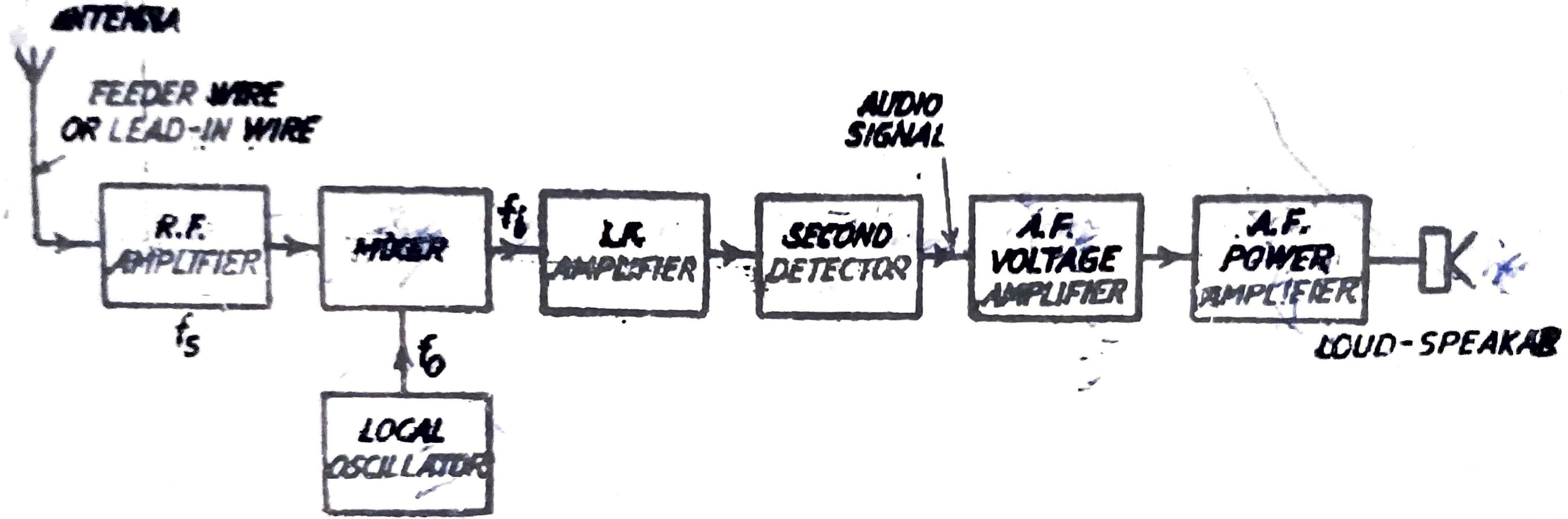


Fig. 9.3. Block diagram of superheterodyne receiver.

18

Broadcast Television Receivers

18.1. Block Diagram and Function

Fig. 18.1 gives the block diagram of a broadcast television receiver. It is a VHF or UHF superheat receiver providing high gain, good selectivity and good signal-to-noise power ratio. The TV receiving antenna picks up the TV signal and feeds it to the R.F. amplifier stage. This input signal to the R.F. amplifier is weak. The R.F. amplifier consisting of one or two tuned amplifier stages amplifies this weak TV signal and feeds it to the frequency mixer. The frequency mixer uses a nonlinear device and heterodynes or mixes this amplified R.F. signal with the output of the local oscillator to produce the I.F. (Intermediate Frequency) signal. The I.F. amplifier consisting of 3 or 4 stagger tuned stages of appropriate bandwidth amplifies the signal to a sufficiently high level before feeding it to the video detector. The detected signal consists of (*i*) the video signal (*ii*) the sync signals and (*iii*) the sound I.F. difference carrier. This video signal so obtained is amplified in several stages of video amplifier and then fed to the picture tube. The sync signals after proper processing are fed to the vertical and horizontal deflection systems of the picture tube. The sound I.F. carrier after having been amplified and limited is fed to the F.M. detector. The audio signal obtained at the output of the F.M. detector is amplified and is then fed to the loudspeaker.

18.2. R.F. Tuner

The TV signal picked up by the TV receiving antenna gets fed to the antenna terminals of the TV receiver through either a 300 Ω twin wire feeder or a 75 Ω coaxial cable. The receiver input circuit is designed to have input impedance of 300 Ω so as to provide impedance match with 300 Ω twin wire feeder. However, if 75 Ω coaxial cable is used, it is necessary to use a 75 Ω to 300 Ω balun for impedance matching.

The R.F. tuner subassembly consists of R.F. amplifier, frequency mixer and local oscillator. Thus the R.F. tuner converts the weak TV signal into reasonably large I.F. signal.

Functional Requirement of R.F. Tuner. The following are the functional requirements of R.F. tuner, also called the *Front-end* of the TV receiver :

(*i*) It matches the feeder line impedance to its own impedance.

(*ii*) It selects the desired channel by switching pre-tuned circuits in the R.F. amplifier and the local oscillator.

(*iii*) It amplifies the input TV signal to provide good signal-to noise ratio. The amplifier gain is controlled by the A.G.C. voltage.

(*iv*) It converts the modulated R.F. signal into similarly modulated I.F. signal by mixing in the frequency mixer the input signal with the voltage generated in the local oscillator and feeds it into the I.F. amplifier.

(*v*) It offers high I.F. signal rejection, *i.e.* disallows signals at intermediate frequency from entering the receiver.

(*vi*) Through use of R.F. amplifier stage, it isolates the local oscillator from the antenna *i.e.* it prevents the local oscillator voltage from reaching the antenna and thus prevents radiation of local oscillator voltage.

(*vii*) It offer high image signal rejection through use of selective circuits tuned to the signal frequency.

The tuner may be single channel tuner or multichannel tuner. The multichannel VHF tuner may be a step switch type tuner using preset tuning circuits or a rotary switch. The UHF multichannel tuner on the other hand, uses continuous tuning employing either transmission lines or strip-line tuned circuits.

Block Diagram of VHF Tuner. Fig. 18.2 gives the block diagram of VHF tuner.

