Video Transmission

VID2: Analog Video Transmission

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Color in an Analog TV Signal

- Luminance – original intensity signal (Y)
- Chrominance – two additional color signals
  - B – Y: Blue minus luminance (intensity)
  - R – Y: Red minus luminance (intensity)
  - Chrominance allocated reduced bandwidth
  - IQ-modulated onto a higher subcarrier
- NTSC Scheme is called “YIQ”
  - Chrominance is split into Blue-Yellow, Green-Purple
  - Blue-Yellow portion more sensitive to human eye
- *Never Wear a Red Tie on Analog TV*

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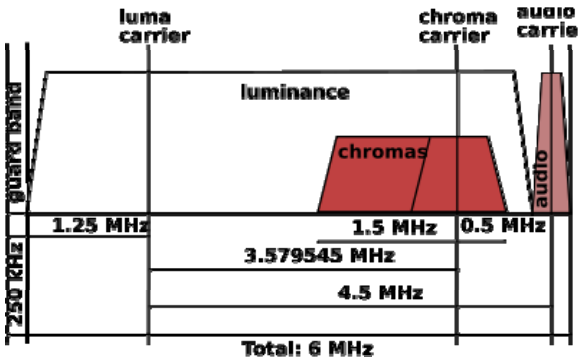
Adding Chrominance to Analog Signals



*from Wikipedia

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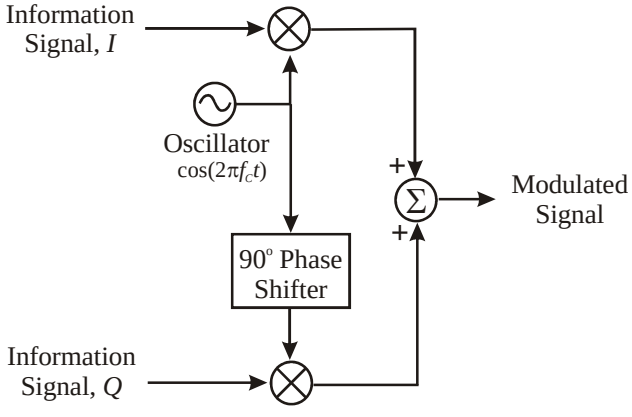
Quadrature Amplitude Modulation



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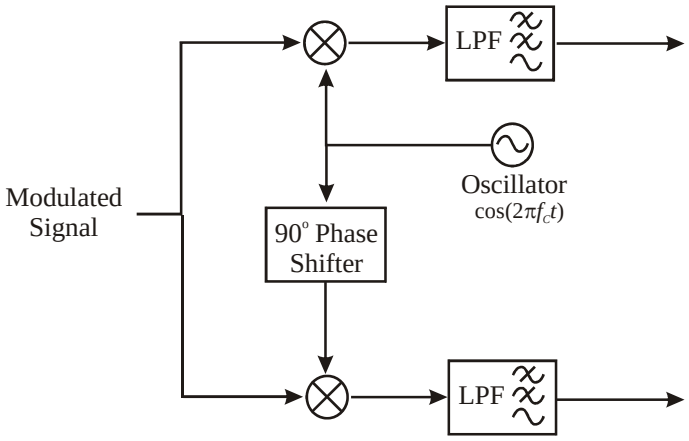
QAM Demodulation



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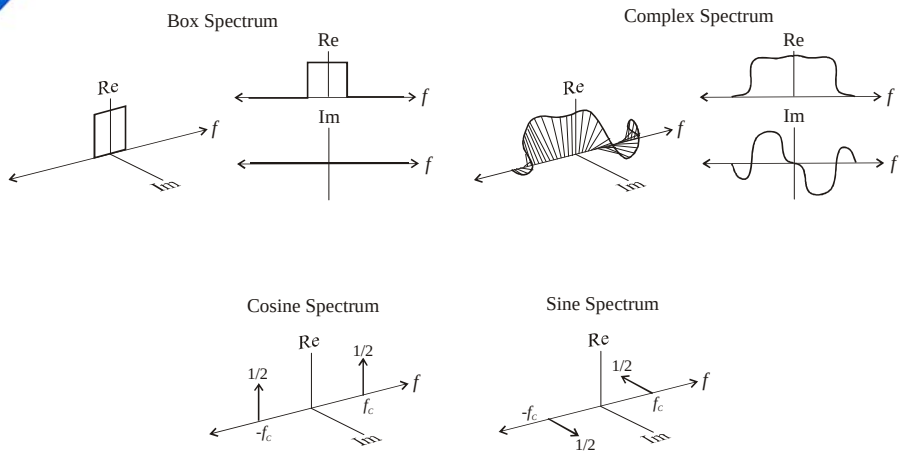
5

