

VID2: Analog Video Transmission

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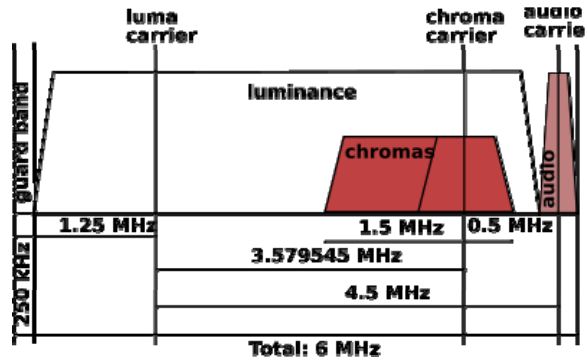
Color in an Analog TV Signal

- 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*

2



Adding Chrominance to Analog Signals

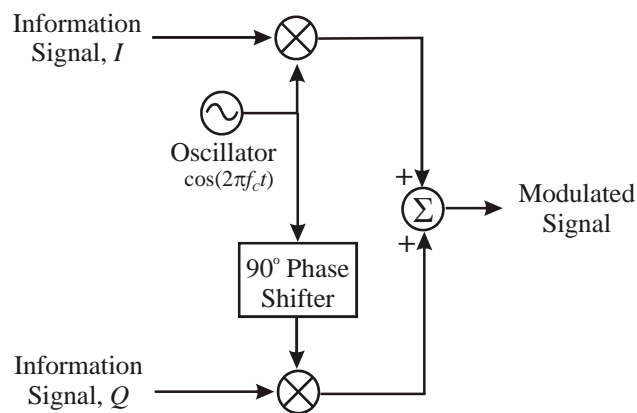


*from Wikipedia

3

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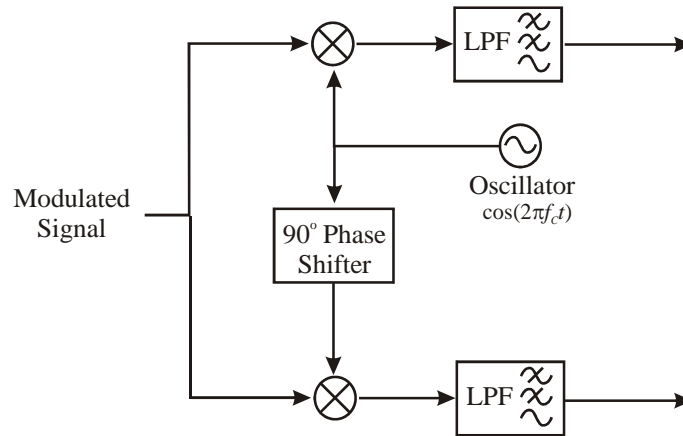
Quadrature Amplitude Modulation



4

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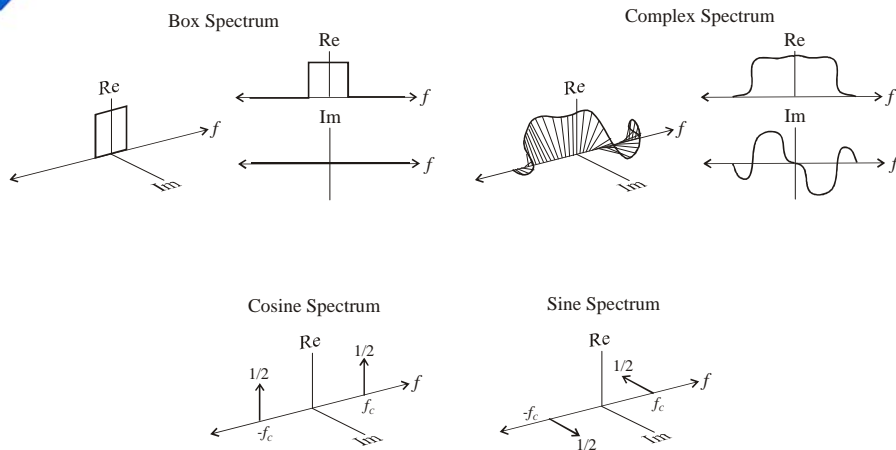
QAM Demodulation



5

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Quick Spectrum Review...

