CHAPTER 17
Video Recorder

17.1 Magnetic Tape Recording Process:

The basics of magnetic tape recording process involves magnetizing very small particles of a magnetic coating (Ferric Oxide Fe_2O_3, Chromium Dioxide CrO_2 or metallic alloy) on the surface of a plastic tape. The magnetic materials employed in tape coatings are chosen because they possess elemental permanent magnets on a submicroscopic or molecular scale (known as domains). These domains are randomly oriented. When the tape passes over a recording head (Fig. 17.1), these magnetic domains will be realigned in such a direction and to the extent which depend on the magnetic polarity and field strength at the trailing edge of the recording head gap.

As the tape passes across the gap, an ac magnetic field is created there. Since the gap is filled with a nonmagnetic material, it offers high reluctance to the magnetic flux, while the tape offers a low reluctance path, and thus, the magnetic flux flows across the gap via the tape leaving it magnetized. On replay, the magnetized tape moves across the head gap of a similar head. Now, the magnetic flux on the tape flows through the head, inducing a current in the coil, hence, providing an electrical output. Normally, a professional tape recorder has three heads. This allows for the tape to be first erased, then three recorded and then monitored (read) by the third head.

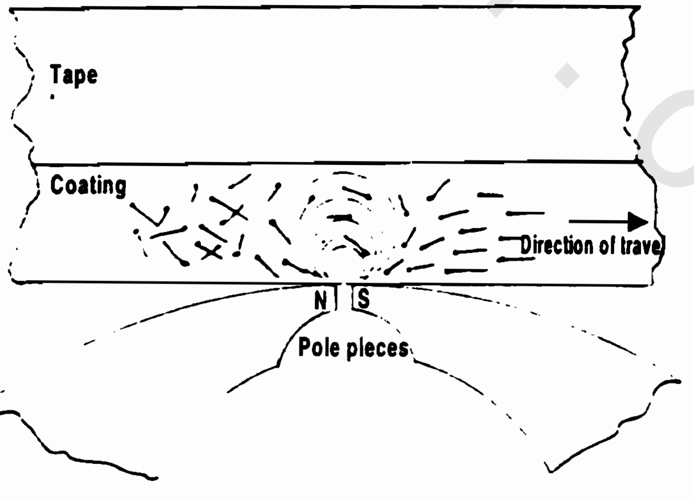


Fig. 17.1 The alignment of magnetic domains as the magnetic tape passes over the recording head

It is known that a magnetic field is generated by an electric current passing through a coil, wound around a steel bar or another hard material. This material is then magnetized. Once the current is removed, a certain amount of magnetism remains in the bar, which becomes a permanent magnet. The retained magnetism is measured in terms of the flux density B. If B is plotted against the magnetizing force H, we obtain Fig.17.2a. Starting from point O, as the magnetizing force increases, so does the flux density B. However, it is not linear. The flux density increases slowly at first, due to the magnetic inertia of the material. Then, as H is further increased, there is a steep rise in the graph - as the flux density rapidly increases - up to a limiting point S_p. This is where the material saturates and cannot absorb any more flux. When the magnetizing force H is reduced back to O, the flux density in the material does not reduce to zero, but remains at a value R_p. This is the retained flux density of a permanent magnet (Fig. 17.2b).

If the magnetizing force is reversed, the flux density now gradually reduces, until it passes through the zero axis of B at $-H$. Then, the flux is reversed, until it saturates in the negative direction at point S_n. When the magnetizing current is reduced back to zero, the reverse polarity flux remains at point R_n. Increasing the magnetizing current again in the positive direction reduces the reversed polarity flux density. It passes through the H axis, and the material saturates again at S_p. This produces B/H loop (called hysteresis loop) for soft material (as a magnetic tape) (Fig. 17.2b), or a hard material (Fig. 17.2c). The hysteresis loop is the magnetizing curve followed by the flux of an alternating current.

When we wish to remove the stored flux (demagnetize the material), we apply an ac current, and then gradually reduce its amplitude to zero. In this way, the B/H loop gets smaller, until it vanishes to a point at the origin, with no residual magnetism. This process is called degaussing.

In the process of recording on magnetic tape, the signal current causes a hysteresis loop for a certain peak of the signal current. As this peak varies, we have different hysteresis loops. What counts is the residual values of flux for different values of H. This obtained by applying incremental values of H (starting at $H = 0$). We get the corresponding B from the B/H curve. Then, by removing H, we get the residual flux at point R_p. We plot R_p against H that was applied. This is how the transfer characteristic is obtained (Fig. 17.3a,b).

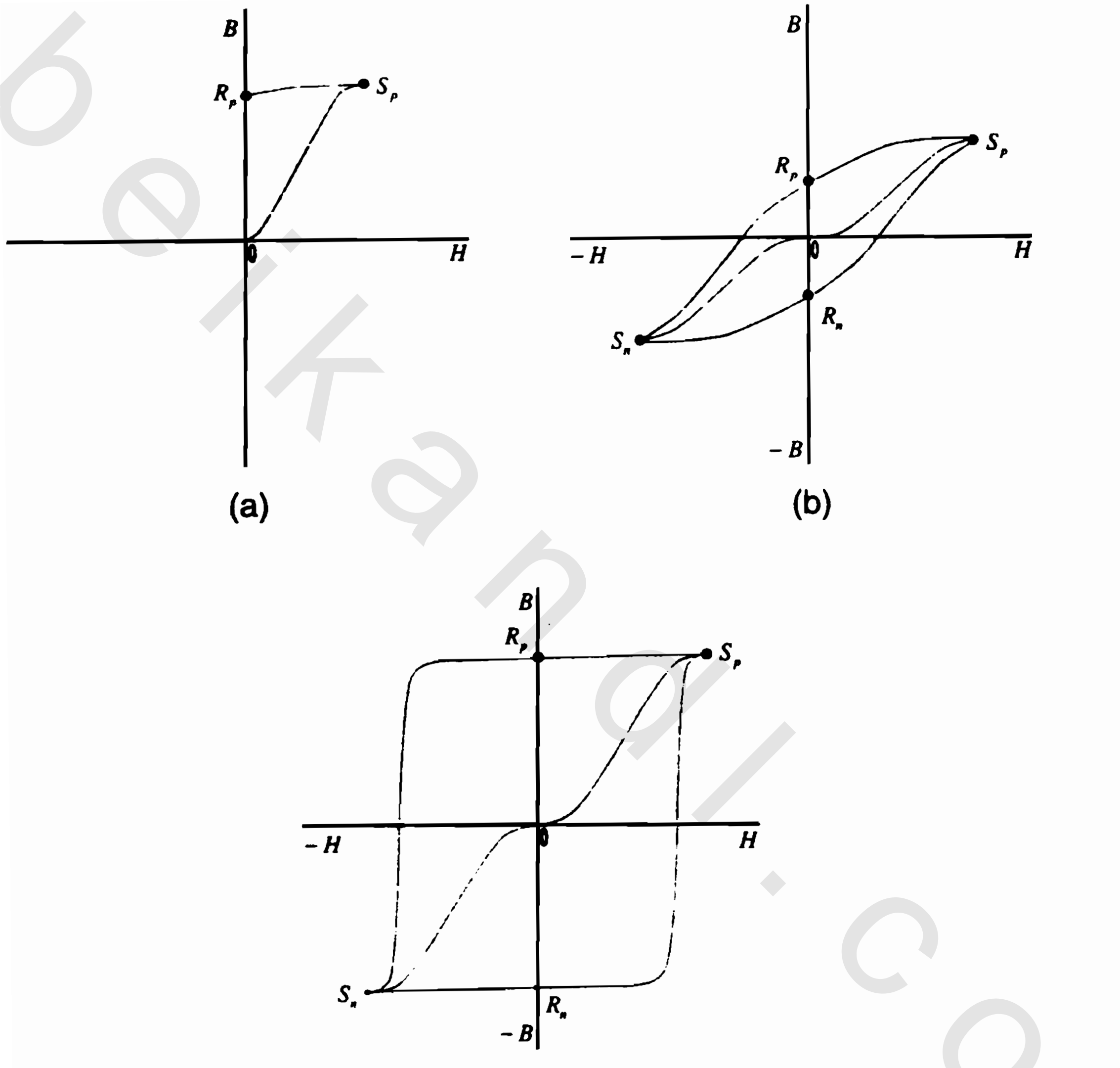
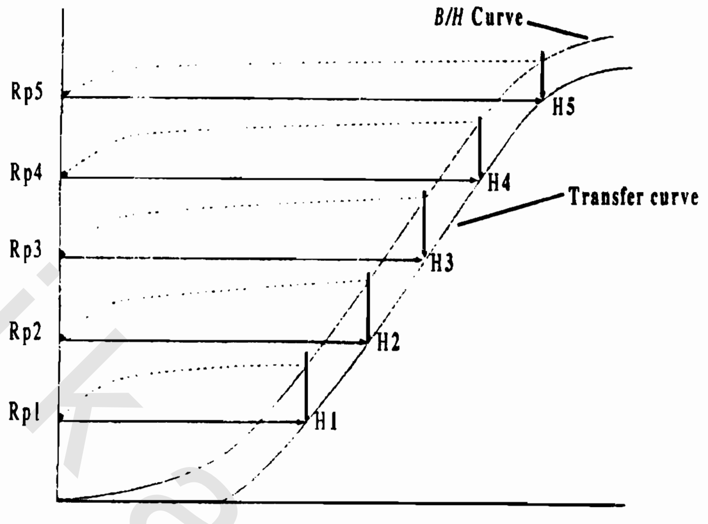


Fig. 17.2 B/H **characteristics**

a) B/H curve b) soft B/H loop c) hard B/H loop

(a)



(b)

