ज्ञानेन प्रकाशते जगत्

INDUS UNIVERSITY

Video Engineering (EC0605)

Unit-1

B.Tech (Electronics and Communication)

Semester-VI

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Fundamental Concept Of Television

Objective

To comprehend the concept of

- Working principle of camera tube and picture tube.
- Television transmitter and receiver
- Scanning requirements and types of scanning
- Synchronization, Blanking and composite video signal
- Modulation technique to transmit composite video signal
- Picture transmission
- TV Channels used in India

INTRODUCTION

Video is the

- Technology of electronically capturing, recording, processing, storing, transmitting and reconstructing a sequence of images representing scenes in motion
- Recording, reproducing or broadcasting of moving visual images
- A recording of moving pictures and sound, especially as a digital file (DVD)
- A copy of a film or television programme
- Visual multimedia source that combines a sequence of images to form a moving picture

- Since video is created from a variety of sources, we begin with the signals themselves
- Analog video is represented as a continuous (time-varying) signal
- Digital video is represented as a sequence of digital images

- Video was first developed for mechanical television systems, which were quickly replaced by cathode ray tube(CRT) systems which were later replaced by flat panel displays of several types.
- Video systems vary in display resolution, aspect ratio, color capabilities and other qualities. Analog and digital variants exist and can be carried on a variety of media, including magnetic tape, optical discs, computer file, and network streaming.

- The fundamental aim of a television system is to extend the sense of sight beyond its natural limits, along with the sound associated with the scene being televised.

- The picture signal is generated by a TV camera and sound signal by a microphone.

- 625 line CCIR monochrome and PAL-B colour TV systems adopted by INDIA.

- **CCIR(**International Radio Consultative Committee**)** System was the 625-line analog broadcast **television** system which was the system used in most countries. It is being replaced across Western Europe, part of Asia and Africa by digital broadcasting.

- The Federal Communications Commission (FCC) is an independent agency of the united states government to regulate interstate communications by radio, television, wire, satellite, and cable. The FCC works towards six goals in the areas of broadband access, fair competition, radio frequency use, media responsibility, public safety, and homeland security
- The ITU Radio communication Sector (ITU-R) is the sector of the International Telecommunication Union and is responsible for radio communication

- There are three television standards in the world: **NTSC**, **PAL**, and **SECAM**. Each has their own attributes and they are not compatible with each other.
- **NTSC** (National Television Standards Committee) is the oldest existing standard, developed in the USA and first used in 1954.
- **PAL** (Phase Alternating Line) was developed in 1967 by the United Kingdom & Germany.

- **SECAM** (Sequential Colour a memory or "Sequential colour with memory") was developed in France in 1967. SECAM uses the same bandwidth and resolution (720x576) as PAL but transmits the color information sequentially

Elements of a television system

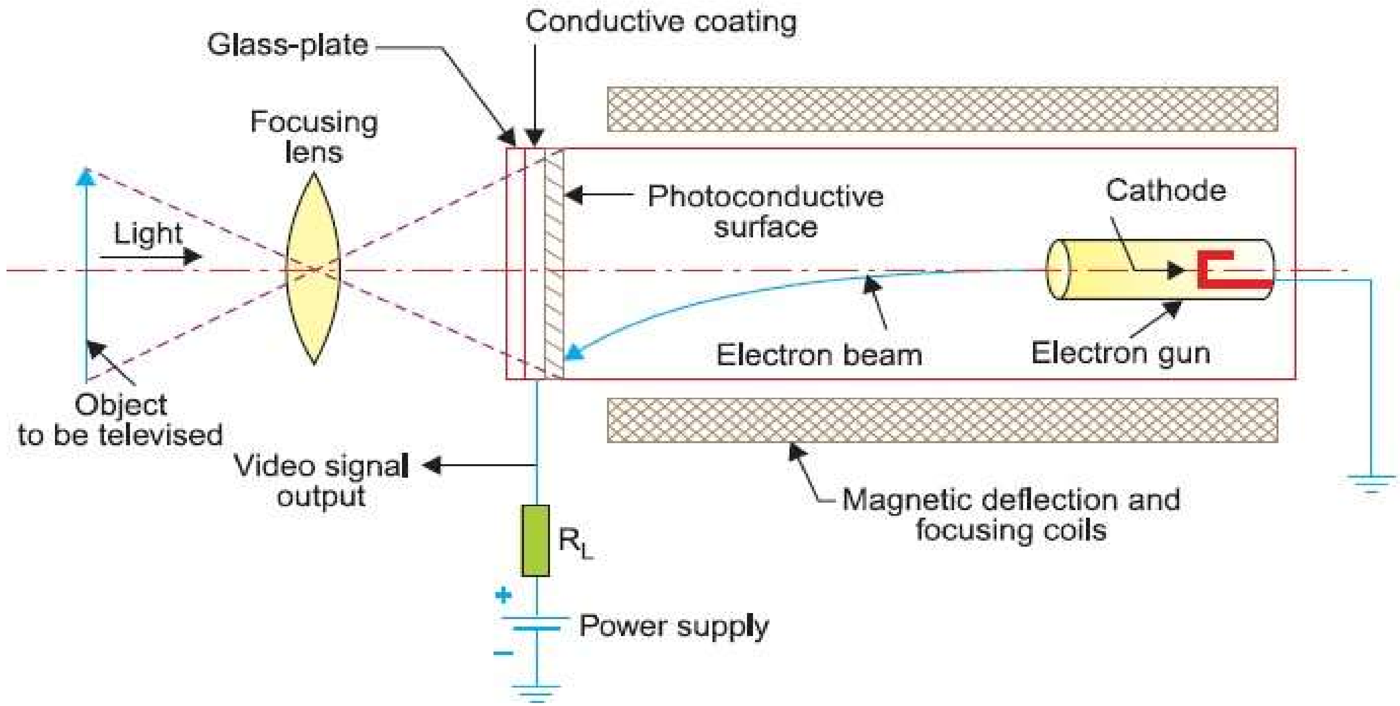
The elements of a simple broadcast television system are:

- An image source - This is the electrical signal representing the visual image, and may be from a professional video camera in the case of live television, a video tape recorder for playback of recorded images
- A sound source. This is an electrical signal from a microphone or from the audio output of a video tape recorder.
- A transmitter - which generates radio signals and encodes them with picture and sound information.

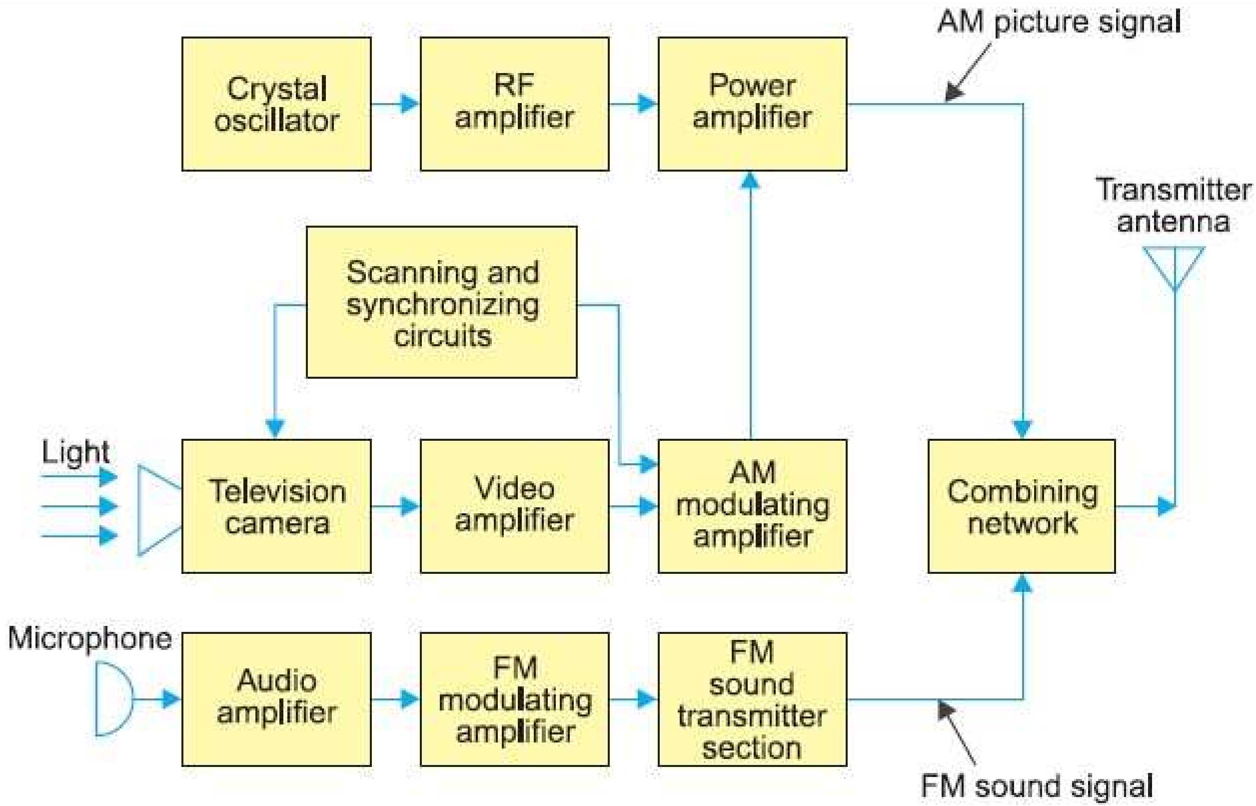
- A television antenna – which coupled to the output of the transmitter for broadcasting the encoded signals.
- A television antenna to receive the broadcast signals.
- A receiver - which decodes the picture and sound information from the broadcast signals, and whose input is coupled to the antenna of the television set.
- A display device - which turns the electrical signals into visual images.
- An audio amplifier and loudspeaker - which turns electrical signals into sound waves (speech, music, and other sounds) to accompany the images.

Simplified cross section view of vidicon camera tube

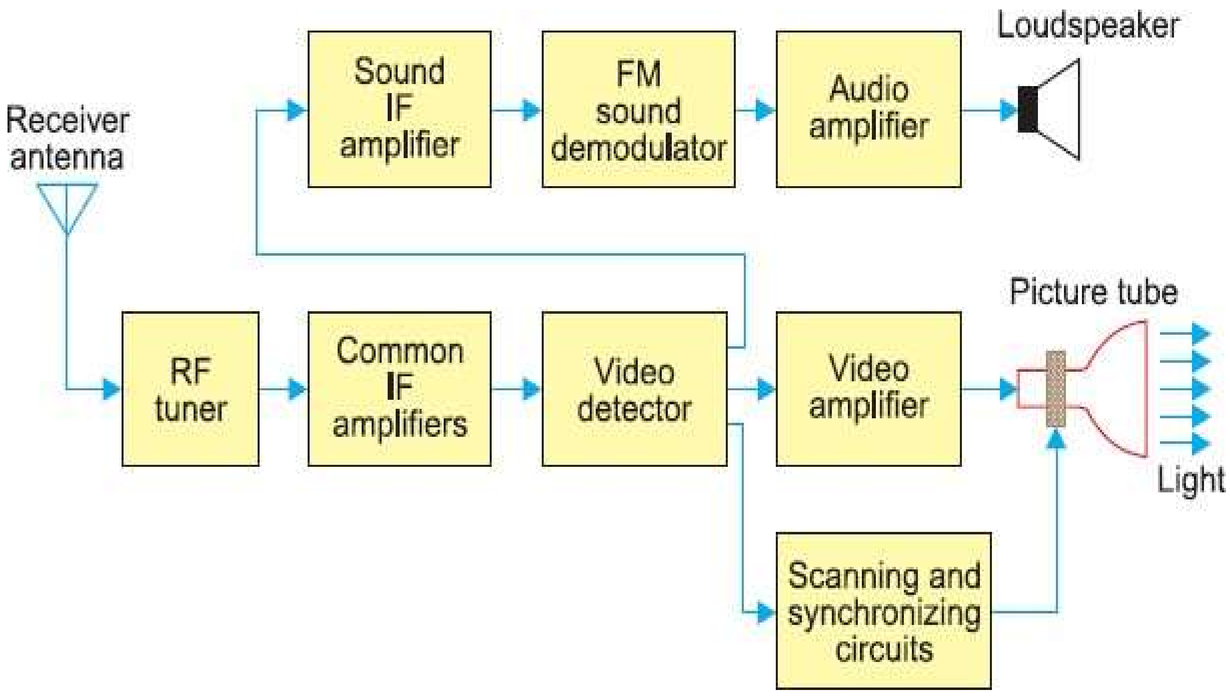
A TV camera, the heart of which is a camera tube, is used to convert the optical information into a corresponding electrical signal, the amplitude of which varies in accordance with the variations of brightness.



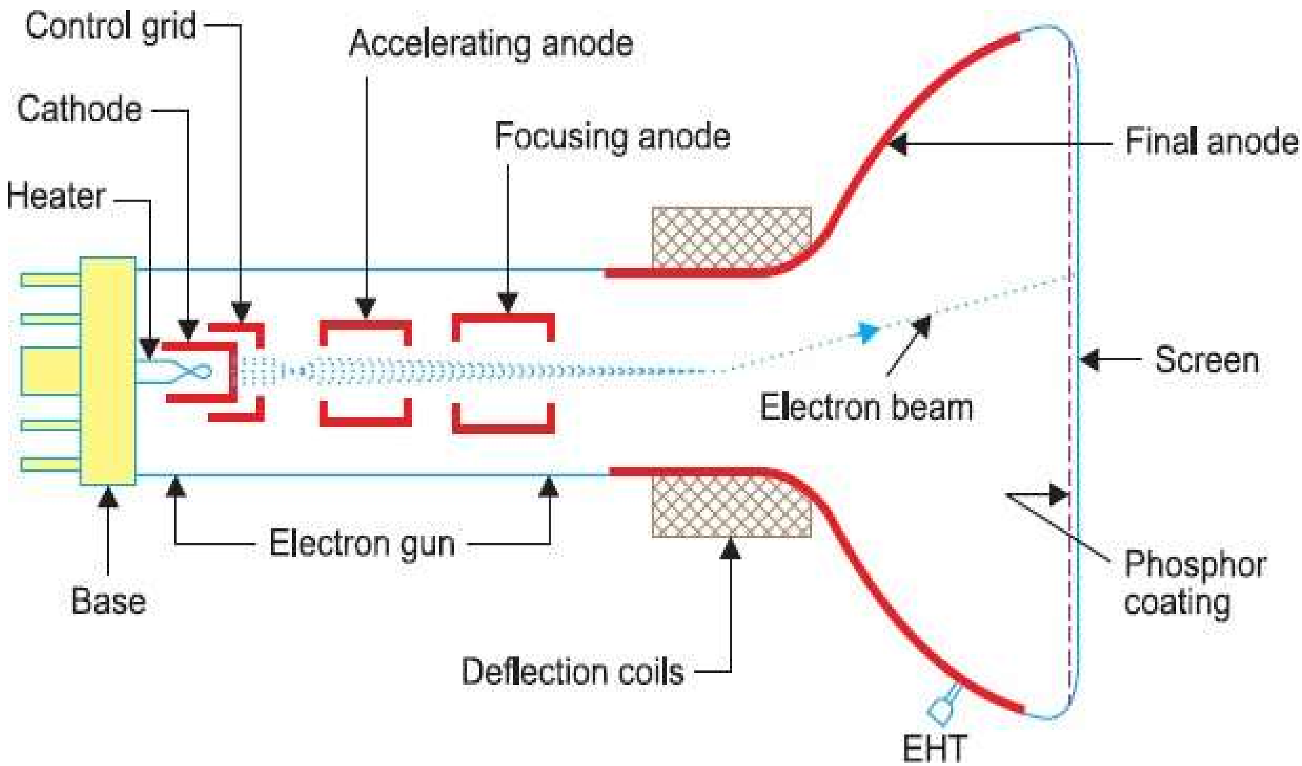
Elementary Block Diagram of Monochrome Television Transmitter



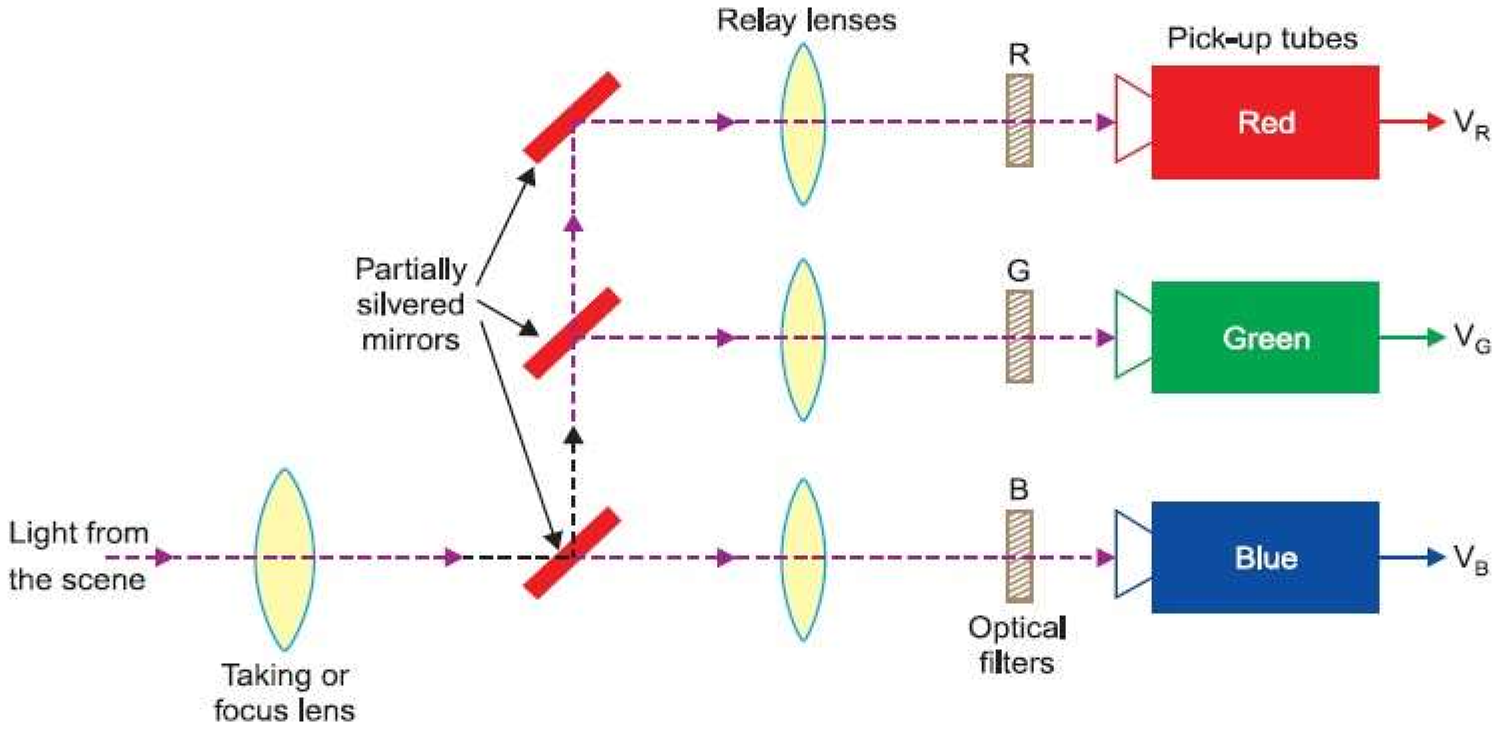
Simplify Block Diagram of Black and white TV Receiver



Elements of a Picture Tube



Simplify Block Diagram of colour camera



Picture Transmission

- The picture information is optical in character and may be thought of as an assemblage of a large number of bright and dark areas representing picture details. These elementary areas into which the picture details may be broken up are known as 'picture elements' or 'pixels'. which when viewed together, represent the visual information of the scene.