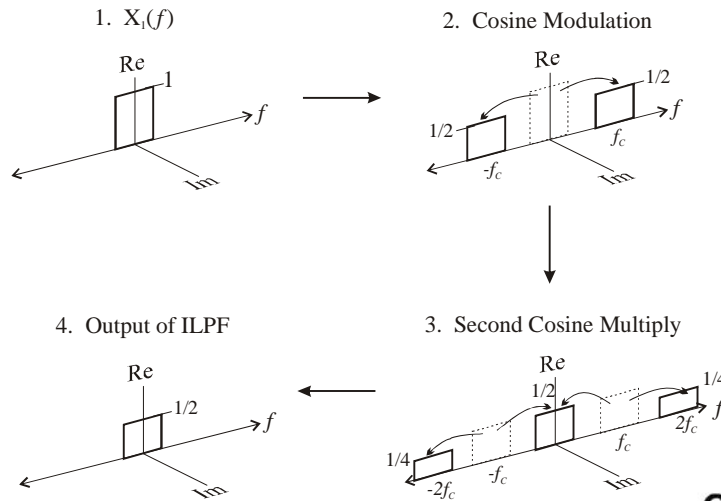


6

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In-Phase Signal Branch

Cosine Modulation

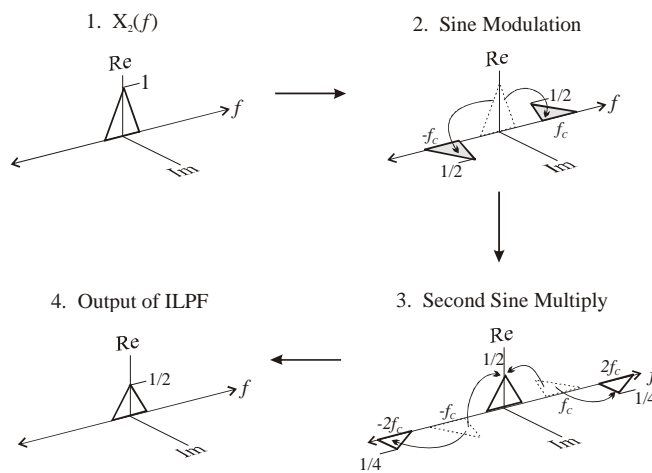


7

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Quadrature Signal Branch

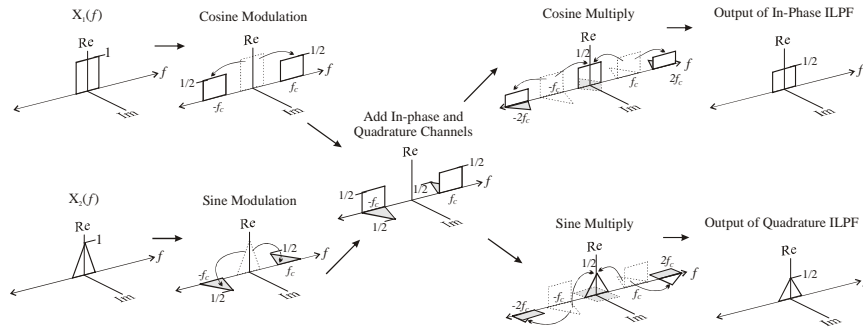
Sine Modulation



8

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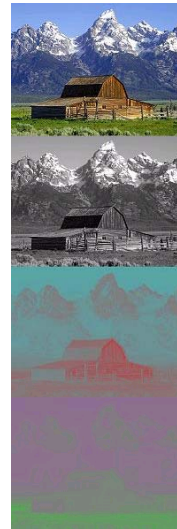
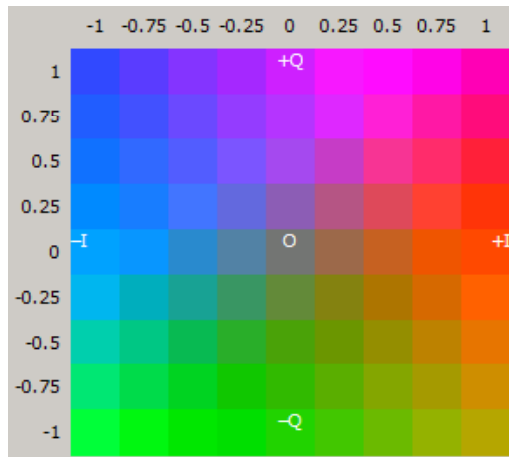
Full QAM Modulation & Demodulation



9



IQ-Color Information in NTSC



YIQ

Y

I

Q

*from Wikipedia



10

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

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

11



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

12



Frequency Modulation

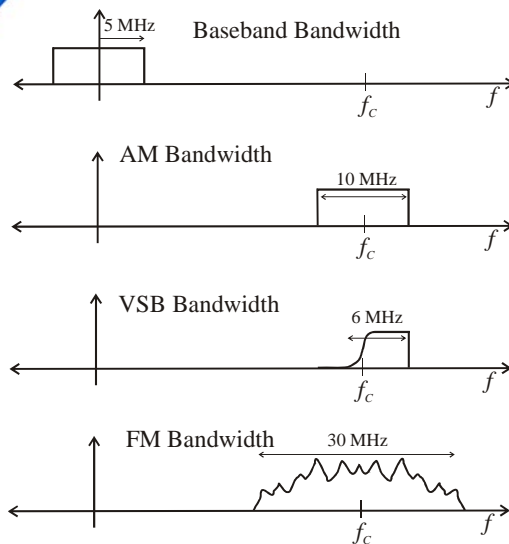


- Trades-off bandwidth for fidelity (higher CIR)
- Receiver is simple (differentiator + envelope detector)
- FM bandwidth is *always* higher than AM
- Typical analog video satellite has 24 transponder channels

13



Example of Modulated Signal Spectrum



Carson's Rule for
FM Bandwidth

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

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

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

15



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

16



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

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

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

17



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



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

19



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

20