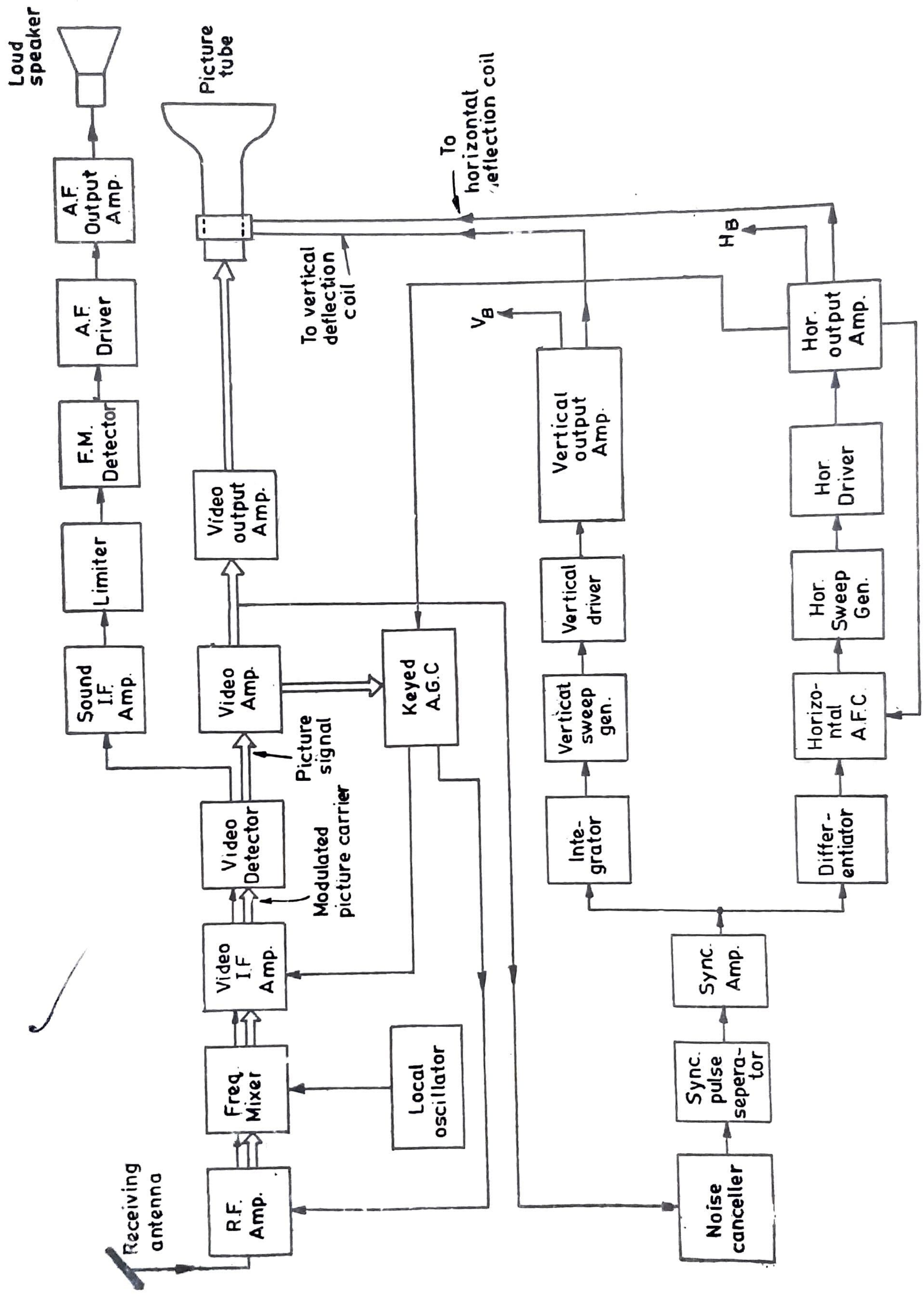


Fig. 18.1. Block diagram of broadcast television receiver.

Balun. The TV receiver input circuit is designed for input impedance of 300 Ω so as to provide impedance match when fed from 300 Ω twin wire ribbon feeder. However, if 75 Ω coaxial cable is used as the feeder, a balun is used to match the 75 Ω feeder impedance to 300 Ω input impedance of the receiver circuit. The balun is typically in the form of a ferrite core on which are wound four tightly coupled and evenly

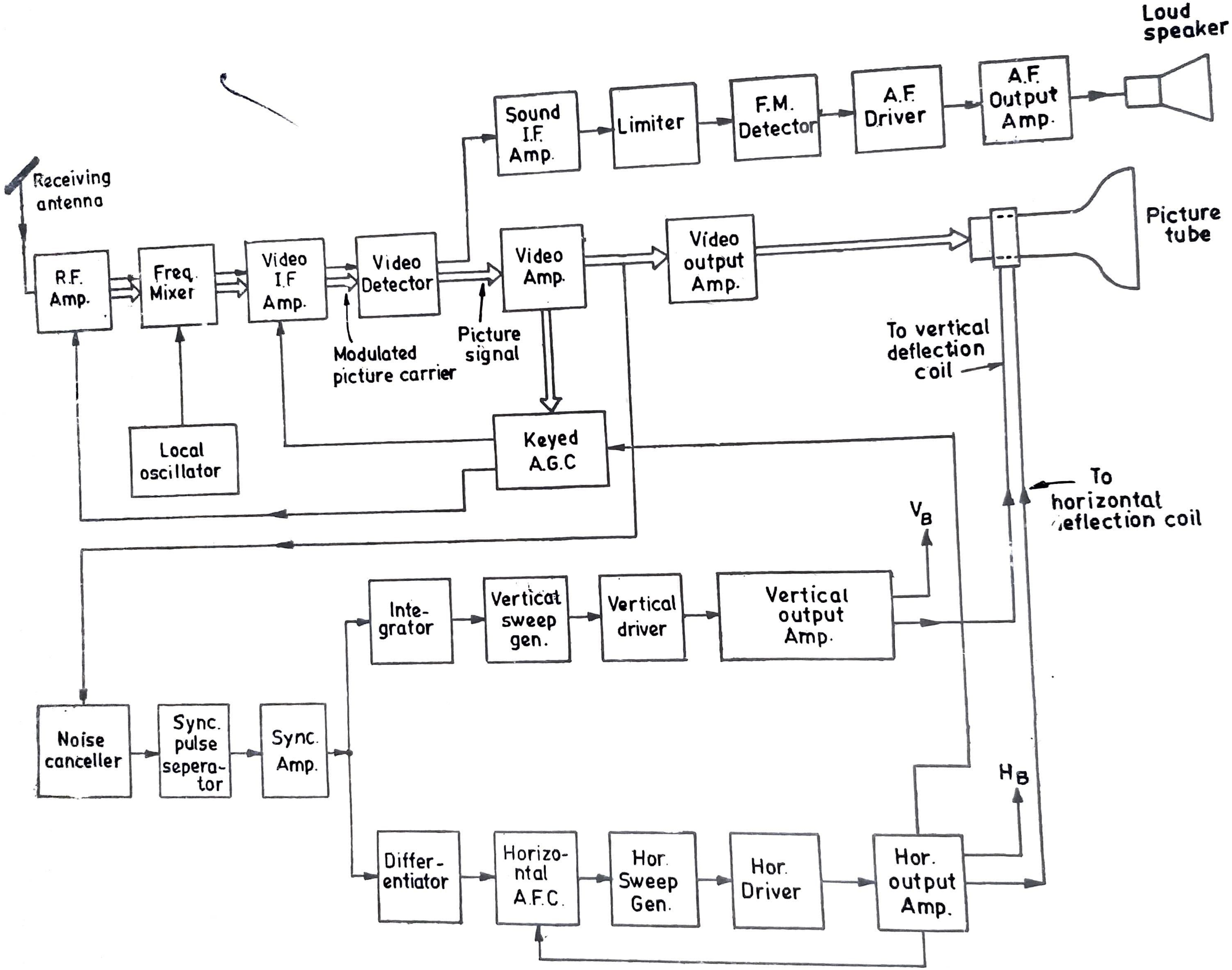


Fig. 18.1. Block diagram of broadcast television receiver.

spaced bifilar windings each of a couple of turns and connected as shown in Fig. 18.3. These windings form two $\lambda/4$ lines each of impedance 150 Ω. These $\lambda/4$ lines form series connection on the receiver input side of provide an impedance of 300 Ω and form parallel connection on the antenna side to provide impedance of 75 Ω unbalanced by grounding one terminal as shown.

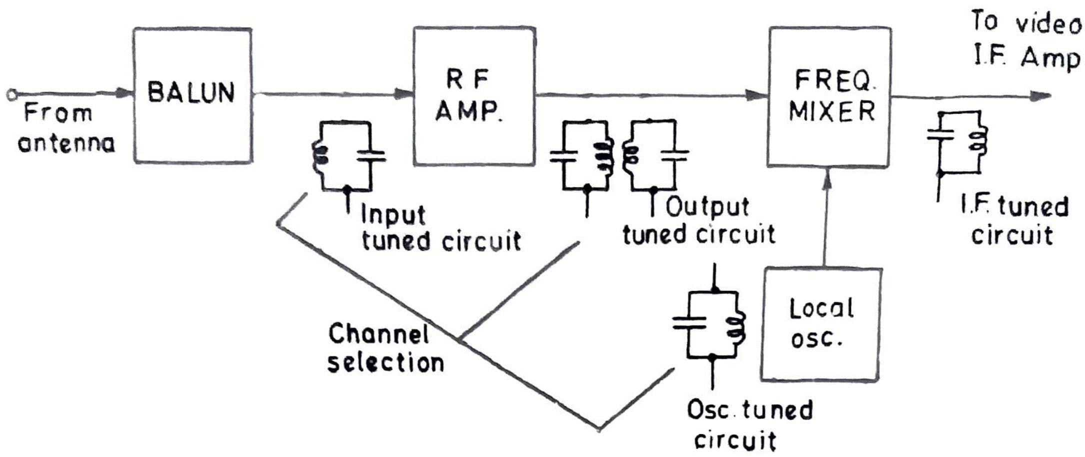


Fig. 18.2. Block diagram of a VHF tuner.