- Thus the problem of picture transmission is fundamentally much more complex, because, at any instant there are almost an infinite number of pieces of information, existing simultaneously, each representing the level of brightness of the scene to the reproduced.

- In other words the information is a function of two variables, time and space.

- Ideally then, it would need an infinite number of channels to transmit optical information corresponding to all the picture elements simultaneously.

- Presently the practical difficulties of transmitting all the information simultaneously and decoding it at the receiving end seem insurmountable(too difficult) and so a method known as scanning is used instead.

- Here the conversion of optical information to electrical form and its transmission are carried out element by element, one at a time and in a sequential manner to cover the entire scene which is to be televised.

- Scanning of the elements is done at a very fast rate and this process is repeated a large number of times per second to create an illusion of simultaneous pick-up and transmission of picture details.

- Another important requirement is that the same coordinates should be scanned at any instant both by the camera tube beam and the picture tube beam in the receiver.

- Synchronizing pulses are transmitted along with the picture information to achieve exact congruence (uniformity) between transmitter and receiver scanning systems.

- The frame adopted in all television systems is rectangular with width/height ratio,

There are many reasons for this choice.

- In human affairs most of the motion occurs in the horizontal plane and so a larger width is desirable.
- The eyes can view with more ease and comfort when the width of a picture is more than its height. The usage of rectangular frame in motion pictures with a width/height ratio of 4/3 is another important reason for adopting this shape and aspect ratio. This enables direct television transmission of film programmes without wastage of any film area.

- Dimensions of a TV receiver are specified by the diagonal length of the screen.

- When width is 4x and height is 3 x, diagonal would be 5 x.

- Determine height and width of a TV screen of 30cm size.

  Solution:

  5 x=3 0cm therefore x=6cm

  Hence, height=6*3=18cm and width=6*4=24cm

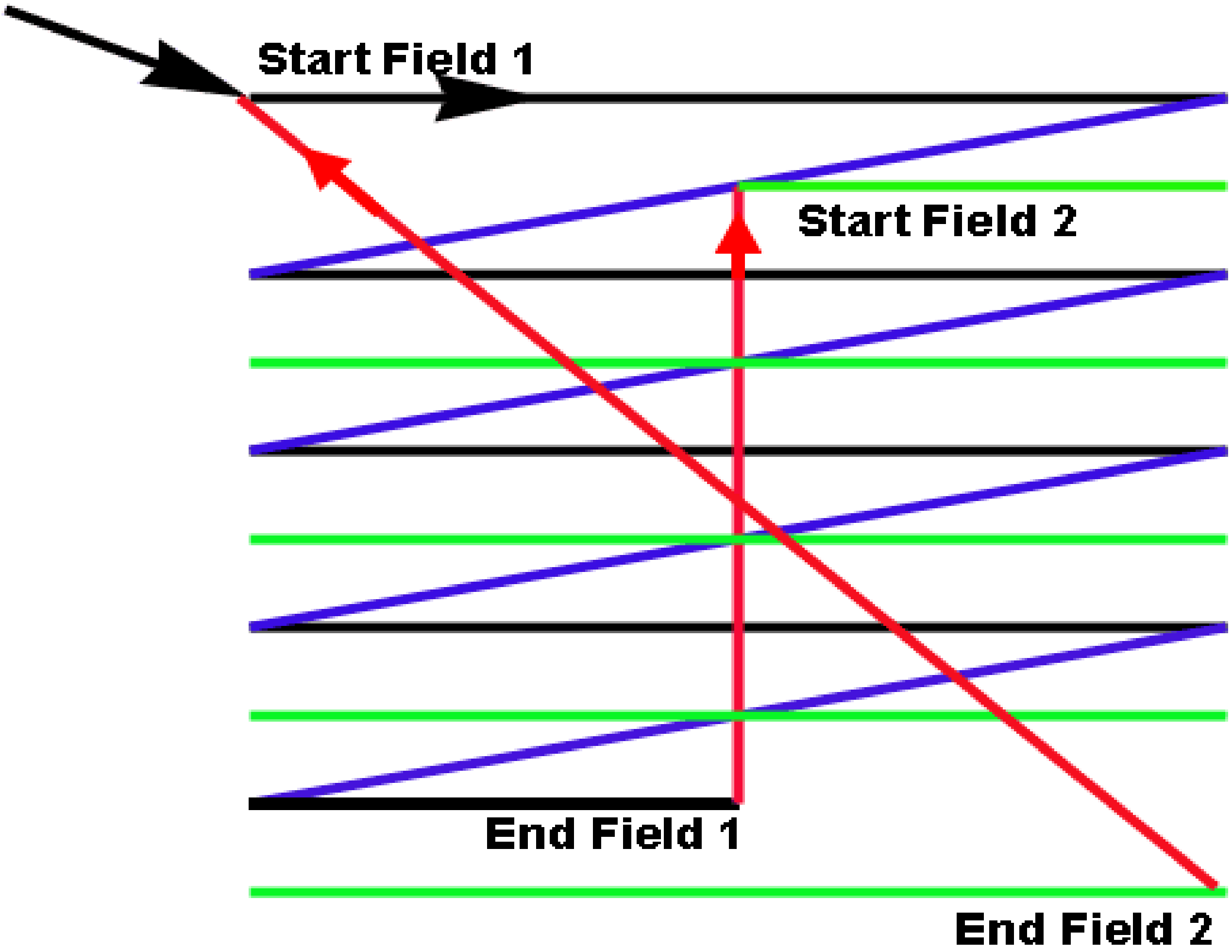
Scanning

- The scene is scanned rapidly both in the horizontal and vertical directions simultaneously to provide sufficient number of complete pictures or frames per second to give the illusion of continuous motion.

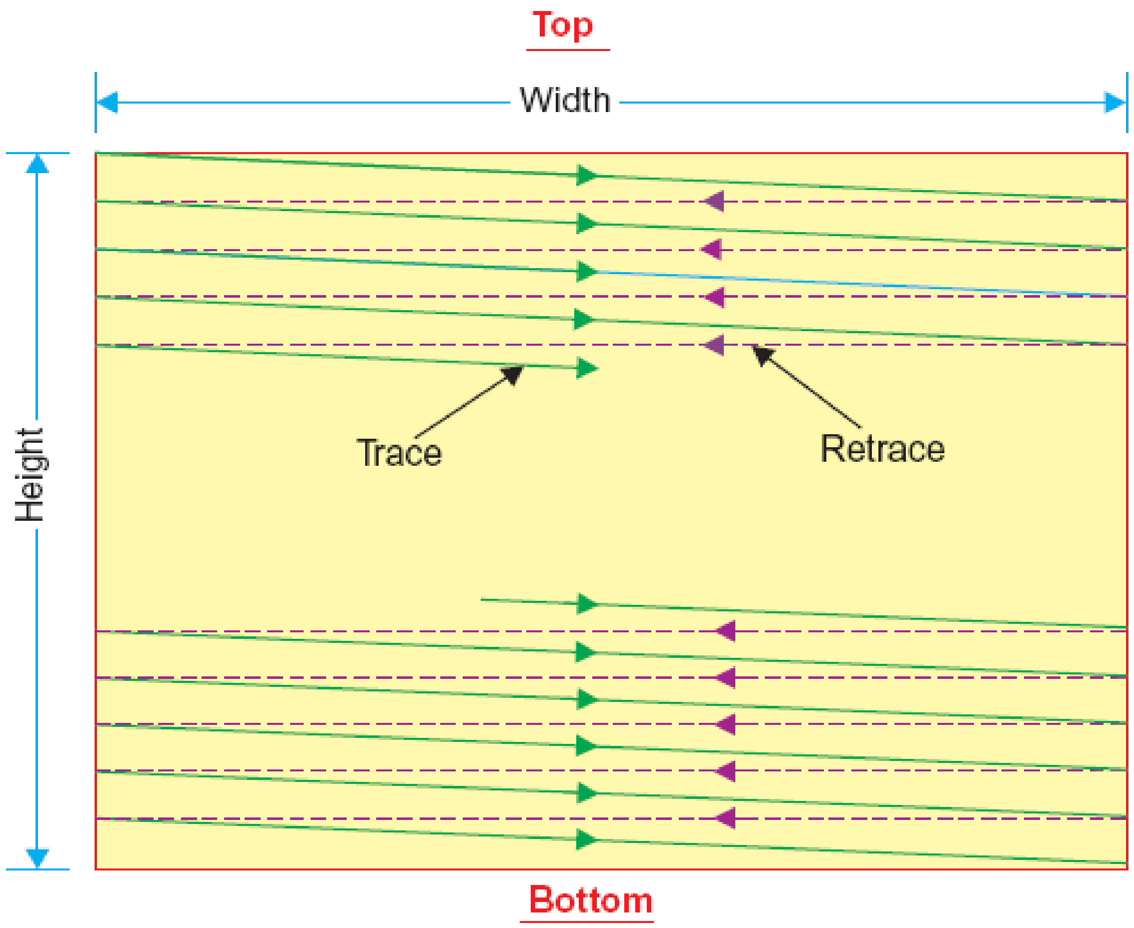
- Scanning is the process of extracting signals pertaining to the individual elements of a picture(pixels) in quick succession with the help of electronic beam one after the other.
- The process of extraction of signal from point to point is called scanning and interruption is called blanking.

- Values of light(intensity and colour) in a scene are function of space.
- Sound are single valued function of time.
- Scanning of the charge image converts the charges on the surface of the target into electrical signal varying in time frame called video signal.

- Instead of the 24 as in commercial motion picture practice, the frame repetition rate is 25 per second in most television systems.


Start Field 1
Start Field 2
End Field 1
End Field 2

Path of scanning beam in covering picture area



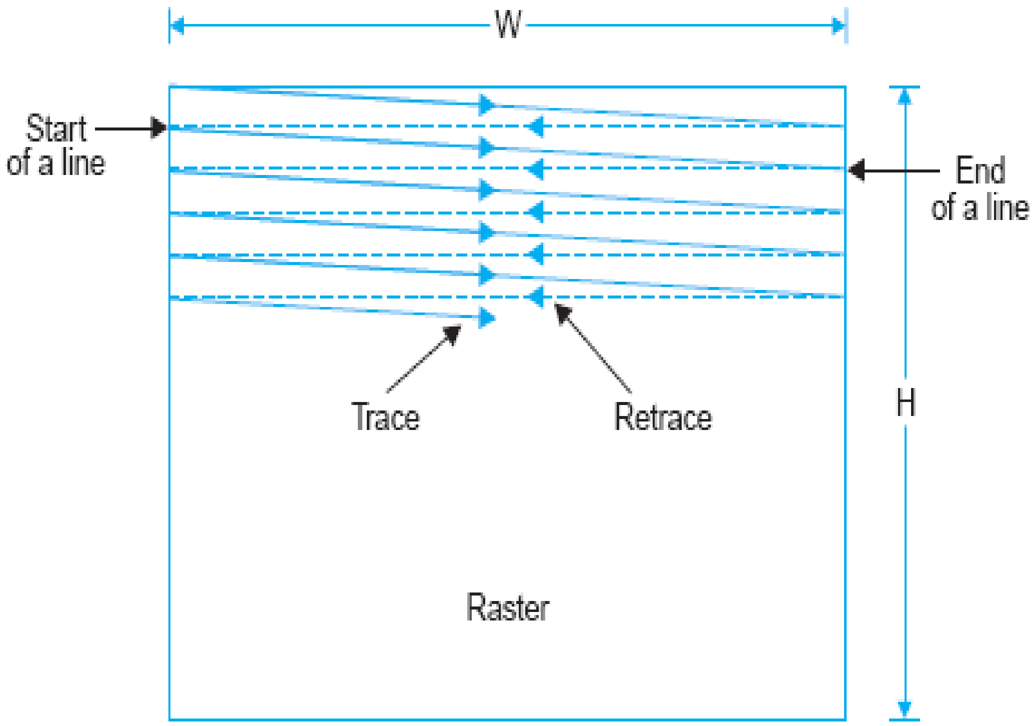
Horizontal Scanning

- Fig. shows the trace and retrace of several horizontal lines. The linear rise of current in the horizontal deflection coils deflects the beam across the screen with a continuous, uniform motion for the trace from left to right.

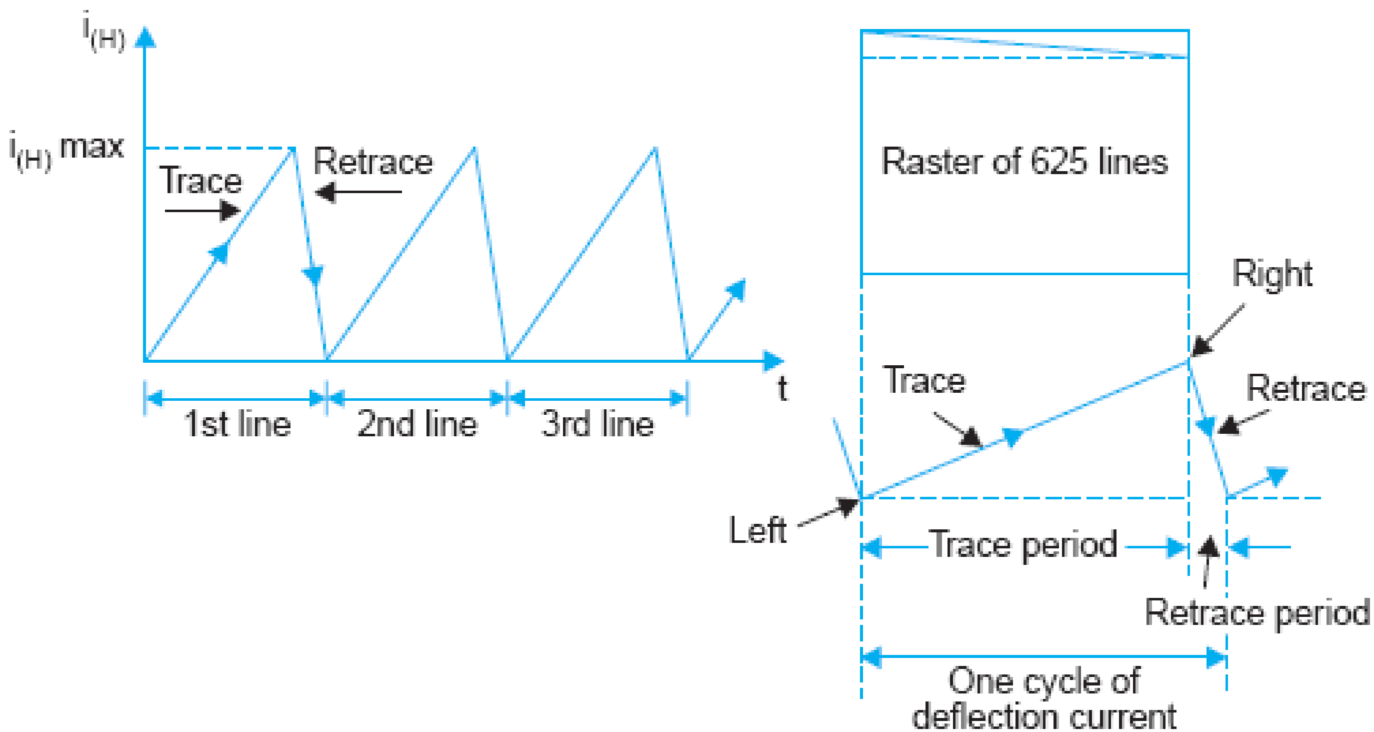
- At the peak of the rise, the saw tooth wave reverses direction and decreases rapidly to its initial value. This fast reversal produces the retrace or fly back. The start of the horizontal trace is at the left edge.

- Horizontal deflection is fast and it takes 64us for one scanning line.