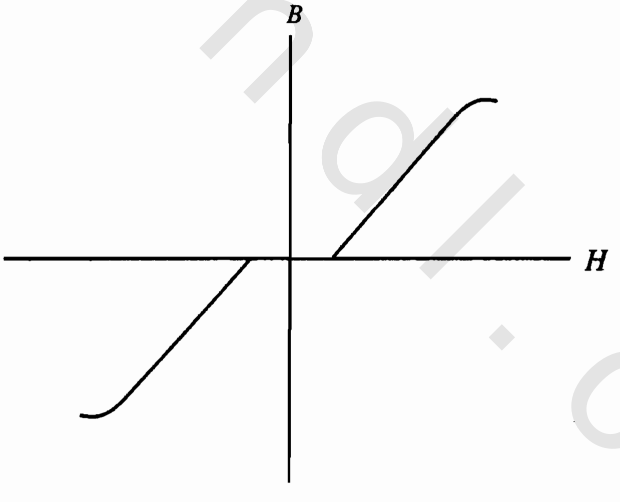


Fig. 17.3 The transfer characteristic

a) obtaining the transfer characteristic from the B/H curve

b) sketch of the transfer characteristic

We note that this characteristic is nonlinear at the bottom and top, but fairly linear in the middle. The recording signal must be kept within the linear part of the transfer curve. Therefore, it must be biased into this area. Otherwise, distortion will result when we apply an ac signal, as parts of the waveform in the output flux will be chopped off (Fig. 17.4).This type of distortion is called crossover distortion. One way to apply a bias is to premagnetize the tape with a dc magnet before it passes over the recording head. This dc magnetization, however, causes tape noise, giving poor S/N.

Alternatively, a dc bias may be applied for the ac waveform. This bias centers the signal on the transfer curve, thus, keeping the ac signal in the linear section of the transfer curve (Fig. 17.4c).

Neither of the methods described above takes full advantage of the magnetizing capabilities of the tape, as the reverse polarity area is not used, which reduces the playback level, and hence, leads to a reduction in S/N. On the other hand, if the level of the ac signal is increased with respect to the dc level, signal peaks will be flattened by the nonlinear upper portion of the transfer curve.

The best way to bias the tape is to add or mix the recording signal with a high frequency ac bias signal. This frequency is much higher than the signal frequency. Thus, the signal is kept on the linear parts of the transfer curve in both positive and negative quadrants (Fig. 17.5). The signal sits on the top and bottom of the bias waveform, which gives a larger replay output that has good S/N and low distortion, provided that the ac bias is large enough to maintain the signal on the linear part of the transfer curve. Any crossover distortion in the lower parts of the transfer curve affects only the ac bias waveform. Since the recording signal is added to the ac bias, and does not modulate it. Then, the recording signal is unaffected by this distortion of the ac bias waveform. Care is taken in the design of the tape head to ensure that it is not saturated by the bias signal, otherwise the signal will be distorted. High frequency bias is not reproduced, and is lost by bandwidth limitations and ac losses (Fig. 17.5c).

In the recording process, losses occur in the transfer from electrical to magnetic signal. There are four main reasons for such losses: magnetization loss, eddy current loss, impedance loss and penetration loss. Magnetization loss refers to the initial amount of energy required to establish the magnetic field. Eddy current loss refers to the establishment of magnetic flux due to eddy currents in the core of the recording head, opposed to the magnetic flux of the signal. For a constant voltage signal drive to the recording head, recording current will decrease as the frequency of the signal increases, due to the rising impedance of the head with frequency.

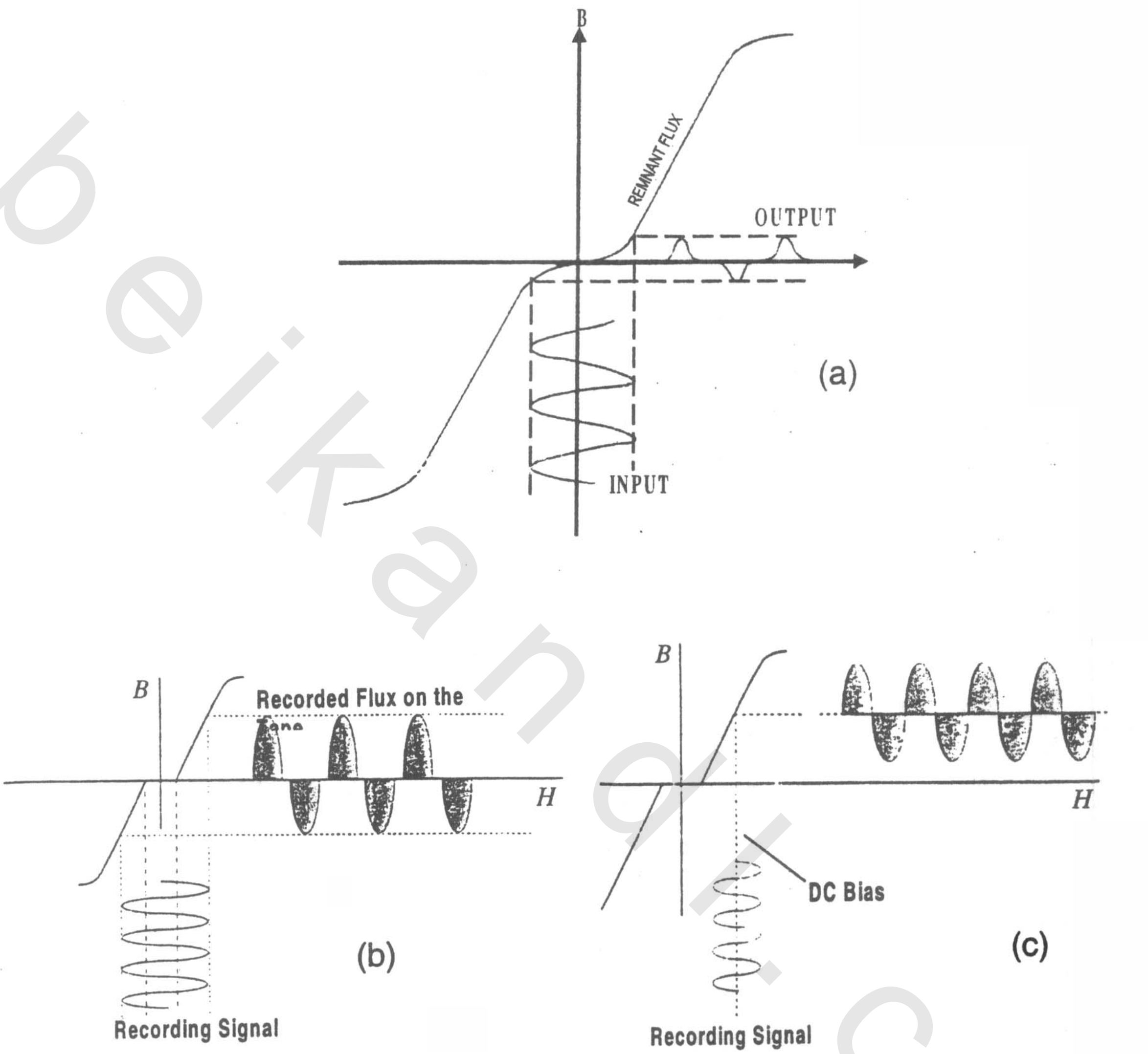


Fig. 17.4 DC bias in magnetic recording

a) crossover distortion for a small signal swing
b) crossover distortion for a large signal swing
c) the effect of dc bias

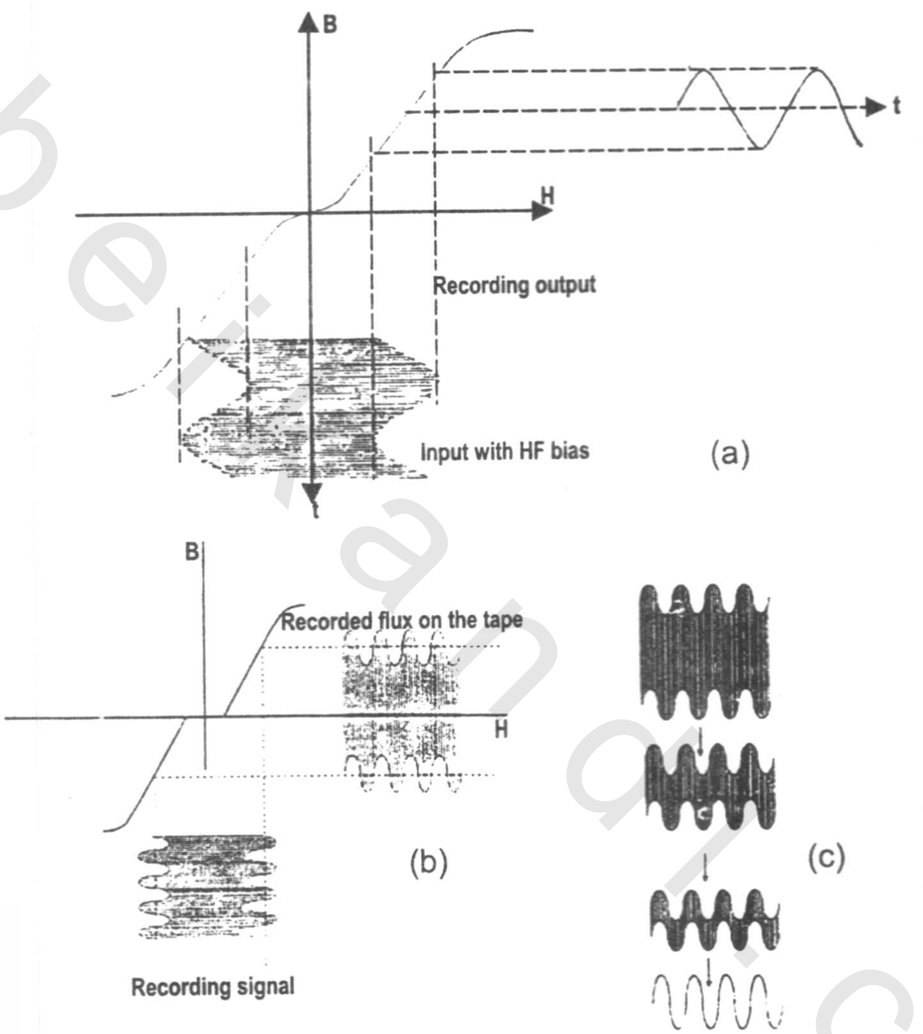


Fig. 17.5 AC bias in magnetic recording

a) application of HF bias (superposition not modulation)
b) immunity of recorded signal from crossover distortion
c) cancellation of HF bias due to losses in the record/replay process

