18ECC205J ANALOG AND DIGITAL COMMUNICATION
UNIT-1

S-4 Linear method-Collector modulator

S-5 Non-linear Modulation-Balanced Modulator

S-6 Linear diode detector

GENERATION OF AM WAVES

- Linear method-Collector modulator
- Non-linear Modulation-Balanced Modulator

Linear modulation

- It is operated in the linear region of its transfer characteristics
- A>Em
- Used in High level modulation
- Types

Transistor and switching modulator

Non linear Modulation

- It is operated in the non-linear region of its transfer characteristics
- A<Em
- Used in low level modulation
- Types

Square law and Balanced Modulator

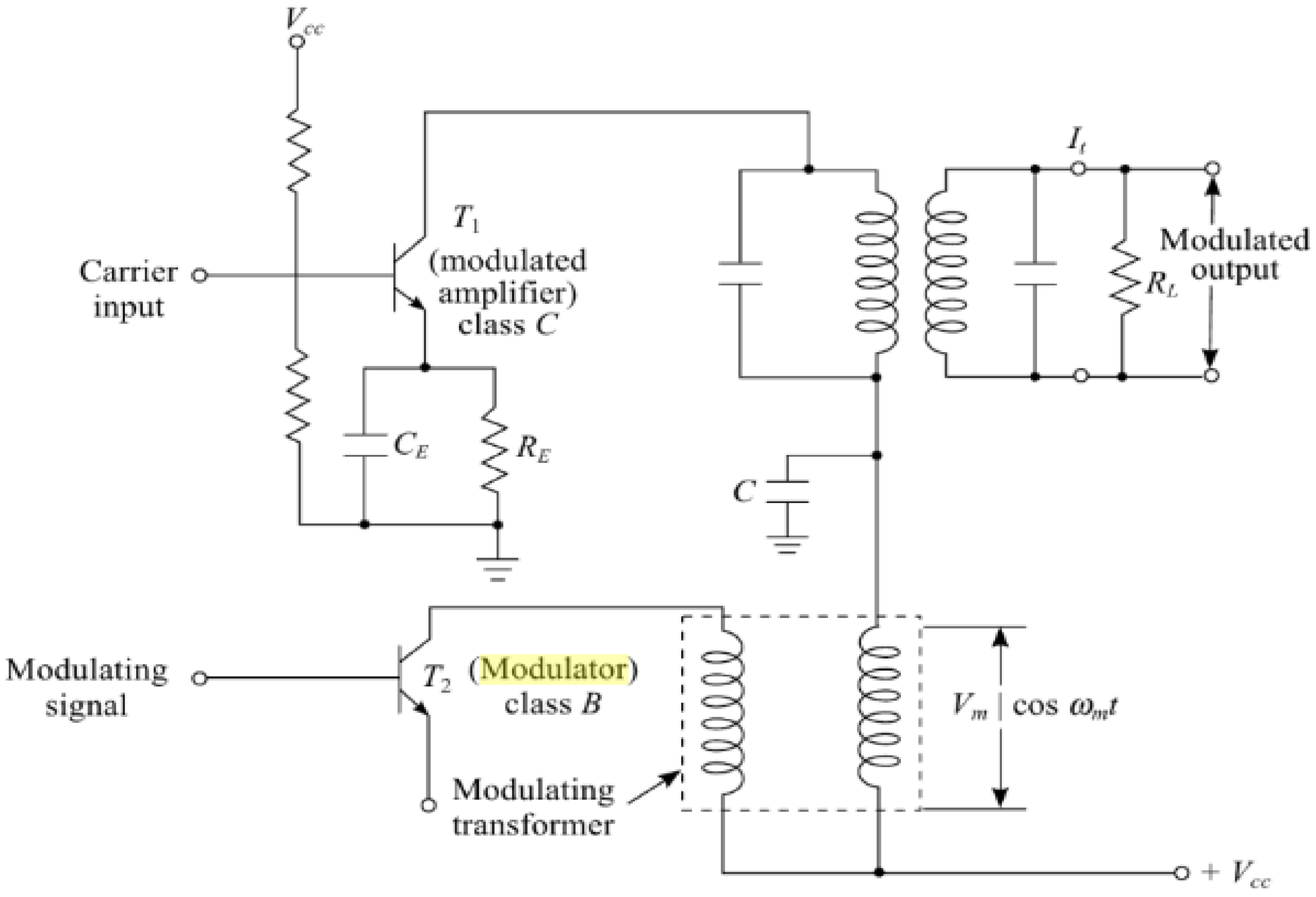
Non linearity equation

- I=a v1+(av1)2+….

