



## ECE 516E – ANTENNA & RADIOWAVE PROPAGATION

### STUDY GUIDE: ANALOGUE TELEVISION SCANNING

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#### **OBJECTIVES:**

1. Explain the necessity of scanning for television transmission.
2. Describe the process of raster scanning, including horizontal and vertical deflection.
3. Differentiate between progressive and interlaced scanning, stating the advantages and disadvantages of each.
4. Interpret a standard analogue video waveform, identifying the visual information, blanking, and synchronization pulses.
5. Perform basic calculations related to scanning lines, frame rate, field rate, and bandwidth.

## **2. TRANSMITTING A 2D IMAGE OVER A 1D CHANNEL**

### **2.1 The Challenge**

A television image is a two-dimensional array of brightness information (pixels, in modern terms). The transmission channel (a radio wave or cable) is a single, time-varying signal (one-dimensional). Scanning is the process of converting this 2D image into a 1D electrical signal for transmission, and then reconstructing the 2D image at the receiver.

### **2.2 The Solution: Scanning**

The entire image is not sent at once. Instead, the scene is systematically broken-down point-by-point and line-by-line, and these points are sent sequentially over time.

### **2.3 The Raster: Foundation of the Picture**

A raster is a rectangular pattern of scanning lines that, when illuminated, creates the visible display. Think of it as the path the electron beam follows on the face of a Cathode Ray Tube (CRT).

**Aspect Ratio:** The ratio of the picture width to height. Standard for analog TV was **4:3**.

**Number of Lines:** The total number of distinct horizontal lines that make up a complete picture. This is a key standard (e.g., 525 lines in NTSC, 625 lines in PAL/SECAM).

## **3. THE SCANNING PROCESS**

The process involves two synchronized motions:

### **3.1 Horizontal Scanning (Line Scan):**

The electron beam moves rapidly from the **left side to the right side** of the screen, modulating its intensity to create bright and dark spots along the line.

At the end of the line, the beam must rapidly **fly back** to the left to start the next line. This period is called the **Horizontal Blanking Interval**.

### 3,2 Vertical Scanning (Frame Scan):

- While moving horizontally, the beam is also moving slowly downward.
- After scanning the last line at the bottom, the beam must fly back to the top-left corner to start a new picture. This period is the **Vertical Blanking Interval**.
- **The "Blanking" Concept:** During the flyback periods, the beam is intentionally shut off (**blanked**) to prevent visible retrace lines on the screen. The blanking intervals are essential parts of the video signal.

## 4. CRITICAL ENGINEERING TRADE-OFF: FLICKER VS. BANDWIDTH

**4.1 Persistence of Vision:** The human eye retains an image for a brief moment after it disappears. To create the illusion of smooth motion, a sufficient number of static images (frames) must be displayed per second.

**4.2 Critical Flicker Frequency (CFF):** The rate at which a flickering light appears continuous (typically ~50-60 Hz). Below this rate, the image appears to flicker unpleasantly.

**4.3 Bandwidth Limitation:** Transmitting more frames per second requires a higher signal bandwidth. In the early days of TV, bandwidth was an extremely scarce and expensive resource.

## 5. INTERLACED SCANNING: THE INGENIOUS COMPROMISE

To solve the flicker problem without doubling the bandwidth, **interlaced scanning** was invented.

### 5.1 How Interlacing works

1. A "frame" is divided into two "fields."
2. **Field 1 (Odd Field):** The beam scans all the **odd-numbered lines** (1, 3, 5, ...).
3. **Field 2 (Even Field):** The beam scans all the **even-numbered lines** (2, 4, 6, ...).
4. The two fields are "interlaced" together like the teeth of two combs to create one complete frame.

### 5.2 Why it Works:

The **field rate** is double the **frame rate**.

Example (NTSC): Frame rate = 30 Hz, but Field rate = 60 Hz.

While the entire picture (frame) only updates 30 times per second, any given point on the screen is being refreshed 60 times per second. This elevated refresh rate is above the CFF for most viewers, effectively eliminating perceptible flicker.

### 5.3. Bandwidth Saved

The transmission bandwidth is determined by the frame rate (30 complete pictures/sec), not the field rate.

#### 5.4 Disadvantages of Interlacing:

Interlacing can cause artifacts like "line crawl" or "interlace combing" on sharp horizontal edges and with fast motion.

### 6. PROGRESSIVE SCANNING (FOR COMPARISON)

#### 6.1. Definition:

A simpler method where all lines of the frame are scanned in sequence from top to bottom in a single pass.

#### 6.2. Comparison:

To avoid flicker with progressive scan, the entire frame-rate must be high (e.g., 60 Hz). This requires roughly double the bandwidth of a 30 Hz interlaced system for the same number of lines.

Progressive scanning was not used in standard analogue broadcast TV due to this bandwidth constraint but is today the standard for modern computer monitors and digital TV (e.g., 720p, 1080p).

### 7. SYNCHRONIZATION: LOCKING THE RECEIVER TO THE TRANSMITTER

It is absolutely critical that the electron beam in the TV receiver's CRT is scanning in perfect unison with the beam in the camera tube.

#### 7.1. Synchronization Pulses

These are high-voltage pulses added to the video signal during the blanking intervals to command the receiver's beam to retrace.

- **Horizontal Sync Pulse:** Located within the Horizontal Blanking Interval. Tells the beam to fly back to the left.
- **Vertical Sync Pulse:** A much wider pulse located within the Vertical Blanking Interval. Tells the beam to fly back to the top.

#### 7.2. Composite Video Signal

The complete signal containing:

- **Luminance (Brightness) Signal:** 0 to 0.714 V (for NTSC).
- **Blank Level:** The "black" reference level.
- **Sync Pulses:** Typically going to -0.286 V below blanking.

### 8. KEY FORMULAS AND CALCULATIONS

#### 8.1. Line Time:

Total Line Time = Active Video Time + Horizontal Blanking Time

## 8.2. Horizontal Frequency ( $f_h$ ):

$f_h = \text{Frame Rate} \times \text{Total Number of Lines}$  (for progressive) or  $f_h = \text{Field Rate} \times (\text{Total Number of Lines} / 2)$  (for interlaced).

## 8.3 Relationship for Interlaced Systems

Field Rate = 2 × Frame Rate

### Example (NTSC):

- Frame Rate: 29.97 Hz  $\approx$  30 Hz
- Field Rate: 59.94 Hz  $\approx$  60 Hz
- Total Lines per Frame: 525
- **Horizontal Frequency:** 60 fields/sec  $\times$  (525 lines/field / 2) = 60  $\times$  262.5 = 15,750 Hz

## 9.0 SELF-TEST QUESTIONS

1. Why was scanning necessary in analogue television systems?
2. Explain the problem of flicker and the bandwidth constraint. How did interlaced scanning provide an elegant solution to this problem?
3. Draw a simplified timing diagram for two complete lines of an analogue video signal, labelling the active video, front porch, horizontal sync pulse, and back porch.
4. For a 625-line, 25 fps interlaced system (PAL), calculate the field rate and the horizontal line frequency.
5. What is the purpose of the vertical blanking interval, and what other information (besides the sync pulse) is often transmitted during this time?