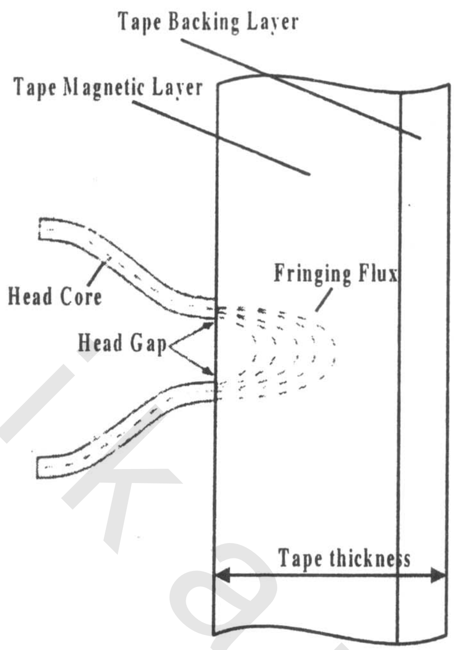


Fig. 17.6 Penetration loss

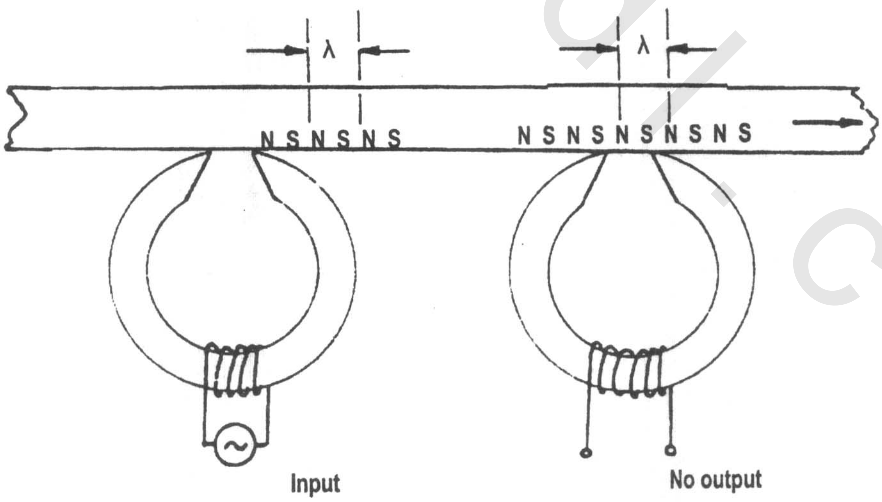


Fig. 17.7 Effects of recorded wavelength on replay head output

Low frequency signals magnetize the coating of the tape much more deeply than higher frequencies. A physical property of magnetic domains causes the flux to penetrate the tape by ripple effect. Each domain magnetizes the next, and the field gradually penetrates the tape. It takes a finite time for the magnetic flux across the head gap to penetrate the tape. Thus, for higher frequencies, the time that the flux is present is less than that for lower frequencies, consequently, penetration is less. The difference in remnant magnetism is, therefore, less for higher frequencies than for lower frequencies. This represents a high frequency loss (Fig.17.6).

17.2 Frequency Response:

If a sinusoidal ac signal of constant amplitude and frequency is applied to the recording head, and the tape is passed over at a constant speed, a sequence of magnetic poles will be laid down on the tape (Fig. 17.7), and the distance between like poles - equivalent to one cycle of recorded signal - is known as the recorded wavelength λ. We note that λ is related to the frequency f and the tape velocity u by the relation.

$$\lambda = \frac{u}{f} \qquad (17-1)$$

When the recorded wavelength is equal to the replay head gap, there will be zero output. This situation is worsened by the fact that the effective replay head gap is - in practice - somewhat larger than the physical separation between the opposed pole pieces, due to the spread of the magnetic field at the gap.

Additional sources for diminished HF response in the recovered signal are: self magnetization within the tape, eddy currents and other losses discussed above. If a constant amplitude sine wave signal is recorded on the tape, the combined effect of recording head and tape losses will lead to a remnant flux on the tape as shown (Fig. 17.8). The HF turn over frequency is principally dependent on the tape speed. Thus, the rate of change of flux across the head gap is not only dependent on the length of the gap, but high frequencies can be achieved as long as the tape is moving fast enough to move the small magnetized domain out of the way, before the signal changes to the next cycle.

Each complete cycle of the recording signal consists of a positive and a negative section each representing 180°. On the tape, the cycle is represented by a small bar magnet, formed by two sections N-S and S-N of opposite polarity, each being equivalent to the positive and negative half cycles. The recording width of the bar magnet length is equal to λ (Fig. 17.9).

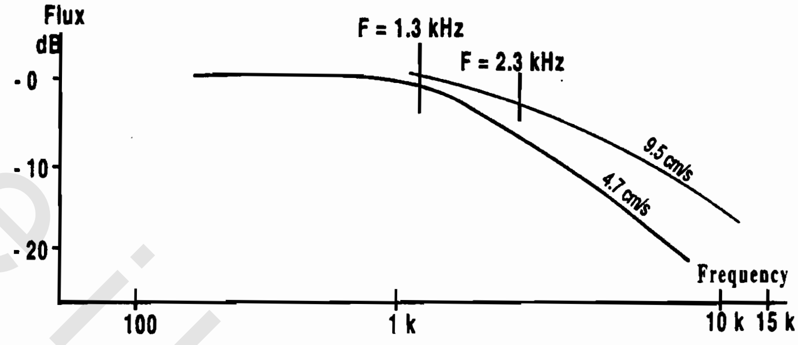


Fig. 17.8 Effect of tape speed on HF replay output

As the frequency rises, a point is reached when the positive cycle has not moved far enough along when the negative cycle starts. Partial erasure of the positive cycle occurs, as the negative cycle records over it, limiting the amplitude of the flux on the tape and reducing recording efficiency.

Thus, the tape speed - not only the head gap, - limits the frequency response of the tape. The tape speed u has to be high enough to move the tape past the head by a distance equal to the recording width λ_c in time t_1, where $t_1 = 1/f_1$ (the period of the highest frequency f_1), i.e.,

$$\lambda_c = ut_1 = \frac{u}{f_1} = \frac{u}{BW} \qquad (17-2)$$

At very low frequencies (below 50 Hz), the recording process becomes inefficient, especially at low tape speeds. The interaction between the tape and the profile of the pole face of the record replay heads leads to a characteristic undulation in the frequency response (Fig. 17.10).

In replay, the tape passes over the head at a constant speed. The output from the head, however, increases with signal frequency. The recorded signal is a row of bar magnets on the tape. At low frequencies, the bar magnets are very long, and they are much shorter at high frequencies.

The output voltage V from a coil within a moving magnetic field is proportional to the rate of change of flux $d\varphi/dt$. Thus, there is a linear relation in the replay signal level with frequency, i.e., the output from the replay head doubles for each octave (6dB/octave).

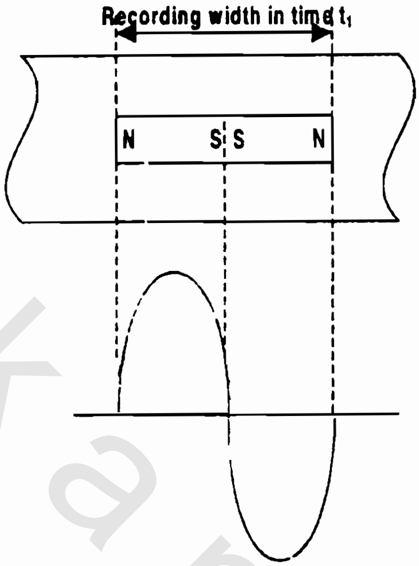


Fig. 17.9 Recording wavelength

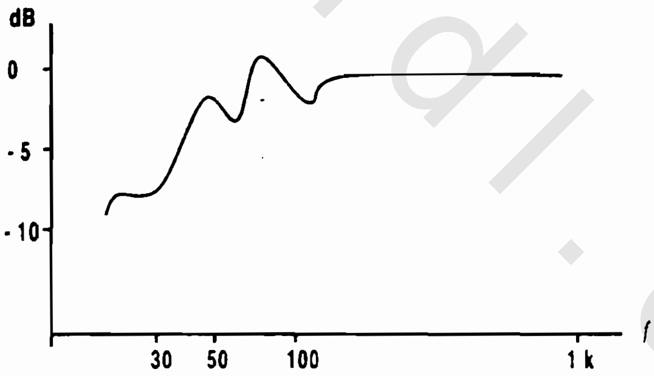


Fig. 17.10 Non-uniformity in low frequency response due to pole piece contour effects

At very low frequencies, the bar magnets are long in comparison with the replay head gap, and this causes a reduction in the replay level. This is due to the flux following a path external to the replay head (Fig. 17.11). The flux takes a path through air rather than through the head core. A loss occurs due to the higher reluctance of the air path.

The replay response is shown (Fig. 17.12). From point O, the curve of the replay head output rises slowly up to point S, due to the losses of long wavelength at low frequencies. Between S and T, the rise in the output is steady and linear at the rate of 6dB/octave.