COLLECTOR MODULATOR

- The diode modulator does not provide Amplification.
- Amplifying device like Transistor and FET can provide amplification. It can be used for amplitude modulation by varying their Gain parameter, if Transistor is used then it is called as collector modulator.
- Transistor ---T1---Class c Amplifier---Carrier signal is applied,Vcc is collector supply used for biasing
- Transistor---T2--- Class B Amplifier---Message signal is applied,after amplification modulating signal appears across the modulating transformer
- Capacitor C offer low path to carrier(prevents carrier to flow in modulating transformer)

Collector Modulator Circuit



Principle of operation

- The output voltage is replica of input voltage
- The amplitude of output voltage is equal to Vcc ,When there is no message signal(fig a)
- When Message signal is applied,the net effect is slow variation in output(fig b)
- The slow varying supply voltage Vc is given by

$$V_c = V_{cc} + V_m \cos \omega_m t$$

$$= V_{cc}[1 + m_a \cos\omega_m t] \cos \omega_c t$$

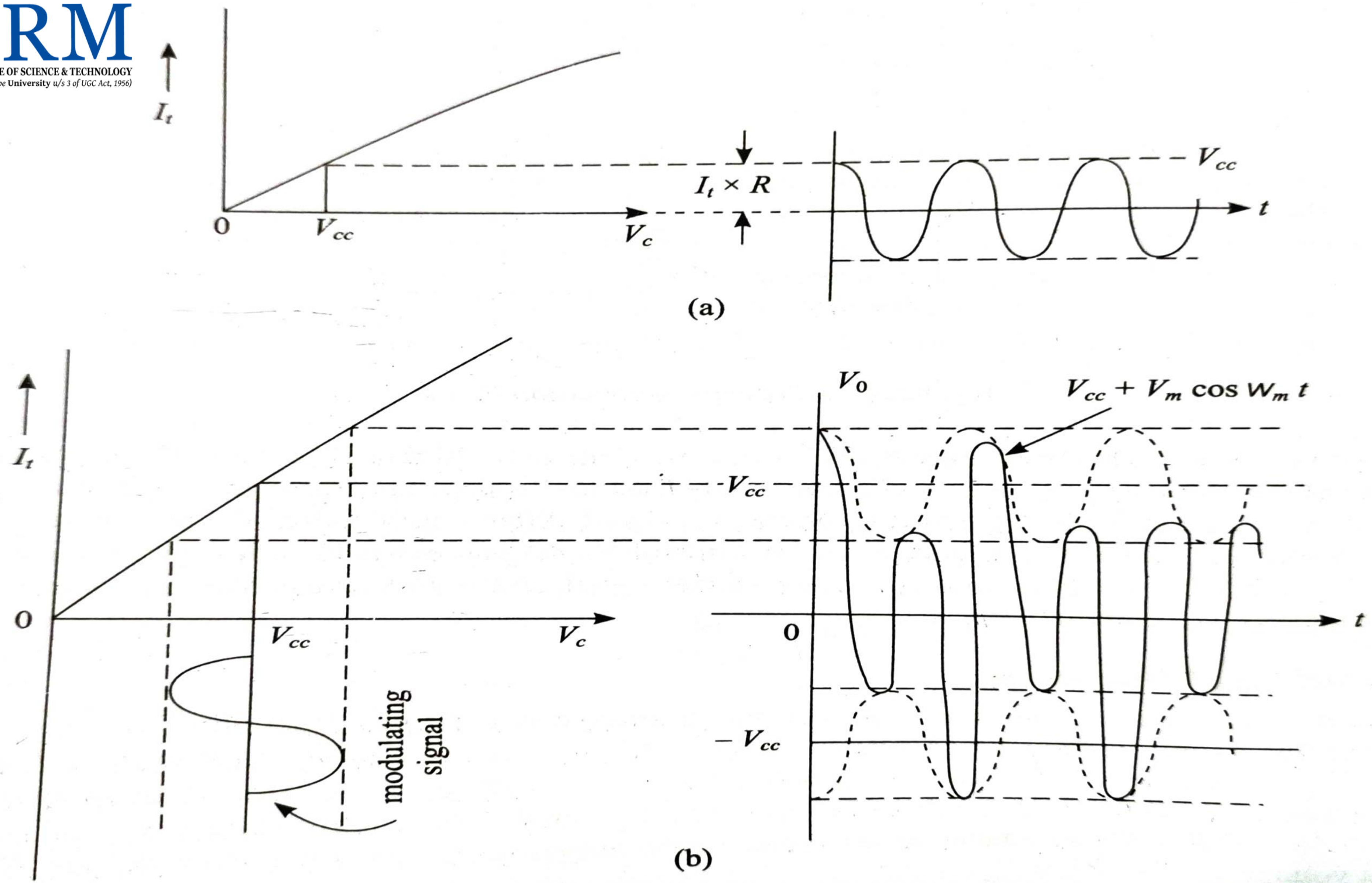


Fig. 5.5.4 Modulated Class C Amplifier

and the modulated output voltage V_o is given by

$$V_o = V_{cc}[1 + m_a \cos \omega_m t] \cos \omega_c t$$

where m_a is the modulation index given by

$$m_a = \frac{V_m}{V_{cc}}$$

OVER MODULATION