Path of scanning beam in covering area



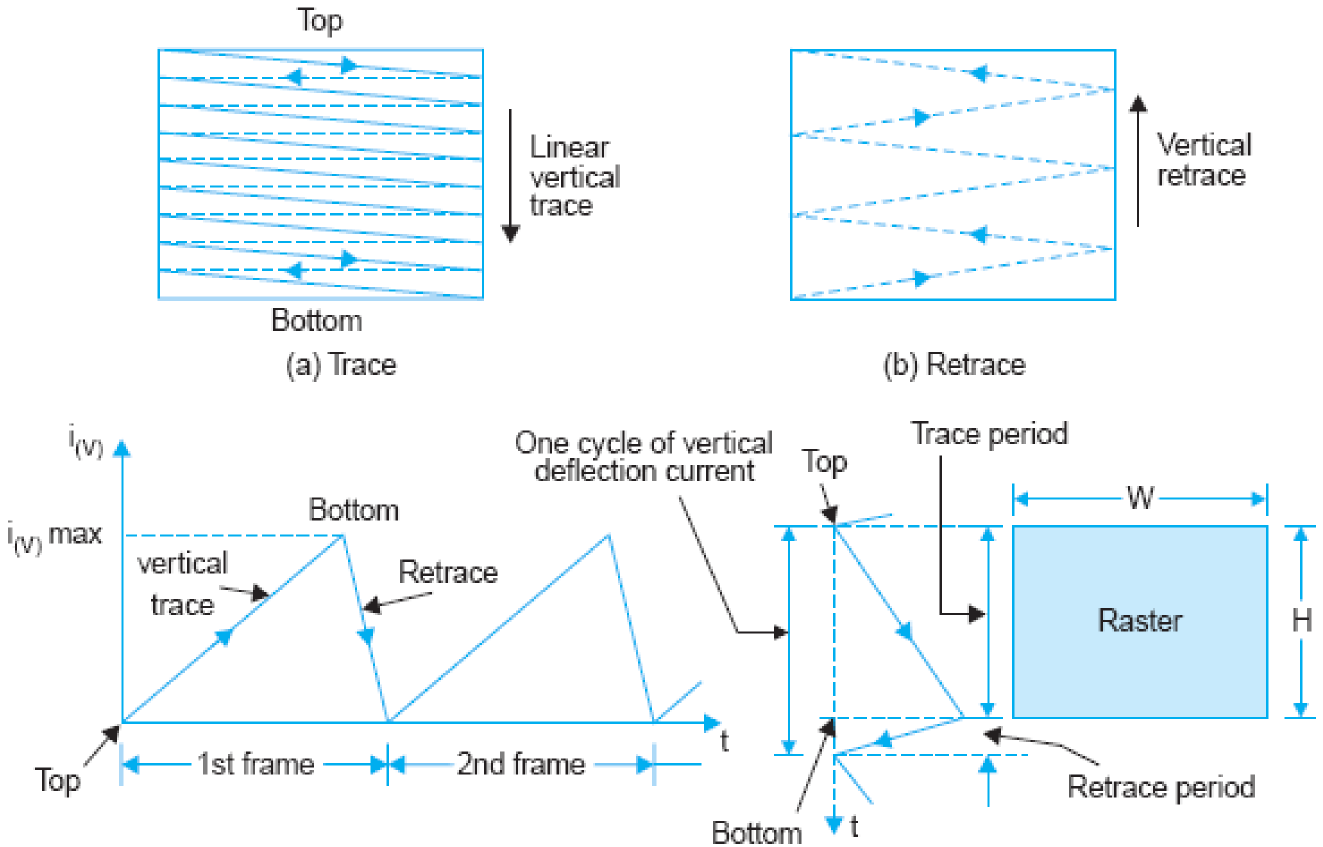
Horizontal deflection and deflection Current



Vertical scanning

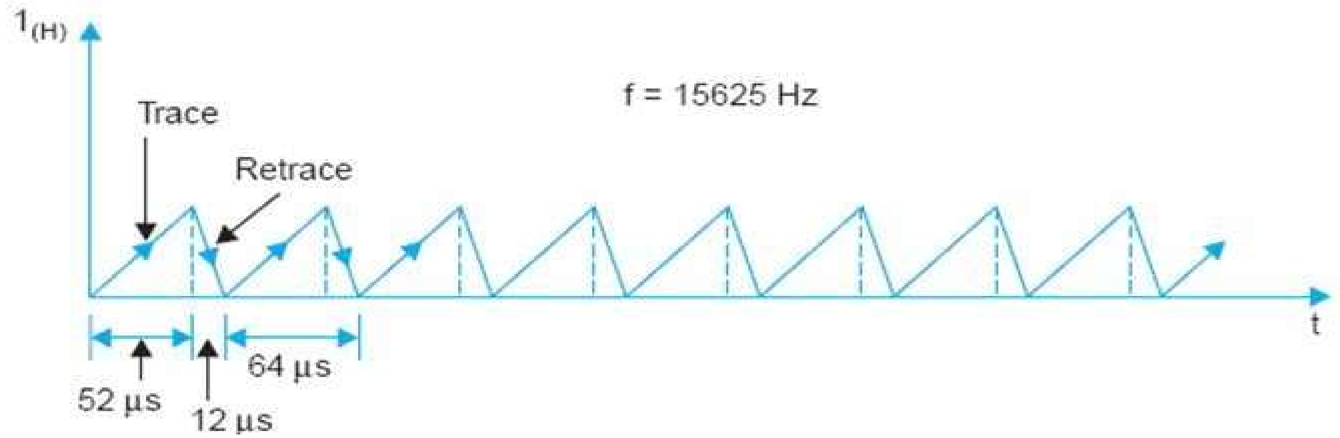
- The saw tooth current in the vertical deflection coils moves the electron beam from top to bottom of the raster at a uniform speed while the electron beam is being deflected horizontally. Thus the beam produces complete horizontal lines one below the other while moving from top to bottom.
- Vertical deflection is slow and takes 20ms.
- Saw tooth current are produced by charging a capacitor linearly through a resistor of the appropriate value for trace(ramp) signal and to discharge it rapidly through a low resistance transistor switch for retrace.

Vertical deflection and deflection Current

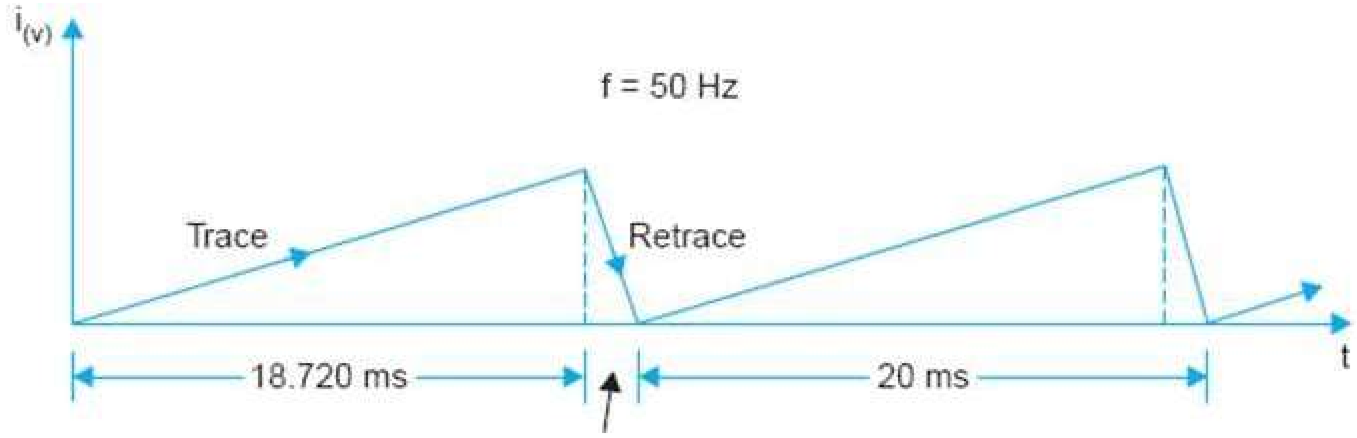


(c) Current waveform in vertical deflection coils

Scanning periods



Horizontal deflection current.



Vertical deflection current.

Types of Scanning

- Progressive Scanning
- Interlace scanning

- When one cycle of vertical saw tooth current completes scanning of one frame and the next cycle starts scanning of a new frame , it is called Progressive Scanning.
- Each sequence of scanning is called frame.
- Frame after frame scanned in progressive scanning.

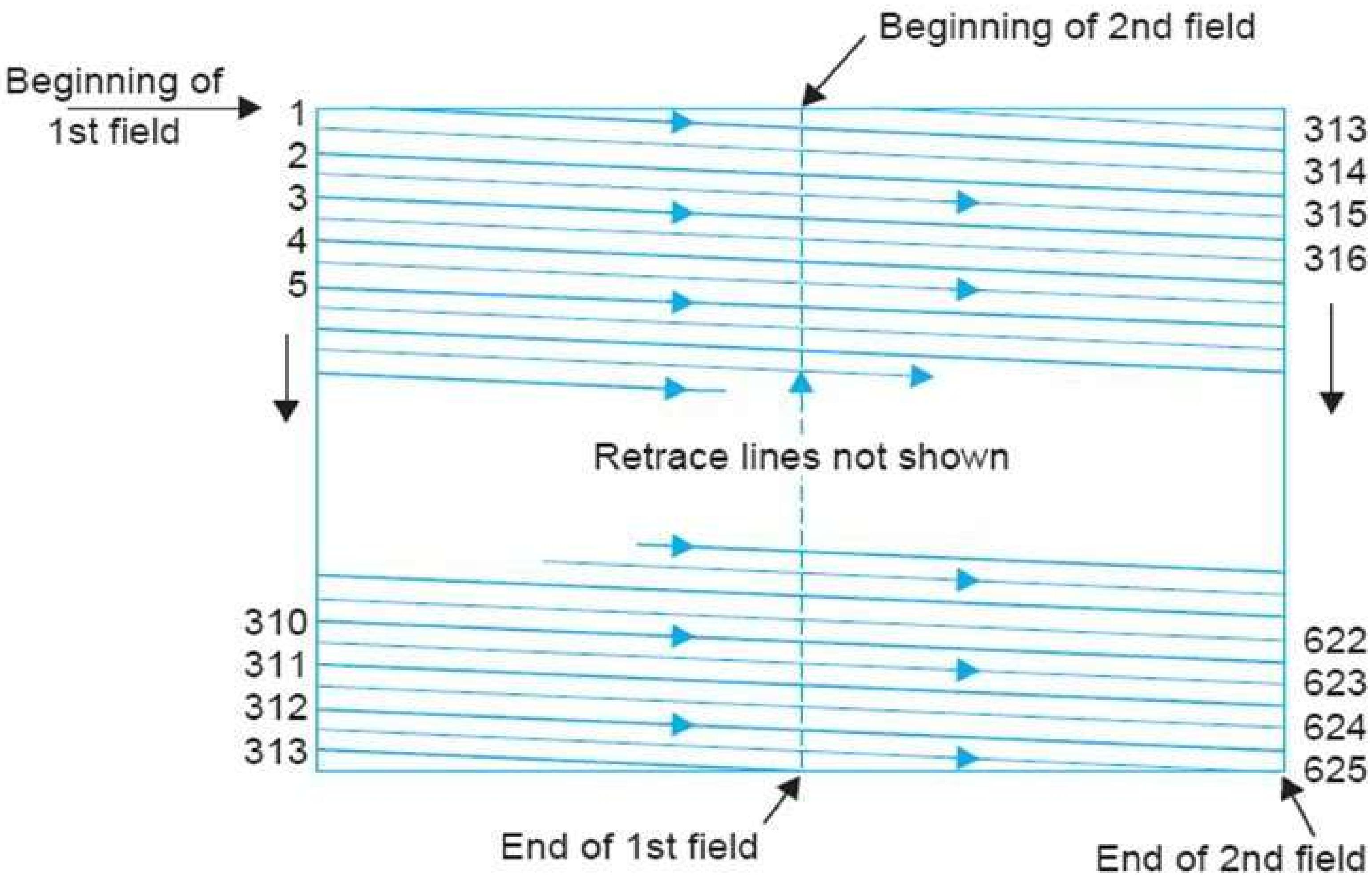
Disadvantage of progressive scanning

- In progressive scanning 25 frames per second are scanned.
- When scanning beam flips from bottom to top of the picture frame it takes about 1280us(20 lines).
- Screen appears black during this time.
- As persistence of vision is more for dark light.
- This interruptions become visible as flicker on the screen.

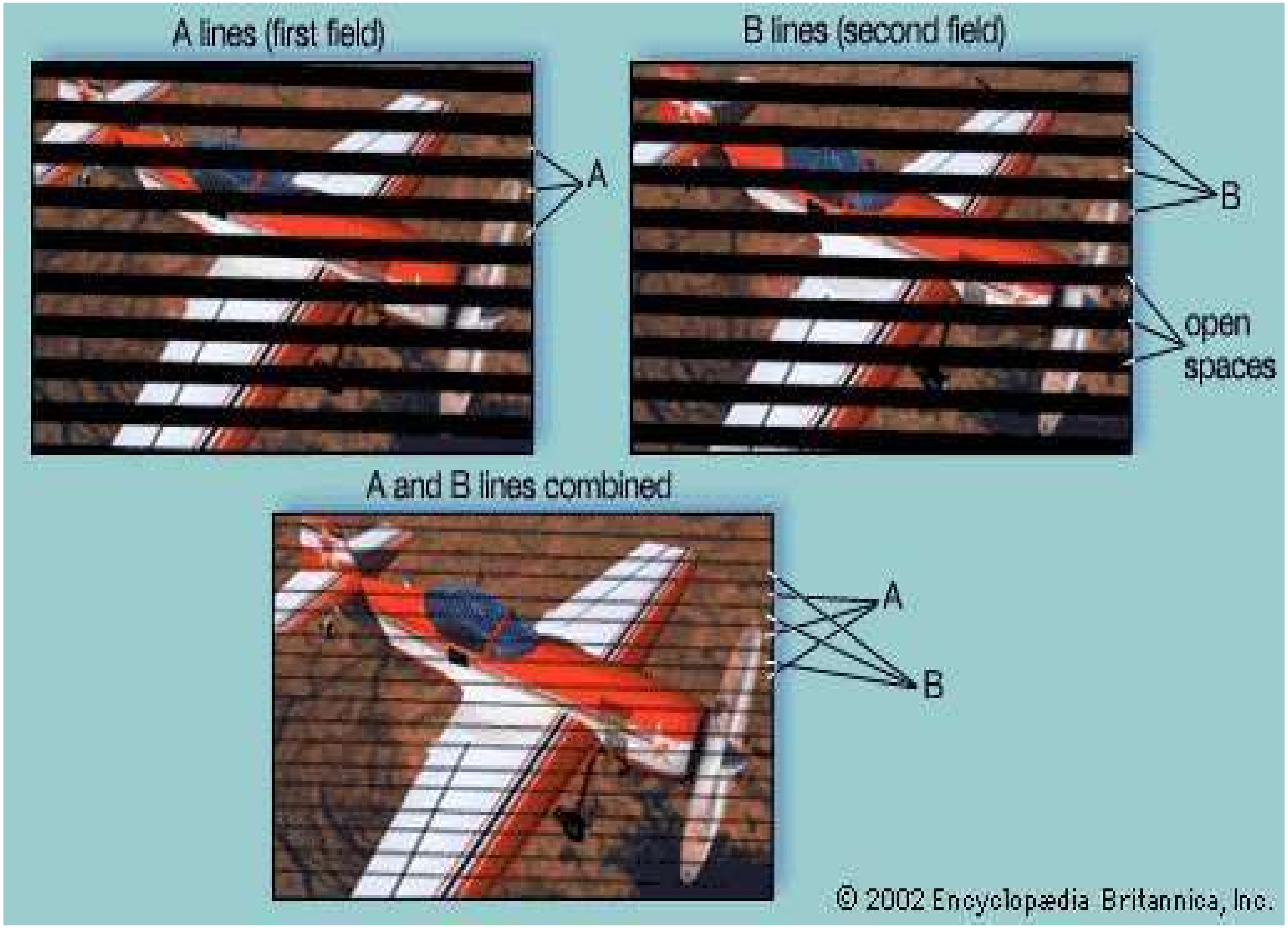
Interlace Scanning

- How one can Reducing flicker without increasing the BW?
- The scanning process which allows each frame to be scanned twice is called interlace scanning.
- The rate of interruption become 50 per second while complete frames are scanned at 25 frames per second
- This technique does not increase the scanning speed but remove flicker by doubling the number of interruptions.
- Consequently BW is conserved while flicker is removed

Interlaced scanning



Principle of interlaced scanning


A lines (first field)
A
B lines (second field)
B
open
spaces
A and B lines combined
A
B
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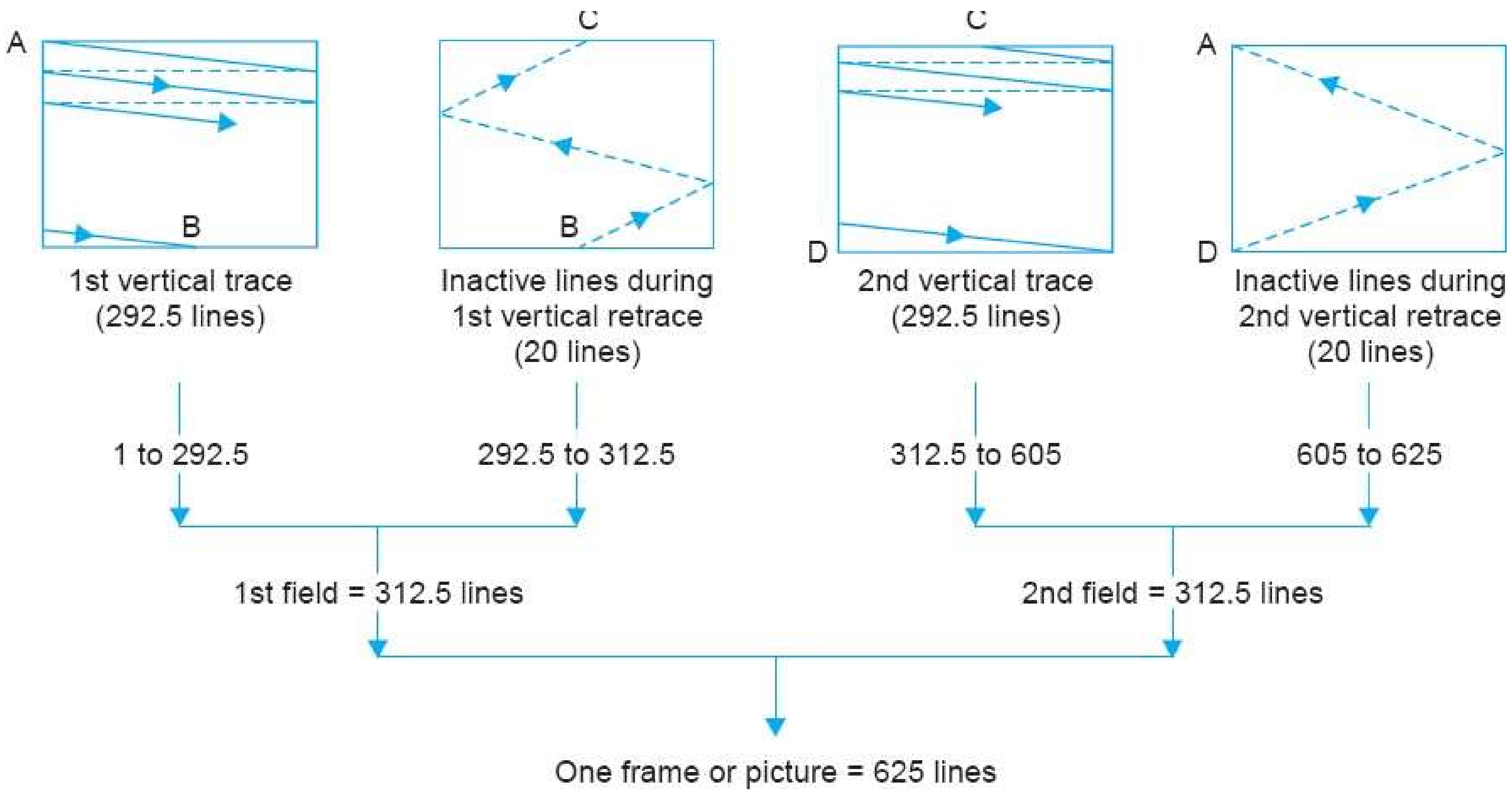
Frame , Field and line frequency

- Each sequence of scanning in the interlaced scanning method is called field.
- Odd numbered sequences are called odd fields
- Even numbered sequences are called even fields
- There are two field per frame hence the number of fields per second is 50
- In European system the rate of scanning the frames is 25 frames per second.