After point T, a peak is reached at point M. Actually, M is the practical maximum, while N is the theoretical maximum, as it is the real point of maximum output. But due to increasing high frequency losses, the result is down by 3dB. Between the peak of the signal and the 3dB point, the high frequency losses are a combination of head to tape contact, replay head inductance, eddy current losses and head alignment tolerances. The curve now falls rapidly to zero at the extinction frequency point E. At the theoretical peak point (Fig. 17.13a), we have

$$G = \frac{\lambda_P}{2}, \qquad (17-3)$$

where G is the gap width and λ_P is λ at the peak point. At the extinction point (cut off) (Fig. 17.13c), the bar magnet length is equal to the width of the head gap.

$$\lambda_{ex} = G \qquad (17-4)$$

Both magnetic polarities of the bar magnet exist across the gap, so they, cancel each other. In between, some part of the negative half cycle occurs in the same domain as the positive one (Fig. 17.13b). Some subtraction takes place and the overall signal output is decreased (Fig. 14.14).

Ex. 17.1
Obtain a relation between the extinction frequency and the tape speed.

Solution:
From eqns. (17-2) and (17-4),

$$G = \lambda_{ex} = ut_{ex} = \frac{u}{f_{ex}}$$

$$f_{ex} = \frac{u}{G} \qquad (17-5)$$

Thus, the extinction frequency is directly proportional to the tape speed and inversely proportional to head gap width.

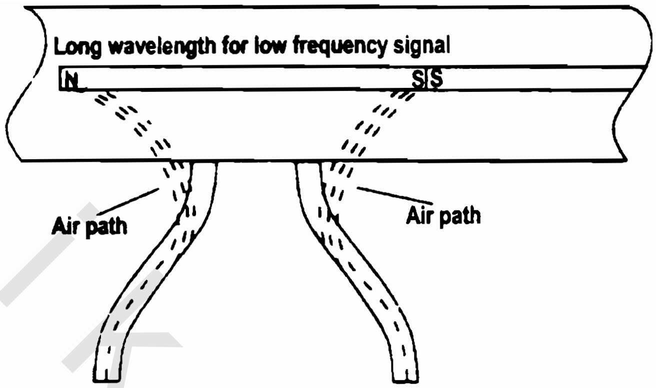


Fig. 17.11 Low frequency losses

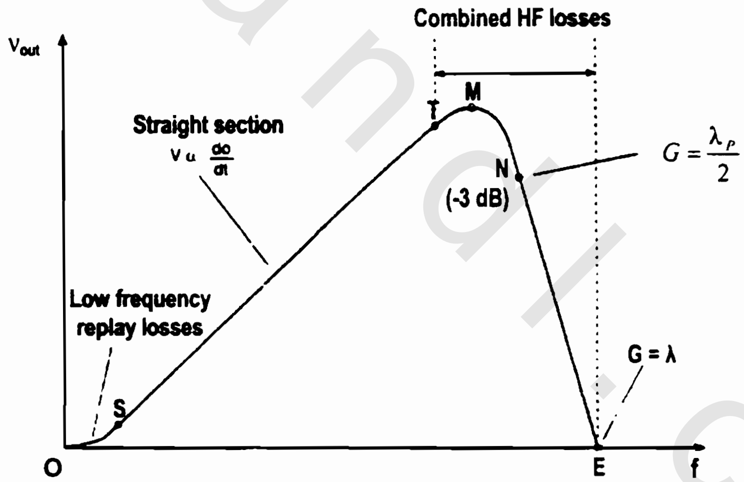


Fig. 17.12 Replay response curve

17.3 Record Play Equalization:

In order to obtain a flat frequency response in the record/play process, the electrical characteristics of the record and replay amplifiers are modified to compensate for the nonlinearities of the recording process. This electronic frequency response adjustment is known as equalization. In tape recording, it is assumed that the total inadequacies of the recording process will lead to a remnant magnetic flux in the tape - following a recording which has been made at a constant amplitude - which has the frequency response characteristics shown in

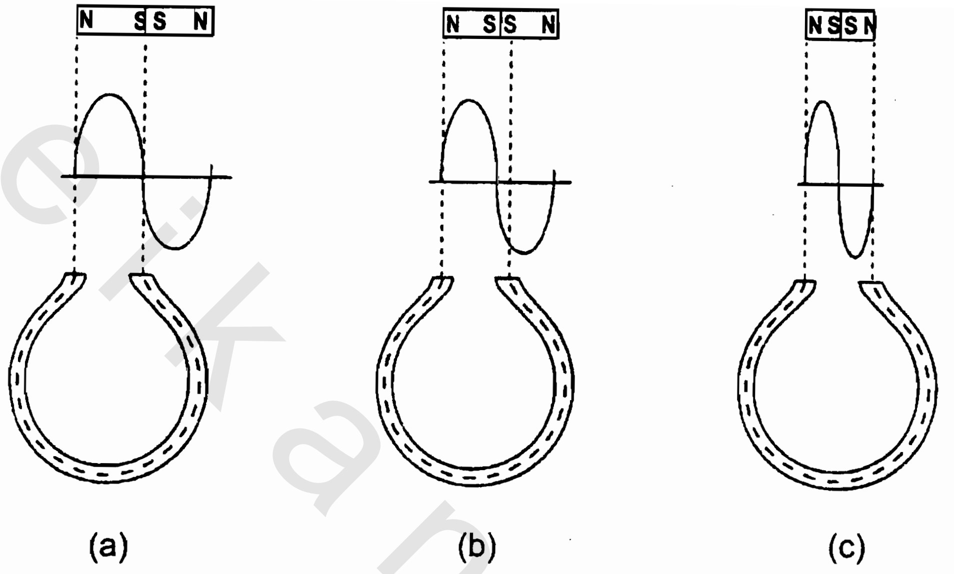


Fig. 17.13 Wavelength compared to head gap

a) $\lambda_P = 2G$ b) $\lambda_P > \lambda > \lambda_{ex}$ c) $\lambda_{ex} = G$

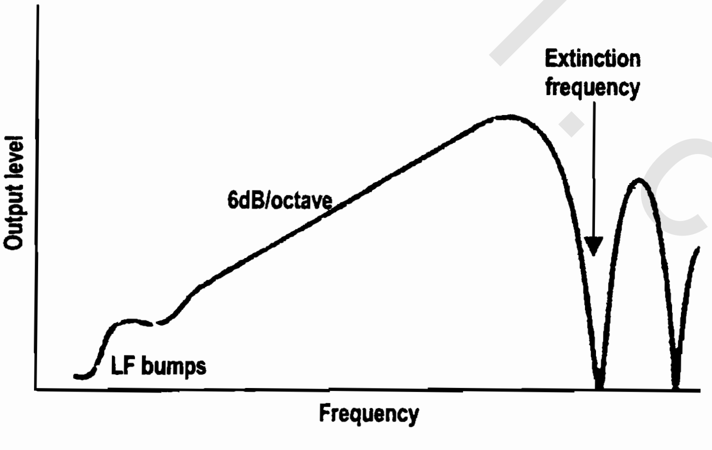


Fig. 17.14 Replay frequency response

(Fig. 17.15) for various tape speeds. It includes a small amount of bass (low frequency) pre-emphasis, so that the replay de-emphasis (electronically induced or inherently built-in in the head response) may lessen hum pick up and low frequency losses.

The design of the replay amplifier must then be chosen so that the required flat frequency response output would be obtained on replaying a tape having the flux characteristics shown in Fig17.15. This leads to a replay characteristic of the kind shown in Fig.17.16.

Here a 6dB/octave fall in the output with increasing frequency is required to compensate for the increasing output during replay of a constant recorded signal. (Fig. 17.17). The leveling off shown in curves a-d of (Fig. 17.16), account for the anticipated fall in the magnetic flux density above the turn over frequency for various tape speeds. However, this does not allow for other head losses, so some additional replay HF boost is also used (curves e-h). Such replay equalization is used to ensure that a flat response is available at the tape machine's output.

It compensates for losses in the recording/replay process, the rising output of the replay head with frequency, the fall off when the recorded wavelength approaches the head gap width. The recording amplifier is then designed to conform to Fig.17.15. This will generally require some HF and LF pre-emphasis of the kind shown (Fig. 17.17).

