Course Title: Microwave and Antennas	**Course Code: 20EC520**
Credits: 4	**Total Contact Hours (L: T: P): 52:0:0**
Type of Course: Theory	**Category: Professional Core Course**
CIE Marks: 50	**SEE Marks: 100**

Course Outcomes: After completing this course, students should be able to:

CO2:	Analyze different terminologies associated with satellite communication, TV, RADAR, their applications.

Unit No.	Course Content	No. of Hours
3	**Radiometry:** Introduction to TV signal standards, scanning principles, composite video, VSB transmission, colour transmission, TV cameras, HDTV principles. **SLE**: Audio and Video compression standards	**10**

Radiometry is the science and technology of quantifying and measuring essential properties of electromagnetic radiation, visible light, Infrared, UV Light, radio waves, X-rays

Radiometry is a set of techniques for measuring **electromagnetic** radiation, including visible light. Radiometric techniques in optics characterize the distribution of the radiation's power in space, as opposed to photometric techniques, which characterize the light's interaction with the human eye. Radiometry is distinct from quantum techniques such as photon counting.

Introduction to TV Standards:

TV signal consists of two main parts: the sound and the picture. But it is far more complex than that. The sound today is usually stereo, and the picture carries color information as well as the synchronizing signals that keep the receiver in step with the transmitter.

Signal Bandwidth

The complete *signal bandwidth* of a TV signal is shown in Fig. 1, below. The entire TV signal occupies a channel in the spectrum with a bandwidth of 6 MHz. There are two carriers, one each for the picture and the sound.

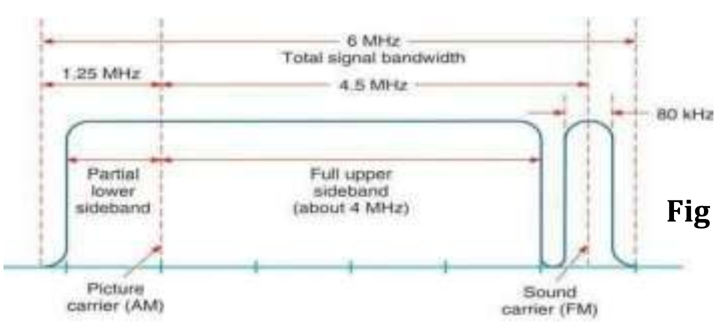

Fig 1: Spectrum of a broadcast TV signal.

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Audio Signal. The sound carrier is at the upper end of the spectrum. Frequency modulation is used to impress the sound signal on the carrier. The audio bandwidth of the signal is 50 Hz to 15 kHz. The maximum permitted frequency deviation is 25 kHz, considerably less than the deviation permitted by conventional FM broadcasting. As a result, a TV sound signal occupies somewhat less bandwidth in the spectrum than a standard FM broadcast station. Stereo sound is also available in TV, and the multiplexing method used to transmit two channels of sound information is virtually identical to that used in stereo transmission for FM broadcasting.

Video Signal. The picture information is transmitted on a separate carrier located 4.5 MHz lower in frequency than the sound carrier (refer again to Fig. 1). The video signal derived from a camera is used to amplitude-modulate the picture carrier. Different methods of modulation are used for both sound and picture information so that there is less interference between the picture and sound signals. Further, amplitude modulation of the carrier takes up less bandwidth in the spectrum, and this is important when a high-frequency, content-modulating signal such as video is to be transmitted.

The color information in a picture is transmitted by way of frequency-division mul tiplexing techniques. Two color signals derived from the camera are used to modulate a 3.85-MHz subcarrier which, in turn, modulates the picture carrier along with the main video information. The color subcarriers use double-sideband suppressed carrier AM. The video signal can contain frequency components up to about 4.2 MHz. Therefore, if both sidebands were transmitted simultaneously, the picture signal would occupy 8.4 MHz. The vestigial sideband transmission reduces this excessive bandwidth. The total bandwidth allocated to a TV signal is 6 MHz.

TV Spectrum Allocation. Because a TV signal occupies so much bandwidth, it must be transmitted in a very high-frequency portion of the spectrum. TV signals are assigned to frequencies in the VHF and UHF range. In the United States, TV stations use the frequency range between 54 and 806 MHz. This portion of the spectrum is divided into sixty-eight 6-MHz channels which are assigned frequencies. Channels 2 through 7 occupy the frequency range from 54 to 88 MHz. The standard FM radio broadcast band occupies the 88- to 108-MHz range. Aircraft, amateur radio, and marine and mobile radio com- munication services occupy the frequency spectrum from approximately 118 to 173 MHz. Additional TV channels occupy the space between 470 and 806 MHz.

PRINCIPLES OF SCANNING:

Scanning is a technique that divides a rectangular scene into individual lines. The standard TV scene dimensions have an aspect ratio of 4 : 3; that is, the scene width is 4 units for every 3 units of height. To create a picture, the scene is subdivided into many fine horizontal lines called *scan lines.* Each line represents a very narrow portion of light variations in the scene. The greater the number of scan lines, the higher the resolution and the greater the detail that can be observed. U.S. TV standards call for the scene to be divided into a maximum of 525 horizontal lines.

Figure 2 below is a simplified drawing of the scanning process. In this example, the scene is a large black letter F on a white background. The task of the TV camera is to convert this scene to an electric signal. The camera accomplishes this by transmitting a voltage of 1 V for black and 0 V for white. The scene is divided into 15 scan lines numbered 0 through

The scene is focused on the light-sensitive area of a vidicon tube or imaging CCD which scans the scene one line at a time, transmitting the light variations along that line as voltage levels. Figure 2 shows the light variations along several of the lines. Where the white background is being scanned, a 0-V signal occurs. When a black picture element is encountered, a 1-V level is transmitted.

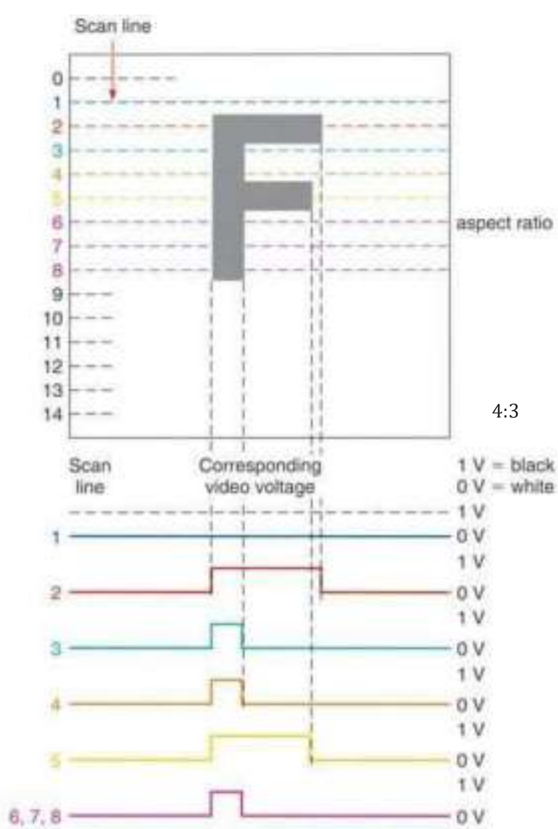

Fig 2: Simplified explanation of scanning.