Odd line interlaced scanning procedure.



Active lines

- All the scanning lines are not visible on the screen due to blanking during retrace period.
- The actual lines which reproduce pixels are called active lines

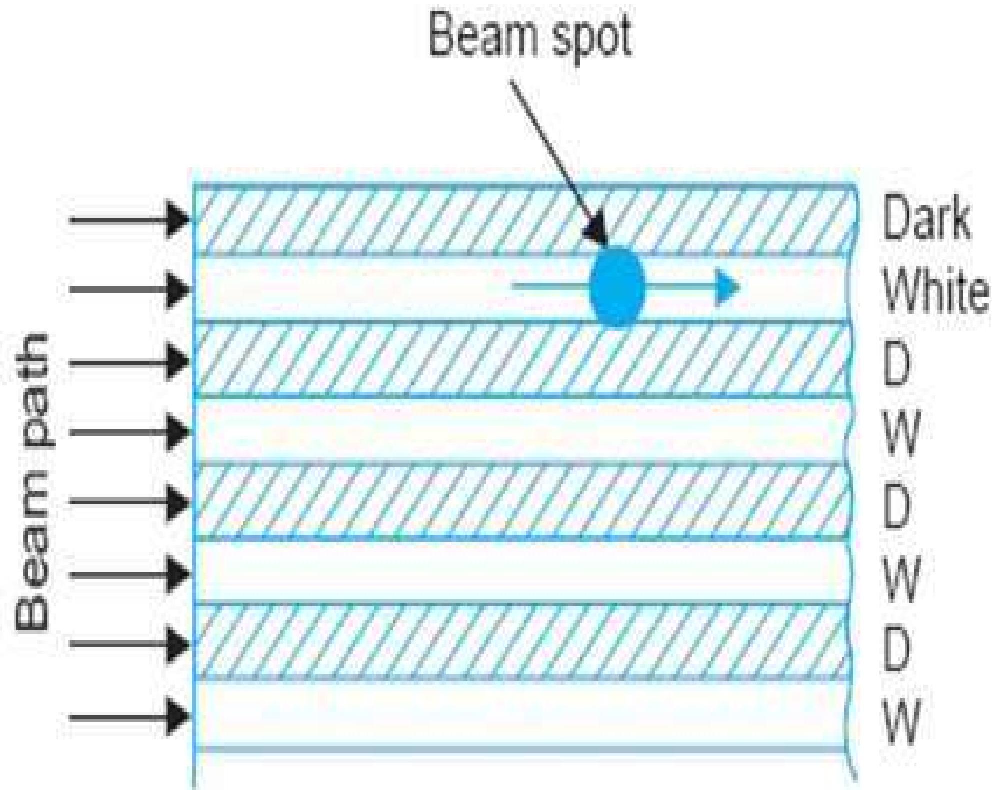
$$N_A = N_T - N_L$$

N_A= No of active lines

N_T= Total scanning line per frame

N_L= lines lost in vertical blanking

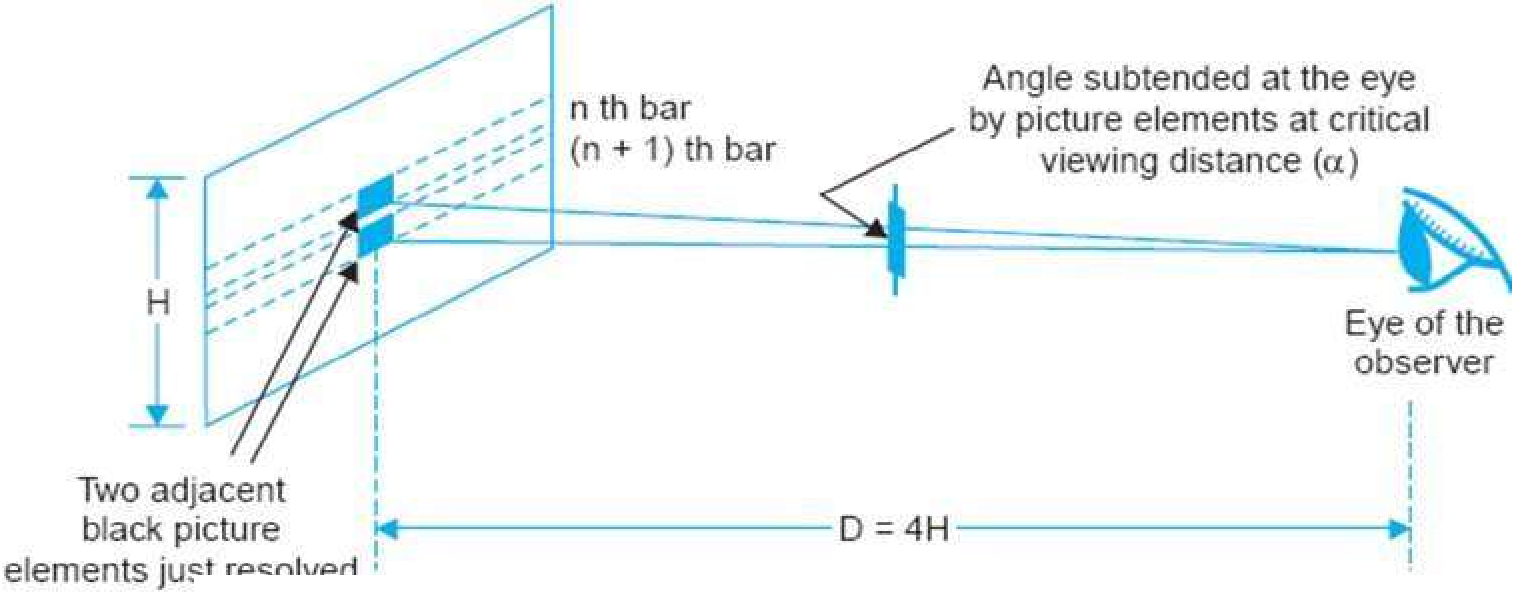
NUMBER OF SCANNING LINES

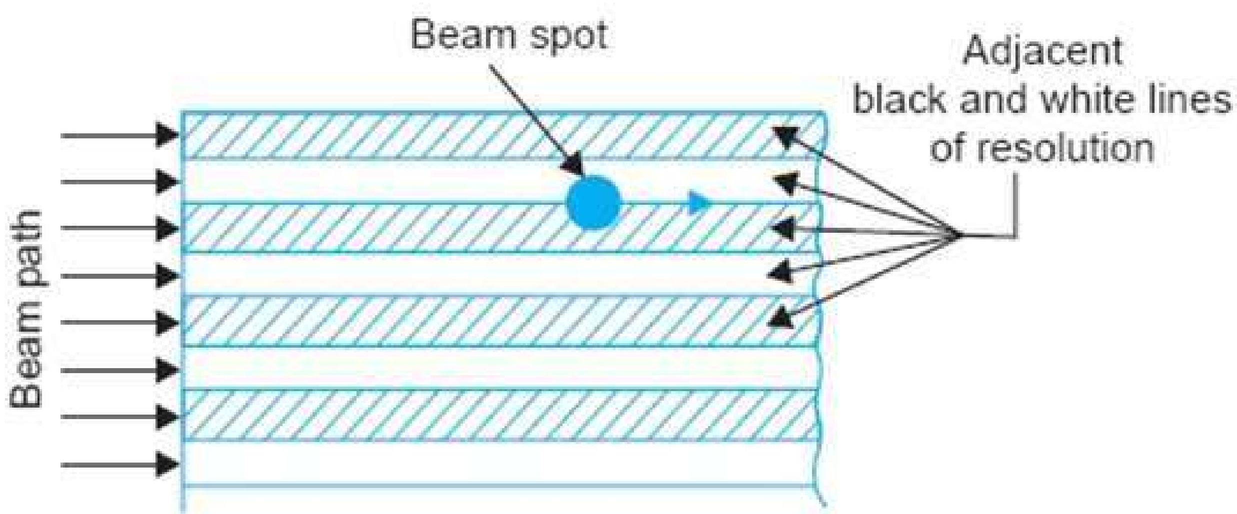


Scanning spot perfectly aligned with black and white lines.

- The maximum number of alternate light and dark elements (lines) which can be resolved by the eye is given by
- $N_v = 1/\alpha\rho$
- where Nv = total number of lines (elements) to be resolved in the vertical direction
- α = minimum resolving angle of the eye expressed in radians
- ρ = D/H = viewing distance/picture height.

Critical viewing distance as determined by the ability of the eye to resolve two separate picture elements.





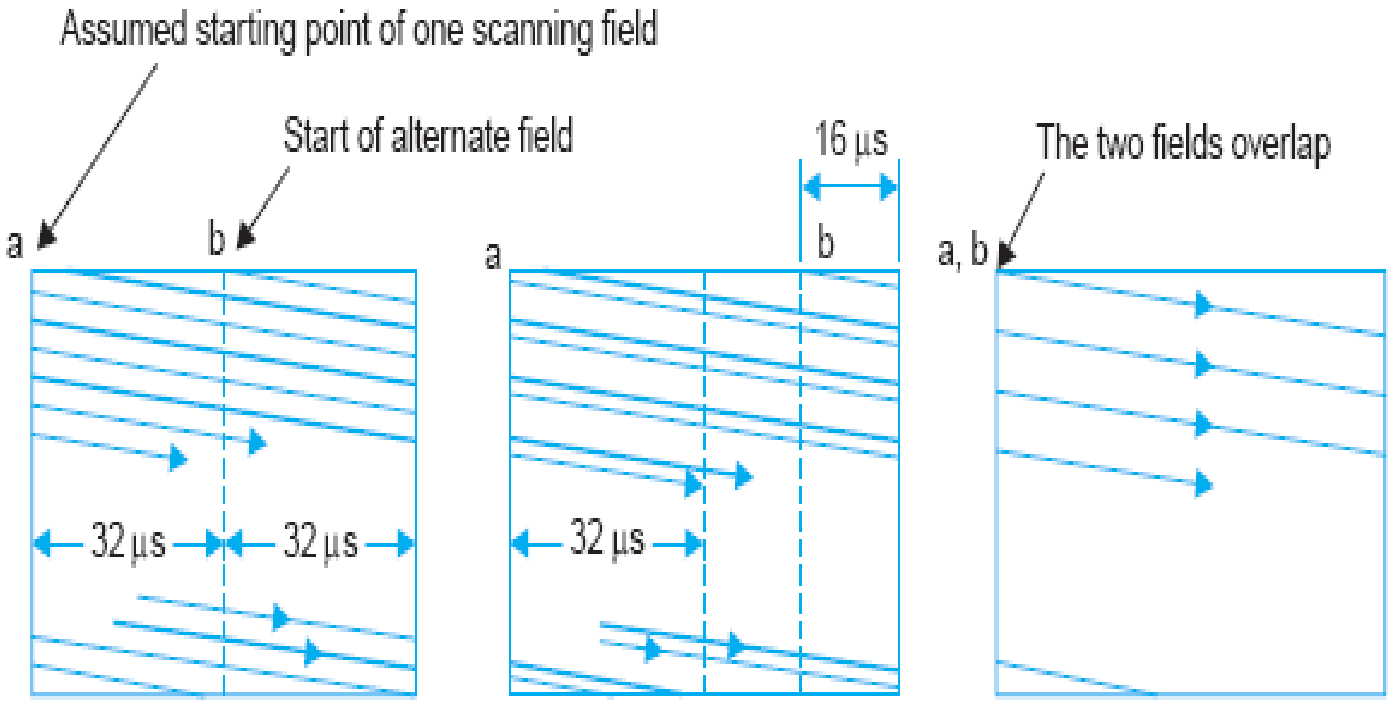
Scanning beam focused on the junction of black and white lines.

Interlace Error

- It occurs due to time difference in starting the scanning of the second field at the exact mid point of the top.

- **Error = {[(32 us +Delay)– 32] /32 } * 100**

Interlace Error



(a) Perfect interlace (b) 50% interlace error (c) 100% interlace error

Picture Resolution

The ability of the image reproducing system to represent the fine structure of an object is known as its resolving power or resolution.

Vertical Resolution.

The extent to which the scanning system is capable of resolving picture details in the vertical direction is referred to as its vertical resolution.

$$V_r = N_a \times k$$

Vr = vertical resolution expressed as number of lines

Na = Active number of lines in the system

K = Resolution factor also known as KELL Factor

Vr = 585*0.69=400 lines

Horizontal Resolution

- The capability of the system to resolve maximum number of picture elements along the scanning lines determines horizontal resolution.
  - Hr=Na*Aspect ratio*K

Hr= Number of alternate black and white segment

- Hr= 585*4/3*0.69= 533

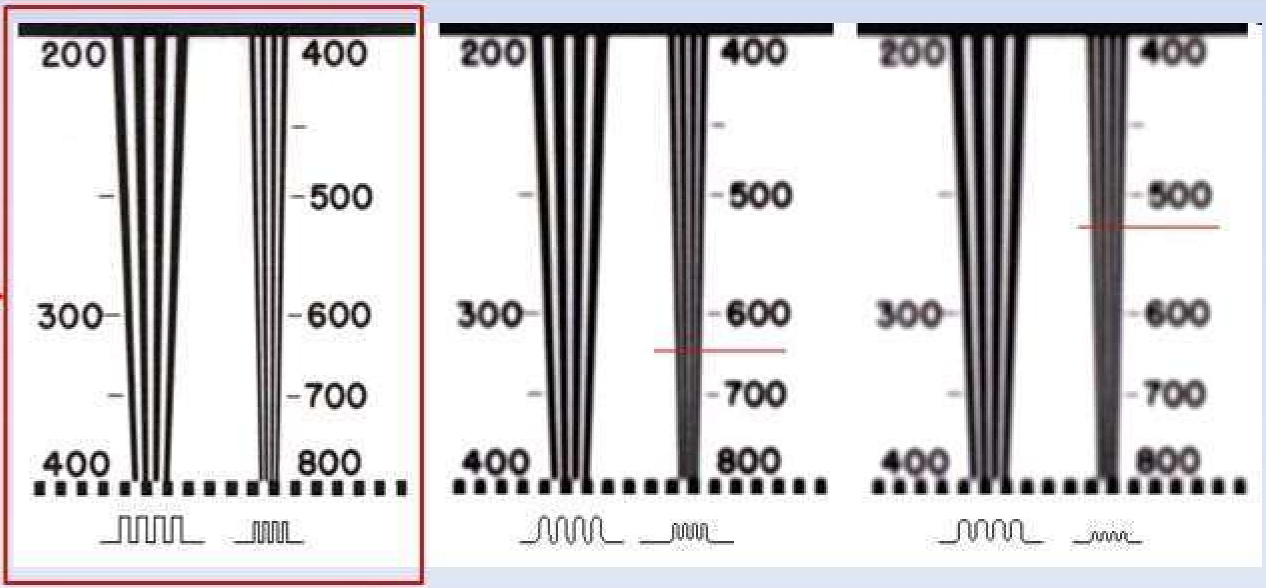
Vertical Resolution - Kell Factor

The Kell Factor is the ratio between actual vertical resolution of TV monitor (as specified in TV lines) and the number of horizontal scan lines

A component of vertical resolution

$$\text{Kell Factor} = \frac{\text{vertical resolution}}{\text{number of scan lines}}$$

Imaged phantom on left side has increased Kell Factor and consequently better resolution



Kell Factor

- Thus Kell effect produces degradation in the resolution of the individual pixels.
- 25 to 30% pixels are lost due to Kell factor.
- Effective lines are worked out by multiplying the active lines by a factor of 0.65 to 0.75.
- This factor is called Kell factor and used to estimating the actual resolution achieved in TV pictures.

Bandwidth

- It is the highest video frequency related to the time taken in scanning two adjacent pixels

$$t_h = \frac{\text{active period of each horizontal line}}{\text{number of cycles}}$$

$$= \frac{52 \times 10^{-6}}{267} \text{ seconds}$$

$$f_h = \frac{1}{t_h} = \frac{267 \times 10^6}{52} = 5 \text{ MHz}$$

Relationship between Resolution and BW

- Smaller the size of pixels that can be reproduced, better would be the resolution
- Smaller the size of pixels , less would be the time taken in scanning two adjacent pixels and hence higher the B W
- Higher BW gives better resolution.
- Bandwidth=Hr/2t

Synchronization

- Scanning in both transmitter and receiver should be identical.
- It should start at the same instant and at the same point of the screen at receiver at which it starts in the transmitter. This is called synchronization
- If the scanning is not synchronized , the picture would be totally displaced, and the objects which are on the top of the original picture may appear on bottom due to the lack of vertical synchronization.
- Lack of horizontal synchronization will split the picture diagonally.

- To ensure synchronization between transmitter and receiver sync pulse are used to start saw tooth signal. Separate sync pulses are required for horizontal and vertical scanning.
- For horizontal scanning the sync pulse appears every 64us.
- For vertical scanning the sync pulse appears every 20ms.