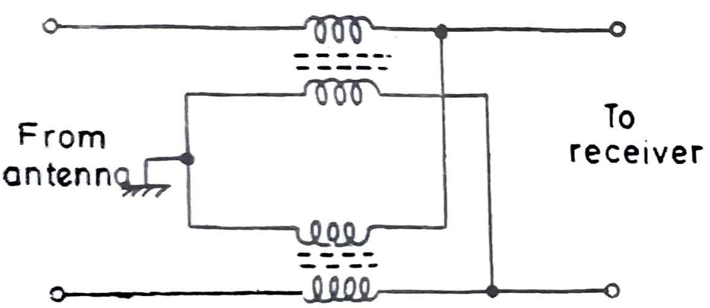


Fig. 18.3. Tuner input balun.

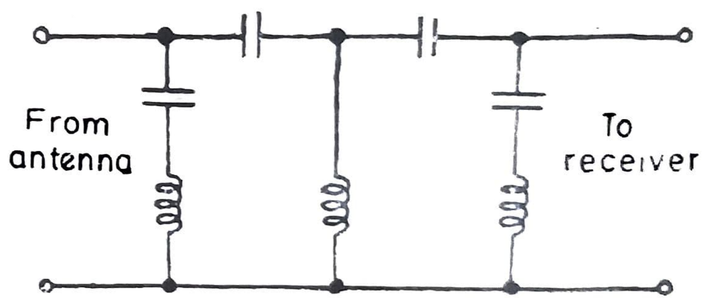


Fig. 18.4. I.F. trap.

A capacitor of say 470 pF is usually placed in the input lead just before balun to block d.c. path from antenna to chassis and prevent damage to the receiver due to lightning. A 2 MΩ resistor is placed across each of these capacitors to discharge any charge accumulated on the capacitor.

I.F. Trap. The low-Q R.F. tuned circuits do not provide enough rejection to unwanted signals in I.F. range (33 to 40 MHz). Hence an I.F. trap shown in Fig. 18.4, is generally placed just beyond the balun to block these unwanted signals in the I.F. range.

R.F. Amplifier. The following functions are served by the R.F. amplifier :

(*i*) *Providing Gain to the Input Signal.* The main function of R.F. amplifier is, of course, to amplify weak signal to a suitably high level before it encounters the noisy mixer stage. Thus R.F. amplifier ensures high Signal-to-Noise, ratio in the output. However, there is a limit to the minimum signal which may be effectively amplified. This is fixed by the equivalent noise voltage at the input of the R.F. amplifier. This noise voltage is typically about 10 μV.

Since the signal level in R.F. amplifier is small, this stage is ideally suited for application of AGC voltage. Delayed AGC is generally used.

(*ii*) *Isolating the antenna from the local oscillator.* The R.F. amplifier isolates the antenna from the local oscillator and thus minimizes radiation of the local oscillator voltage by the antenna. Such radiation, if permitted, causes interference with neighbouring receivers and menifests itself in the form of diagonal line patterns on the picture tube screen. In VHF band, the local oscillator radiation field strength should be less than 100 μV/M at 100 feet. Isolation can be ensured by (*a*) proper placement of coupling coils (*b*) use of R.F. chokes (*c*) use of feed-through capacitors in the tuner supply lines and (*d*) proper tuner case shielding. Further it is desirable to use a separate chassis ground return.

(*iii*) *Providing Image Signal Selectivity.* The image signal of frequency ($f_s + 2f_i$) also produces the intermediate frequency at the mixer output. The image signal is undesirable and should be suppressed. The R.F. tuned circuits provide image signal selectivity. The R.F. amplifier increases the number of tuned circuits sets from one to two, thus providing additional image signal selectivity.

The R.F. amplifier must have large bandwidth so as to accommodate the full channel frequency range of 7 MHz. Double tuned circuits with double hump response characteristic of the type shown in Fig. 18.5 can provide this desired 7 MHz bandwidth and also provide good transient response. The dip between the humps is kept small typically about 1 dB as shown in Fig. 18.5.

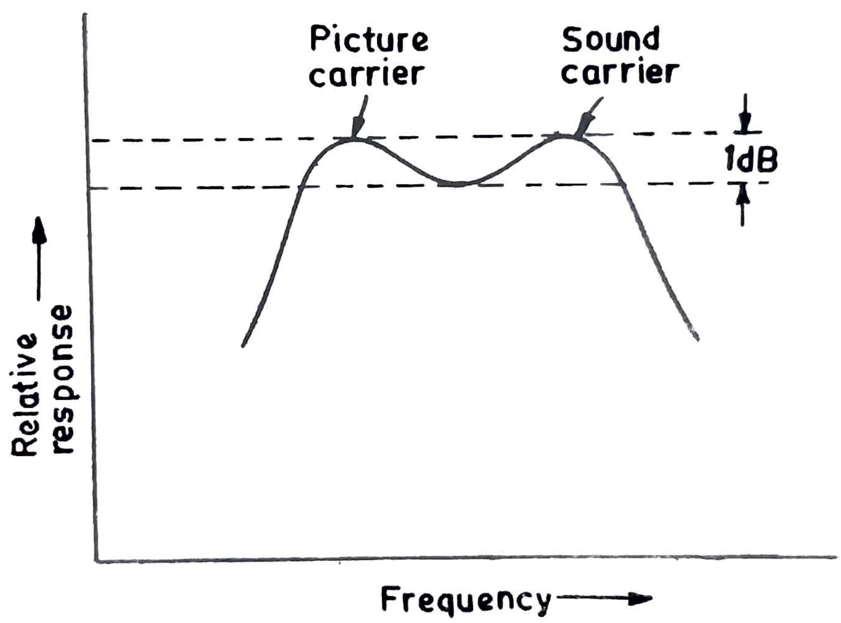


Fig. 18.5. R.F. amplifier frequency response characteristic.

Frequency Mixer. The frequency mixer heterodynes the R.F. signal with the local oscillator voltage to produce the difference frequency which is the intermediate frequency. Since there are two carriers in the TV R.F. signal, two I.F.s get produced namely the picture I.F. equal to 38.9 MHz and the sound I.F. equal to 33.4 MHz. The local oscillator frequency is kept higher than the R.F. signal frequency.

The Local Oscillator. The local oscillator produces a stable frequency free from drift due to temperature variations, aging of components, or small changes in supply voltages. The local oscillator voltage should be free from harmonics. Further the local oscillator frequency should be tunable over a small range. This local oscillator frequency control constitutes the fine tuning control of the receiver. This tuning may be done by manual varactor diode tuning or automatic fine tuning using varactor diode bias control by the d.c. voltage from the frequency discriminator of the AFC.

18.3. R.F. Tuner Circuits

Although vacuum tube have been used in the earlier TV receiver circuits, the modern TV receiver uses transistors and IC's due to the numerous well known merits of these solid state devices namely small size, low power drain, high reliability, instantaneous operation etc. The transistor so used should, however, provide the desired high gain and low-noise figure at the high operating frequencies.