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A more detailed illustration of the scanning process is given in Fig. 3 below. The scene is scanned twice. One complete scanning of the scene is called a *field* and contains 262 ½ lines. The entire field is scanned in 1_60 s for a 60-Hz field rate. In color TV the field rate is 59.94 Hz. Then the scene is scanned a second time, again using 262 ½ lines. This second field is scanned in such a way that its scan lines fall between those of the first field. This produces what is known as *interlaced scanning,* with a total of 2 x 262 ½ = 525 lin

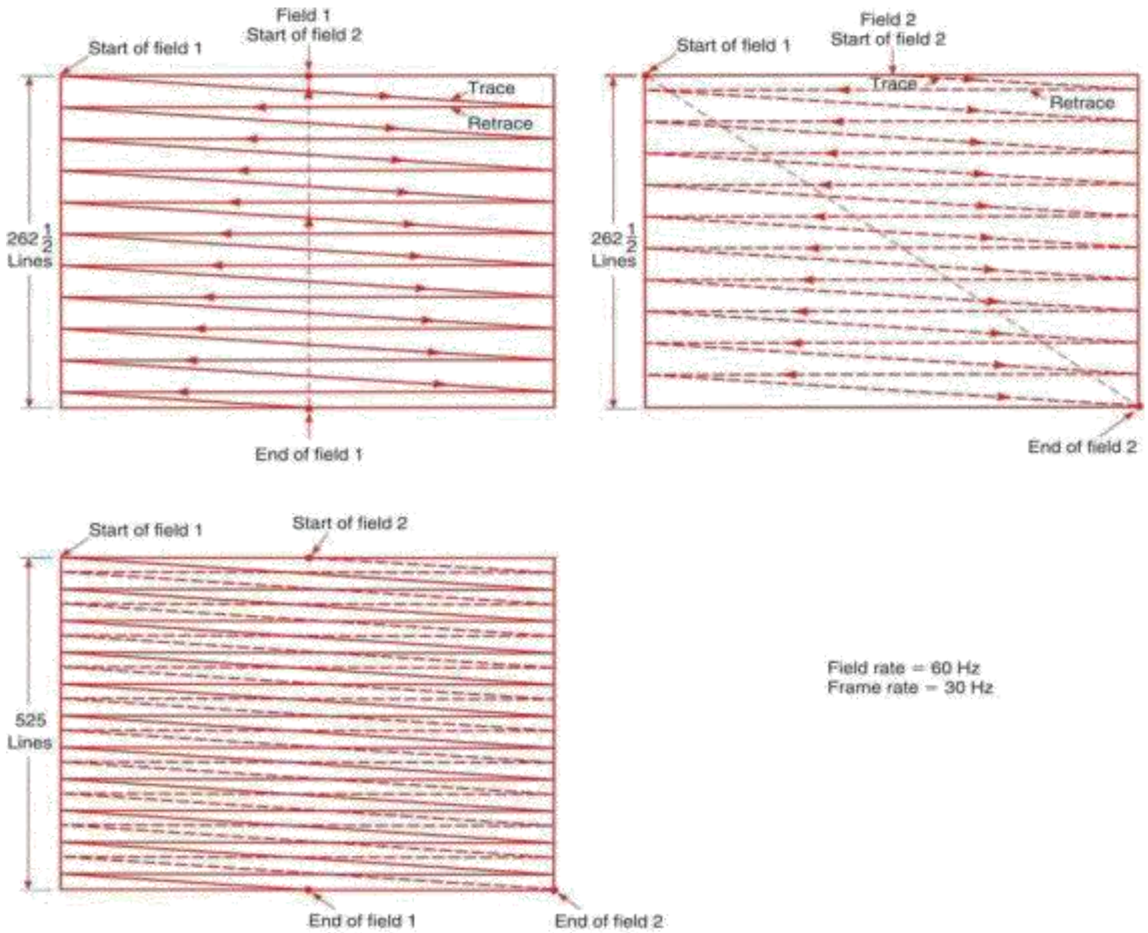


Fig 3: Interlaced scanning is used to minimize flicker.

At the TV receiver, the picture tube is scanned in step with the transmitter to accurately reproduce the picture. To ensure that the receiver stays exactly in synchronization with the transmitter, special horizontal and vertical sync pulses are added to and transmitted with the video signal (see Fig. 4). After one line has been scanned, a horizontal blanking pulse comes along. At the receiver, the blanking pulse is used to cut off the electron beam in the picture tube during the time the beam must retrace from right to left to get ready for the next left-to-right scan line. The horizontal sync pulse is used at the receiver to keep the sweep circuits that drive the picture tube in step with the transmitted signal. The width of the horizontal blanking pulse is about 10μs. Since the total horizontal period is 63.6 μs, only about 53.5μs is devoted to the video signal.

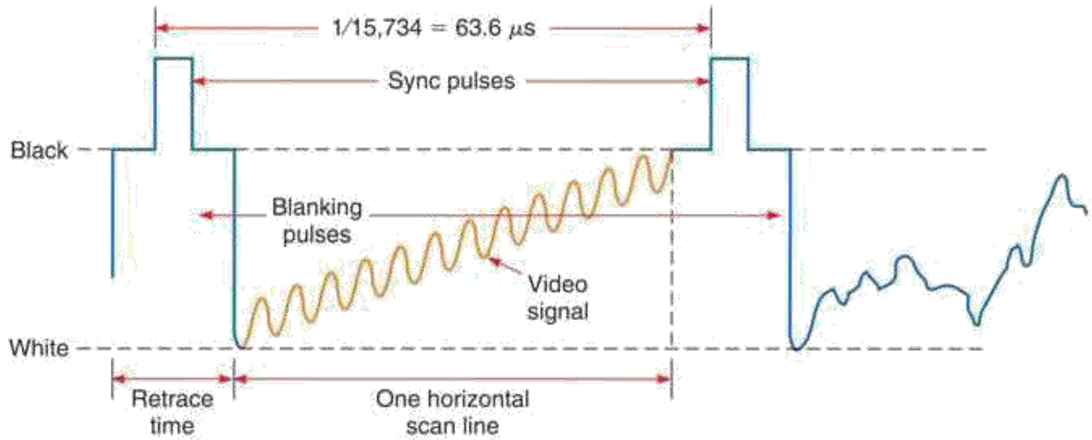


Fig 4: Sync pulses are used to keep the receiver in step with the transmitter.

At the end of each field, the scanning must retrace from bottom to top of the scene so that the next field can be scanned. This is initiated by the vertical blanking and sync pulses. The entire vertical pulse blacks out the picture tube during the vertical retrace. The pulses on top of the vertical blanking pulse are the horizontal sync pulses that must continue to keep the horizontal sweep in sync during the vertical retrace. The equalizing pulses (not shown in Fig. 4) that occur during the vertical retrace period help synchronize the half scan lines in each field. Approximately 30 to 40 scan lines are used up during the vertical blanking interval. Therefore, only 480 to 495 lines of actual video are shown on the screen.

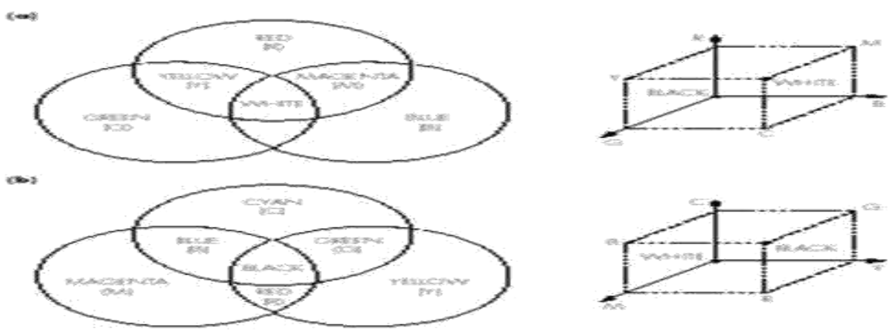
Digitized Pictures:

A good quality black and white picture can be obtained by using 8 bits per picture element. This yields 256 different levels of gray per element.

Color principles:

- C**olor gamut –whole spectrum of colors can be produced by using different proportions** of primary colors red(R), green(G), and blue (B)
- Additive color mixing: produces a black when all three primary colors are zero or in other words mixing of three primary colors produces a white color.
- Subtractive color mixing: produces a white when all three primary pigment colors are zero or in other words mixing of three primary pigment colors produces a white color.

Color derivation principles: (a) additive color mixing; (b) subtractive color mixing.



Raster Scan Principle:

- The picture tubes used in TVsets operate using a raster scan.
- Each complete scan comprises a number of discrete horizontal lines starts at the top left corner of the screen and ends at the bottom of the right corner. It is called as **progressive scanning**.
- Each complete set of horizontal scan is called a **frame**.
- **Pixel depth**: The number of bits per pixel is known as the pixel depth and determines the range of different colors.
- TV picture tubes were designed to display moving images.
- The frame refresh rate must be enough to ensure the eye is not aware the display is continuously being refreshed.
- A low refresh rate leads to flicker which is caused by the previous image fading from the eye retina.
- **Aspect ratio:** Both the number of pixels per scanned line and the number of lines per frame vary the actual numbers used being determined by aspect ratio. It can be defined as the ratio of the screen width to the screen height.

AUDIO:

- We know that the bandwidth of a typical speech signal is from 50Hz through to 10kHz whereas music signal from 15 Hz through to 20kHz
- Therefore the sampling rate selected is : 20ksps (2*10kHz) for speech and 40ksps (2*20kHz) for music
- Music stereophonic (stereo) results in a bit rate double that of a monaural(mono) signal.