Blanking:

- Blanking pulse are used to blank(or cut off the cathode ray tube)during retrace period of horizontal scanning as well as vertical scanning process in the Tr and Re.
- In the absence of blanking, the retrace would have become visible on the screen and will cause distortion in the picture.
- Sinc pulse is placed over the respective blanking pulses by TDM .
- H. Blanking pulse=12us wide
- H. sinc pulse=4.7us wide
- V. Blanking pulse=1280us
- V. Sinc pulse=160us

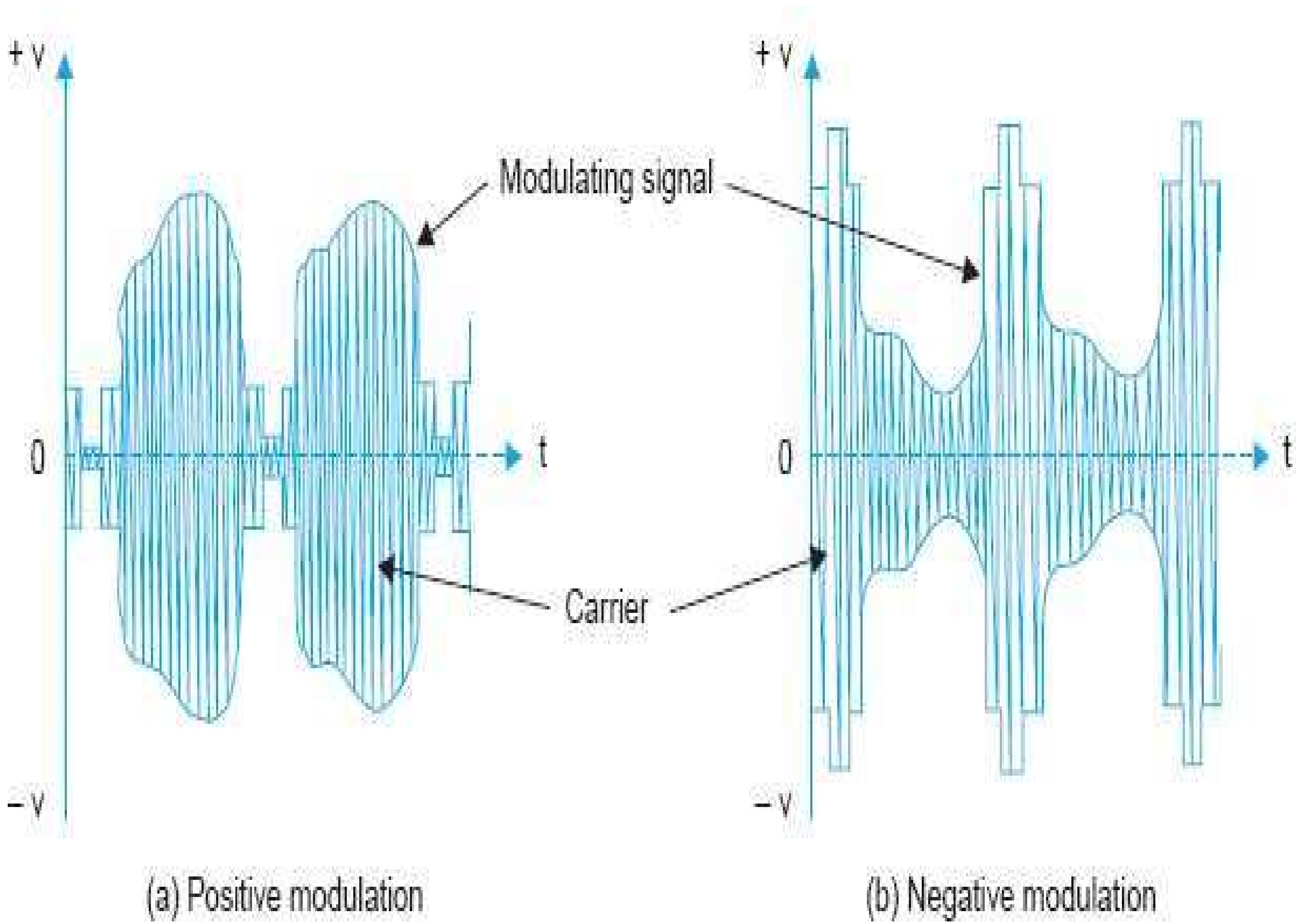
Composite Video Signal

- Picture information(video signal) is not transmitted alone.
- Along with, also transmitted blanking pulses and sync pulses.
- The signal containing all these components is called CVS(composite video signal).
- It can be represented either with positive polarity or with negative polarity.

- Composite video signal consists of a camera signal corresponding to the desired picture information, blanking pulses to make the retrace invisible, and synchronizing pulses to synchronize the transmitter and receiver scanning.
- A horizontal synchronizing (sync) pulse is needed at the end of each active line period whereas a vertical sync pulse is required after each field is scanned.
- The amplitude of both horizontal and vertical sync pulses is kept the same to obtain higher efficiency of picture signal transmission but their duration (width) is chosen to be different for separating them at the receiver.
- Since sync pulses are needed consecutively and not simultaneously with the picture signal, these are sent on a time division basis and thus form a part of the composite video signal.

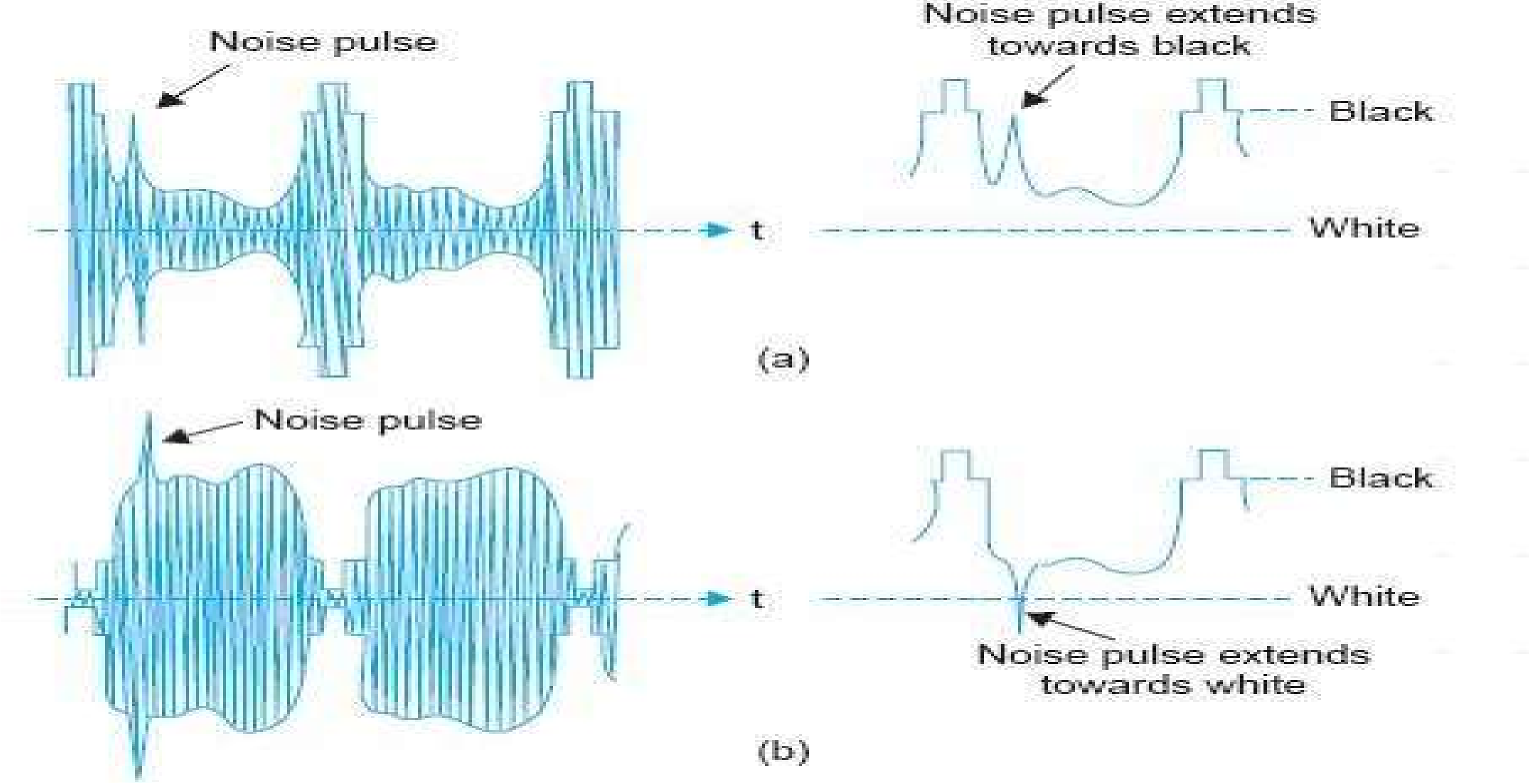
POSITIVE AND NEGATIVE MODULATION

- When the intensity of picture brightness causes increase in amplitude of the modulated envelope, it is called ‘positive’ modulation.
- When the polarity of modulating video signal is so chosen that sync tips lie at the 100 per cent level of carrier amplitude and increasing brightness produces decrease in the modulation envelope, it is called ‘negative modulation’.
- The two polarities of modulation are illustrated in Fig a and b.



Amplitude modulation of video signal (a) Positive modulation (b) Negative modulation

Effect of noise pulses (a)with negative modulation (b) with positive modulation



Merits and Demerits of Negative Modulation

- **Merits:**

- Effect of noise interference on picture signal
- Peak power available from the transmitter
- Reference level for AGC circuits in receivers

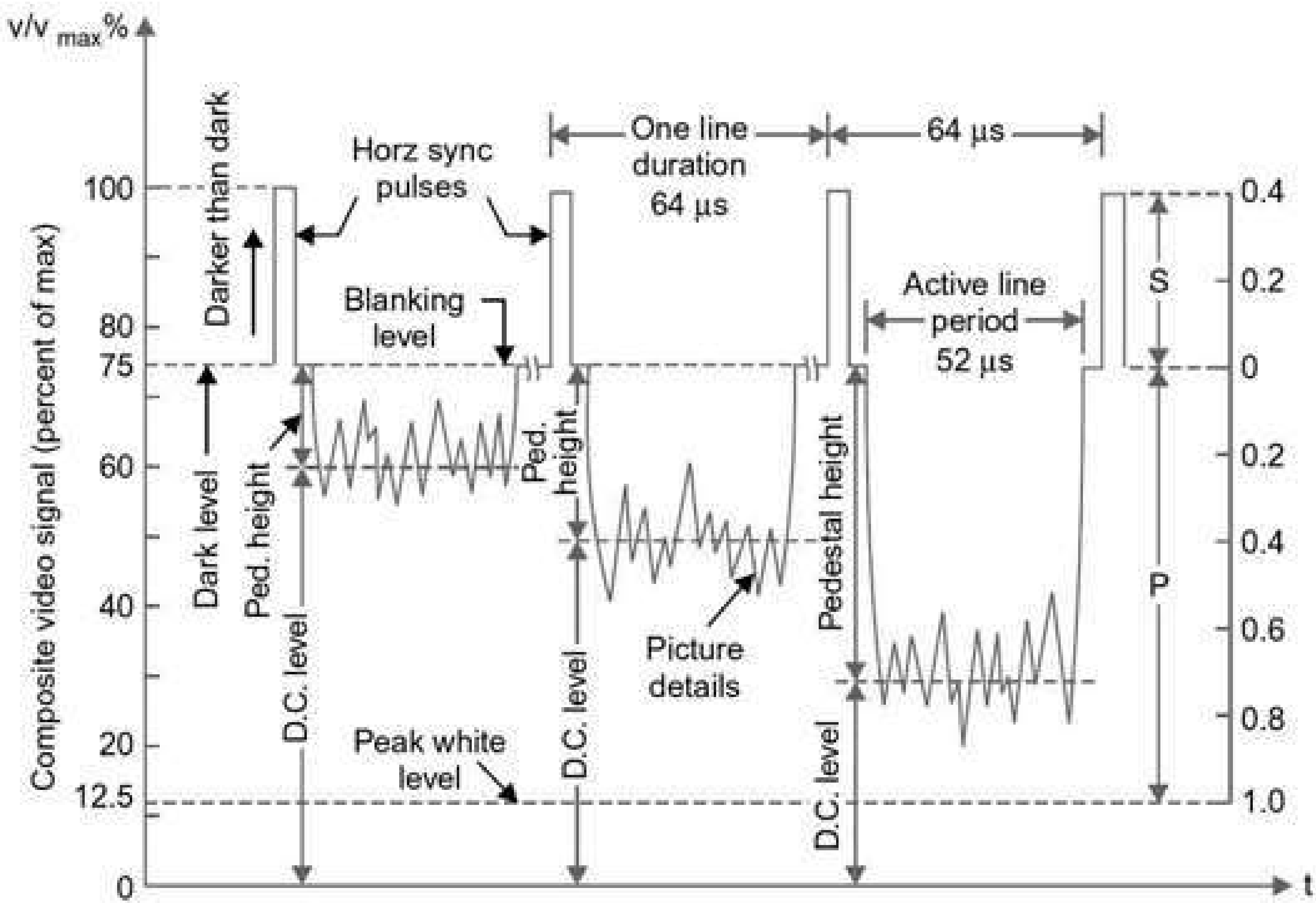
- **Demerit :**
- Effect of noise interference on synchronization

No.	Negative modulation	Positive modulation
1	If peak power available from transmitter is considered then less power is required for more efficiency	More power is required with less efficiency
2	White level of video signal corresponds to 12.5% of the total amplitude	White level of video signal corresponds to 100% total magnitude
3	Blanking level starts at 75%	Black level of video signal corresponds to 25% of total magnitude
4	Blanking level is 75% and sync pulses level at 100% are used as AGC reference level	Blanking level can be taken as AGC reference
5	Horizontal stabilizing circuits are required as noise pulses going in the blanking level may cause synchronization trouble	Noise pulses do not affect synchronization but cause white spots in the picture
6	Noise pulses are seen as less annoying black spots	Noise pulses extend in the white direction during tracing

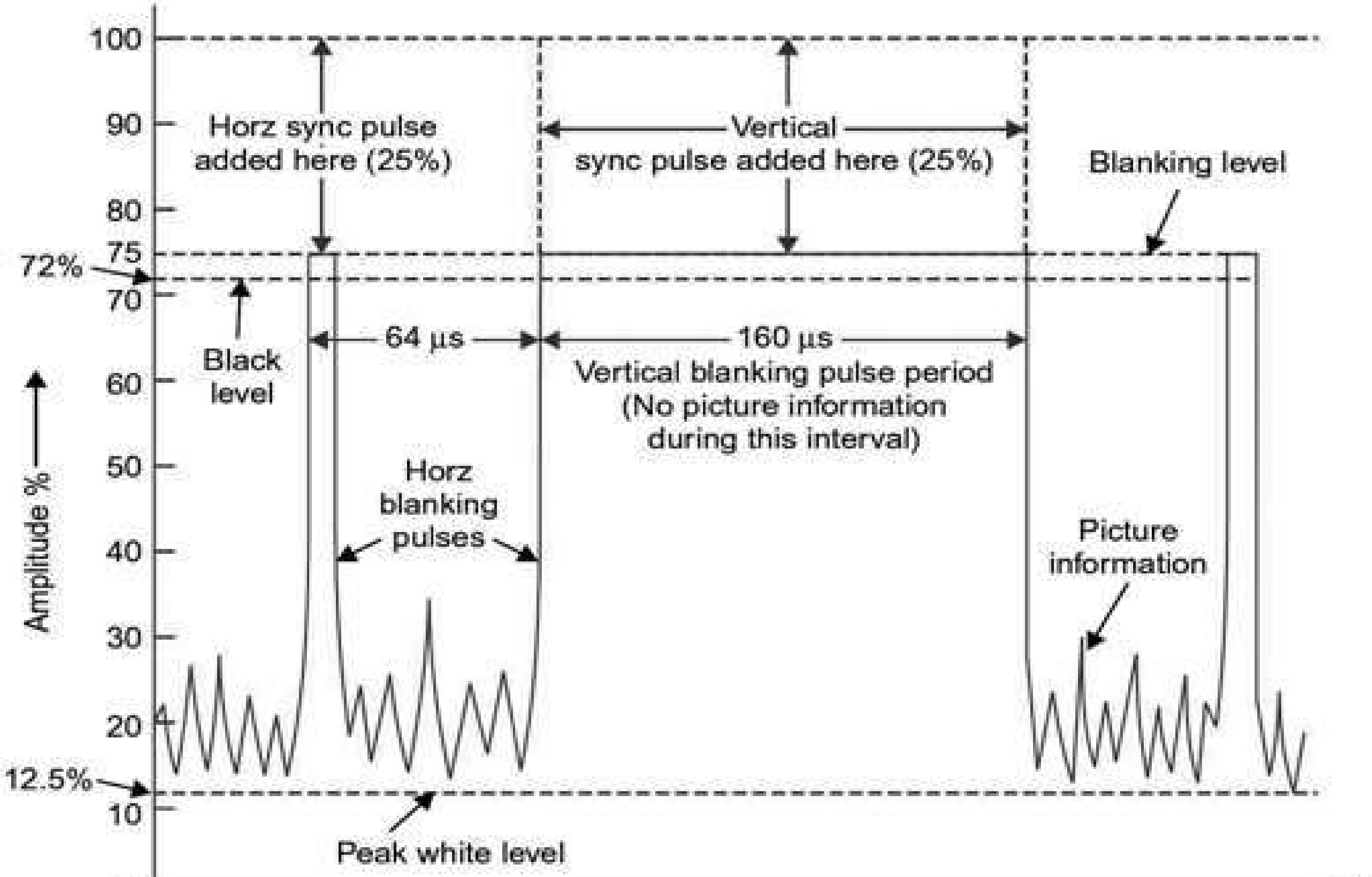
Voltage level

- Voltage level for sync pulse, blanking pulse and video signal are different so that it can be separated easily in the receiver.
- Putting this pulses and signals at different levels in CVS is called voltage division multiplexing and it is achieved by monostable multivibrators (timer circuits)
- There are two level to indicating this level
- IRE Scale(video base band signal)
- Percentage of carrier(modulated signal)

Arbitrary picture signal details of three scanning lines with different average brightness levels