Choice of Configuration. Either common emitter (CE) or common base (CB) configuration may be used for the R.F. amplifier stage. The CE configuration provides higher power gain but, in general, requires neutralization. The CB configuration, on the other hand, gives lower power gain but does not need neutralization. Further CB configuration has low input impedance but this impedance is constant over the entire band III range. The CB amplifier has small signal handling capacity while CE has large signal handling capacity.

Fig. 18.6 (*a*) gives the circuit of a typical transistor R.F. amplifier while Fig. 18.6 (*b*) shows the corresponding transistor frequency mixer and local oscillator assembly. The R.F. amplifier and the frequency mixer (along with the local oscillator) taken together constitute the typical VHF tuner.

R.F. Amplifier Circuit. Variable inductor L_1 along with capacitors C_1 and C_2 form the input tuned circuit tuned to channel frequency by varying L_1. This tuned circuit by a tap on the inductor L_1 offers an impedance of 300 Ω to the balun. The balun transforms this impedance of 300 Ω to 75 Ω on the antenna side to match with 75 Ω impedance of the coaxial cable. In case, a twin wire ribbon feeder is used, no balun is needed. Similarly the tuned circuit is matched to the input impedance of the transistor by the capacitive tap of the two capacitors C_1 and C_2. The AGC bias is fed to the R.F. amplifier transistor T_1 *via* kΩ bias resistors R_1 and R_2 decoupled to the ground by the 3 nF capacitor C_3. A double tuned circuit using inductances L_2 and L_3 is used as the load impedance for the R.F. amplifier. The use of the double tuned circuit provides the desired bandwidth of 7 MHz with a small dip of 1 dB between the two humps (or peaks), one at the picture carrier and the other at the sound carrier.

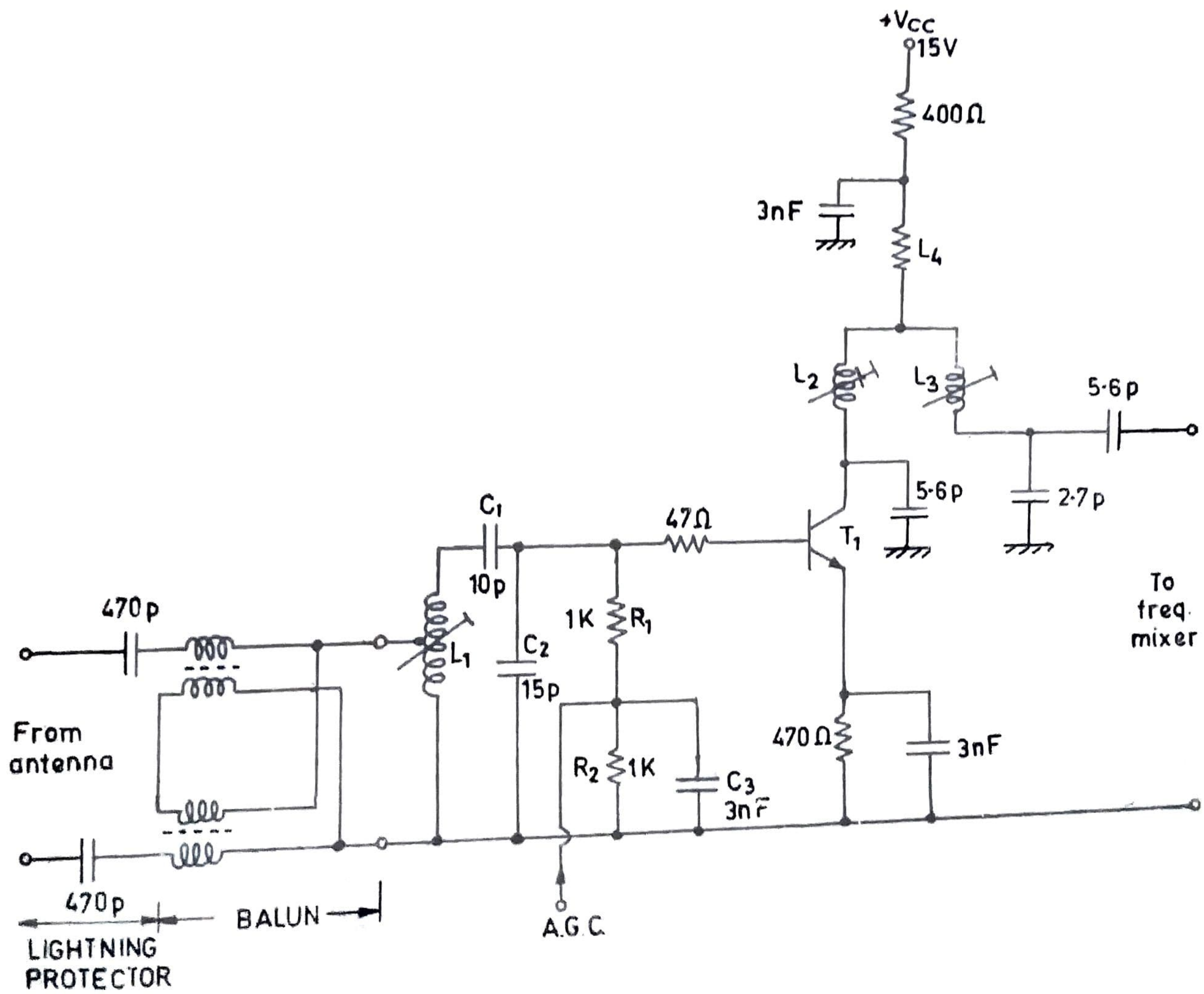
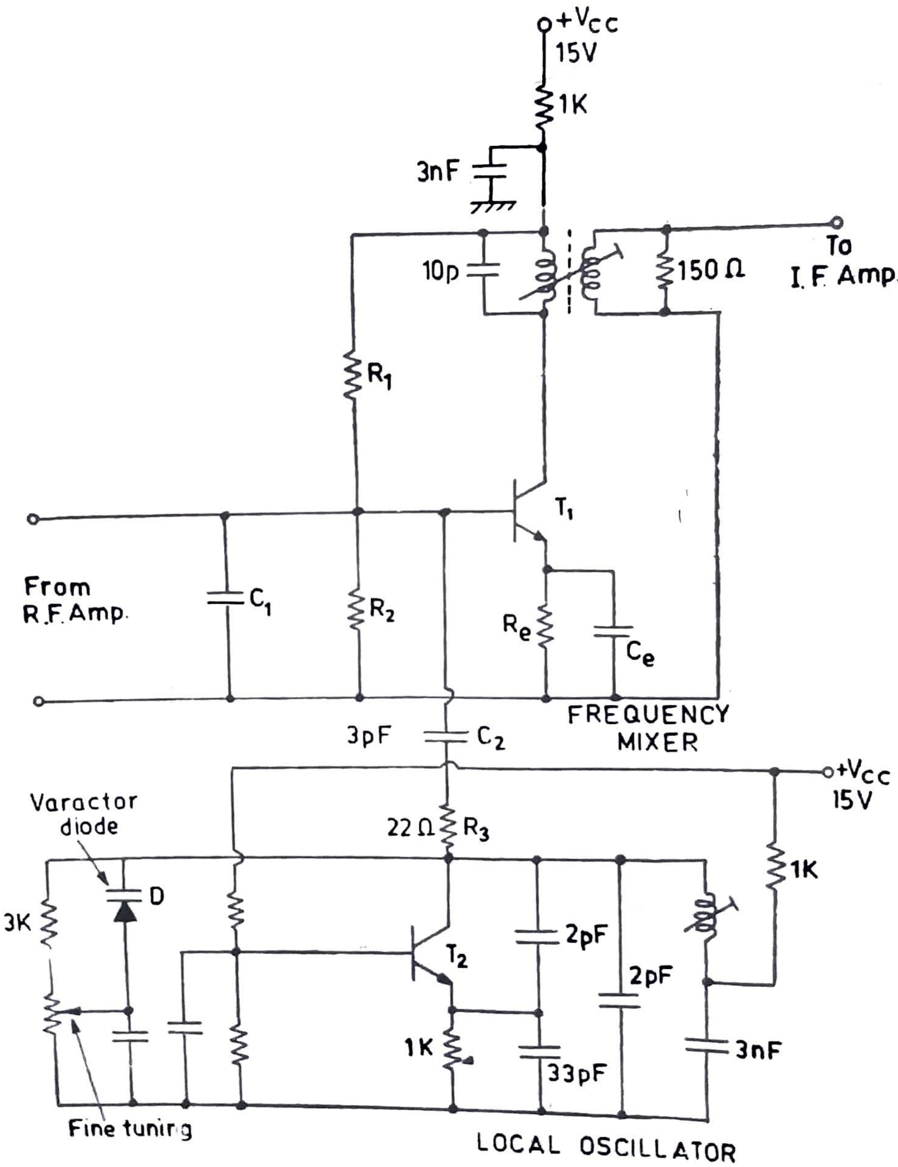


Fig. 18.6 (*a*) R.F. amplifier.