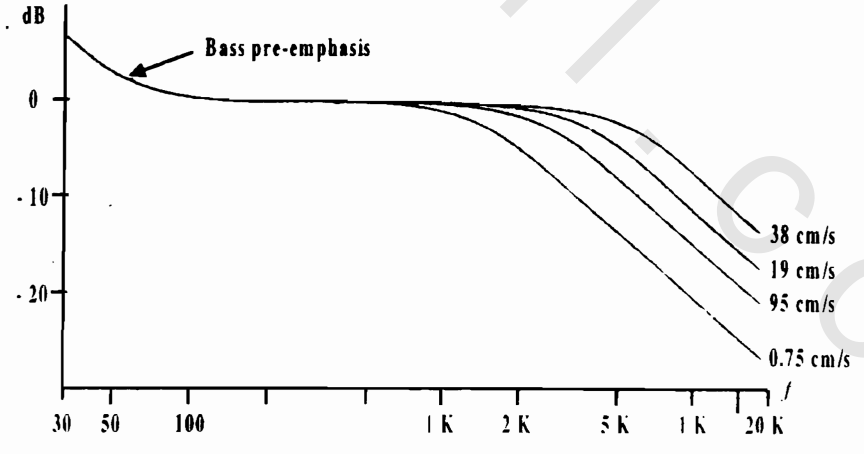


Fig. 17.15 Assumed remnant magnetic flux on tape for various tape speeds in cm/s

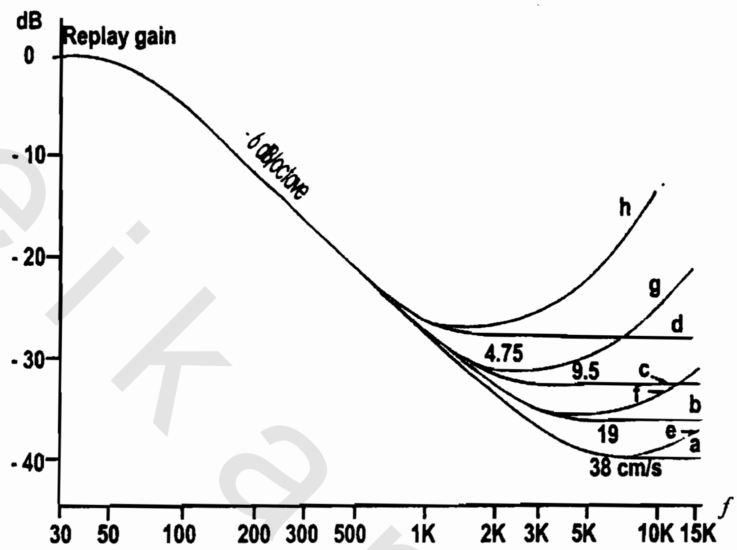


Fig. 17.16 Required replay frequency response for different tape speeds

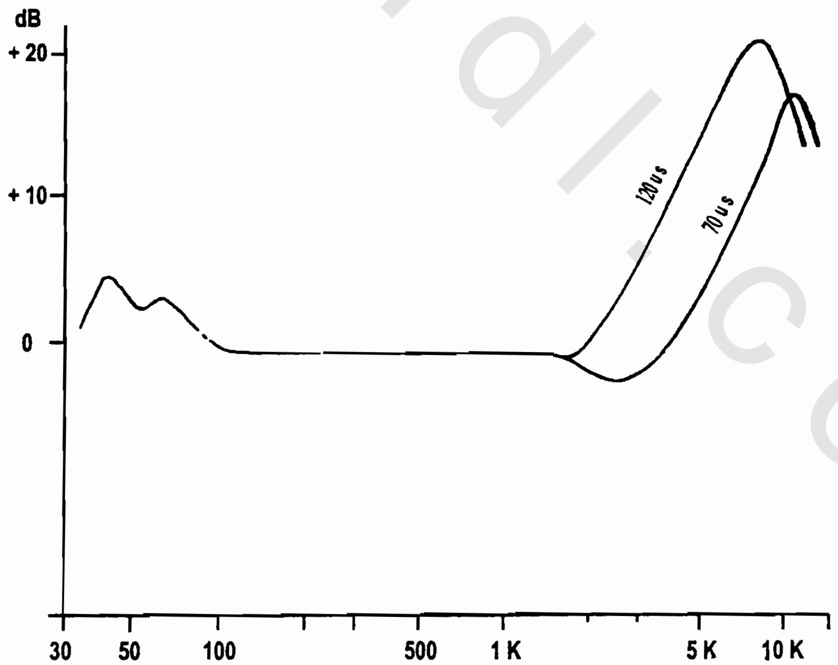


Fig.17.17 Assumed recording frequency response for various HF time constants (roll off – turn over frequencies)

The LF time constant of 3180 μs is introduced to reduce hum. HF time constants - resulting in low turn over frequencies - tend to result in greater replay noise, since HF is boosted over a wider band on replay, thus, amplifying tape noise considerably. That is why tape I cassette tapes (120 μs EQ) sound noisier than type II tapes (70 μs EQ) both running at 4.75 cm/s.

17.4 Dynamic Range:

In order to obtain the maximum output and the best S/N, the replay signal is optimized between two constraints. Saturation of the tape limits the maximum level of signal that can be recorded and replayed without distortion. Residual tape noise will limit S/N at low levels. The average dynamic range is 60 dB. If the output varies by 6 dB/octave, it follows that the maximum usable frequency range is about 10 octaves (Fig. 17.18). Ten octaves is sufficient for audio signals with a frequency response from 25 Hz to 25 KHz, but not enough for a video signal. A video signal has a frequency response extending from 25 Hz to over 5 MHz. This is a dynamic range that is more than 18 octaves.

It is impossible to record and replay the bandwidth of a video signal by using the same techniques as those for an audio signal, as the frequency range of the video signal is 8 octaves over the tape limitation of 60 dB (Fig. 17.18). Some kind of bandwidth compression technique is required to reduce the 18 octave range down to a value that is more manageable. The frequency/octave range is shown (Fig. 17.19).

By taking a carrier signal with a center frequency, and modulating it with a video signal - which is restricted to a bandwidth of 3.2 MHz - the frequency spectrum of the resultant FM carrier - including upper and lower sidebands - is between 1 and 8 MHz. It is seen that this frequency spectrum of 3 octaves will be within the normal record and replay parameters of magnetic tape.

The second advantage of using a frequency modulated carrier is that it is unaffected by amplitude variations that occur due to head tape contact problems in both record and replay. The video heads are subject to bounce and variations in the tape tension, causing the tape to stretch and flex, as it passes through the mechanics, thus contributing to amplitude fluctuations of the FM carrier. An FM modulated carrier can be amplified - then limited - to eliminate amplitude variations, leaving a clean and level FM carrier for demodulation.

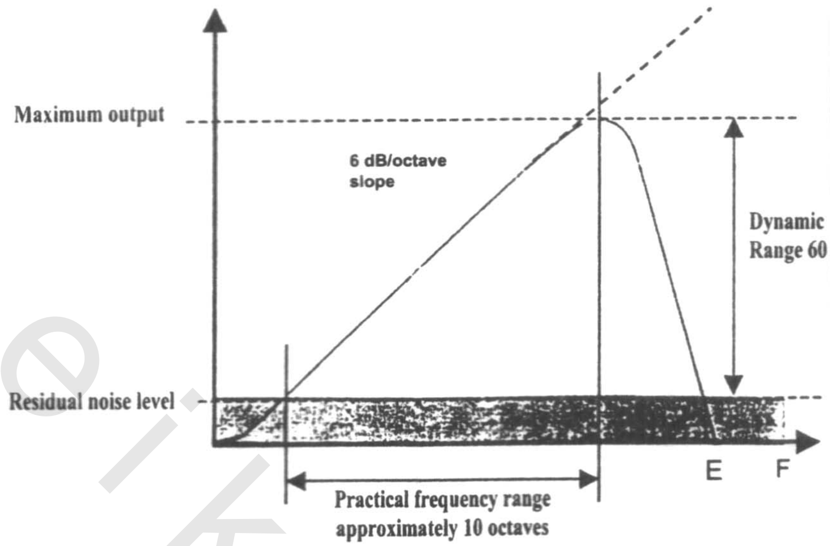


Fig.17.18 Dynamic range

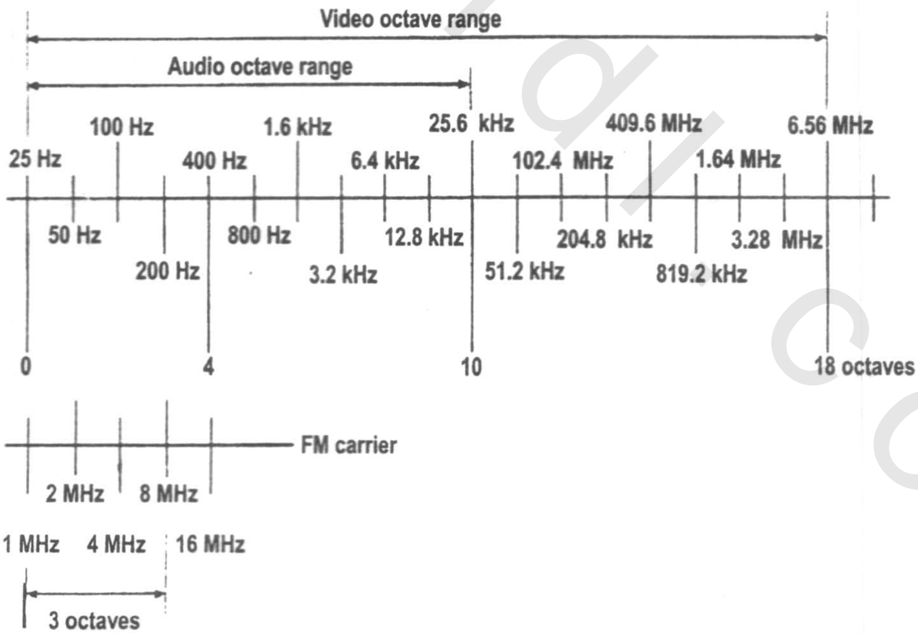


Fig. 17.19 Frequency/octave range

17.5 Video Frequency Modulation:

For the VHS video system, the frequency modulation of the carrier signal is from sync tip at 3.8 MHz to peak white at 4.8 MHz (maximum deviation of ± 0.5 MHz around a carrier at 4.3 MHz), (Fig. 17.20). Bandwidth of the luminance signal (maximum modulating signal) is restricted to 3 MHz. Thus β_f is below 0.5. Thus, only two sidebands are required to successfully carry the video information in its FM form. Most recorders suppress part of the upper sideband to improve S/N on account of high frequency losses. The upper sideband is usually restricted to 6MHz. The sidebands created by FM are limited to 1.3 MHz on the lower sideband and 5.75 MHz on the upper sideband. The total recording spectrum extends from 1.3 MHz 5.75 MHz, which is just over two octaves. The color subcarrier is shifted down under the lower sideband around a new carrier at 627 KHz (Fig. 17.21).

In addition to FM, there are two methods to increase the frequency range or writing speed to accommodate the video signal, namely, micro head gaps and rotating heads.

Ex. 17.2:

Calculate the bandwidth of the recorded video signal in VHS system.