PCM Speech:

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- With PSTN network the BW of speech signal was limited to 200Hz to 3.4 kHz.
- Nyquist rate=6.8kHz but because of poor quality of the band limiting filters the sampling rate selected was 8kHz which was required to avoid aliasing.
- Using 7 bit in north America and 8 bits in Europe yields 56kbps and 64kbps resply.
- The digitization procedure using 8 bit is known as PCM.
- It comprises the compressor and expander. The overall operation is called companding.

CD Quality Audio:

- The standard associated with the storage devices like CD players and CD ROMs is known as CD digital audio(CDDA).
- One of the sampling rate used is 44.1ksps.

Bit rate per channel = sampling rate*bits per sample

$44.1\times10^3\times16=705.6$kbps

Total bit rate = 2*705.6 = 1.411Mbps

Synthesized Audio:

- The memory required to store a digitized audio waveform can be very large.
- Hence synthesized audio is often used in multimedia applications since the amount of memory required can be between two or three orders of magnitude less than that required to store the digitized waveform version.
- There are 3 main components:

  Computer, Keyboard (based on piano), Set of sound generators.

- When the key is pressed a different code word is generated and read by the computer. The control panel contains a range of different switches and sliders that collectively allow

VIDEO:

Video features in a range of multimedia applications:

- Entertainment: Broadcast TV and VCR/DVD
- Interpersonal: video telephony and video conferencing
- Interactive: windows containing short video clips.

Broadcast Television:

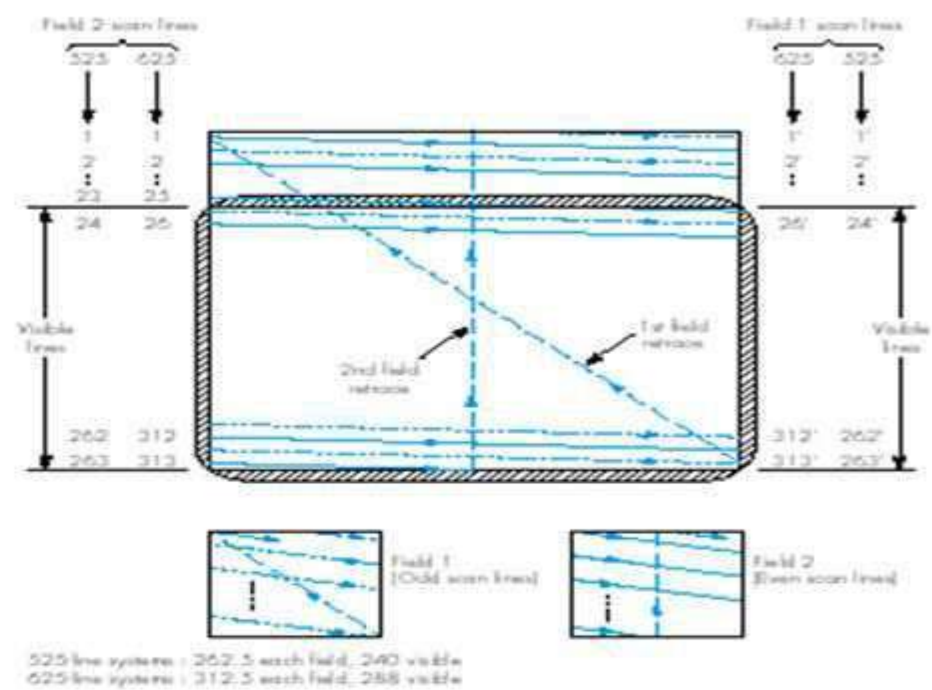
A color picture/image is produced from varying mixtures of the three primary colors red, green and blue.

- Screen of the picture is coated with a set of 3 different phosphors-one for each color-each of which is activated by a separate electron beam.
- The three electron beams are scanned from left to right with a resolution of either 525 lines (NTSC) or 625 lines (PAL/CCIR/SECAM).
- Screen is refreshed at rate of 60 or 50 frames per second respectively.
- The monitors in broadcast TV uses the same picture tubes and hence operates in a similar way.

Scanning Sequence:

- Although a refresh rate of 50 times per second is necessary to avoid flicker, to produce smooth motion, a refresh rate of 25 times per second is sufficient.
- Hence in order to minimize the amount of transmission BW, picture is associated with each frame in two halves. Each is known as a **field.**
- First field comprising of only the odd scan lines and the second the even scan lines.
- The two fields are integrated using a technique called **" interlaced scanning"**
- In a 525 line system only 240 lines are visible whereas in 625 line system 288 lines are visible.

Interlaced scanning principles.



Color Signals:

The three main properties of a color source that the eye makes use of are:

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- **Brightness**: This represents the amount of energy that stimulates the eye and varies on a gray scale from black through white.
- **Hue**: This represents the actual color of the source.
- **Saturation**: This represents the strength or vividness of the color.

The term luminance is used to refer to the brightness of a source whereas the hue and saturation are referred to as its chrominance.

The magnitude of the three signals R,G,B are in the proportion

$$\mathbf{0.299R+0.587G+0.144B} \quad \textit{\textbf{white is produced on the screen.}}$$

For any color source its luminance can be determined by summing together three components that make up a color in proportion

$$Ys = 0.299Rs+0.587Gs+0.144Bs$$

Where Ys is the amplitude of the luminance signal and Rs, Gs and Bs are the magnitudes of the three color component signals that make up the source.

Luminance is a measure of the amount of white light it contains and the other two signals **blue chrominance (Cb)** and **the red chrominance (Cr)** are then used to represent **hue** and **saturation.**

The two color difference signals:

Cb=Bs-Ys and Cr=Rs-Ys

Chrominance Components:

In the PAL system, Cb and Cr are referred to as *U* and *V* respectively. The scaling factors used for the three signals are:

PAL: $Y=0299R+0.587G+0.144B$

$U=0.493(B-Y)$

$V=0.877(R-Y)$

The NTSC system form two different signals referred to as *I* and *Q.*

NTSC: $Y=0299R+0.587G+0.144B$

$I=0.74(R-Y)-0.27(B-Y)$

$Q=0.48(R-Y)+0.41(B-Y)$

Digital Video:

- In most multimedia applications the video signals need to be in a digital form since it becomes possible to store them in a computer memory and to edit and integrate with other media types.
- Therefore digitization of video signals is been done and it is standardized by ITU-R.

4:2:2 FORMATS:

- The original digitization format used in Recommendation CCIR-601.

- The 3 signals have BW up to 6MHz for luminance and less than half this for chrominance signals.
- To digitize signals, it is necessary to use band limiting filters of 6MHz for luminance and 3MHz for chrominance signals with a minimum sampling rate of 12MHz and 6MHz resply.
- In the standard a line sampling rate of 13.5MHz (chosen because it is nearest to 12MHz) for luminance and 6.75MHz for the two chrominance signals is selected both of which independent of NTSC and PAL system.
- The number of samples per line chosen is 702 and can be derived as follows.

525 line system: Total line sweep time=63.56μs
Retrace period=11.56μs
Active line sweep
time=52μs

625 line system: Total line sweep time=64μs
Retrace period=12μs Active
line sweep time=52μs

$2\times10^{-6}\times13.5\times10^{6}$=702 samples per line

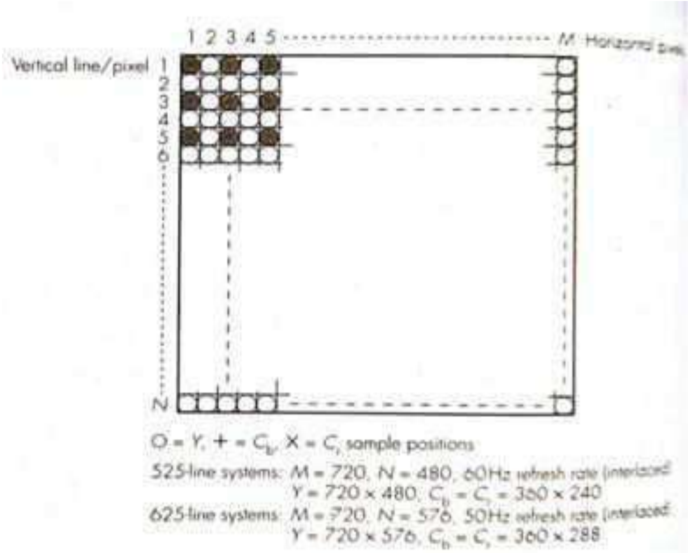
- Therefore a sampling rate of 13.5MHz yields
- The number of samples per line is increased to 720

