



ECE 516E – ANTENNA & RADIO WAVE PROPAGATION

INTRODUCTION TO COLOUR TELEVISION - STUDY GUIDE/REVISION

1. LEARNING OBJECTIVES

1. Explain the fundamental principles of human colour vision and its implications for television design.
2. Describe the core challenge of colour TV (compatibility) and the key engineering solutions (luminance/chrominance, frequency interleaving).
3. Understand the formation and encoding of the composite colour video signal (NTSC/PAL).
4. Diagram the block diagrams of a colour TV transmitter and receiver, explaining the function of each major block.
5. Analyse the technical trade-offs involved in different colour TV standards.
6. Trace the evolution from analogue standards to modern digital television.

2. FOUNDATIONAL CONCEPTS

2.1 Human Visual Perception

2.1.1 Trichromatic Theory

The human eye has three types of colour receptors (cones) sensitive to Red, Green, and Blue light. This is the basis for all three-color imaging systems.

2.1.2 Luminance vs. Chrominance

The eye is more sensitive to changes in brightness (luminance, Y) than to changes in colour (chrominance, C). This is the most important psycho-visual principle for TV bandwidth reduction.

2.1.3 Critical Flicker Fusion & Persistence of Vision

The reason we perceive a rapid sequence of frames as continuous motion.

2.1.4 Monochrome (B&W) Television Fundamentals

Scanning:

Raster scanning (progressive vs. interlaced) to convert a 2D image into a 1D time-varying electrical signal.

Resolution & Bandwidth:

Relationship between horizontal/vertical resolution, number of lines, frame rate, and the required video bandwidth. (Recall the Kell factor).

Vestigial Sideband Modulation (VSB)

How the video signal is modulated onto an RF carrier for broadcast, saving spectrum.

Sync Pulses:

The role of horizontal and vertical synchronization pulses.

3. COMPATIBILITY

This is the central engineering problem that shaped colour TV.

Goal: A colour TV broadcast must be viewable on existing monochrome (B&W) receivers, and monochrome broadcasts must be viewable on new colour receivers.

Constraint: The colour signal must fit within the same **6 MHz channel bandwidth** as the monochrome signal.

4. KEY ENGINEERING SOLUTIONS & SIGNAL ENCODING

4.1 Luminance (Y) Signal

- Derived from the Red, Green, and Blue signals to create a signal a B&W TV can display.
- **Luminance Equation:** $Y = 0.299R + 0.587G + 0.114B$ (Based on the eye's sensitivity to each colour).
- This becomes the "backward compatible" brightness signal.

4.2. Chrominance (Colour) Signal

To avoid adding extra bandwidth, colour information is encoded as a *modulated subcarrier* placed *within* the existing luminance channel.

4.2.1 Color Difference Signals: Instead of transmitting R, G, B (which would triple the bandwidth), we transmit (R-Y) and (B-Y). Why?

- They are zero for white/gray scenes, reducing visibility of the colour subcarrier in B&W pictures.
- G-Y can be derived from Y, R-Y, and B-Y in the receiver, so it doesn't need to be transmitted.

4.2.2 Quadrature Amplitude Modulation (QAM):

- The (R-Y) signal modulates a $\cos(\omega_{sc} t)$ carrier.
- The (B-Y) signal modulates a $\sin(\omega_{sc} t)$ carrier (a 90° phase-shifted version of the same carrier).
- These two modulated signals are added together to form the **Chrominance Signal**. This allows two independent signals to be transmitted on a single subcarrier frequency.

4.3 Frequency Interleaving & The colour Subcarrier

4.3.1 The Problem

How to put the chrominance signal inside the luminance bandwidth without causing visible interference?

4.3.2 The Solution:

The energy of a scanned TV signal is not uniform across the spectrum; it is concentrated at harmonics of the line frequency (f_h).

- **Spectrum of Y:** Energy clusters around multiples of f_h .
- **Choosing the Subcarrier (f_{sc}):** The colour subcarrier frequency is chosen to be an *odd multiple of half the line frequency* ($f_{sc} = (2n-1) * f_h / 2$).

4.3.3 Result:

The spectrum of the chrominance signal falls *midway between* the clusters of the luminance spectrum. The luminance and chrominance signals are **frequency interleaved**, minimizing mutual interference. This is a brilliant application of signal processing.