When $V_m > V_{cc}$, the envelope crosses the zero axis and an envelope distortion occurs

Collector circuit efficiency

P_{in} = input power in the collector circuit
P_{out} = output power delivered to a load R_L and
P_d = power dissipation in the collector circuit

$$P_d = P_{in} - P_{out}$$

$$= P_{in}\left(1 - \frac{P_{out}}{P_{in}}\right)$$

$$\eta_c = \frac{P_{out}}{P_{in}}$$

$$P_d = P_{in}(1 - \eta_c)$$

$$P_{in} = \int_0^{2\pi} V_{cc}(1 + m_a \cos \omega_m t) I_c (1 + m_a \cos \omega_m t) d\omega t$$

$$= V_{cc} I_c + \frac{m_a^2}{2} V_{cc} I_c = V_{cc} I_c \left(1 + \frac{m_a^2}{2}\right)$$

$$= P_{cc}\left(1 + \frac{m_a^2}{2}\right)$$

$$P_d = V_{cc} I_c \left(1 + \frac{m_a^2}{2}\right)(1 - \eta_c)$$

When the modulation index $m_a = 0$, the power dissipation P_{do} is,

$$P_{do} = V_{cc} I_c (1 - \eta_c)$$

$$P_d = P_{do} \left(1 + \frac{m_a^2}{2}\right)$$

$$P_{out} = \eta_c P_{in} = \eta_c V_{cc} I_c \left(1 + \frac{m_a^2}{2}\right)$$

BALANCED MODULATOR

- A simple diode can be used as non linear modulator by restricting its operation to non-linear region of its characteristic.
- The diode modulator does not provide amplification, this limitation can be overcome by using amplifying device like transistor ,FET or an electron tube in balanced mode.
- The circuit is similar to AM-SC generation,except that the feeding point of carrier and modulating signals are interchanged.

