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# ECE 462 – Data and Computer Communications

## Lecture 4: Data Transmission

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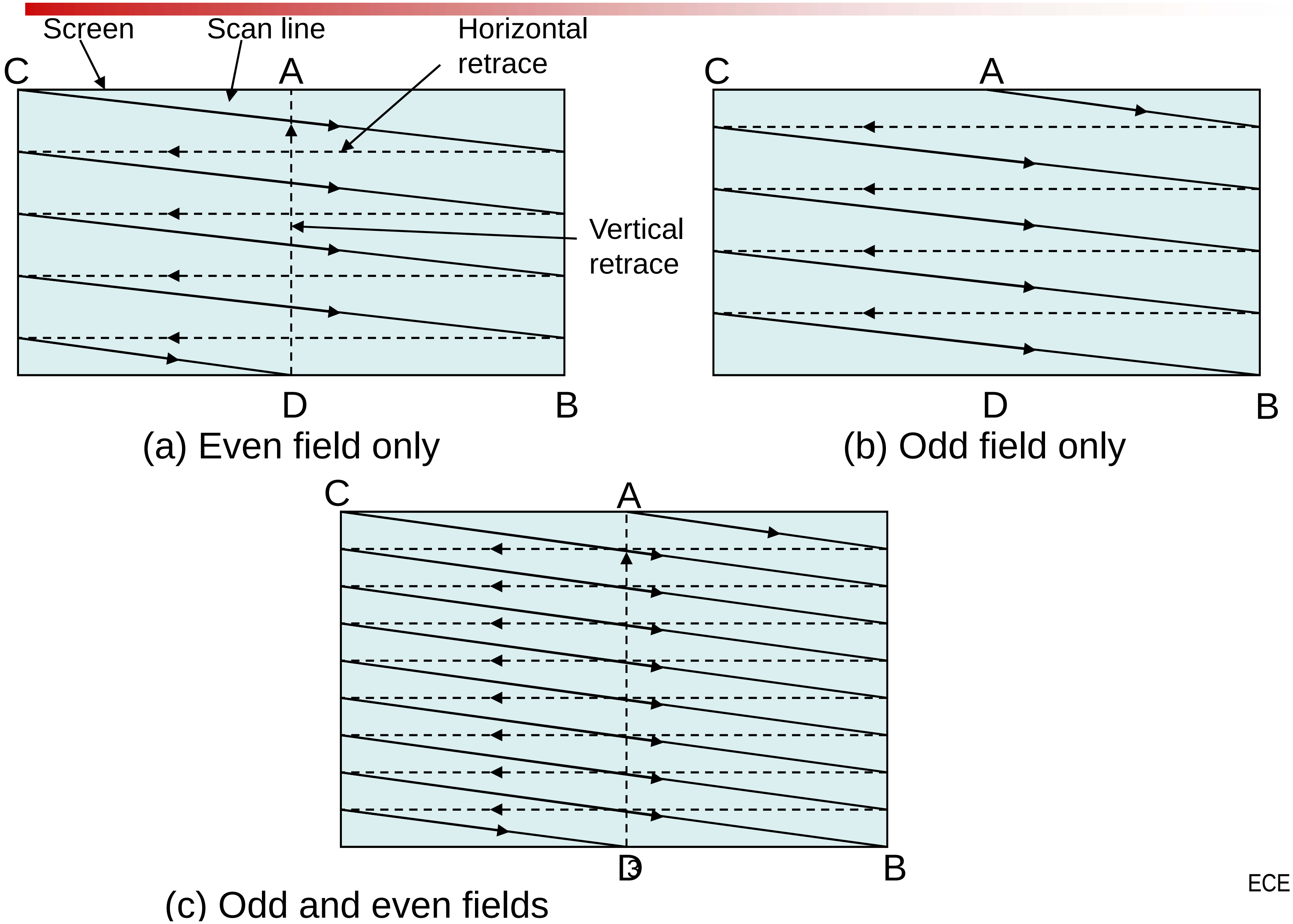
# Video Components