The Mixer Stage. The mixer stage using a transistor in CE configuration receives the local oscillator voltage at its base through 3 pF capacitor C_2 and 22 Ω resistor R_3. The R.F. signal from the R.F. amplifier is also applied to the base. These two voltages heterodyne to produce the different frequency signal at the standard intermediate frequency. Resistors R_1 and R_2 in conjunction with resistor R_e provide the proper bias. The signal at intermediate frequency is developed across the double tuned circuit in the collector circuit of the mixer. The I.F. voltage across the secondary is fed through 75 Ω coaxial cable to the I.F. amplifier. The output impedance of the mixer across the secondary of the double tuned circuit is designed to be 75 Ω so as to match the 75 Ω impedance of the coaxial cable.



(b) Frequency mixer and local oscillator.

Fig. 18.6. Transistor UHF tuner.

The Local Oscillator. The local oscillator uses a transistor in CE configuration in a colpitts circuit. Fine tuning of the oscillator is provided by varying the reverse bias at the varactor diode D by a 10 kΩ potentiometer. The tap on the potentiometer is bypassed to ground so that the capacitances offered by the leads of the band mounted potentiometer do not influence to fine tuning.

18.4. Video I.F. Amplifier

The following are basic requirements of the video I.F. amplifier stage :

(*i*) To provide high and stable gain of 60 to 80 dB to raise the I.F. signal level typically from about 1 mV to several volts.

(*ii*) To provide bandwidth of about 7 MHz and to have the bandpass response curve to compensate for the vestigial sideband TV signals and thus provide equal gain to all video frequencies and the sound frequencies.

(*iii*) To provide good adjacent channel selectivity.

(*iv*) The shape of the bandpass response curve should be almost independent of AGC voltage variation.

Choice of Intermediate Frequencies. The intermediate frequency should be as low as possible from the consideration of high and stable gain and high selectivity. On the other hand, the intermediate frequency should be high enough to provide the required bandwidth and image signal selectivity. These are conflicting requirement. Accordingly a compromise value is sought. The CCIR system-B receivers use picture I.F. of 38.9 MHz and sound I.F. of 33.4 MHz.

Fig. 18.7 gives video I.F. amplifier response requirement. This response requires that :

(*i*) The response at the picture I.F. (38.9 MHz) should be 6 dB below (at 50%) of the maximum response.

(*ii*) The bandwidth of the response curve between the 6 dB points should be 5 MHz.

(*iii*) The response at the sound I.F. should be 20 dB below (*i.e.* 10% of) the response at the picture I.F. This amounts to response of 5% of the maximum response.

(*iv*) The response at the adjacent channel sound carrier (40.4 MHz) should be at least 40 dB below the maximum response.

(*v*) The response at the adjacent channel picture carrier (31.9 MHz) should be at least 46 dB below (*i.e.* 0.05% of) the maximum response.

(*vi*) The response in the range 35 to 38 MHz should be flat within 2 dB.

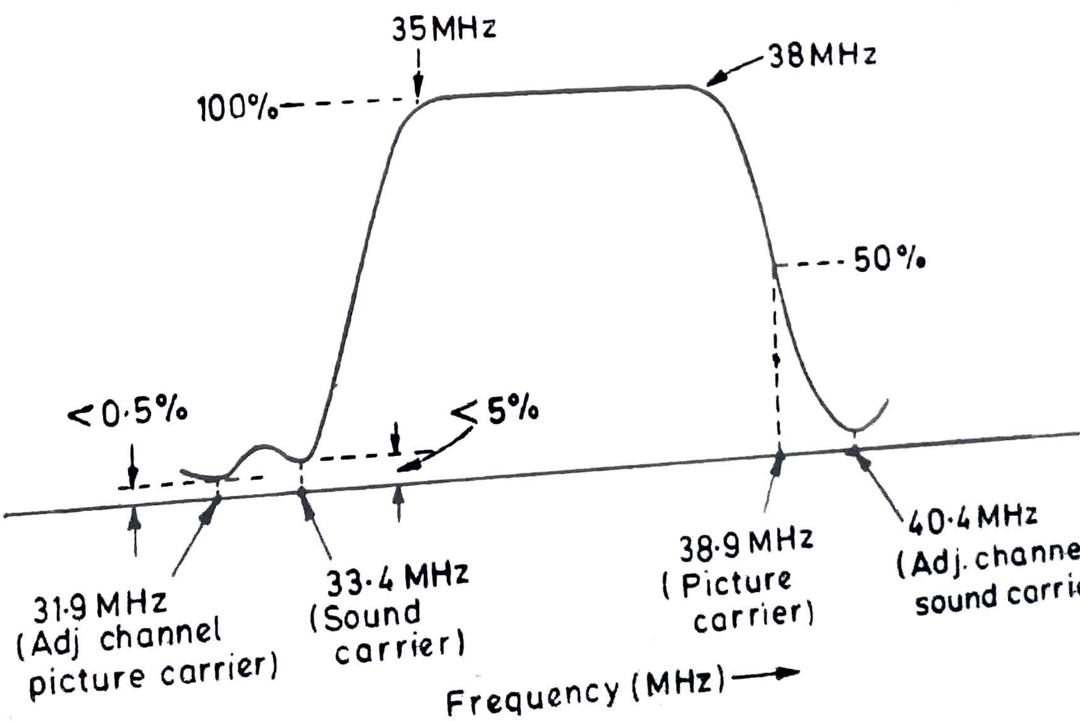


Fig. 18.7. Video I.F. amplifier response requirement.

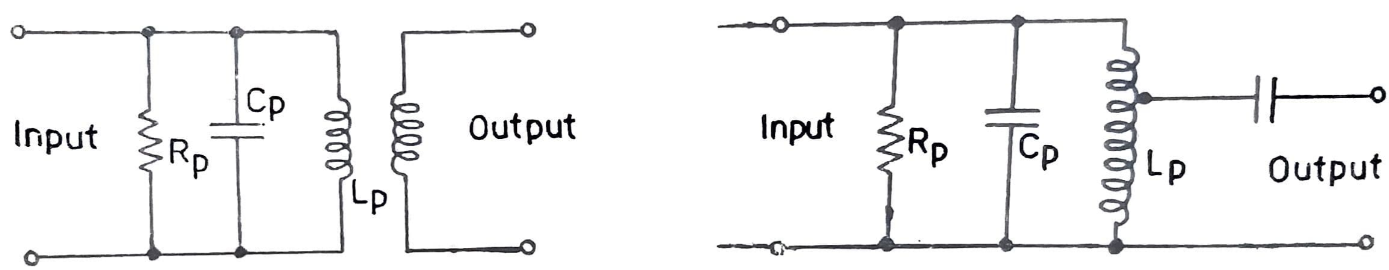
Phase Response. The phase response is not so important in double sideband (DSB) system in which the steep flanks of the amplifier bandpass lie in the extreme high frequencies. But in vestigial sideband (VSB) system, since the carrier and the major frequencies lie on the flanks, the envelope delay distortion becomes prominent in the video frequency range. The overall video response thus gets distorted.