Quick Spectrum Review…



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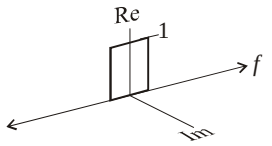
6

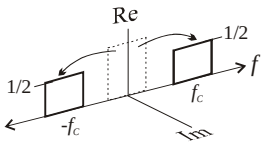
In-Phase Signal Branch

Cosine Modulation

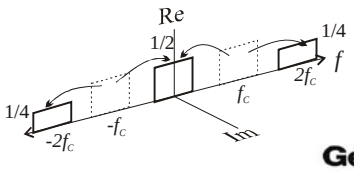
1. $X_1(f)$



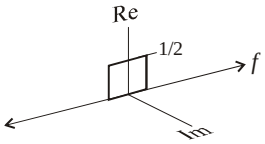
2. Cosine Modulation



3. Second Cosine Multiply



4. Output of ILPF



7

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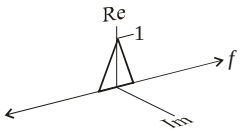
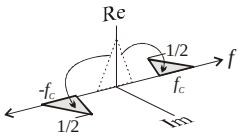
Quadrature Signal Branch

Sine Modulation

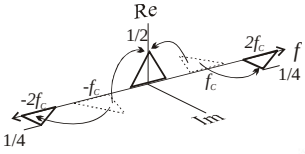
1. $X_2(f)$



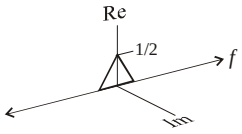
2. Sine Modulation



3. Second Sine Multiply



4. Output of ILPF



8

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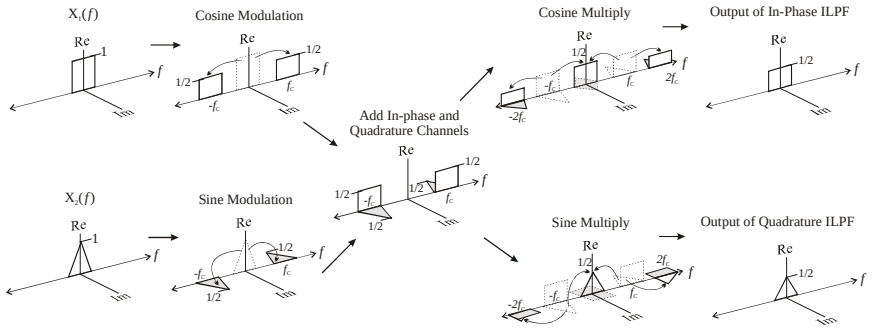
Full QAM Modulation & Demodulation



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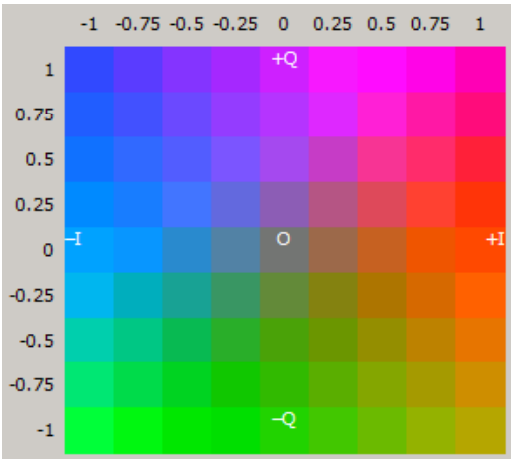
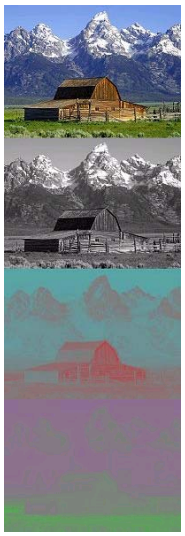
IQ-Color Information in NTSC





YIQ

Y

I

Q

*from Wikipedia

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Color Conversion Formulas

Conversion from YIQ to RGB

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.9563 & 0.6210 \\ 1 & -0.2721 & -0.6474 \\ 1 & -1.1070 & +1.7046 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