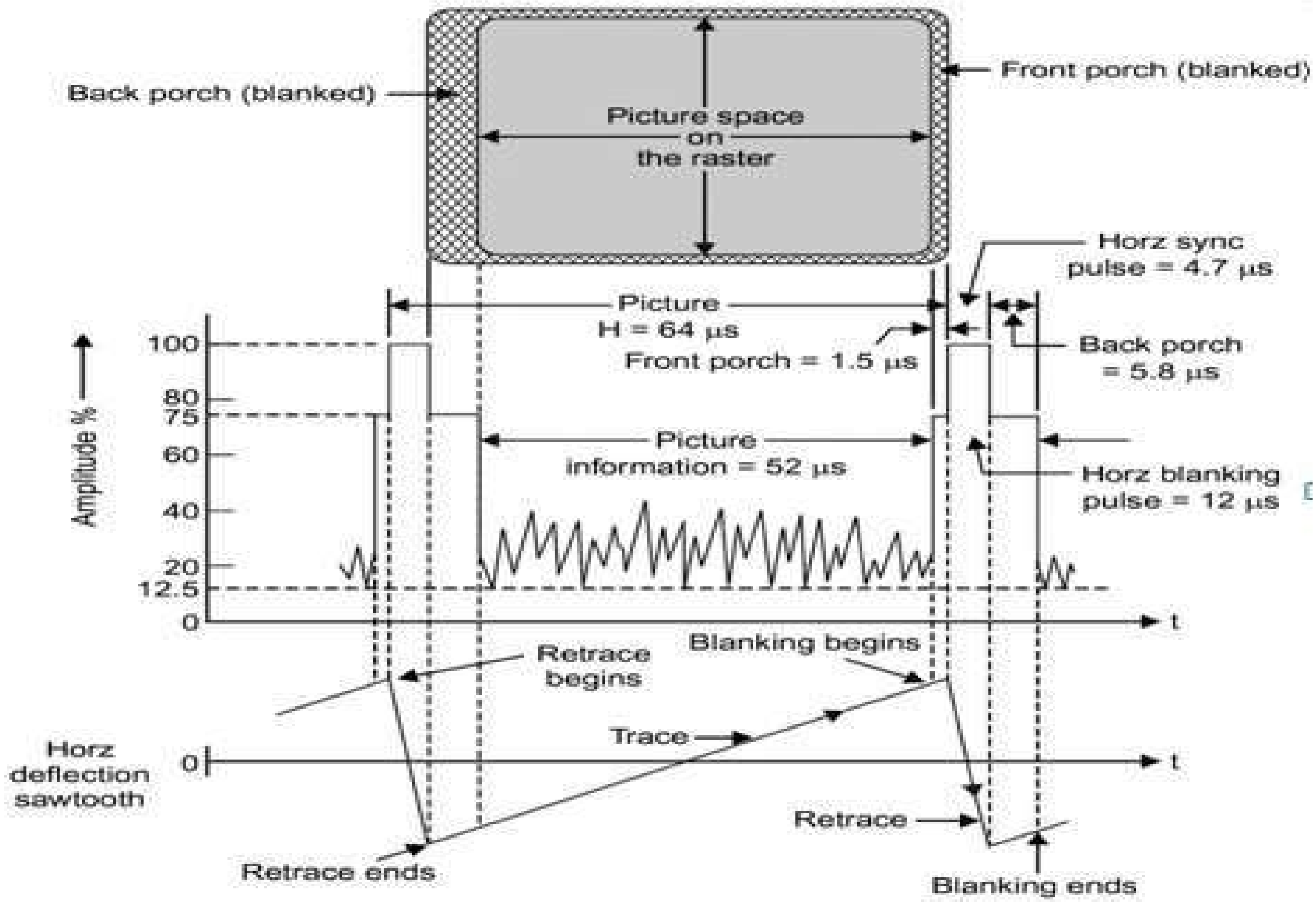
Horizontal and vertical blanking pulses in video signal. Sync pulses are added above blanking level and occupy upper 25% of the composite video signal amplitude



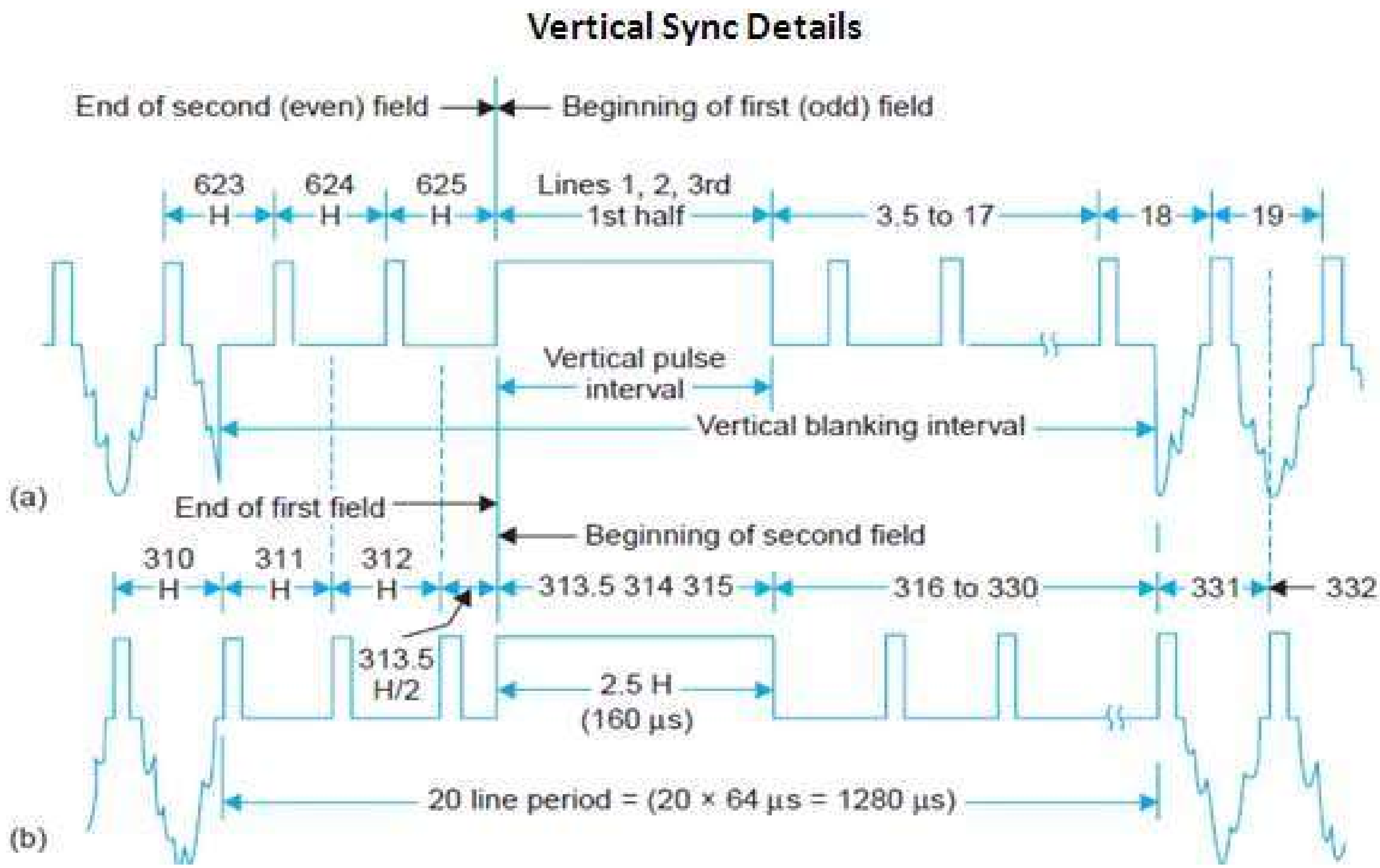
Details of horizontal scanning

Period	*Time* (μs)
Total line (*H*)	64
Horz blanking	12 ± .3
Horz sync pulse	4.7 ± 0.2
Front porch	1.5 ± .3
Back porch	5.8 ± .3
Visible line time	52

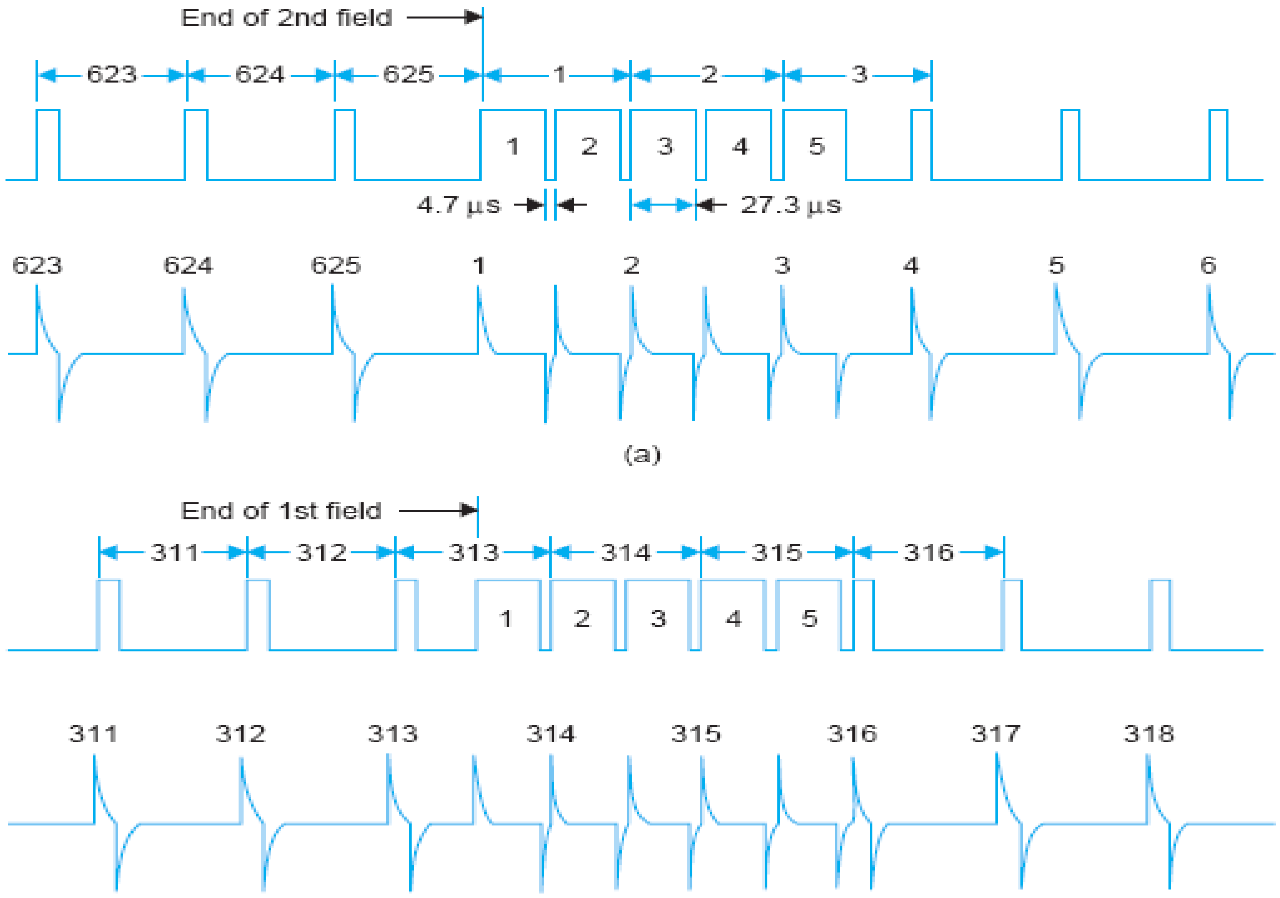
Horizontal line and sync details compared to horizontal deflection saw tooth and picture space on the raster



Composite video waveforms showing horizontal and basic vertical sync pulses at the end of (a)second(even) field (b)first (odd)field

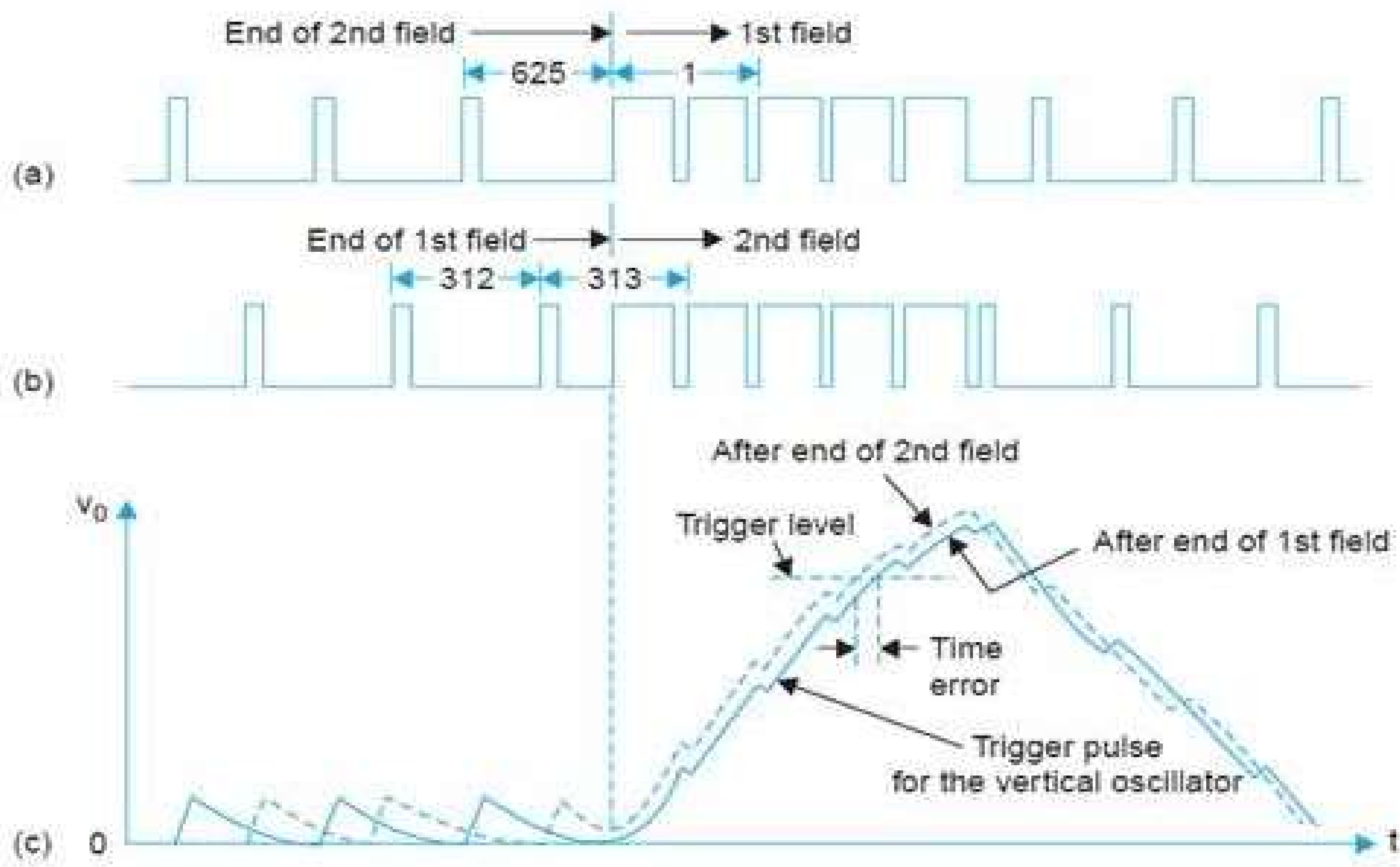


Differentiating waveforms



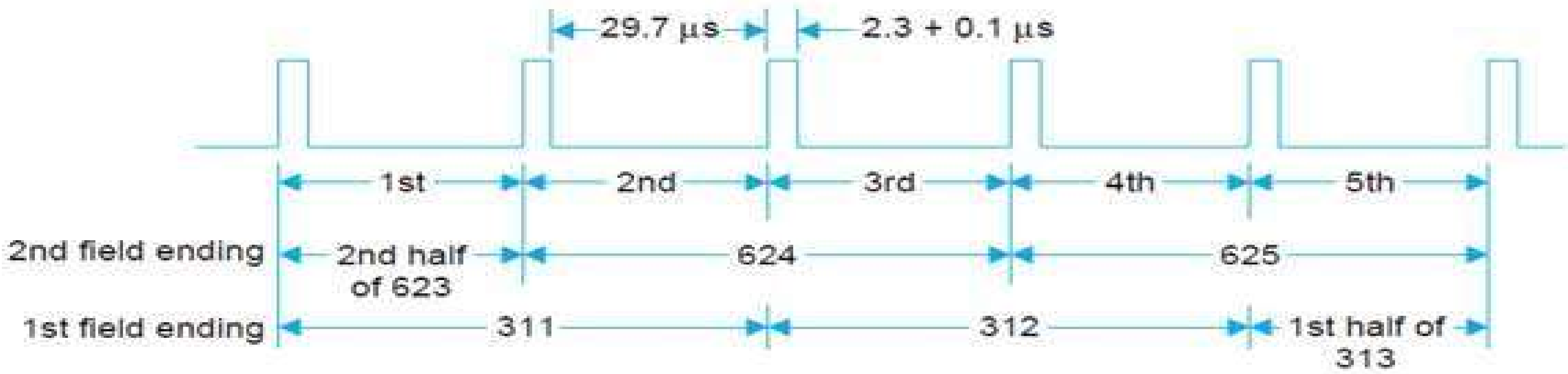
(a)

(b)

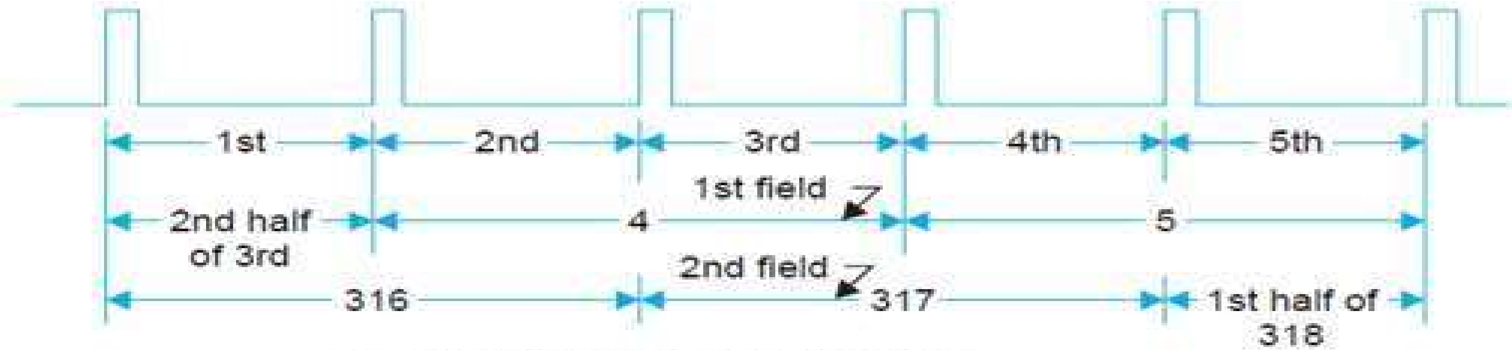


End of 2nd field
1st field
625
1
(a)
End of 1st field
2nd field
312
313
(b)
After end of 2nd field
v_0
Trigger level
After end of 1st field
Time
error
Trigger pulse
for the vertical oscillator
(c)
0
t

Equalizing pulse



(a) Pre-sync equalizing pulses (five)