Solution:

From eqn. (17-3) for maximum replay output,

$$G = \frac{\lambda_P}{2} \qquad (17-7)$$

$$\lambda_P = 2G \qquad (17-8)$$

We also have

$$\lambda_P = \frac{u}{f_P} \qquad (17-9)$$

From eqns. (17-8) and (17-9),

$$2G = \frac{u}{f_P} \qquad (17-10)$$

$$u = 2Gf_P \qquad (17-11)$$

In a video recorder, the head drum rotates fast, whereas the linear tape speed is quite slow. This means that u is not the tape speed, but the head to tape speed.

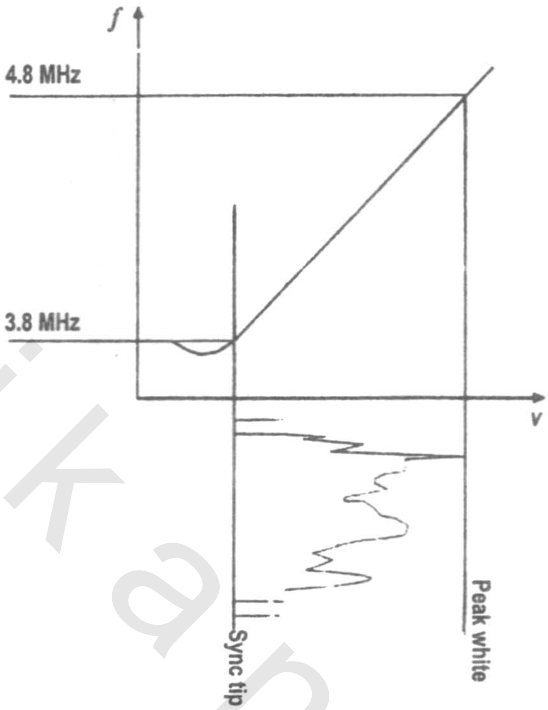


Fig. 17.20 Video signal voltage to frequency modulation

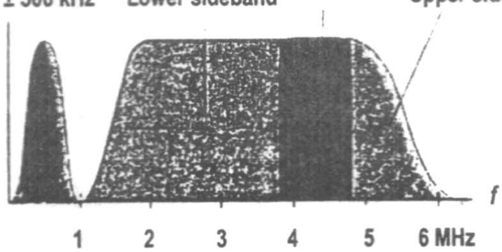


Fig. 17.21 FM modulation with color under carrier

The drum diameter is 62 mm, half the circumference (portion per head for two head system) is π X 0.062 m = 0.1948 m. Rotation speed is 25 revolutions /s, so the head to tape speed is 25 X 0.948 = 4.87 m/s. We now have to take into account that the linear tape speed is 0.02 m/s (23.39 mm/s). As this is in the same direction as the head, it must be subtracted to give 4.85 m/s. The video gap is 0.3m.

From eqn. (17-11),

$$f_P = \frac{u}{2G} = \frac{4.85}{0.6x\,10^{-6}} = 8\times10^{6} = 8\text{MHz} \qquad (17-12)$$

However, due to the normal HF losses the practical range is 6 MHz.

17.6 Video Heads:

From eqn. (17-12), we see that the record and playback frequency limits are inversely proportional to the head gap. A smaller head gap produces a shorter wavelength, since the bars are closer together. However, there are physical and electrical limits to making the head gap smaller.

The gap must always be narrower than the wavelength of the highest frequency to be recorded and played back (eqn. 17-7). Video head gaps are typically 0.6 µm for Beta and 0.3 µm for VHS. For this reason, it is necessary to increase the tape speed to accommodate the video frequency range.

To increase the relative speed between the tape and the head - and hence the writing speed - rotating heads are used. In audio tape recording, a slow tape speed is sufficient for recording conversation. But music requires a faster speed (typically 19 cm/s) for good sound quality. If we assume that the top frequency for recording music is 20 kHz, and that the top frequency limit for video signal is 4 MHz (200 times that for music), the required tape speed is 38 m/s, and would require a video cassette the size of a truck tire for 1 hour of playing time (problem 17.9).

Instead of using a tape at a high speed, the video heads are rotated to produce a high relative speed between the head and the tape. Fig. 17.22 shows how the heads and the tape move in relation to each other. While the video heads rotate in a horizontal plane, the tape passes the heads diagonally. This is known as the helical scan system, which produces slant tracks or diagonal tracks for the video recording. Note that the audio head and control track head (mounted one above the other) are stationary, and are separate from the video heads, as in the erase heads. The relative speed of the Beta system is typically 6.9 m/s, whereas the typical VHS relative speed is 5.8 m/s. The actual tape speed is in the range of 2 cm/s. The drum or cylinder (scanner) rotates at a speed of 1800 rpm. Fig.17.23

shows a simplified diagram of the relationship between the video heads and the video tracks recorded on the tape.

Video heads A and B are positioned 180° apart on a drum (or cylinder), which rotates at a rate of 30 times a second. The tape is wrapped around the drum (or cylinder) in the form of an omega Ω shape. The tape passes diagonally across the surface of the drum. Each head contacts the tape once each 1/60 s. Thus, each head completes one rotation in 1/30 s, and one slant (or diagonal track) is recorded on the tape during half a rotation (1/60 s). Since the tape is moving, after the first head has completed one track on the tape, the second head records another track immediately behind the first track.

If head A records during the first 1/60 s, head B records during the second 1/60 s. The recording continues in a pattern A-B-A-B and so on. During playback, the heads trace the tracks in the same sequence, and pick up the signal, producing an FM signal that corresponds to the recorded video signal. Fig.17.24 shows the relationship among tracks, fields, frames and vertical sync pulses. Since there are two heads, 60 diagonal tracks are recorded every second. One field of the video signal is recorded on one track on the tape, and two fields (adjacent tracks A and B) make up one frame. In actual practice there is some overlap between the two tracks.

The video signal recorded by head A (just leaving the tape) is simultaneously applied to head B (just starting its track). During playback this overlap is eliminated electronically, so that the output from the two heads appears as a continuous signal. We note that guard bands (gaps) separate the tracks.

While one video head is properly aligned on track and replaying maximum FM signal, the other is off the track with improper tracking. Although the second head is not scanning the full width of the FM magnetic track, there is still a reasonable replay due to pick up. If the guard band were not present, and the video head wandered off its track onto the next one, there would be replay of both tracks together, i.e., a replay of two fields at the same time, and considerable crosstalk and patterning would occur.

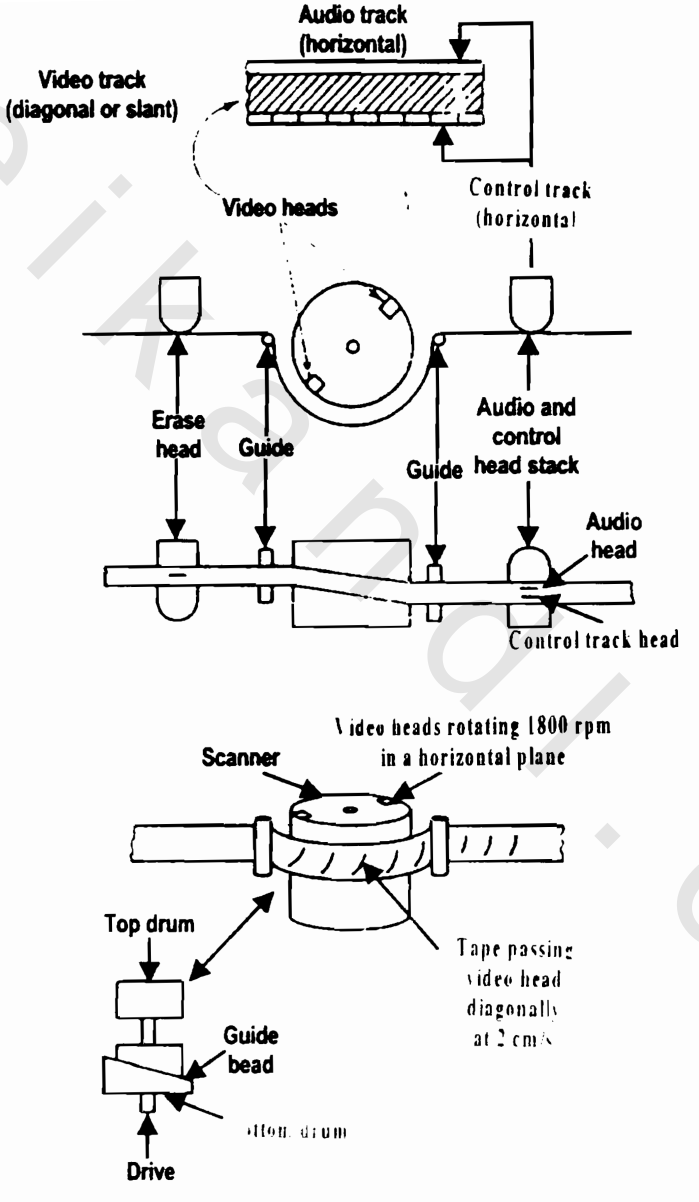


Fig. 17.22 Relationship of heads and tape movement

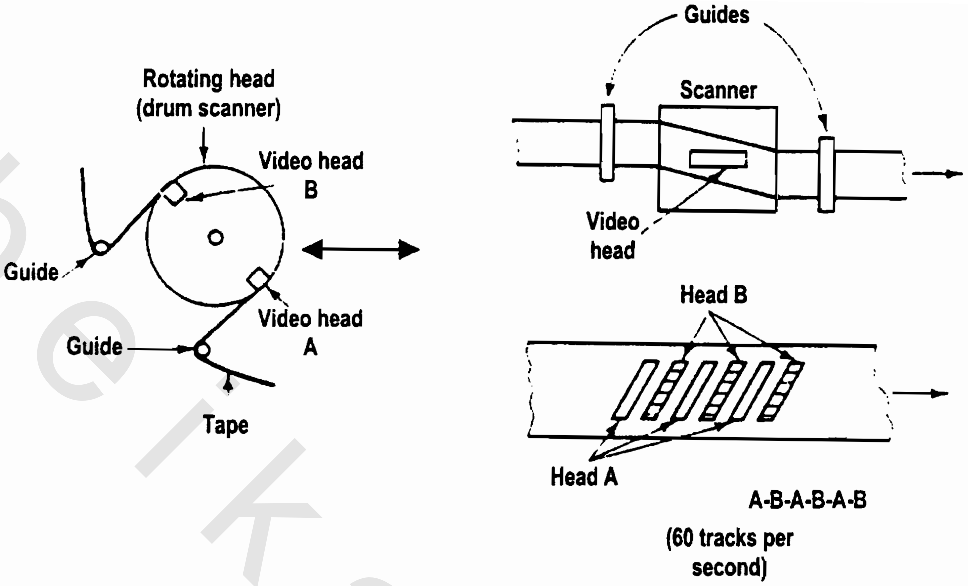


Fig. 17.23 Relationship between the video heads and the video tracks recorded on the tape