18.5. Interstage Coupling Methods

Video amplifier stage should provide a gain of 60-80 dB and uses cascode multistage tuned amplifier. Typically 3 stages are used. AGC bias is applied to the first stage and sometimes to the second stage also.

The amplifier may use single tuned circuits or double tuned circuits. Further these tuned circuits may use synchronous tuning, *i.e.* tuned to the same frequency or may be stagger tuned, *i.e.* tuned to slightly different frequencies. We here consider the different coupling method.

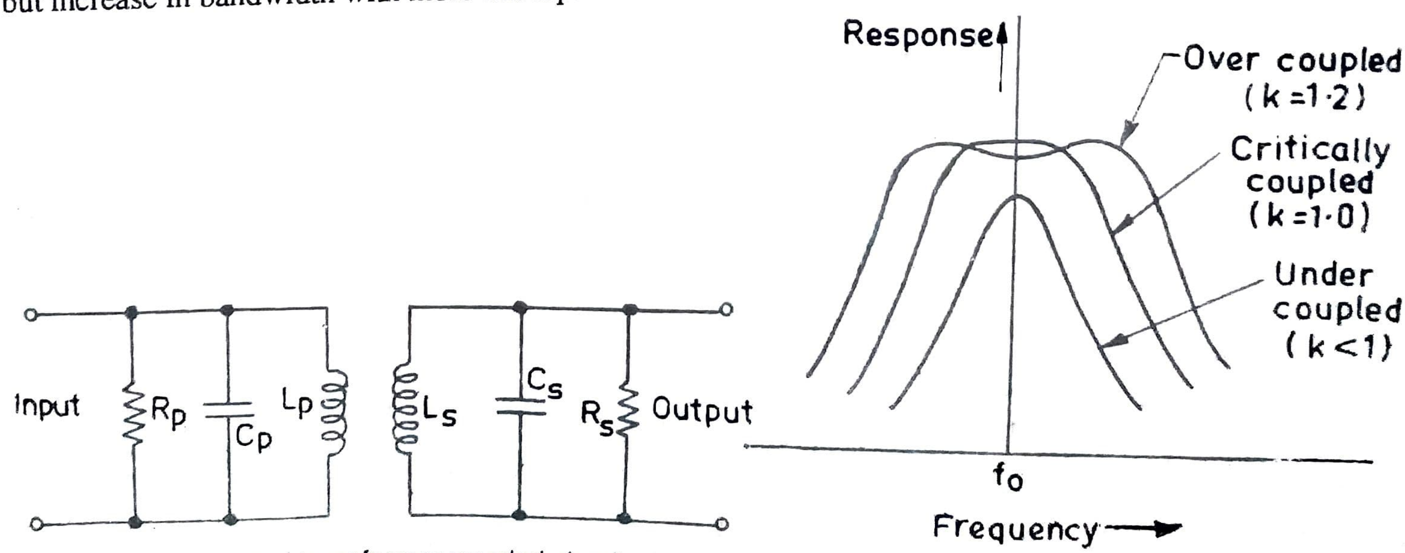
(A) **Single Tuned Circuit.** In this case, a single tuned circuit is used in the collector circuit as the load impedance coupled to the next stage inductively through an untuned secondary or through a coupling capacitor connected at a tap on the tuned circuit. Impedance match is achieved by selecting proper turns ratio or by suitable tap on the circuit. Fig. 18.8 shows the circuit arrangement.



(*a*) Transformer coupling. (*b*) Tapped coupling.

Fig. 18.8. Single tuned circuit with transformer coupling or tapped coupling.

(B) **Double Tuned Circuit.** In this case, two tuned circuits are used and are generally inductively coupled with coefficient of coupling adjusted to obtain the desired double hump response curve of Fig. 18.9. With weak coupling ($K < 1$), the response curve is similar to that of a single tuned circuit namely single peaked. At critical coupling ($K = 1$), broad single peak characteristic is obtained while in overcoupled circuit ($K = 1.2$ typically) double hump characteristic is obtained. By inserting resistors (R_p and R_s) in shunt with the tuned circuits, the effective Q's of the tuned circuits get reduced. This causes reduction in hump, reduction in gain but increase in bandwidth with more flat top.



(*a*) Double tuned transformer coupled circuit. (*b*) Response curve.

Fig. 18.9. Double tuned transformer-coupled circuits and their response.

(C) **Impedance Coupling.** In this case, an impedance common to the output circuit of one stage and the input circuit of the next stage provides the necessary coupling. Then this common impedance along with the tuning elements of the two stages may form a band pass filter providing the desired I.F. response. Fig. 18.10 shows a few typical impedance coupling arrangements. In Figs. 18.10 (*b*) and (*c*), the common element Z_k may be a resistor an inductor or a capacitor, or a combination of these. Adjustment of the common element provides the variable coupling.