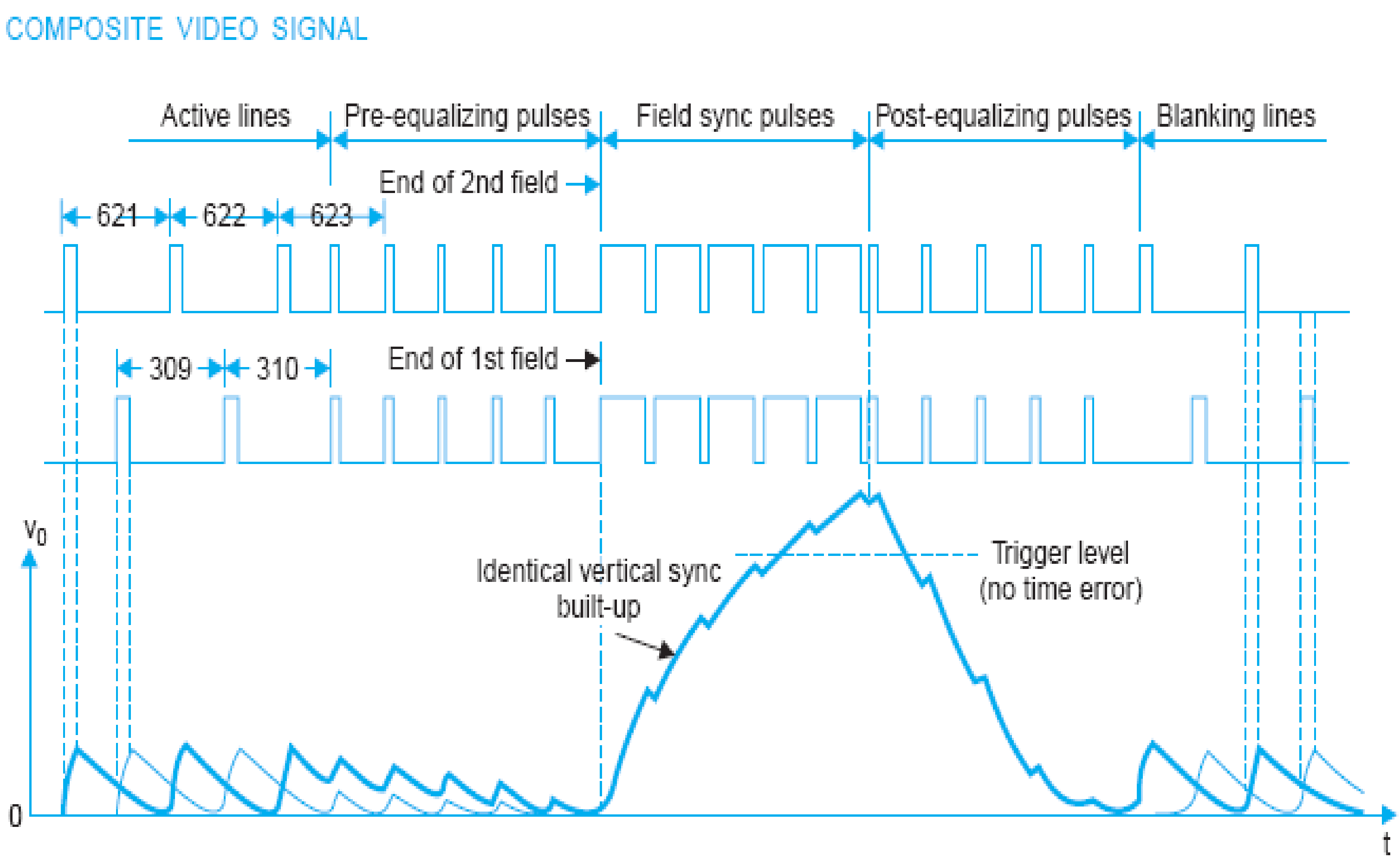
(b) Post-sync equalizing pulses (five)

Function of Equalizing Pulses

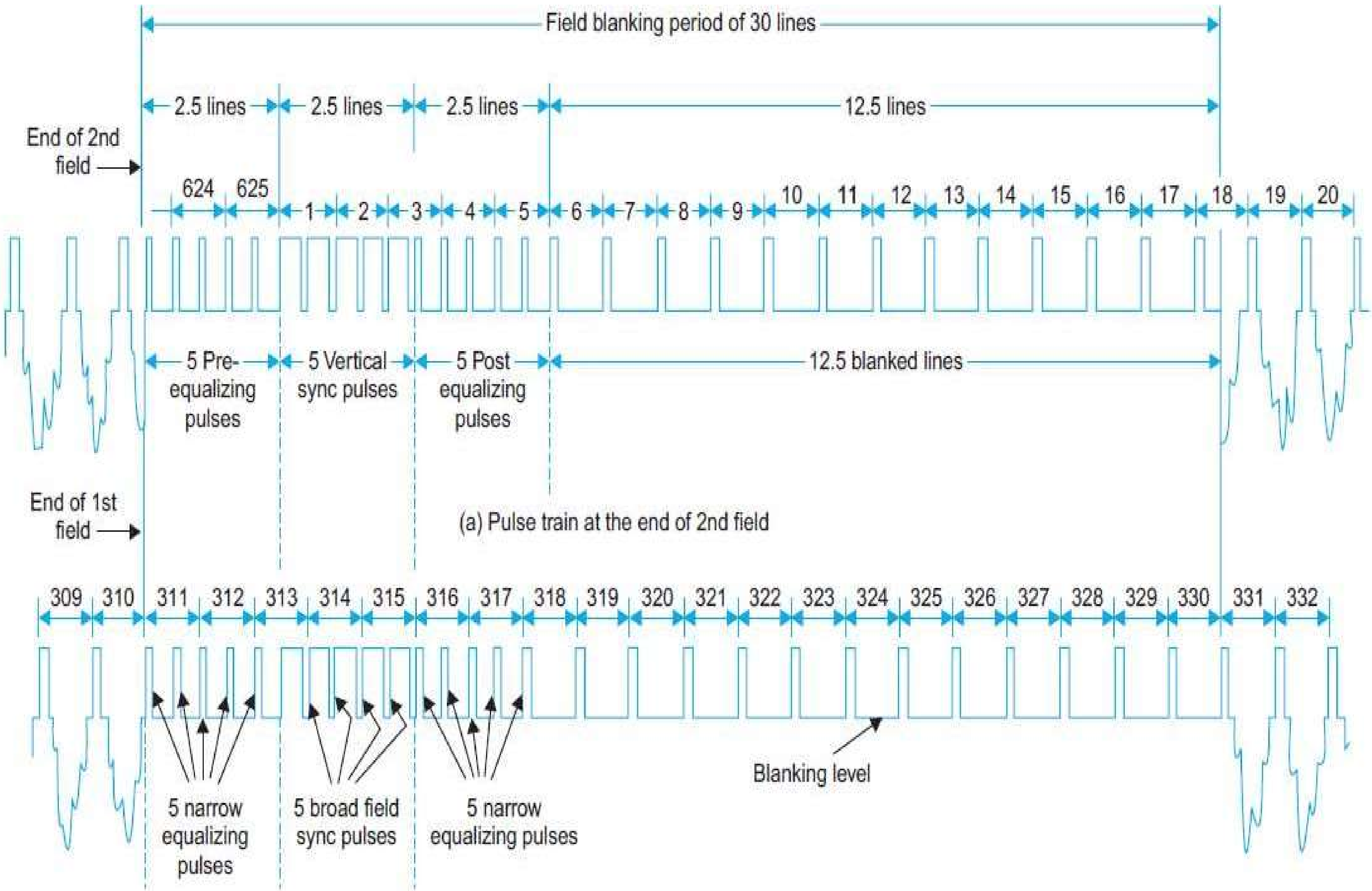
Vertical slots of 4.7us duration that are inserted in the vertical sync period to achieve horizontal synchronization are called **serrated pulses**.

- Triggering to the vertical oscillator
- HO receives triggering pulses even during the vertical blanking due to the presence of serrated pulses
- Vertical sync pulses are available at the end of the line of second field and at the middle of the line at the end of first field.
- The equalizing pulses are provided to avoid timing error at VO.
- The shape of the vertical trigger pulse is maintained at both even and odd fields.

Identical vertical sync voltage built-up across the integrating capacitor.



Field synchronizing pulse trains of the 625 lines TV system.



(a) Pulse train at the end of 2nd field

(b) Pulse train at the end of 1st field

SCANNING SEQUENCE DETAILS

- A complete chart giving line numbers and pulse designations for both the fields is below :
- **First Field (odd field)**
- *Line numbers : one to 1st-half of 313th line (312.5 lines)*
- 1, 2 and 3rd 1st-half, lines 2.5 lines—Vertical sync pulses
- 3rd 2nd-half, 4, and 5 2.5 lines—Post-vertical sync equalizing pulses.
- 6 to 17, and 18th 1st-half 12.5 lines—Blanking retrace pulses
- 18th 2nd-half to 310 292.5 lines—Picture details
- 311, 312, and 313th 1st-half 2.5 lines—Pre-vertical sync equalizing pulses
- for the 2nd field.
- *Total number of lines = 312.5*
- **Second field (even field)**
- *Line numbers : 313th 2nd-half to 625 (312.5 lines)*
- 313th 2nd-half, 314, 315 2.5 lines—Vertical sync pulses
- 316, 317, 318th 1st-half 2.5 lines—Post-vertical sync equalizing pulses
- 318th 2nd-half-to 330 12.5 lines—Blanking retrace pulses
- 331 to 1st-half of 623rd 292.5 line—Picture details
- 623 2nd-half, 624 and 625 2.5 lines—Pre-vertical sync equalizing pulses
- for the 1st field
- *Total number of lines = 312.5*
- *Total Number of Lines per Frame = 625*

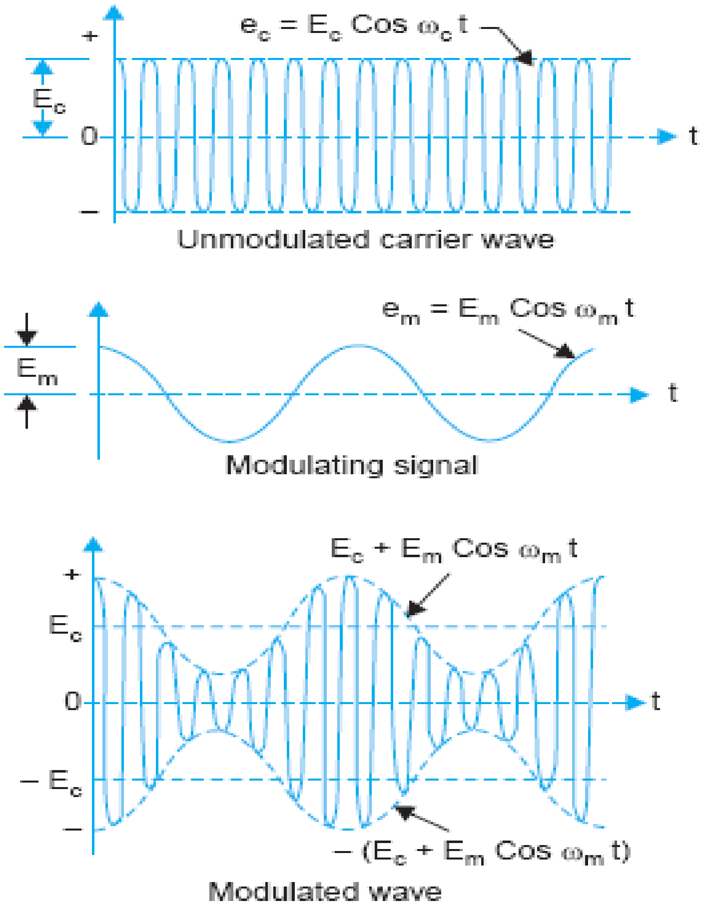
Signal Transmission

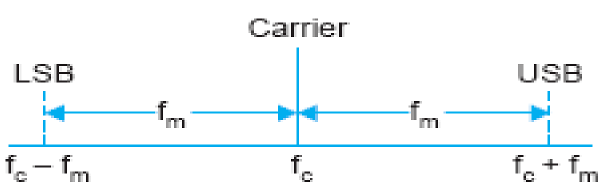
- In most television systems as also in the C.C.I.R 625 line, the picture signal is amplitude modulated and sound signal frequency modulated before transmission. The channel bandwidth is determined by the highest video frequency required for proper picture reception and the maximum sound carrier frequency deviation permitted in a TV system.

AMPLITUDE MODULATION

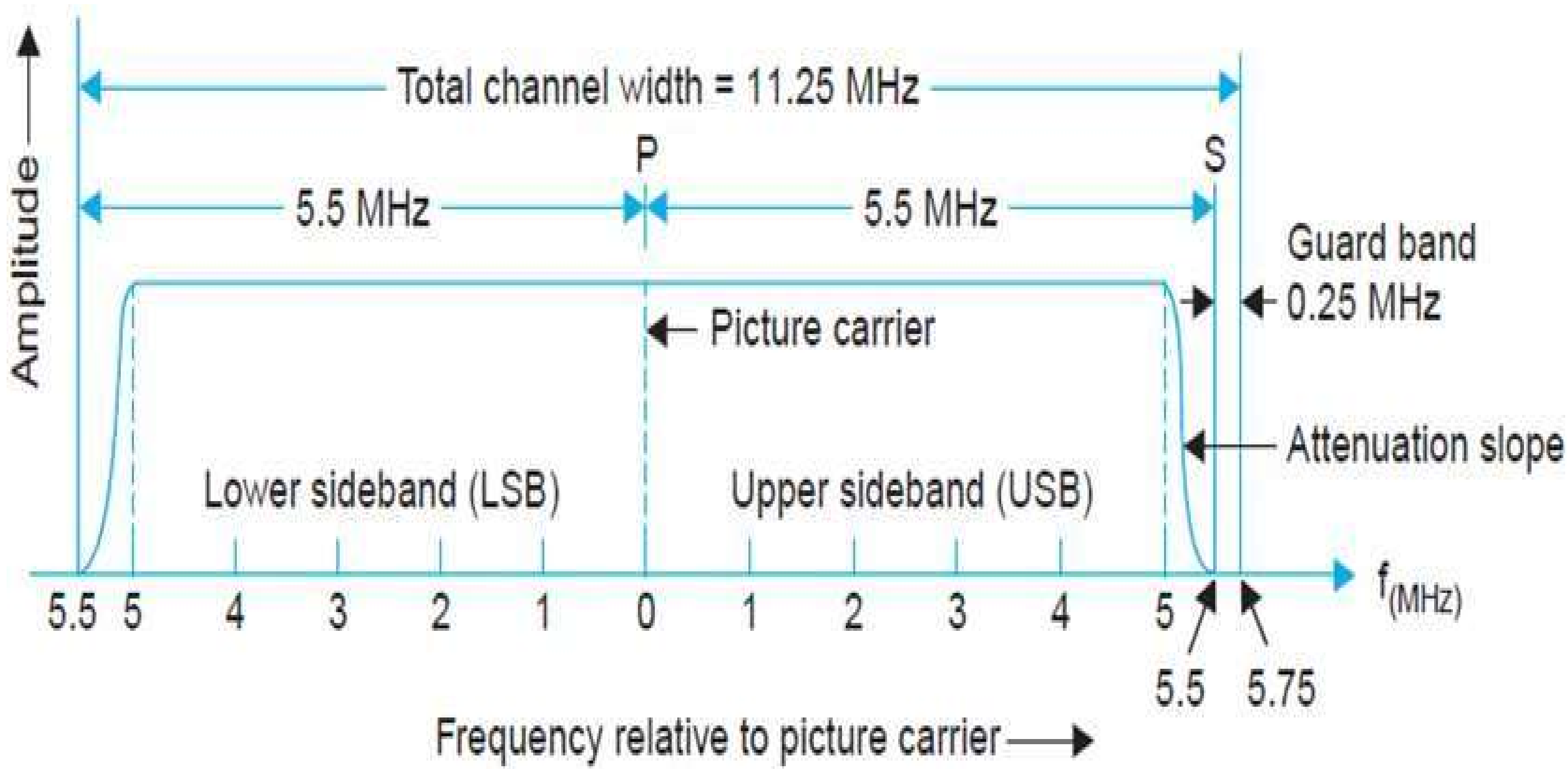
- An amplitude modulated signal is shown in Fig.
- $e_c = E_c \cos\omega_c t$ is the carrier wave
- $e_m = E_m \cos\omega_m t$ is the modulating signal.

Modulation of RF carrier with signal frequency and Frequency spectrum of AM wave.



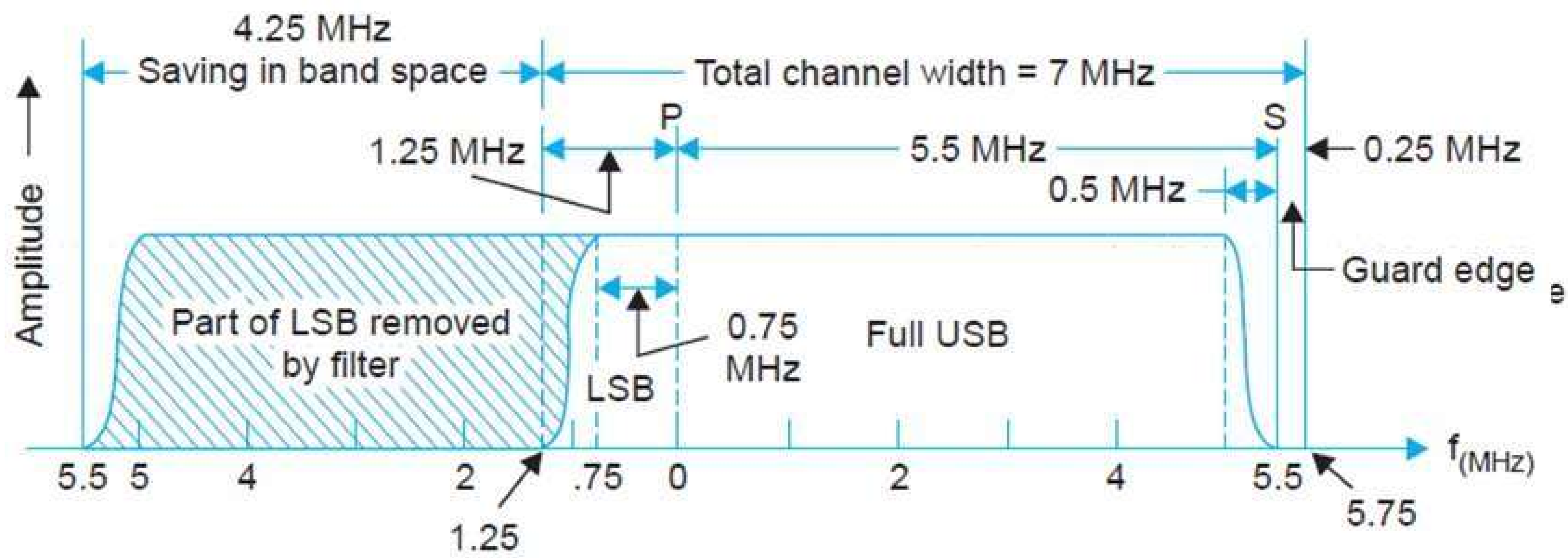


CHANNEL BANDWIDTH



Total channel bandwidth using double sideband picture signal.
P is picture carrier and S is sound carrier.