Conversion from RGB to YIQ

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Video Over Satellite

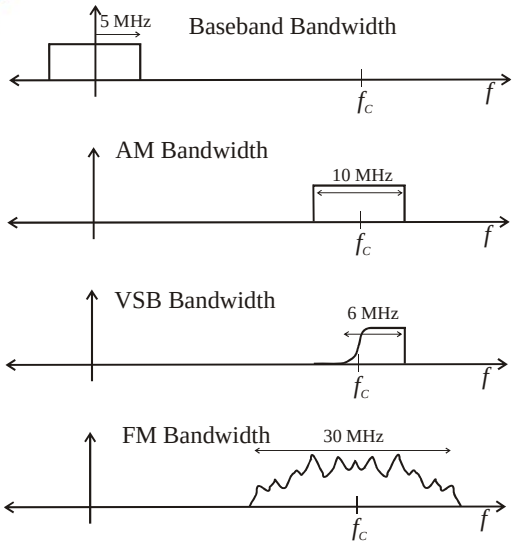
- Terrestrial Broadcast Spectrum
  - VHF Low (44 - 87.5 MHz, Channels 1-6)
  - VHF High (174 - 216 MHz, Channels 7-13)
  - UHF (470 - 890 MHz, Channels 14-83)
- Satellite Broadcasts
  - much less available signal power from satellite
  - higher carrier frequencies with much more bandwidth
  - candidate for FM modulation
  - originally based on 24 FDM transponders, operating in C-band, 3.9-4.2 GHz

Frequency Modulation

- Trades-off bandwidth for fidelity (higher CIR)
- Receiver is simple (differentiator + envelope detector)
- FM bandwidth is *always* higher than AM
- Typical analog video satellite has 24 transponder channels

13

Example of Modulated Signal Spectrum



Carson's Rule for FM Bandwidth

$$B_{\text{FM}} = 2(f_{\max} + f_{\text{peak}})$$

14

Mathematical Form of FM

$$x_{RF}(t) = A\cos\left(2\pi\int_0^t (f_c + k_f x(t'))\,dt'\right)$$

Instantaneous Frequency: $f_i = f_c + k_f x(t)$

$$f_{peak} = k_f \max(x(t))$$

Reception of FM Signals

$$\frac{dx_{RF}(t)}{dt} = -A\,(f_c + k_f x(t))\sin\left(2\pi\int_0^t (f_c + k_f x(t'))\,dt'\right)$$

- Differentiate as the first step of demodulation
- Signal now looks like large-carrier AM
  - Cheap receiver (follow with envelope detector)
  - Changes power spectral density of noise

FM Signal Processing Gain

- Increases with greater RF bandwidth
- Pre-emphasis filtering gain with optional *P*
- Video quality perception factor, *Q*, often added
- Note about noise
  - Increased bandwidth will add more thermal noise
  - Starting C/N will be *lower* than in AM signal

$$\text{FM SNR (in dB)} = \left(\frac{C}{N}\right)_{\text{dB}} + 10\log_{10}\left(\frac{B_{\text{RF}}}{f_{\max}}\right) + 20\log_{10}\left(\frac{f_{\text{peak}}}{f_{\max}}\right) + 1.8 + P$$

$$B_{\text{FM}} = 2(f_{\max} + f_{\text{peak}})$$

17

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Video Quality Factor

- What is a good SNR for analog video?
  - < 35 dB is unwatchable
  - 45 dB is slightly “snowy”
  - > 55 dB is perceived to be “crystal clear”
- Note: typically add *Q*=8 dB to FM SNR equation
  - Human eye is very forgiving (much more so than ear)
  - FM distortions are perceived +8 dB by eye

18

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Pre-emphasis/De-emphasis Filtering

- White noise is “colored” by the act of detection
  - First step is differentiation
  - Noise power spectrum is parabolic
- Solution: Pre-emphasis/De-emphasis Filtering
  - Pre-emphasize the information signal with parabolic filter at the transmitter before modulation
  - De-emphasize the demodulated signal with inverse parabolic filter at the receiver
    - Whitens the noise by “smashing down” high frequency
    - Adds 9 dB to the final FM SNR

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Summary Analog Video

- Digital transmissions now dominate video
  - More design freedom/control of distortions
  - Easier to trade-off fidelity against physical quantities
  - Allows regenerative repeating
  - More flexibility in multiple access schemes
- Need to know analog spectral concepts to grasp digital modulation technique
- Still found in satellite communications today
- February 2009: Termination of all Analog Terrestrial Broadcasts in US

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