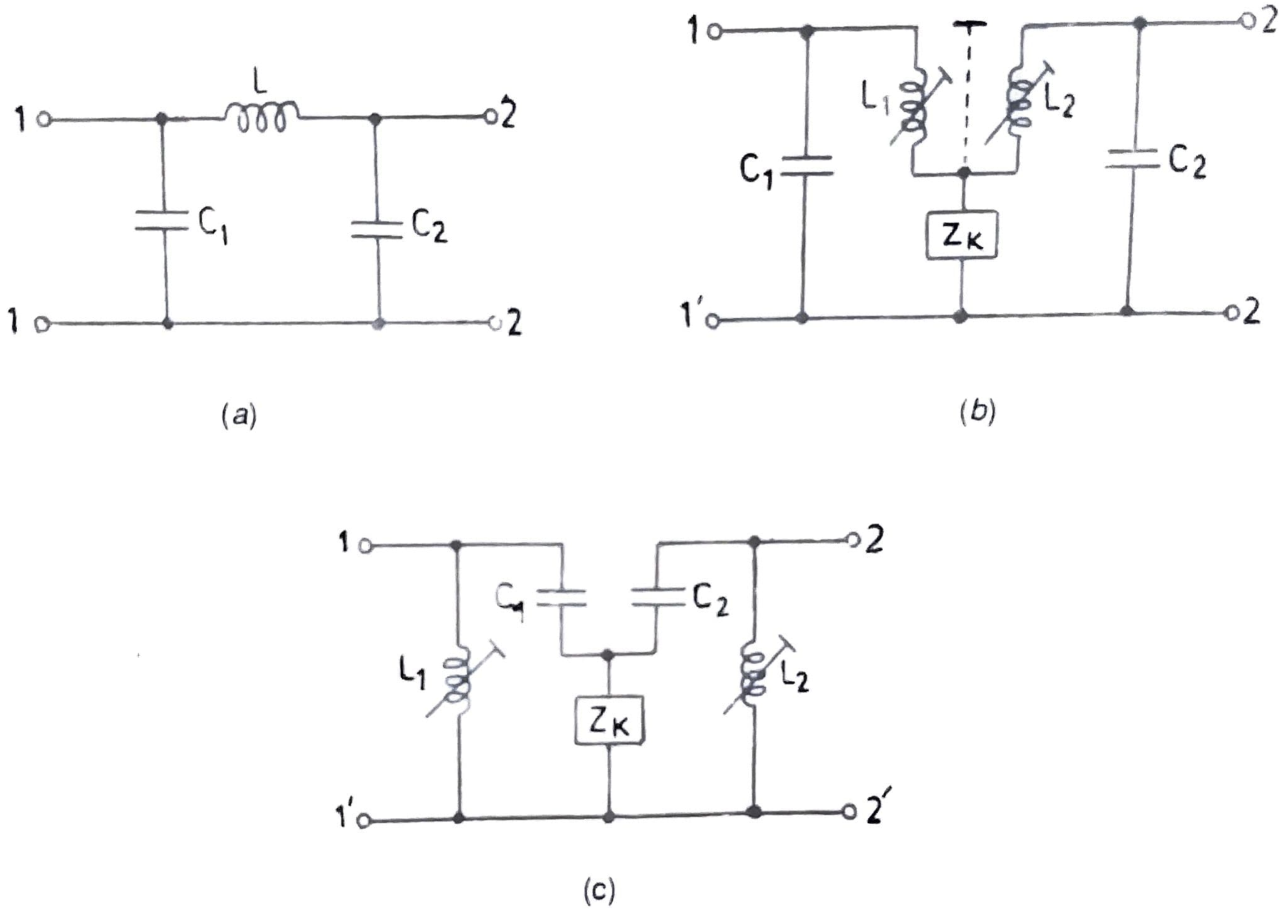


Fig. 18.10. Impedance coupling arrangements.

The π-filter arrangement of Fig. 18.10 (*a*) is used when a shielded cable is used for coupling *e.g.* for coupling the R.F. tuner output to the I.F. amplifier input. In that case, the cable capacitance forms a part of C_2. Sometimes a series *R-C* circuit may be connected between points 1 and 2 to provide additional coupling.

(*D*) **Coaxial Link Coupling.** A 75 Ω coaxial cable is sometimes used for coupling the mixer stage output to the first I.F. amplifier stage input as shown in Fig. 18.11.

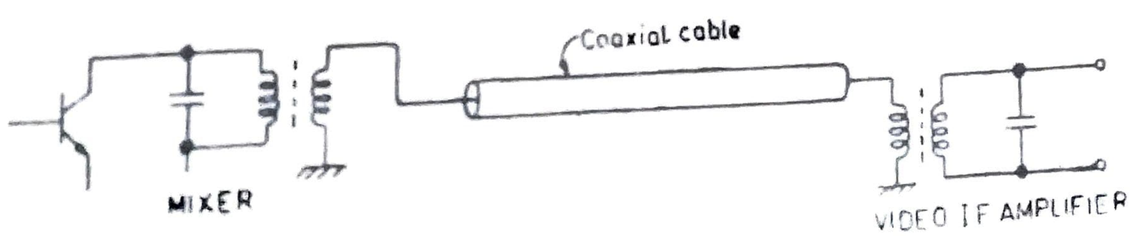


Fig. 18.11. Coaxial cable coupling.

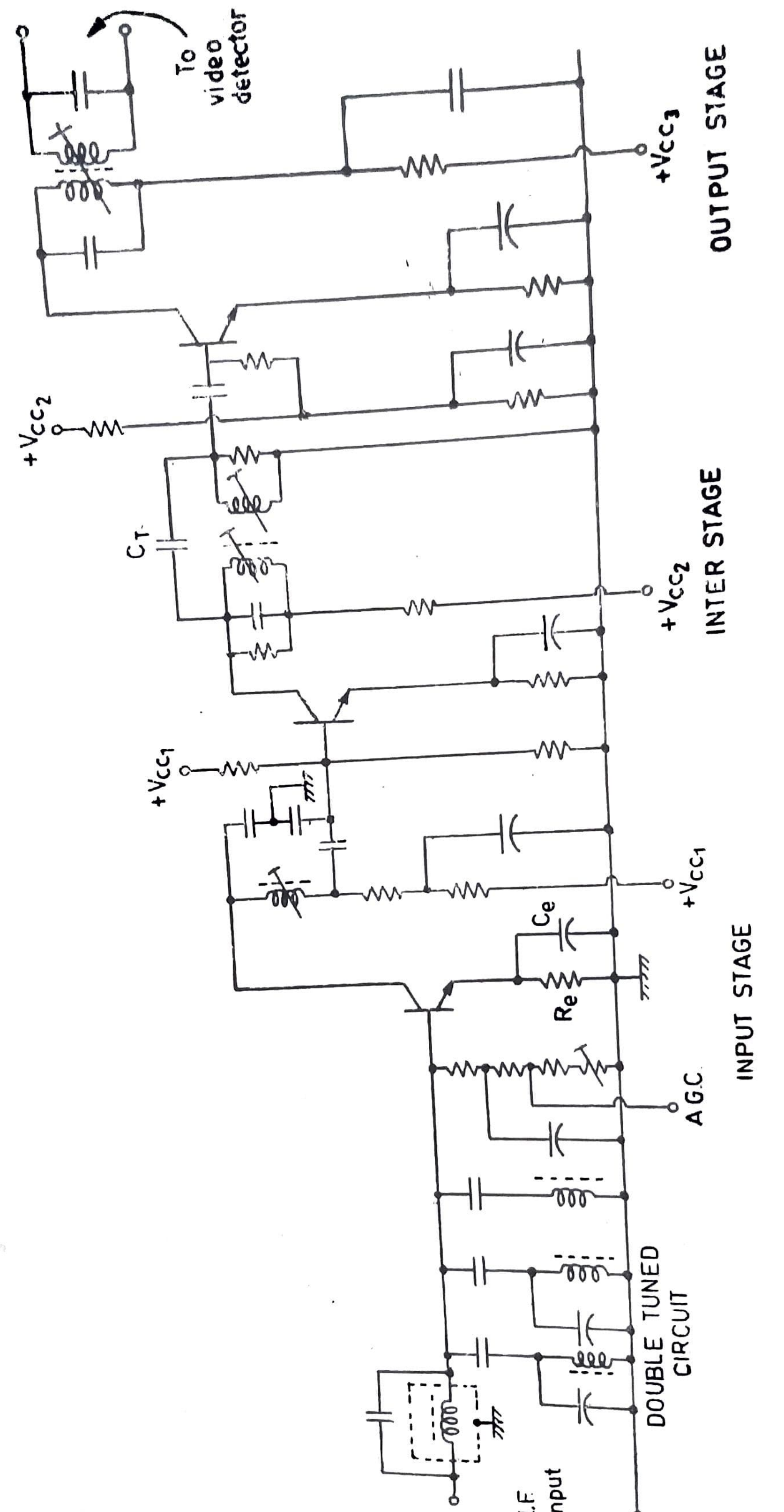


Fig. 18.12. 3-stage transistor video I.F. amplifier with bandpass filter.

18.6. Transistor Video I.F. Amplifier Circuits

Typically video I.F. amplifier consists of 3 stages. The problem confronted is that of impedance match between the high output impedance (several kilo-ohms) of the collector circuit to the low input impedance (< 1 k Ω) of base circuit of the next stage. This impedance match is secured either by using transformer coupling with suitable step down ratio or by using suitable impedance coupling. The I.F. amplifiers use high frequency transistors having f_T of 400 MHz or more and forward transfer conductance exceeding 100 mΩ. Use of such