In order to achieve longer times on the tape, it must be slowed down and the magnetic track packing density increased, i.e., to put more information on the same area of the tape. While the guard band served a useful purpose for protection against crosstalk, it was - in fact - wasted tape space that could be better utilized to carry a signal. The technique used is to cut the gaps in the video heads at an angle one way for one head and the opposite way for the other head. Video head A records with the azimuth of its air gap at +6° and video head B records its magnetic track with the azimuth slanted -6°. The result of the azimuth tilt is that each head can only record and replay its own magnetic track of FM signal, the one with the same azimuth angle as the playback head (Fig. 17.25a).

The magnetic tracks appear as herringbone pattern (Fig. 17.25b), due to the azimuth difference between the video heads. Thus, the tape can be slowed down, the guard bands are now filled with signal and longer recording times are achieved. Additionally, active luminance crosstalk filters are added to clean up any luminance signal that is not sufficiently attenuated by the azimuth slant.

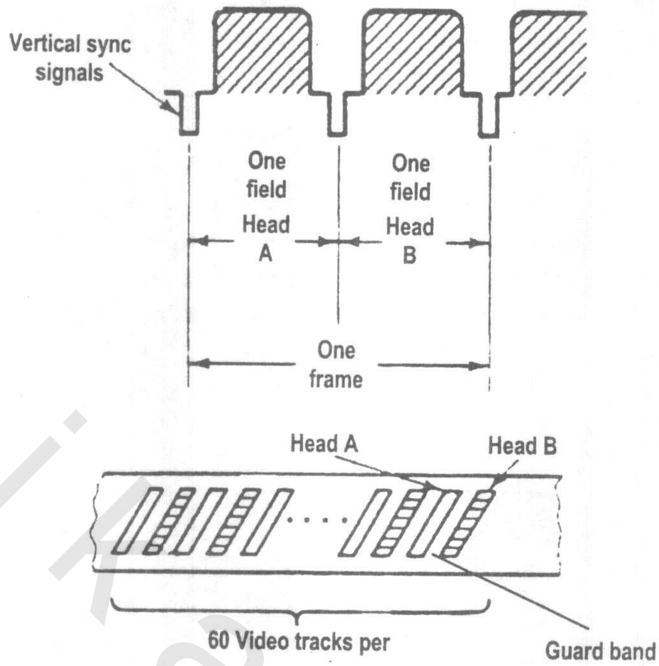


Fig. 17.24 Relationship among tracks, fields, frames and vertical sync pulses

17.7 The Video Cassette Recorder (VCR):

The block diagram of a VCR is shown (Fig. 17.26). In this figure, the signal splitter provides signal for TV receiver and the VCR tuner. For recording, the VCR tuner selects the desired RF channel, and the VCR demodulates the video and audio signals for the recording heads. For playback, the recorded video and audio signals are used for modulating an RF carrier. The tuner on the TV receiver must be tuned to that RF to see the recorded picture.

The composite video signal (including chroma) in Fig.17.27 is sent to four paths. In the record condition, the composite video signal is sent directly to the TV receiver, which enables the user to monitor the program being recorded. In the second path (luminance signal path), the first group of circuits provide premodulator processing, which includes:

1) reduction of the video bandwidth to 3.5 MHz.
2) AGC for video signal.
3) pre-emphasis.
4) FM deviation clamping.

Following the premodulator processing, the luminance signal is applied to the FM modulator (VCO). The output of the VCO is an RF square wave, which varies in frequency in accordance with the luminance video signal. This FM wave is then applied to the record amplifier. Its function is to supply sufficient current to the video head to saturate the tape magnetically. The record amplifier also provides some frequency equalization. A HPF is placed between the FM modulator

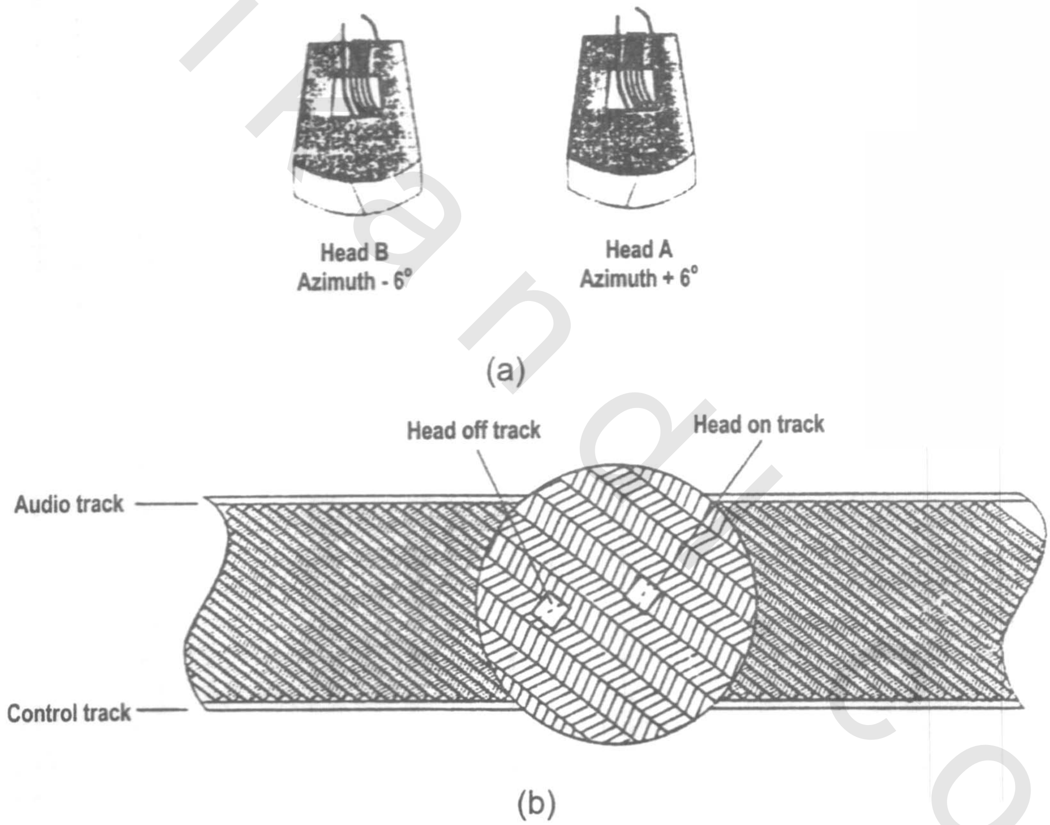


Fig. 17.25 Azimuth tilt
a) heads b) tracks

and the record amplifier. This prevents FM sidebands from existing below about 1 MHz, where the chroma signal with reduced carrier (688 kHz Beta and 629 kHz for VHS) exists. The processed chroma signal is fed to the video head together with the processed luminance signal.

The combination signal forms a composite video signal suitable for tape recording. Both the luminance and the color signals are recorded on the same tape track, while audio and control signals are recorded on separate tracks.

Fig.17.28 shows a tape layout in VCR. The ½ in. (1.27 cm) tape leaves the supply reel and moves past the erase head, which is activated only for recording. Next, the tape passes the audio and control track heads. The audio head receives and plays back only audio frequencies on a separate track. The control head records amplified vertical sync pulses. These pulses are used on playback through a servo system to synchronize the head-drum position and speed (tracking). Next, the tape passes around the head drum in a helical fashion.

The playback circuits perform the following basic functions:

1) amplifyimg the weak signals picked up from the tape.
2) de-emphasis.
3) time delay equalization between chrominance and luminance signals.
4) noise cancellation.
5) FM demodumation.
6) restoration of the 3.58 MHz chrominance signal subcarrier and sidebands.
7) combining recorded chrominance and luminance signals.
8) placing the signal on a VCR carrier for TV tuner.