- The corresponding number of samples for each of the two chrominance signals is 360 samples per active line

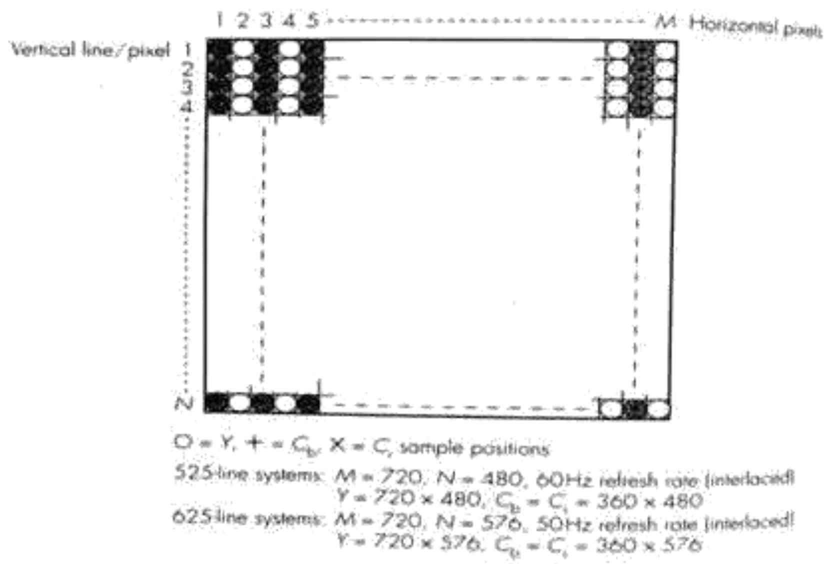
- This results in 4Y samples for every 2Cb, and 2Cr samples

- The numbers 480 and 576 being the number of active (visible) lines in the 525 and 625 line respective system.

Refer 4:2:0 & 4:2:2 formats.

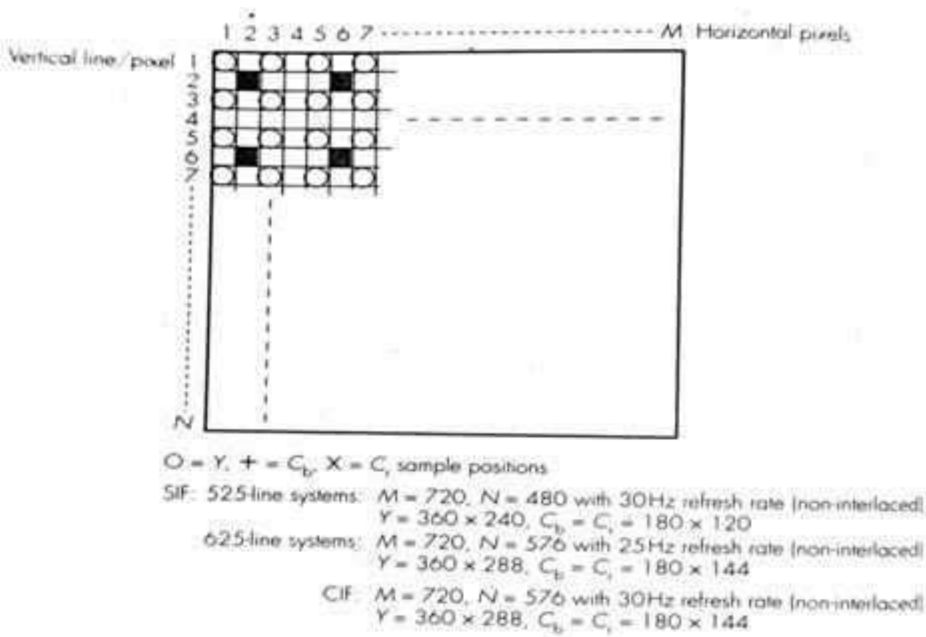


Sample positions in 4:2:0 digitization format.



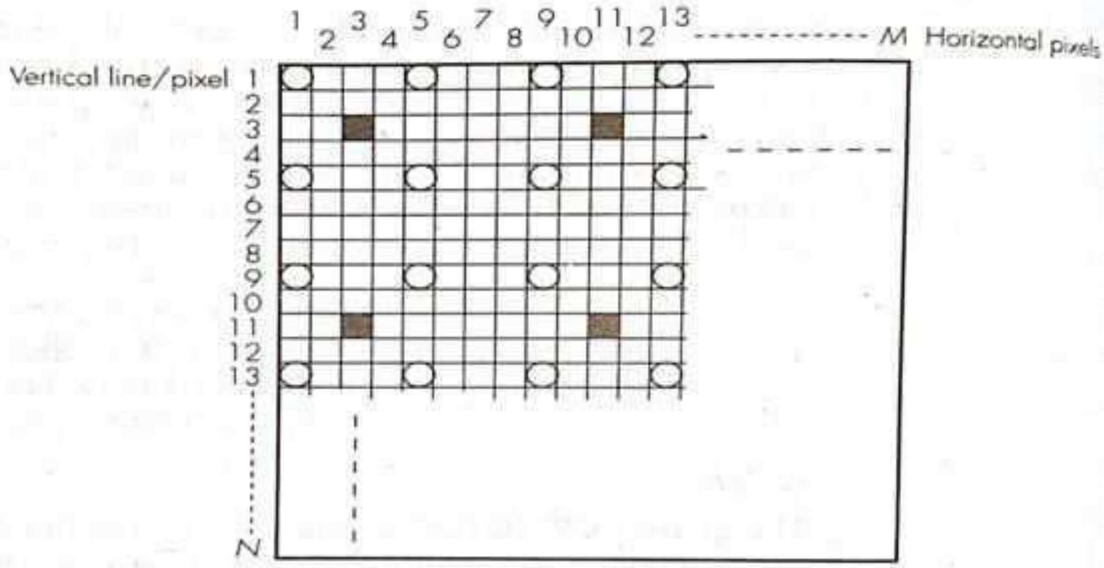
Sample positions with 4:2:2 digitization format.

Sample Positions for SIF and CIF:



Sample positions for SIF and CIF.

Sample Positions for QCIF:



O = Y, + = C_b, X = C_r sample positions

$M = 720$, $N = 576$ with 15 Hz or 7.5 Hz refresh rate (non-interlaced)

$Y = 180 \times 144$, $C_b = C_r = 90 \times 72$

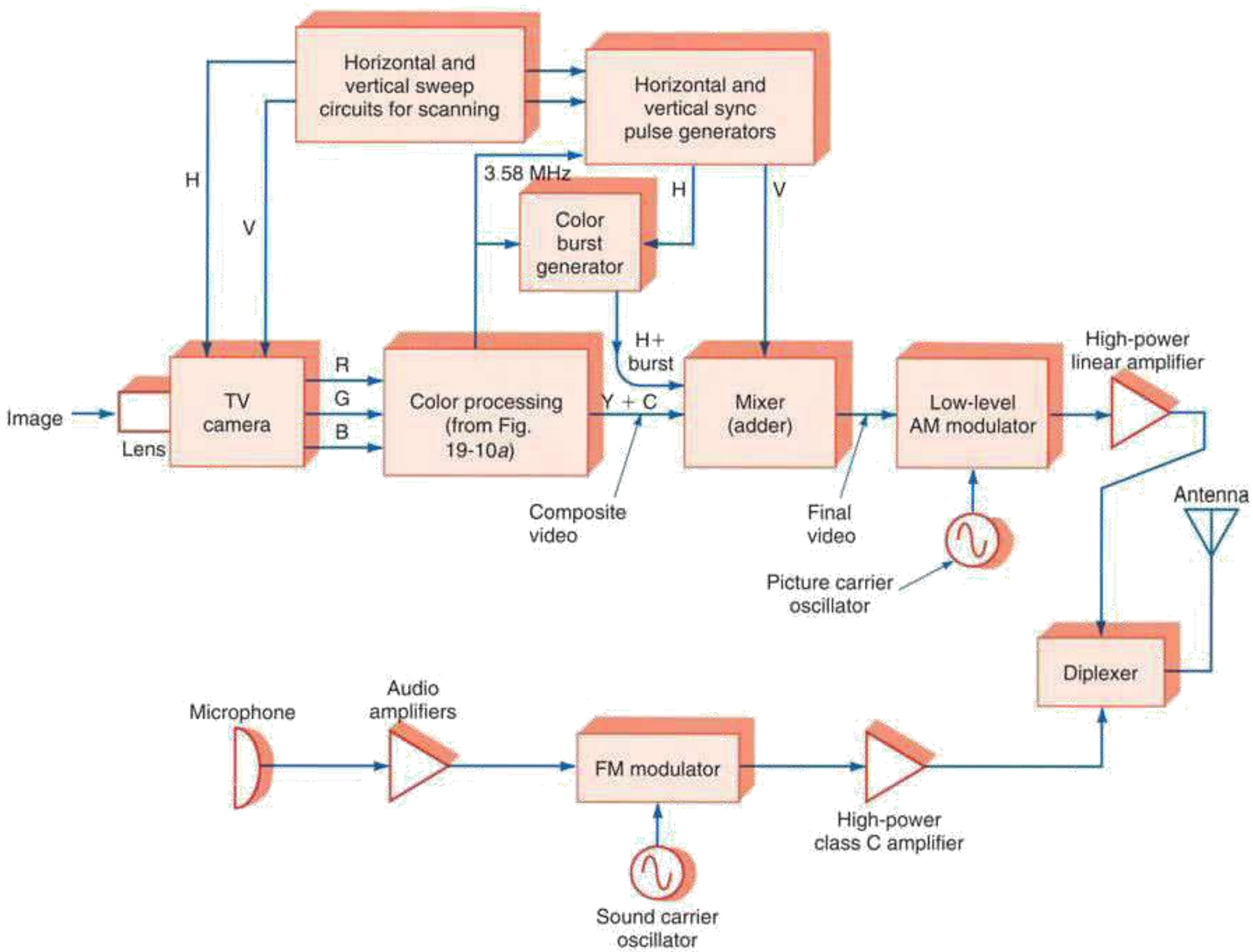
Sample positions for QCIF.