- USA - 483 lines scanned per frame at 30 frames per second
  - 525 lines but 42 lost during vertical retrace
- So 525 lines x 30 scans = 15750 lines per second
  - 63.5$\mu$s per line
  - 11$\mu$s for retrace, so 52.5 $\mu$s per video line
- Max frequency if line alternates black and white
- Horizontal resolution is about 450 lines giving 225 cycles of wave in 52.5 $\mu$s
- Max frequency of 4.2MHz

# Video Interlaced Scanning



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# Bandwidth of TV Signal

- US 525 line standard
- Vertical Retrace= 42 lines
- Net= 525-42= 483 lines
- 30 scans (60 frames)
- 525* 30 scans/sec= 15750 lines /sec
- Each line is 1/15750= 63.5 usec
- 11 usec for horizontal retrace
- Total of 52 .5 usec per video line
- Based on a horizontal resolution of H=450 lines
  - Assume B&W dots, then H/2 cycles/sec
  - BW=(H/2)/52.5= 4.28 MHz

# Nyquist Bandwidth

- If rate of signal transmission is 2W then signal with frequencies no greater than W is sufficient to carry signal rate
- Given bandwidth W, highest signal rate is 2W
- Given binary signal, data rate supported by W Hz is 2W bps
- Can be increased by using M signal levels
- $C= 2W \log_2 M$

Example: voice channel W=3.1 KHz, M=8

$C=2x3.1x10^3 x \log_2 8=18.6$ Kbps

# Shannon capacity formula

- SNR (signal-to-noise ratio)
  - $SNR_{dB} = 10 \log_{10} \dfrac{\text{signal power}}{\text{noise power}}$
- Shannon Capacity formula
  - $C = W \log_2 (1 + SNR)$

    where $C$ is the capacity in bits per second and $W$ is the bandwidth of the channel in Hertz.

# Shannon Capacity Formula

- Consider data rate, noise and error rate
- Faster data rate shortens each bit so burst of noise affects more bits
  - At a given noise level, high data rate means higher error rate
- Signal to noise ratio (in decibels)

$$SNR_{db} = 10 \log_{10} (\text{signal/noise})$$

- Capacity $C = W \log_2(1+S/N)$

# Example 3.4

- Let us consider an example that relates the Nyquist and Shannon formulations. Suppose that the spectrum of a channel between 3 MHz and 4MHz and $SNR_{dB}$ = 24 dB. then

  W =4 MHz – 3 MHz = 1MHz

  $SNR_{dB} = 24 \text{ dB} = 10 \log_{10}(SNR)$

  SNR = 251

  Using Shannon's formula,

$$C = 10^6 \times \log_2(1+251) \approx 10^6 \times 8 = 8\ Mbps$$

# Example 3.4 (continued)

- This is a theoretical limit and, as we have said, is unlikely to be reached. But assume we can achieve the limit. Based on Nyquist's formula, how many signaling levels are required? we have

$$C = 2W \log_2 M$$

$$8 \times 10^6 = 2 \times (10^6) \times \log_2 M$$

$$4 = \log_2 M$$

$$M = 16$$

# Example 3.5

- For binary phase-shift keying (defined in Chapter 5), $E_b/N_0$ = 8.4 dB is required for a bit error rate of $10^{-4}$ (one bit error out of every 10,000). If the effective noise temperature is 290ºK(room temperature) and the date rate is 2400 bps, what received signal level is required?

We have

$$8.4 = S(dBW) - 10\log 2400 + 228.6dBW - 10\log 290$$
$$= s(dBW) - (10)(3.38) + 228.6 - (10)(2.46)$$
$$S = -161.8dBW$$

# Example 3.6

- Suppose we want to find the minimum $E_b/N_0$ required to achieve a spectral efficiency of 6 bps/Hz. Then

$$E_b / N_0 = (1/6)(2^6 - 1) = 10.5 = 10.21dB$$