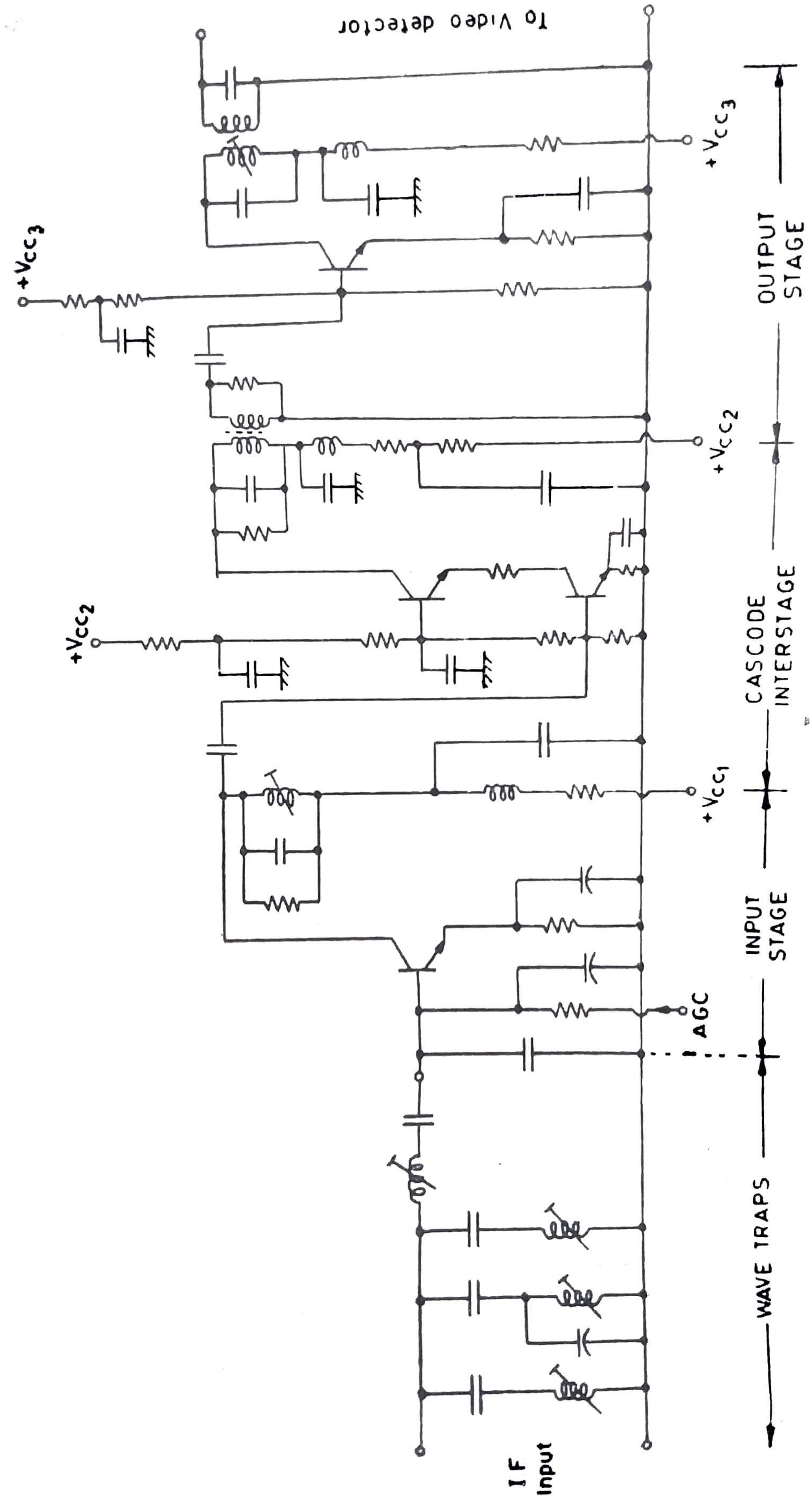


Fig. 18.13. 3-stage transistor video I.F. amplifier with cascode interstage.

transistor permits design aiming at high stability avoiding need for neutralization at the cost of gain by introducing impedance mismatch. CE stages are most popularly used providing high power gain although CB stages provide improved feedback isolation and high stability. Sometimes cascode configuration is used combining the good features of both CE and CB configurations namely high power gain and better feedback isolation. Both types of circuits are discussed here.

(*A*) **Three-Stage CE Video I.F. Amplifier.** Fig. 18.12 shows a 3-stage CE video I.F. amplifier providing gain exceeding 90 dB. The AGC is applied to only the input stage. Wave traps are generally placed at the input of the amplifier to reduce the undesired signals from entering the amplifier and reducing the chances of cross-modulation. The input stage employs single tuned circuits as the load in the collector circuit and a tap on the tuned circuit capacitance is used to couple the output to the base of the second stage, *i.e.* the intermediate stage.

The interstage I.F. amplifier employs a double tuned circuit with proper damping resistances in shunt with the tuned circuits for proper bandwidth. Sometimes a capacitive top coupling is used (capacitor C_T in Fig. 18.12).

The I.F. amplifier output stage also uses a double tuned bandpass circuit with bifilar wound inductive coupling feeding the video detector. In order to prevent the radiation of harmonics of the picture I.F. carrier generated in the video detector, the double-tuned B.P. filter and the detector circuit are enclosed within a screening can.

(*B*) **Transistor Video I.F. Amplifier with Cascode Interstage.** Fig. 18.13 shows a typical 3-state transistor video I.F. amplifier using cascode interstage. This cascode stage provides a high gain and high stability due to better isolation between the stages. Shunt traps have been used at the input of the amplifier.

The input stage is single tuned CE stage with capacitance coupling to the next stage. AGC is applied to the base of this transistor. The interstage uses a cascode stage with single tuned load inductively coupled to the output stage. The output is a CE stage using single tuned bandpass filter.

The decoupling RC filters in the collector supply leads include RF chokes also for effective coupling at high frequencies.

18.7. Video Detector

The output of the last video I.F. amplifier is fed to the video detector which is commonly a diode detector. This video detector demodulates the amplitude modulated video I.F. signal by the rectification process. Fig. 18.14 gives the basic circuit of video detector. The rectified output of diode detector contains (*i*) I.F. component (*ii*) video frequency components (*iii*) d.c. components (*iv*) harmonics of video frequencies. The I.F. components in the video detector output is eliminated by a low pass filter (typically of π configuration) or by a simple bypass filter capacitor as shown in Fig. 18.14. The desired video frequency component gets developed across the load resistance R_L and may be coupled to the video amplifier stage.

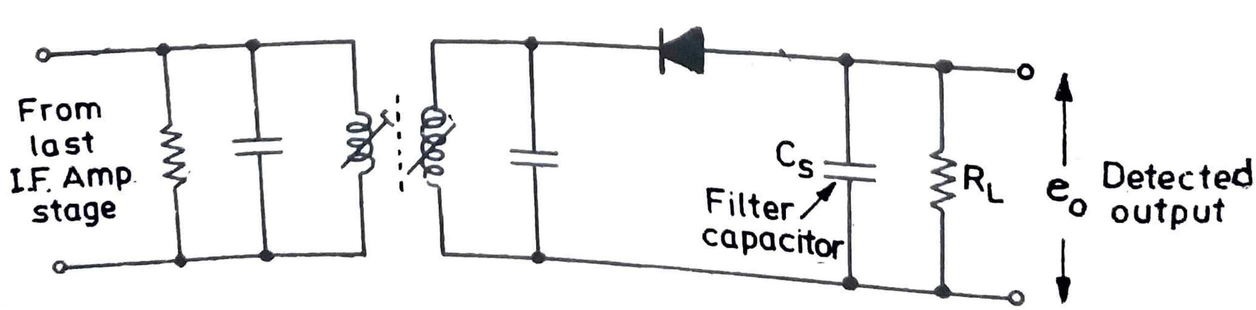


Fig. 18.14. Simple diode detector.

For optimum performance, it is desired that (*i*) the detection efficiency is maximum and (*ii*) distortion due to clipping is zero. The detection efficiency is defined as the ratio of peak-to-peak detector output to the peak-to-peak signal in the modulated envelope. For maximum detection efficiency, it is necessary that (*i*) the detector load impedance R_L be much greater than the diode forward resistance r_f and (*ii*) filter capacitor C_S be much greater than the diode capacitances C_S. But C_S cannot be made too large otherwise the time constant $R_L C_S$ becomes too large and causes diagonal clipping at high modulation frequencies due to slow rate of discharge of C_S through R_L.