PC video digitization formats.

Digitization format	System	Spatial resolution	Temporal resolution
4:2:0	525-line	$Y = 640 \times 480$ $C_b = C_r = 320 \times 240$	60 Hz
	625-line	$Y = 768 \times 576$ $C_b = C_r = 384 \times 288$	50 Hz
SIF	525-line	$Y = 320 \times 240$ $C_b = C_r = 160 \times 240$	30 Hz
	625-line	$Y = 384 \times 288$ $C_b = C_r = 192 \times 144$	25 Hz
CIF		$Y = 384 \times 288$ $C_b = C_r = 192 \times 144$	30 Hz
QCIF		$Y = 192 \times 144$ $C_b = C_r = 96 \times 72$	15/7.5 Hz

TV – Transmitter:

A block diagram of a TV transmitter is shown in Fig. below. Note the sweep and sync circuits that create the scanning signals for the vidicons or CCDs as well as generate the sync pulses that are transmitted along with the video and color signals. The sync signals, luminance *Y,* and color signals are added to form the final video signal that is used to modulate the carrier. Low-level AM is used. The final AM signal is amplified by very high-power linear amplifiers and sent to the antenna via a diplexer, which is a A block diagram of a TV transmitter is shown in Fig. below. Note the sweep and sync circuits that create the scanning signals for the vidicons or CCDs as well as generate the sync pulses that are transmitted along with the video and color signals. The sync signals, luminance *Y,* and color signals are added to form the final video signal that is used to modulate the carrier. Low-level AM is used. The final AM signal is amplified by very high-power linear amplifiers and sent to the antenna via a diplexer, which is a set of sharp bandpass filters that pass the transmitter signal to the antenna but prevent signals from getting back into the sound transmitter. At the same time, the voice or sound signals frequency-modulate a carrier that is amplified by class C amplifiers and fed to the same antenna by way of the diplexer. The resulting VHF or UHF TV signal travels by line-of-sight propagation to the antenna and receiver.



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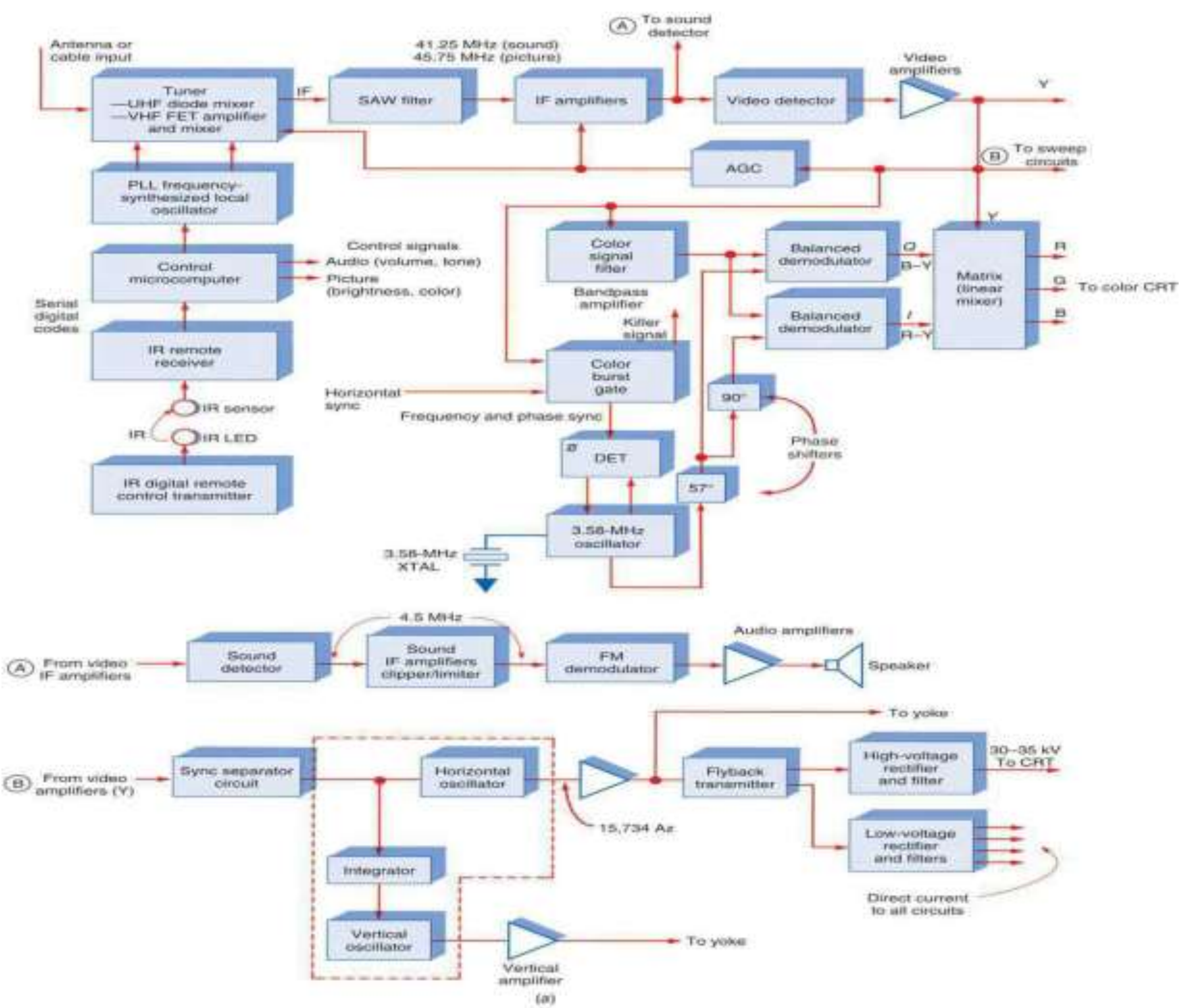
TV Receiver:

The process involved in receiving a TV signal and recovering it to present the picture and sound outputs in a high-quality manner is complex. Over the course of the years since its invention, the TV set has evolved from a large vacuum tube unit into a smaller and more reliable solid-state unit made mostly with ICs.

A block diagram of a *TV receiver* is shown in Fig. below. Although it is basically a super-heterodyne receiver, it is one of the most sophisticated and complex electronic devices ever developed. Today, most of the circuitry is incorporated in large-scale ICs. Yet the typical TV receiver still uses many discrete component circuits.

Tuner

The signal from the antenna or the cable is connected to the *tuner,* which consists of an RF amplifier, mixer, and local oscillator. The tuner is used to select the TV channel to be viewed and to convert the picture and sound carriers plus their modulation to an intermediate frequency (IF).As in most super-heterodyne receivers, the local-oscillator frequency is set higher than the incoming signal by the IF value.



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Tuning Synthesizer. The local oscillators are phase-locked loop (PLL) frequency synthesizers set to frequencies that will convert the TV signals to the IF. Tuning of the local oscillator is typically done digitally. The PLL synthesizer is tuned by setting the feedback frequency-division ratio.