Vestigial Side Band(A5C transmission)

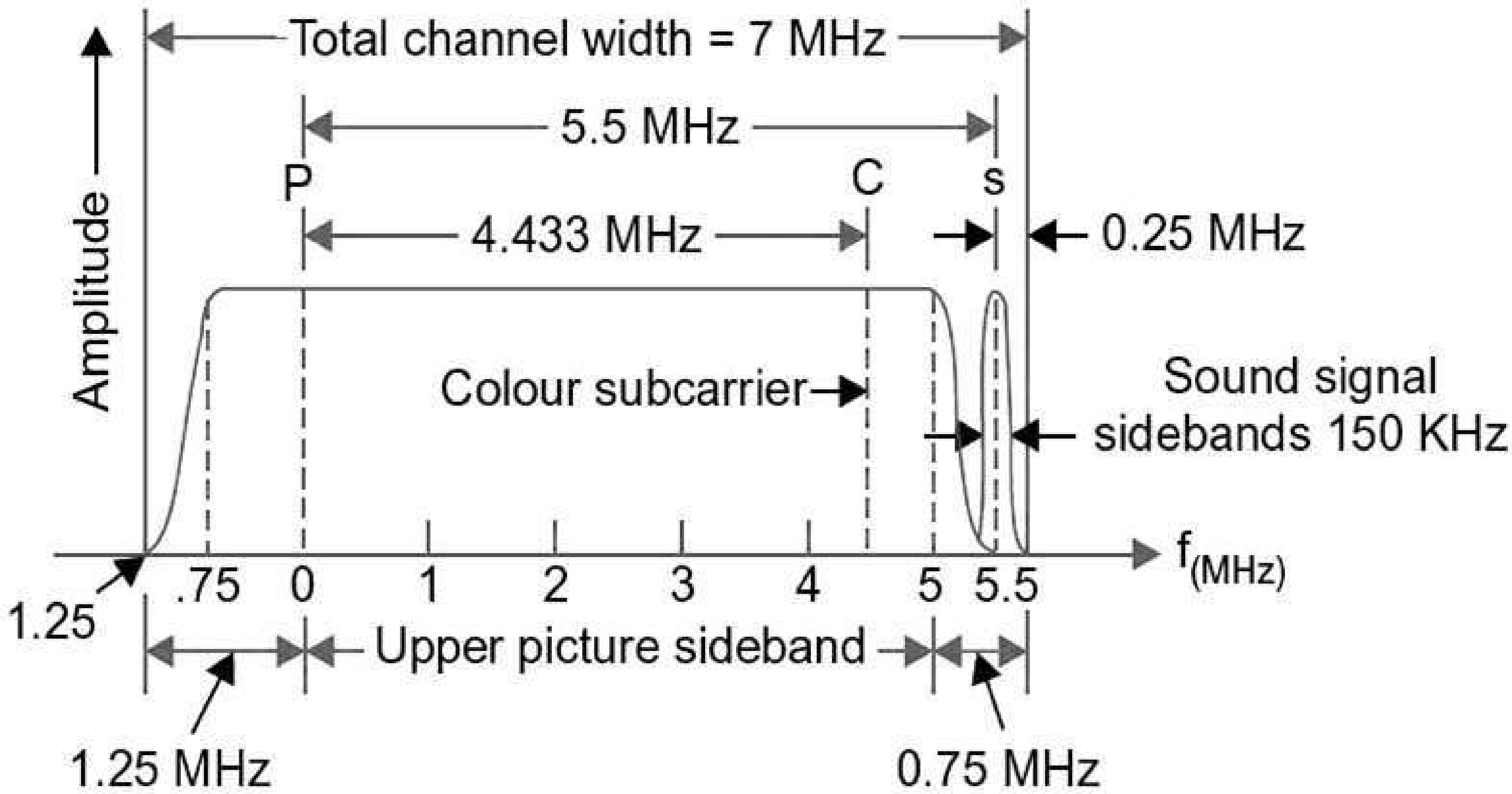


Total channel BW using VSB

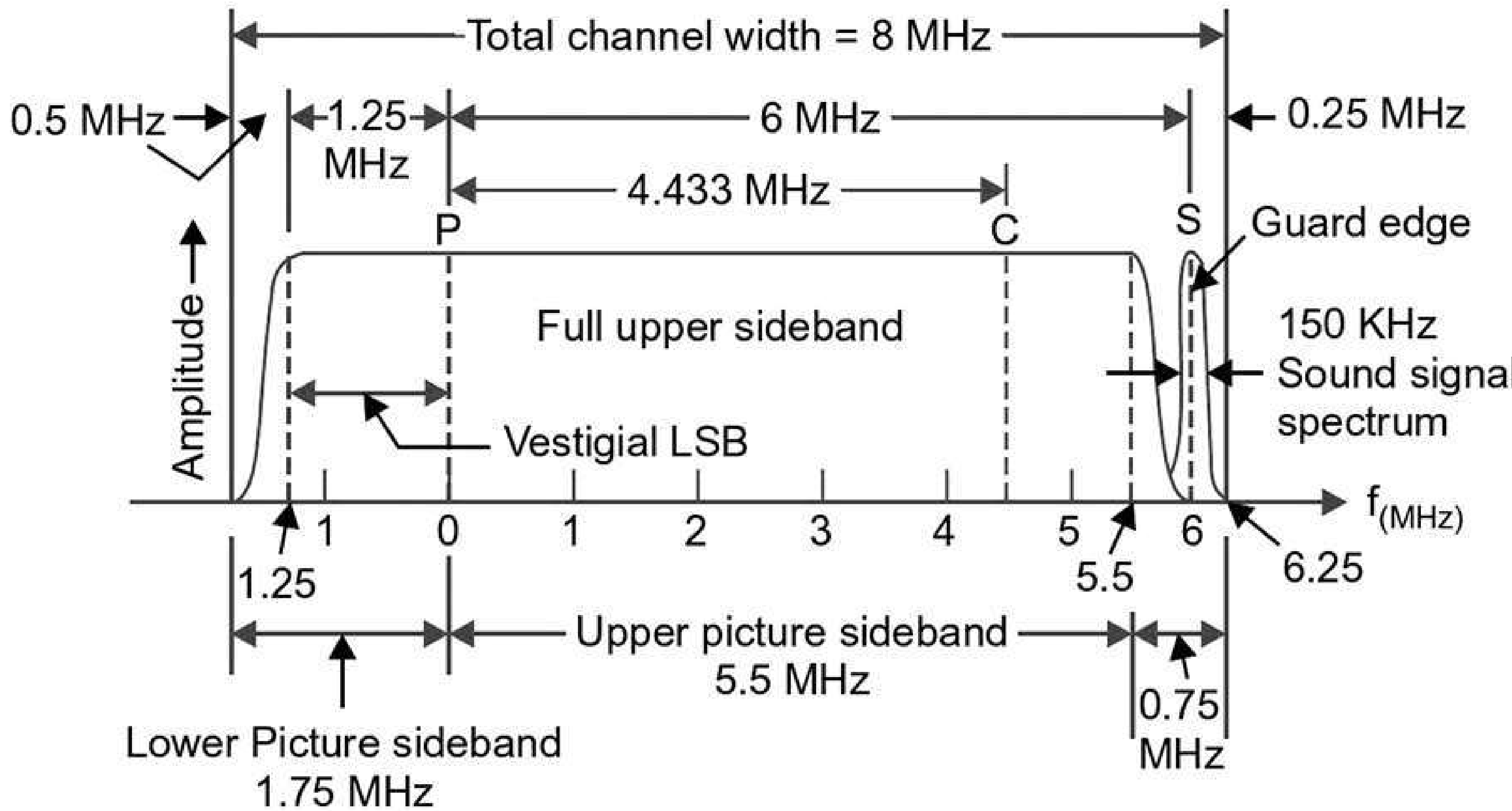
Demerits of VSB:

- A small portion of transmitter power is wasted in the vestigial sideband filter which remove the lower sideband.
- SNR is slightly less than what it would be in total D.S.B.
- Picture quality appears poorer in the system with narrow lower sideband.
- If the lower sideband is completely suppressed then there is distortion which is manifested as “smear” in the picture. Some phase and amplitude distortion of the picture signal occurs even if VSB filter design is near perfect.

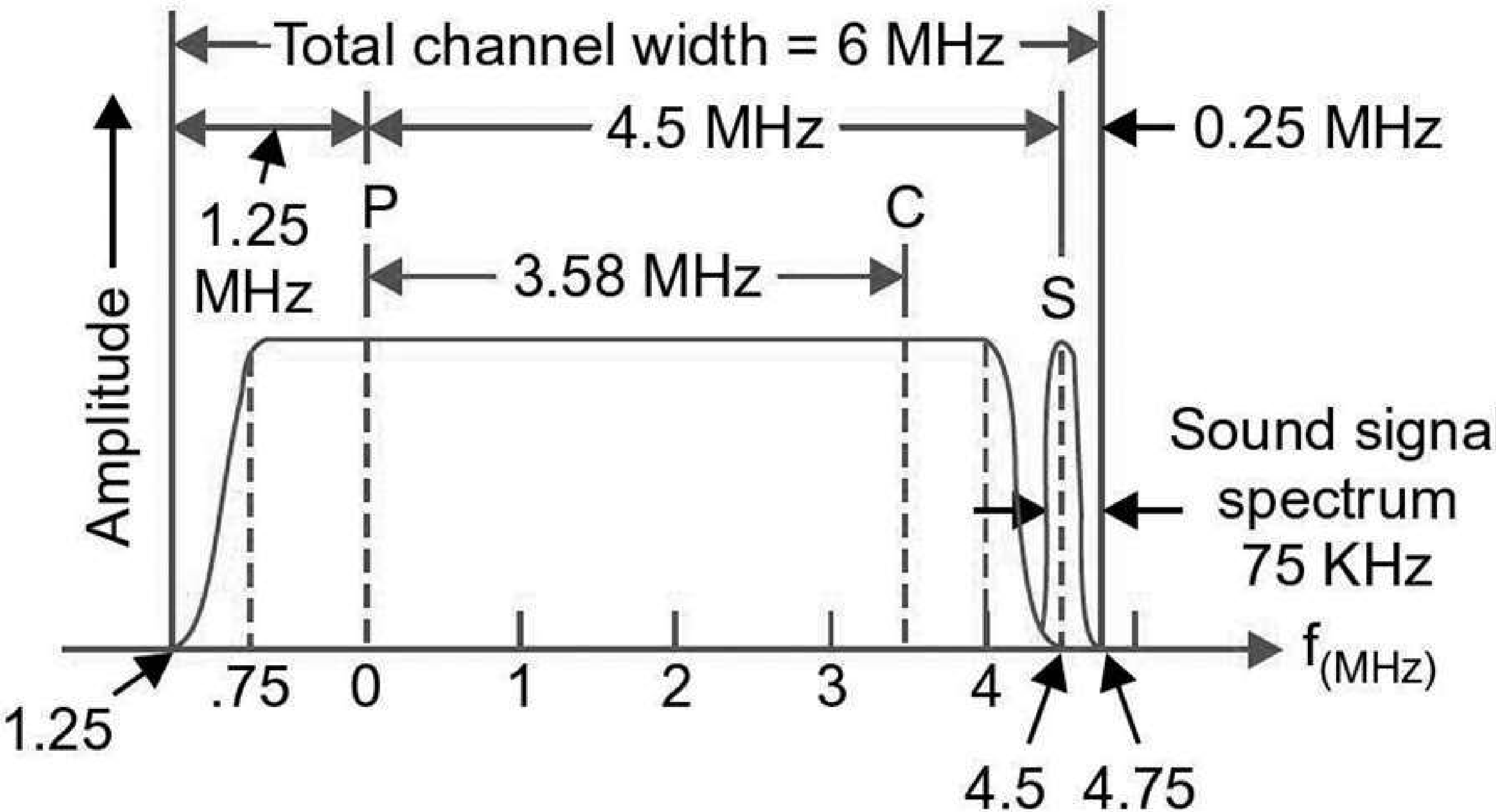
C.C.I.R. (Indian and European) TV channel sideband spectrum. C is colour subcarrier frequency.



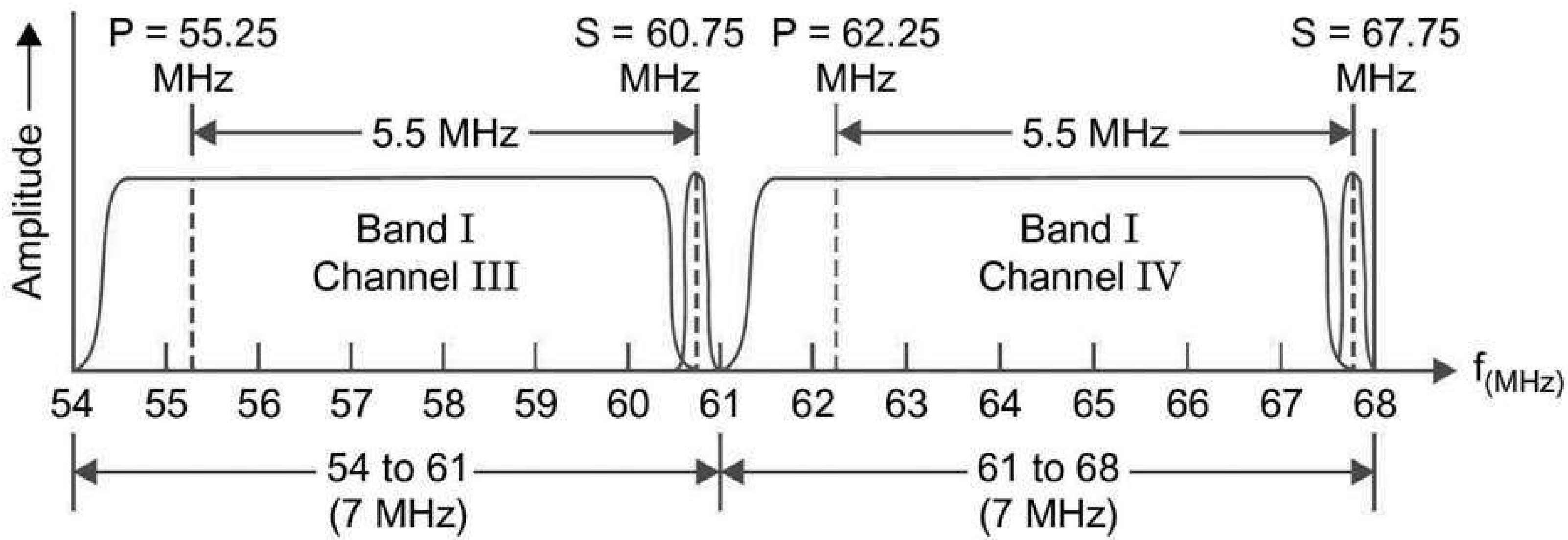
U.K. TV channel standards.



American TV channel standards.



Sideband spectrum of two adjacent channels of the lower VHF band of television station allocations.



Television Broadcast Channels

Band I	Lower VHF range	41 to 68 MHz
Band III	Upper VHF range	174 to 230 MHz
Band IV	UHF range	470 to 598 MHz
Band V	UHF range	606 to 870 MHz

(Band II (88 to 108 MHz) is used for FM broadcasting)

Television Channel Allocation (CCIR) in Bands I and III)

Band	*Channel No.*	*Frequency range*	*Picture carrier Frequency (MHz)*	*Sound carrier Frequency (MHz)*
I	1	41–47 (not used)		
(41-68 MHz)	2	47–54	48.25	53.75
	3	54–61	55.25	60.75
	4	61–68	62.25	67.75
III	5	174–181	175.25	180.75
(174–230 MHz)	6	181–188	182.25	187.75
	7	188–195	189.25	194.75
	8	195–202	196.25	201.75
	9	202–209	203.25	208.75
	10	209–216	210.25	215.75
	11	216–223	217.25	222.75
	12	223–230	224.25	229.75

In the UHF bands while the channel width remains the same at 7 MHz, a band gap of 1 MHz is allowed between adjacent channels to prevent any mutual interference. The frequency allocations are as given on the next page.

UHF BAND IV (470–598 MHz) Channels 21–36

Band (UHF)	*Channel No.*	*Frequency range (MHz)*	*Picture Carrier frequency (MHz)*	*Sound Carrier frequency (MHz)*
IV	21	470 to 478	471.25	476.75
Channel	22	478 to 486	479.25	484.75
21–36	23	486 to 494	487.25	492.75
	24	494 to 502	495.25	500.75
	25	502 to 510	503.25	508.75
	26	510 to 518	511.25	516.75
	27	518 to 526	519.25	524.75
	28	526 to 534	527.25	532.75
	29	534 to 542	535.25	540.75
	30	542 to 550	543.25	548.75
	31	550 to 558	551.25	556.75
	32	558 to 566	559.25	564.75
	33	566 to 574	567.25	572.75
	34	574 to 582	575.25	580.75
	35	582 to 590	583.25	588.75
	36	590 to 598	591.25	596.75

UHF BAND V (606–870 MHz) Channels 37–69

Channel No.	*Frequency band (MHz)*	*Channel No.*	*Frequency band (MHz)*
37	606–614	54	742–750
38	614–622	55	750–758
39	622–630	56	758–766
40	630–638	57	766–774
41	638–646	58	774–782
42	646–654	59	782–790
43	654–662	60	790–798
44	662–670	61	798–806
45	670–678	62	806–814
46	678–686	63	814–822
47	686–694	64	822–830
48	694–702	65	830–838
49	702–710	66	838–846
50	710–718	67	846–854
51	718–726	68	854–862
52	726–734	69	862–870
53	734–742		

Channel	Frequency, MHz
Low-band VHF	
2	54–60
3	60–66
4	66–72
5	76–82
6	82–88
FM broadcast	88–108
Aircraft	118–135
Ham radio	144–148
Mobile or marine	150–173
High-band VHF	
7	174–180
8	180–186
9	186–192
10	192–198
11	198–204
12	204–210
13	210–216
UHF	
14	470–476
15	476–482
16	482–488
17	488–494
18	494–500
19	500–506
20	506–512
21	512–518
22	518–524
23	524–530
24	530–536
25	536–542
26	542–548
27	548–554
28	554–560
29	560–566
30	566–572
31	572–578

Channel	Frequency, MHz
UHF (cont.)	
32	578–584
33	584–590
34	590–596
35	596–602
36	602–608
37	608–614
38	614–620
39	620–626
40	626–632
41	632–638
42	638–644
43	644–650
44	650–656
45	656–662
46	662–668
47	668–674
48	674–680
49	680–686
50	686–692
51	692–698
52	698–704
53	704–710
54	710–716
55	716–722
56	722–728
57	728–734
58	734–740
59	740–746
60	746–752
61	752–758
62	758–764
63	764–770
64	770–776
65	776–782
66	782–788
67	788–794
68	794–800
69	800–806
Cellular telephone	806–902

Reference

- R.R. Gulati, “Modern Television Practice”, Third edition, New Age International Publishers