5. MAJOR ANALOGUE COLOUR TV STANDARDS

5.1 NTSC (National Television System Committee) - Used in North America, Japan

- Key Feature: The first commercially viable colour system.
- Chrominance Signals: I (In-phase) and Q (Quadrature) signals. Originally, I had wider bandwidth than Q based on perceived colour detail.
- Famous Flaw: Susceptible to phase errors, which cause hue shifts. Often joked as "Never The Same colour."
- Line Rate: 525 lines, 59.94 Hz field rate.

5.2 PAL (Phase Alternating Line) - Used in Europe, Asia, Australia

- Key Innovation: The phase of the V component ((R-Y)) is reversed on alternate lines.
- Advantage: Cancels out phase errors, making it more robust than NTSC.
- Trade-off: Slightly more complex receiver and reduced vertical colour resolution.
- Line Rate: 625 lines, 50 Hz field rate.

5.3 SECAM (Séquentiel Couleur à Mémoire) - Used in France, Eastern Europe

- Key Innovation: Transmits the two-colour difference signals (D_B and D_R) sequentially, one per line.
- Advantage: Eliminates cross-colour interference completely.
- Trade-off: Requires a one-line delay (a "memory") in the receiver to simultaneously have both colour signals. More complex receiver.

6. COLOUR TV RECEIVER BLOCK DIAGRAM

1. **Tuner & IF Stages:** Selects the channel and amplifies the RF signal, outputting the composite video signal.

2. Video Amplifier & Sync Separator:

- Splits the signal into Luminance (Y) for the picture tube.
- Extracts sync pulses for the deflection circuitry.

3. **Chrominance (Bandpass) Amplifier:** Isolates the chrominance signal around the colour subcarrier frequency.

4. Colour Demodulator (The Core of colour Recovery):

- A synchronous demodulator requires a regenerated subcarrier at the exact frequency and phase.
- **Color Burst:** A short burst of the unmodulated subcarrier (8-10 cycles) is transmitted on the "back porch" of the horizontal sync pulse. This acts as a phase reference.
- **Burst Gate & Crystal Oscillator:** The burst is separated and used to lock a local crystal oscillator (in a Phase-Locked Loop) in the receiver.
- The chrominance signal is demodulated using the regenerated subcarrier to recover the (R-Y) and (B-Y) signals.

5. **Matrix Network:** Combines Y, (R-Y), and (B-Y) to reconstruct the original R, G, and B signals.

- $G-Y = -(0.299/0.587)(R-Y) - (0.114/0.587)(B-Y)$

6. Colour Picture Tube (CRT):

- Three electron guns (for R, G, B).
- A **shadow mask** or aperture grille with tiny holes that ensure each electron beam only strikes its corresponding colour phosphor dot.

7. EVOLUTION TO DIGITAL TELEVISION

7.1 Component Digital Video (ITU-R BT.601): The move to digital began in studios by sampling Y, C_B, C_R (digitally scaled versions of B-Y and R-Y) separately. This avoids the artifacts of composite analogue encoding.

7.2 Chrominance Subsampling: Exploits the eye's lower sensitivity to colour detail.

- **4:2:2:** Horizontal colour resolution is halved. Common in professional video.
- **4:2:0:** Horizontal and vertical colour resolution are halved. Universal in consumer digital TV (MPEG, JPEG, etc.). This is the direct digital equivalent of the bandwidth-saving principle in analogue TV.

7.3 Digital Compression (MPEG-2, H.264/AVC, HEVC): Allows multiple digital TV channels to fit in the bandwidth of one old analogue channel.

7.4 ATSC vs. DVB: The digital terrestrial broadcast standards that replaced NTSC and PAL/SECAM.

8. STUDY TIPS & RESOURCES

1. **Focus on Principles:** Don't just memorize facts. Understand *why* each technique was used (e.g., why (R-Y) and (B-Y)? Why QAM? Why an odd half-line subcarrier?).

2. **Draw Block Diagrams:** Repeatedly draw and label the transmitter and receiver block diagrams until you can do it from memory and explain every block's function.
3. **Think in the Frequency Domain:** The concept of frequency interleaving is crucial. Sketch the spectrum of the composite video signal.
4. **Compare and Contrast:** Create a table comparing NTSC, PAL, and SECAM, highlighting their key features, advantages, and disadvantages.