Video Intermediate Frequency and Demodulation

The standard TV receiver IFs are 41.25 MHz for the sound and 45.75 MHz for the picture. For example, if a receiver is tuned to channel 4, the picture carrier is 67.25 MHz, and the sound carrier is 71.75 MHz (the difference is 4.5 MHz). The synthesizer local oscillator is set to 113 MHz. The tuner produces an output that is the difference between the incoming signal and local-oscillator frequencies, or 113 – 67.25MHz or 45.75 MHz, for the picture and 113 – 71.75MHz or 41.25 MHz, for the sound. Because the local oscillator frequency is above the frequency of incoming signals, the relationship of the picture and sound carriers is reversed at the intermediate frequencies, the picture IF being 4.5 MHz above the sound IF.

HDTV Standards:

HDTV for the United States was developed by the Adanced Television Systems Committee (ATSC) in the 1980s and 1990s. HDTV uses the scanning concept to paint a picture on the CRT, so you can continue to think of the HDTV screen in terms of scan lines, as you would think of the standard NTSC analog screen. However, you should also view the HDTV screen as being made up of thousands of tiny dots of light, called *pixels*. Each pixel can be any of 256 colors. These pixels can be used to create any image. The greater the number of pixels on the screen, the greater the resolution and the finer the detail that can be represented. Each horizontal scan line is divided into hundreds of pixels. The format of a HDTV screen is described in terms of the numbers of pixels per horizontal line by the number of vertical pixels (which is the same as the number of horizontal scan lines).

One major difference between conventional NTSC analog TV and HDTV is that HDTV can use *progressive line scanning* rather than *interlaced scanning*. In progressive scanning each line is scanned one at a time from top to bottom. Since this format is compatible with computer video monitors, it is possible to display HDTV on computer screens. Interlaced scanning can be used on one of the HDTV formats. Interlaced scanning minimizes flicker but complicates the video compression process. Progressive scanning is preferred and at a 60-Hz frame rate, flicker is not a problem.

The FCC has defined a total of 18 different formats for HDTV. Most are variations of the basic formats as given in Table-1, below. Most plasma, LCD and larger screens only display these formats.

Table -1

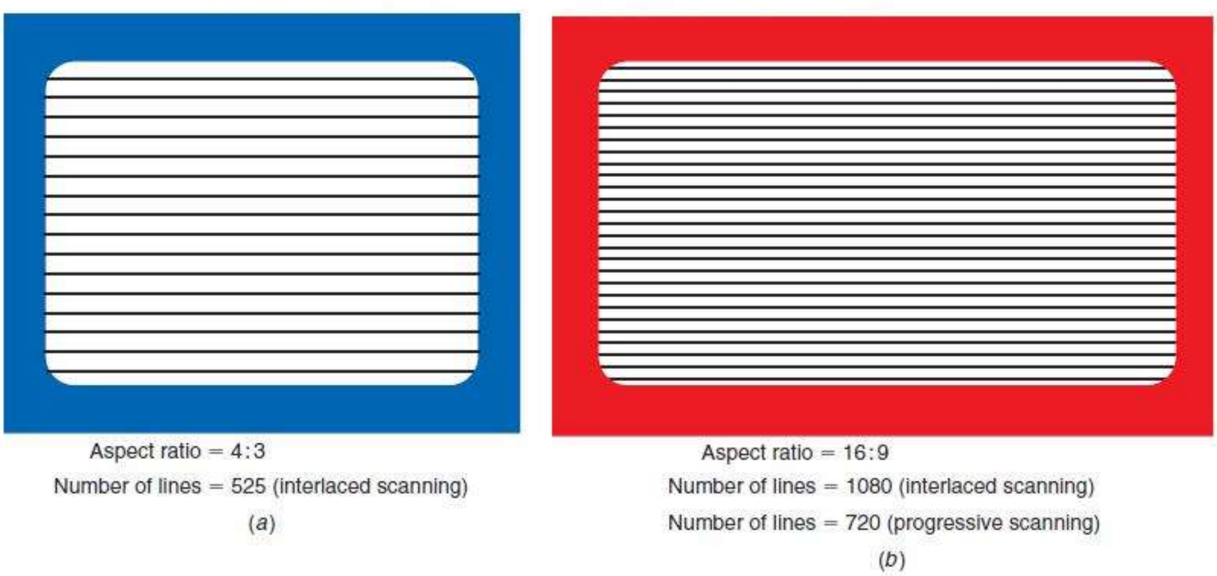
Standard	Aspect Ratio	Pixels/ Horizontal Line	Vertical Pixels*	Scan Rate, Hz
480p	4:3	640	480	24, 30, 60†
480i/p	4:3 or 16:9	704	480	24, 30, 60
720p	16:9	1280	720	24, 30, 60
1080i	16:9	1920	1080	24 or 30

*Number of scan lines.
†Standard PC VGA format.

HDTV Transmission Concepts:

In HDTV both the video and the audio signals must be digitized by A/D converters and transmitted serially to the receiver. Because of the very high frequency of video signals, special techniques must be used to transmit the video signal over a standard 6-MHz-bandwidth TV channel. And because both video and audio must be transmitted over the same channel, multiplexing techniques must be used. The FCC**'s requirement is** that all this information be transmitted reliably over the standard 6-MHz TV channels now defined for NTSC TV.

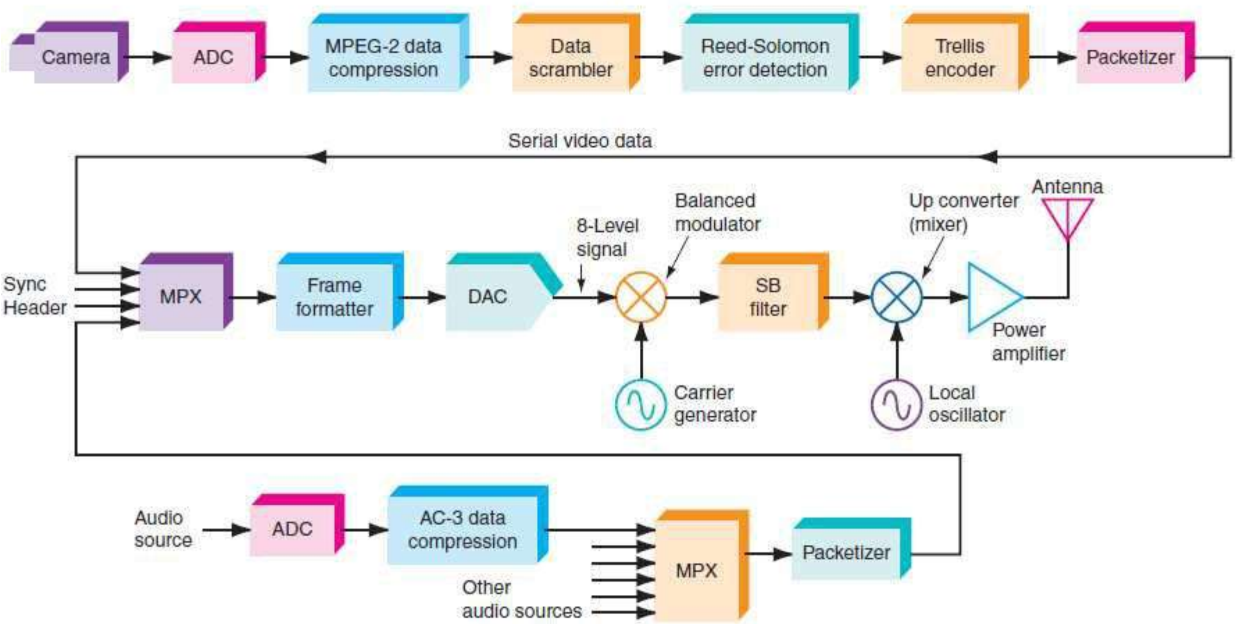
TV picture standards. (*a*) Current standard. (*b*) HDTV standard.



HDTV Transmitter. Figure below shows a block diagram of an HDTV transmitter. The video from the camera consists of the *R*, *G*, and *B* signals that are converted to the luminance and chrominance signals. These are digitized by A/D converters. The luminance sampling rate is 14.3 MHz, and the chroma sampling rate is 7.15 MHz. The resulting signals are serialized and sent to a data compressor. The purpose of this device is to reduce the number of bits needed to represent the video data and therefore permit higher transmission rates in a limited-bandwidth channel. MPEG-2 is the data compression method used in HDTV.