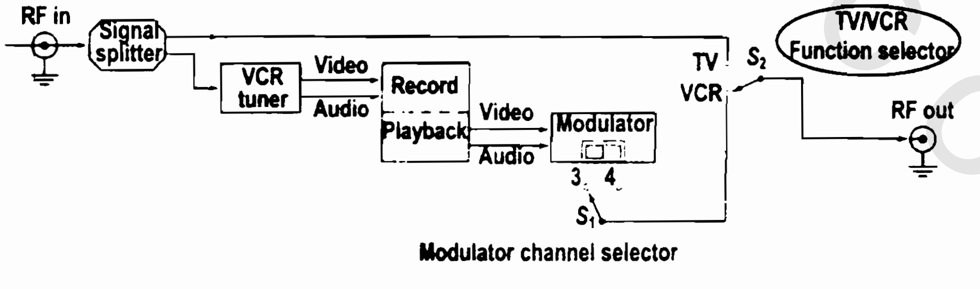


Fig. 17.26 Signal path in VCR

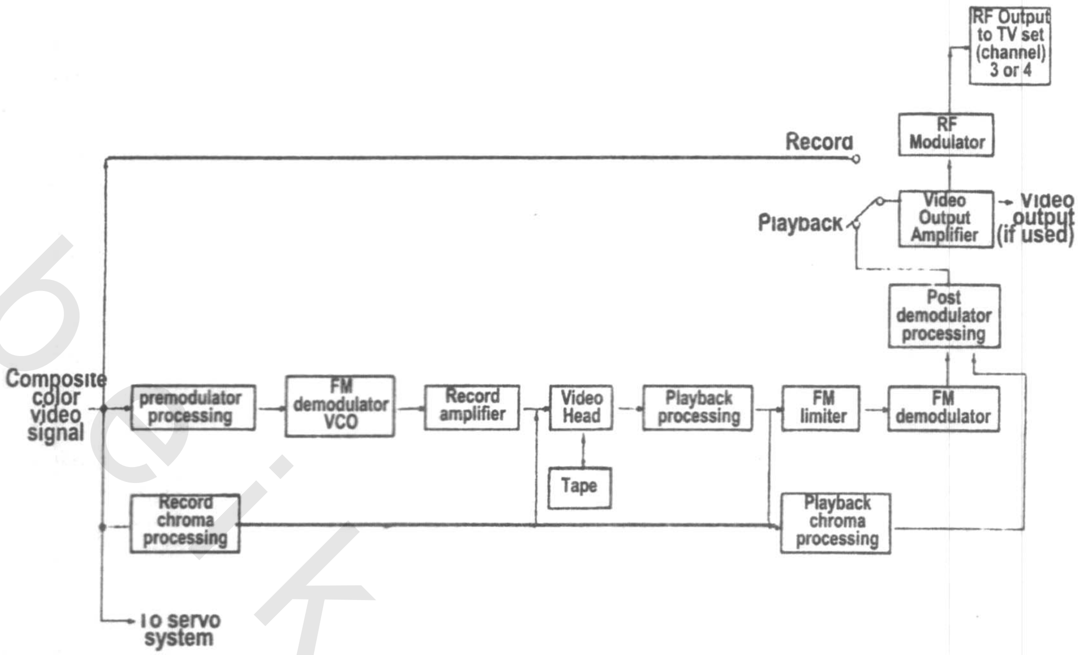


Fig. 17.27 A simplified block diagram of record/playback system in VCR

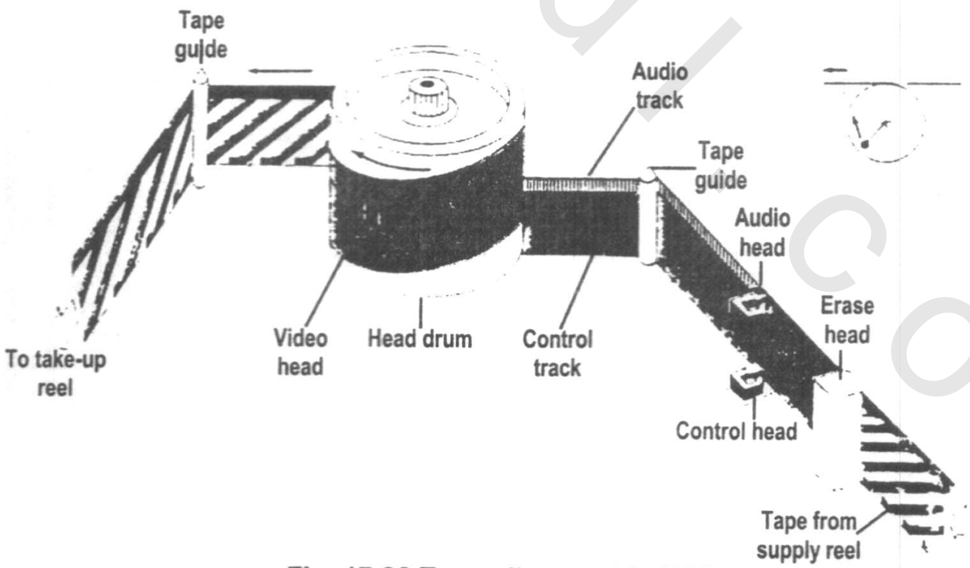


Fig. 17.28 Tape alignment in VCR

At the output of the playback preamplifier, there is a HPF which passes the luminance FM frequencies, but rejects the lower frequency chrominance signals. The limiter removes amplitude variations from the FM luminance signal. The output of the limiter feeds the FM demodulator. The luminance FM signal is a square wave. The FM demodulator operates on a different principle than the FM receiver. Actually, the FM process in video recording is more like digital coding. The modulator is a coder, which codes the voltage value to a frequency code. The FM demodulator is more like a decoder, which decodes the frequency code, back to a voltage signal.

Thus what is involved is counting the number (average value) of positive pulses, which varies in accordance with the FM square wave deviation frequency. The changes in the average value represent the shape of the original video luminance signal.

The output of the FM demodulator feeds into the post demodulator processing circuits, together with the output of the playback chroma processing circuits. The playback chroma processing circuits handle the color signals, in a manner opposite to that which occurred during record-chroma processing.

The chroma signals - which were heterodyned down from 3.58 MHz to 688 kHz (or 629 kHz) - are now heterodyned back up to 3.58 MHz. When the composite FM video signal from the playback preamplifier is applied to the playback chroma processing circuits, it first encounters a LPF. The filter passes only the 688 kHz (or 629 kHz) chrominance signal. Next, the chrominance signal is heterodyned back up to 3.58 MHz.

The 3.58 MHz chrominance signal next passes through a BPF, which passes only the desired 3.58 MHz subcarrier and its sidebands to the post-demodulator processing circuits. Here, the outputs from the FM demodulator and from the playback chroma processing circuits are added together to from a composite color video signal. This signal is basically identical with the original signal that was applied to the input record circuits.

A record/play switch connects the post modulator processing output signal to the video output amplifier when it is in the playback position. The video output amplifier - which is a power amplifier - brings the level of the composite signal to a level suitable for application to the VHF section. The RF modulator circuits include a switchable crystal oscillator, an AM modulator and a mixer.

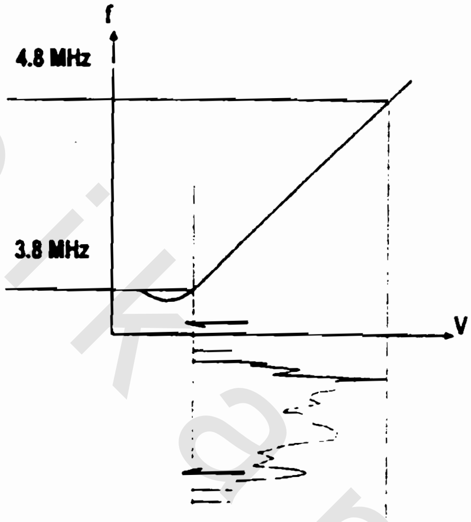
The video carrier selected is applied to an AM modulator, together with the composite color video signal. The audio signal is applied to a varactor tuned at 4.5 MHz. The audio signal produces frequency deviations of the 4.5 MHz oscillator, producing an audio FM signal. This signal is now applied to a mixer, where it heterodynes with the video carrier signal. As a result, the FM sound signal is moved up to the normal FM sound carrier of the channel allocated for VCR operation.

The composite video signal at the correct RF video carrier frequency and the FM sound signal at the correct RF sound carrier frequency are now added together. The result is a composite RF video and sound signal which is equivalent to that transmitted by a TV station.

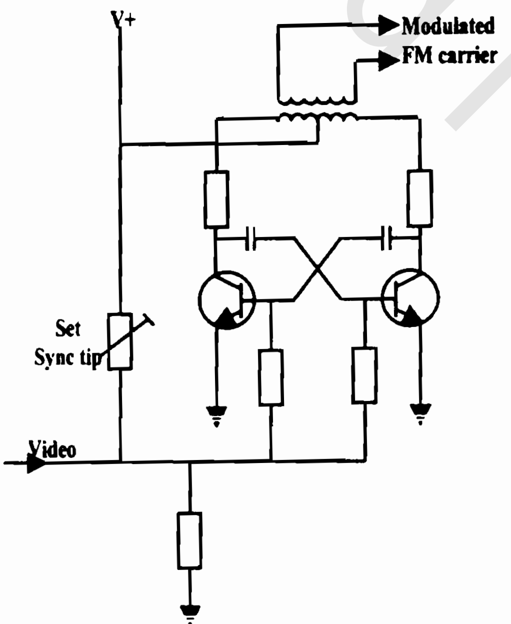
This composite RF signal is fed to the antenna terminals of a TV receiver tuned to that RF channel. The choice of the RF channel is dictated by lack of transmission at that RF frequency, to prevent interference with received broadcast channels. The TV receiver then processes this input signal in an identical manner as it would a TV signal transmitted over the air or in cables. Video recording is also possible for the baseband signals (which do not have RF). This is done through A/V terminals, by taking the baseband video and audio signals directly and separately.

Problems:

1- Analyze the FM modulator (Fig. 17.29) assuming rectangular waveform. Make any reasonable assumptions.



(a)



(b)

Fig. 17.29 Video modulator

a) characteristic b) circuit

2- Obtain an expression for the turn over frequency with tape speed. Discuss the result.
3- In Fig. 17.15, find the turn over frequency for tape speeds 4.75 cm/s and 9.5 cm/s.
4- Find the corresponding extinction frequencies in the problem above.
5- If the turn over frequency for a 4.75 cm/s tape is 1.3 KHz, find the turn over frequency for 19 cm/s tape. What do you conclude?
6- Suggest a circuit for recording pre-emphasis.
7- Suggest a circuit for replay de-emphasis.
8- In Ex. 17.2, the head gap of S-VHS is 0.2 μm, find the practical frequency range. What do you conclude?
9- Calculate the tape speed, and estimate the size of the tape recorder for 4 MHz video signal, using nonrotating heads. Make any reasonable assumption.
10- Analyze the VCO circuit shown for video recording.

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