAL is: 625/50/2:1 scanning
- HDTV is: 1125/60/2:1 scanning

- **Blanking intervals**
- Most systems require horizontal blanking time between scan lines and vertical blanking time between frames
- Conventional CRT displays: had to turn off the beam while retracing from bottom right position to top left position
- Example: for NTSC, which is 525/59.94: for square pixels, the picture will be: 483x644 pixels, but the total information of the digital video raster is 525x780
- Make good use of excess data capacity
- Digital video: May convey audio information, alternate language tracks, closed caption information, etc.

- **Data rate**
- Bits per pixel * pixels per line * lines per frame * frame rate

- **Quantization**
- Assigning to each set of sampled intervals of amplitude a discrete, numbered level
- Add quantization noise when you restrict a signal to a finite number of discrete amplitude levels

- **Dithering**
- Display device may have only a small number of grayscale values or color values at each pixel
- If viewer is sufficiently distant, can play games with adjacent pixels to represent more than the available number of levels

Lecture 2: CS8113
More on Video Basics

- **Last time, talked about encoding monochrome video signals as a sequence of one-dimensional voltages**
- Synchronization signals indicated end of line or beginning of a frame
- Digitizing data: sampling and quantization
- Raster: left-to-right, top-to-bottom
- Portraying motion:
    - frames-per-second (at least 20 for smooth motion)
    - flashes per second (approximately double frame rate to make images appear constant)
- Defining meaning of voltage levels: standards (NTSC, PAL, HDTV)

- Hardware: takes care of details for converting the signal back to two-dimensional array of values called pixels (picture elements)
- Pixel typically 8-bit integers for monochrome imagery
- Up to 24 bits typically for color: three 8-bit RGB components

- **Interlacing**
- Each image has two fields, one with odd lines and one with even lines
- Because of interlacing, even and odd lines of image are temporally and spatially offset
- Can have effects like freeze frame field motion: imagine a pendulum that is in different positions in the odd and even fields

- Square pixels: means that pixels have the same veritcal and horizontal sample pitch
- Example: NTSC contains 483 active lines per frame (262.5 per odd/even field)
- A line is a row of pixels
- Aspect ratio (horizontal to vertical size ratio) is 4:3 for conventional TV
- (16:9 for HDTV, cinema: 1.85:1 or 2.35:1)
- So, for pixel to have same aspect ratio as entire picture, must sample a line 644 times (644:483 is 4:3)

- **Displays:**