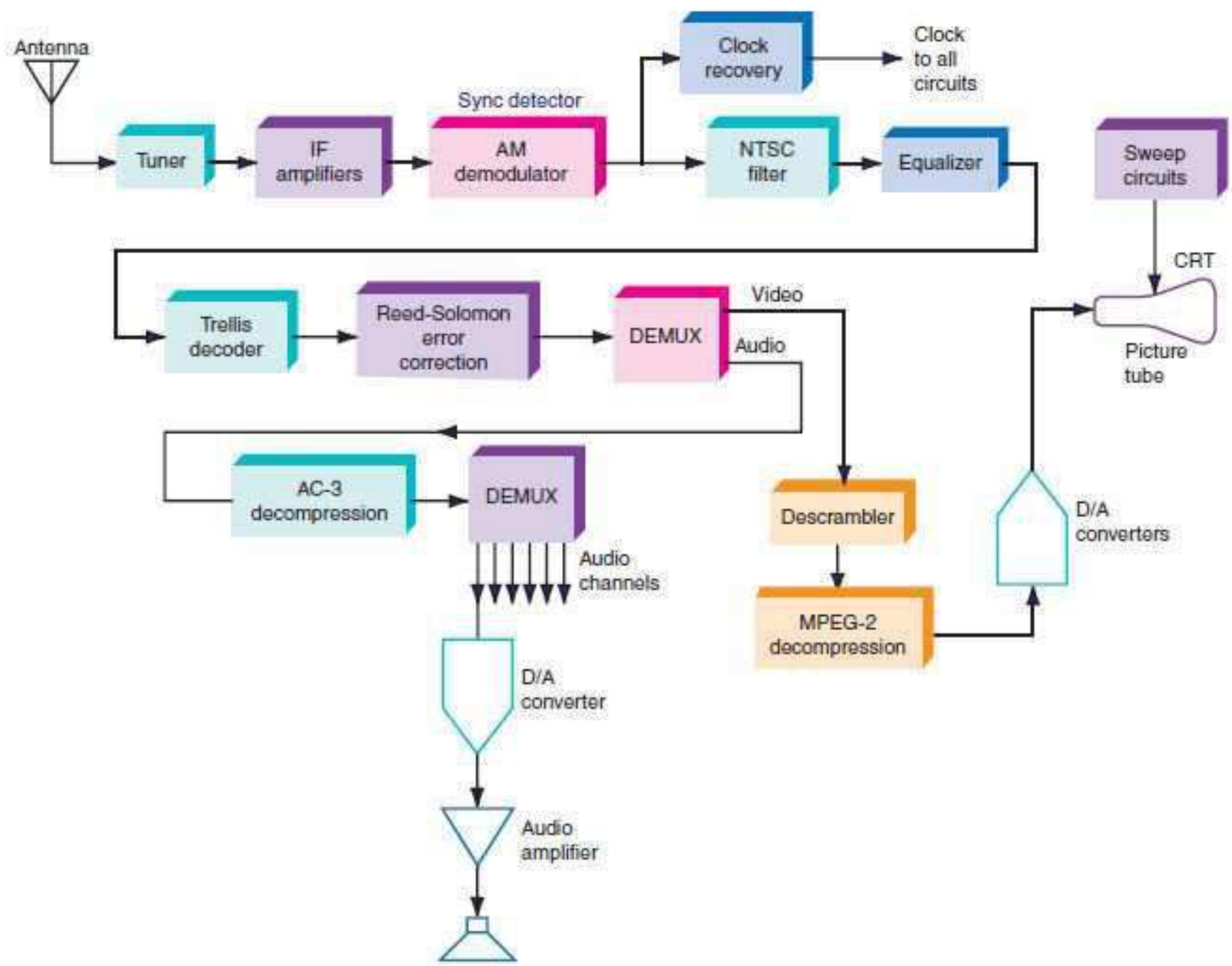
The MPEG-2 data compressor processes the data according to an algorithm that effectively reduces any redundancy in the video signal. For example, if the picture is one-half light blue sky, the pixel values will be the same for many lines. All this data can be reduced to one pixel value transmitted for a known number of times. The algorithm also uses fewer bits to encode the color than to encode the brightness because the human eye is much more sensitive to brightness than to color. The MPEG-2 encoder captures and compares successive frames of video and compares them to detect the redundancy so that only differences between successive frames are transmitted.

HDTV transmitter.



HDTV Receiver. An HDTV receiver picks up the composite signal and then demodulates and decodes the signal into the original video and audio information. A simplified receiver block diagram is shown in Fig. 23-30. The tuner and IF systems are similar to those in a standard TV receiver. From there the 8-VSB signal is demodulated (using a synchronous detector) into the original bit stream. A balanced modulator is used along with a carrier signal that is phase-locked to the pilot carrier to ensure accurate demodulation. A clock recovery circuit regenerates the clock signal that times all the remaining digital operations.

HDTV receiver.



The signal then passes through an NTSC filter that is designed to filter out any one channel or adjacent channel interference from standard TV stations. The signal is also passed through an equalizer circuit that adjusts the signal to correct for amplitude and phase variations encountered during transmission.

The signals are demultiplexed into the video and audio bit streams. Next, the trellis decoder and RS decoder ensure that any received errors caused by noise are corrected. The signal is descrambled and decompressed. The video signal is then converted back to the digital signals that will drive the D/A converters that, in turn, drive the red, green, and blue electron guns in the CRT. The audio signal is also demultiplexed and fed to AC-3 decoders. The resulting digital signals are fed to D/A converters that create the analog audio for each of the six audio channels.

VSB MODULATION & DEMODULATION

- In case of SSB modulation, when a sideband is passed through the filters, the band pass filter may not work perfectly in practice. As a result of which, some of the information may get lost.
- Hence to avoid this loss, a technique is chosen, which is a compromise between **DSB-SC** and **SSB**, called as **Vestigial Sideband (VSB)** technique. The word vestige which means "a part" from which the name is derived.
- The exact frequency response requirements on the sideband filter in SSB-SC system can be relaxed by allowing a part of the unwanted sideband called vestige to appear in the output of the modulator.
- Due to this, the design of the sideband filter is simplified to a great extent .
- But the bandwidth of the system is increased slightly .
- To generate a VSB signal, we have to first generate a DSB-SC signal and then pass it through a sideband filter as shown in fig. 1 . This filter will pass the wanted sideband as it is along with a part of unwanted sideband .

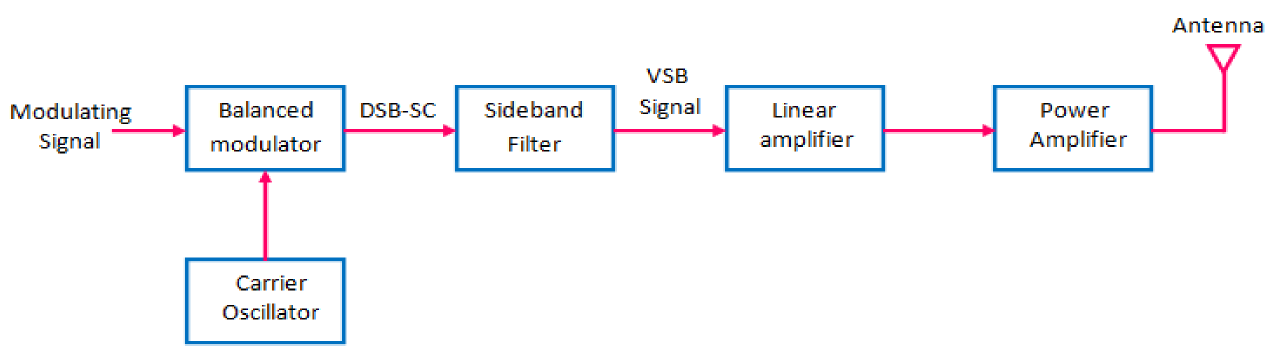
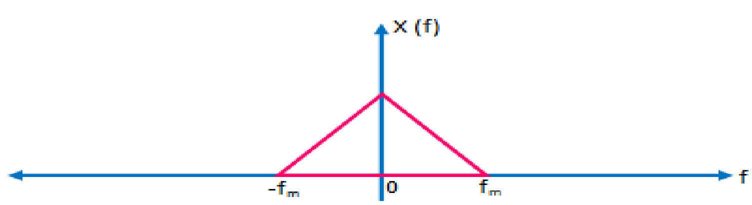


Fig.1 : VSB Transmitter

Frequency Spectrum

The spectrum of VSB is as shown in fig. 2 .



(a) Spectrum of message signal

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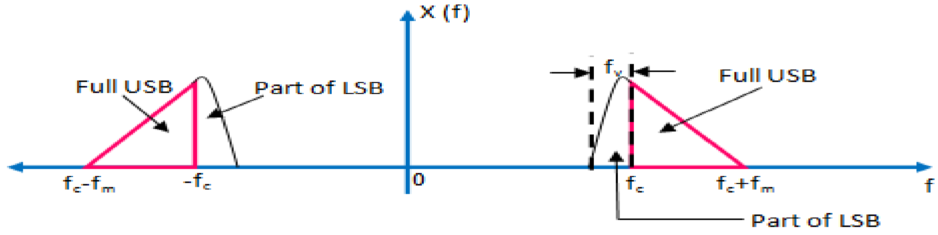


Fig. 2 (b) Spectrum of VSB Signal

- The spectrum of message signal x(t) has also been shown .
- In the frequency spectrum, it is assumed that the upper sideband is transmitted as it is and the lower sideband is modified into vestigial sideband .

Transmission Bandwidth

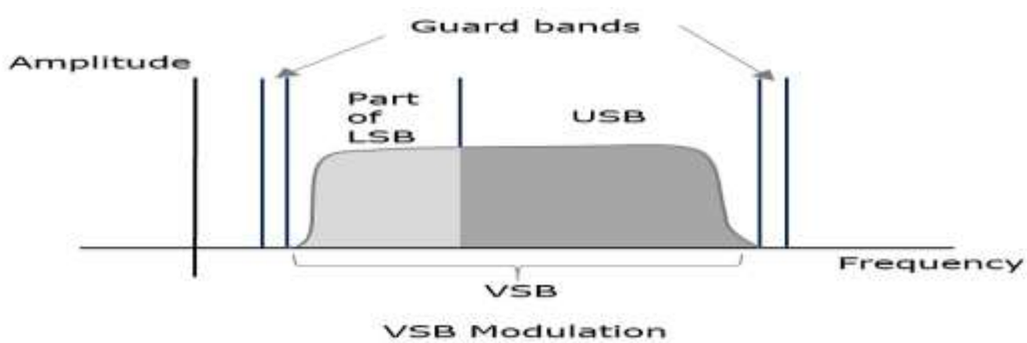
From fig. 2 (b), it is evident that the transmission bandwidth of the VSB modulated wave is given by : $B = (f_m + f_v)Hz$

Where f_m = Message bandwidth
f_v = Width of the vestigial sideband

Vestigial Sideband

Both of the sidebands are not required for the transmission, as it is a waste. But a single band if transmitted, leads to loss of information. Hence, this technique has evolved.

Vestigial Sideband Modulation or **VSB Modulation** is the process where a part of the signal called as **vestige** is modulated, along with one sideband. A VSB signal can be plotted as shown in the following figure.



Along with the upper sideband, a part of the lower sideband is also being transmitted in this technique. A guard band of very small width is laid on either side of VSB in order to avoid the interferences. VSB modulation is mostly used in television transmissions.

Transmission Bandwidth
The transmission bandwidth of VSB modulated wave is represented as –
B=f_m+ f_v) H
Where
f_m = Message bandwidth
f_v = Width of the vestigial sideband
Generation of VSB Modulated Wave

The block diagram of a VSB modulator is shown in fig.3 .

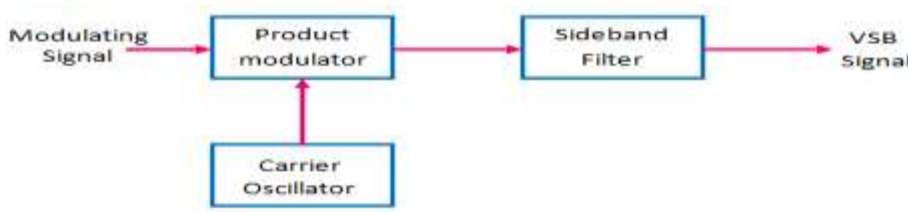


Fig.3 : Generation of VSB Signal

The modulating signal x(t) is applied to a product modulator . The output of the carrier oscillator is also applied to the other input of the product modulator . The output of the product modulator is then given by :

m(t) = x(t) . c(t)

= x(t) . $V_c \cos(2\pi f_c t)$
This represents a DSB-SC modulated wave .

This DSB-SC signal is then applied to a sideband shaping filter . The ddesign of this filter depends on the desired spectrum of the VSB modulated signal.
This filter will pass the wanted sideband and the vestige of the unwanted sideband .
Let the transfer function of the filter be H(f) .
Hence, the spectrum of the VSB modulated signal is given by :

$$S(f) = \frac{V_c}{2}[X(f - f_c) + X(f + f_c)]H(f)$$

Demodulation of VSB Wave

The block diagram of the VSB demodulator is shown in fig.4 .

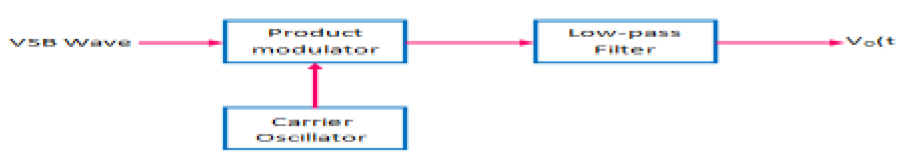


Fig.4 : VSB demodulator

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Working Operation

The VSB modulated wave is passed through a product modulator where it is multiplied with the locally generated synchronous carrier .

Hence, the output of the product modulator is given by :

$$m(t) = s(t) \times c(t) = s(t)V_c \cos(2\pi f_c t)$$

Taking the Fourier transform of both sides, we get

$$M(f) = S(f) \times \left[\frac{1}{2}\delta(f + f_c) + \frac{1}{2}\delta(f - f_c)\right] = \frac{1}{2}S(f + f_c) + \frac{1}{2}S(f - f_c)$$

But

$$S(f) = \frac{V_c}{2}[X(f - f_c) + X(f + f_c)]H(f)$$

Hence, we have

$$M(f) = \frac{V_c}{2}[X(f - 2f_c)H(f - f_c) + X\big((f + 2f_c)H(f + f_c)\big] + \frac{V_c}{4}[X(f)[H(f - f_c) + H(f + f_c)]$$

The first term in the above expression represents the VSB modulated wave, corresponding to a carrier frequency of $2f_c$ .This term will be eliminated by the filter to produce output $v_o(t)$.
The second term in the above expression for M(f) represents the spectrum of demodulated VSB output .

Therefore ,

$$V_O(f) = \frac{V_c}{4}[X(f)[H(f - f_c) + H(f + f_c)]$$

This spectrum is shown in fig.5 .

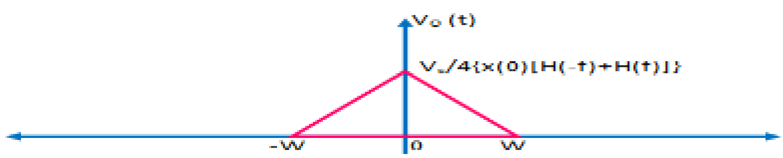

fig 5: Spectrum of VSB Demodulator

In order to obtain the undistorted message signal x(t) at the output of the demodulator, $V_o(f)$ should be a scaled version of X(f) .
For this the transfer function H(f) should satisfy the following conditions :

$$H(f - f_c) + H(f + f_c) = 2H(f + f_c)$$

Where $H(f_c)$ is constant .

VSB Modulation – Advantages

Following are the advantages of VSB –

- Highly efficient.
- Reduction in bandwidth.
- Filter design is easy as high accuracy is not needed.
- The transmission of low frequency components is possible, without difficulty.
- Possesses good phase characteristics.

VSB Modulation – Disadvantages

Following are the disadvantages of VSB –

- Bandwidth when compared to SSB is greater.
- Demodulation is complex.

VSB Modulation – Application

The most prominent application of VSB is in the transmission of television signals. Zenith developed the very first eight-level VSB (8-VSB), which has since been incorporated into the Advanced Television Systems Committee (ATSC) standards. Using VSB to transmit television signals is the most efficient and convenient technique, especially in scenarios where you need to keep bandwidth usage at a minimum.

Not only does it make the transmission of low-frequency components possible, but the filter design also doesn't require high accuracy. VSB is the standard for TV broadcasting worldwide since it supports the transmission of both audio and video signals at the same time.