Balanced Modulator

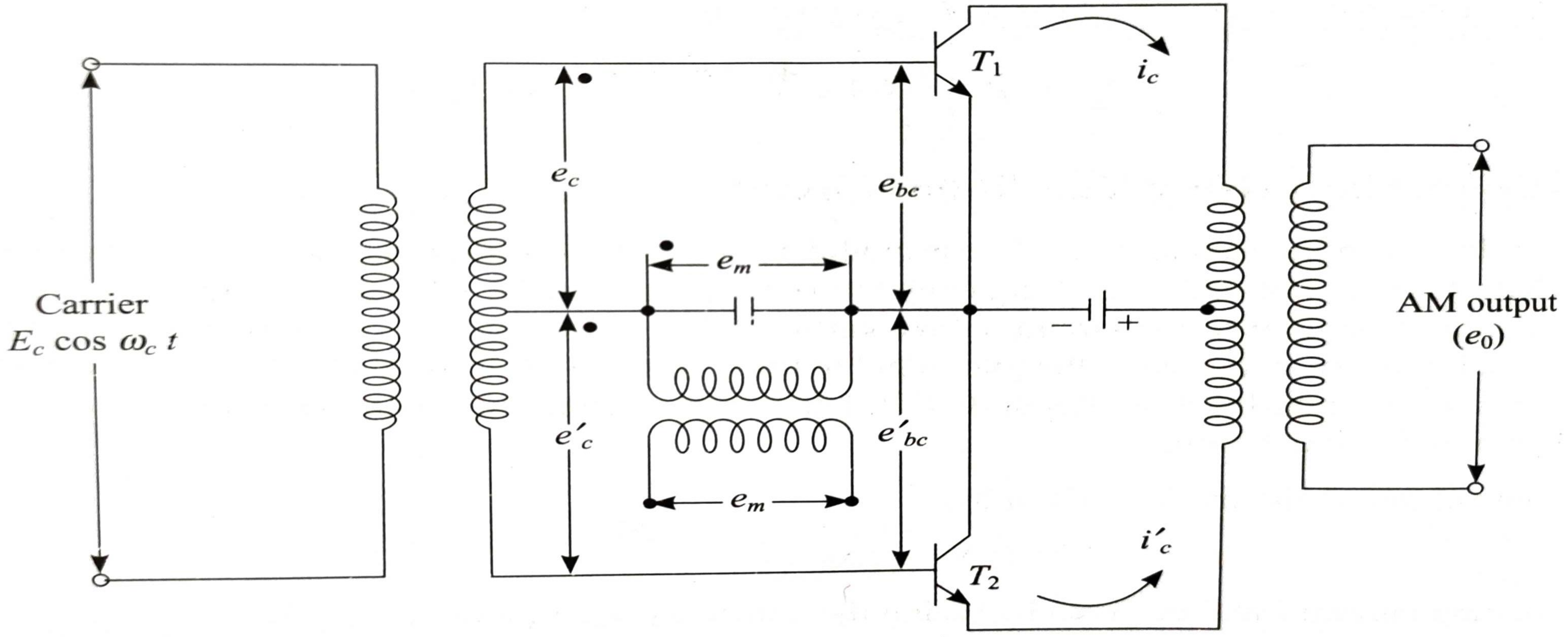


Fig. 5.5.5 *Balanced Modulator (AM)*

Balanced Modulator

A transistor balanced modulator circuit used for AM generation is shown in Fig. 5.5.5.

The circuit is similar to the AM-SC generator shown earlier in Fig. 5.1.15 except that the feeding points of the carrier and the modulating signal are interchanged. The carrier voltage across the two windings of a centre-tap transformer are equal, and opposite in phase, i.e. $e_c = -e_c'$.

The input voltage to transistor T_1 is given by

$$e_{bc} = e_c + e_m = E_c \cos \omega_c t + E_m \cos \omega_m t \tag{5.5.11}$$

since, both e_c and e_m are in phase.

Similarly, the input voltage to transistor T_2 is given by

$$e'_{bc} = e'_c + e_m = -E_c \cos \omega_c t + E_m \cos \omega_m t \tag{5.5.12}$$

This is because e'_c and e_c are in phase opposition, i.e. $e_c = -e'_c$.

By the non-linearly relationship,

$$i_c = a_1 e_{bc} + a_2 e_{bc}^2$$

and

$$i_c' = a_1 e_{bc}' + a_2 e_{bc}'^2$$

Substituting the values of e_{bc} and e'_{bc} from Eqs 5.5.11 and 5.5.12, we get

$$\begin{aligned} i_c &= a_1[E_c \cos\omega_c t + E_m \cos\omega_m t] + a_2[E_c \cos\omega_c t + E_m \cos\omega_m t]^2 \\ &= a_1(E_c \cos\omega_c t + E_m \cos\omega_m t) + a_2[E_c^2 \cos^2\omega_c t + E_m^2 \cos^2\omega_m t + \\ &\quad 2E_m E_c \cos\omega_c t \cos\omega_m t] \end{aligned} \quad (5.5.13$$

Similarly,

$$i'_c = a_1[-E_c \cos\omega_c t + E_m \cos\omega_m t] + a_2[E_c^2 \cos^2\omega_c t + E_m^2 \cos^2\omega_m t - 2E_c E_m \cos\omega_c t \cos\omega_m t] \quad (5.5.14)$$

The output AM voltage e_o is given as

$$eo = K(i_c - i'_c) \quad (5.5.15)$$

This is because the currents i_c and i'_c flow in opposite directions in the tuned circuit. K is a constant depending on impedance and other circuit parameters.

Substituting Eqs 5.5.13 and 5.5.14 in Eq. 5.5.15, we get

$$e_o = 2K\,a_1\,E_c \cos\omega_c t + 4\,Ka_2\,E_c\,E_m \cos\omega_c t \cos\omega_m t$$

The other terms are balanced out. We can write,

$$\begin{aligned} e_o &= 2\,KE_c a_1 \left[1 + \frac{2a_2 E_m}{a_1}\cos\omega_m t\right]\cos\omega_c t \\ &= 2\,Ka_1\,E_c[1 + m_a \cos\omega_m t]\cos\omega_c t \end{aligned} \quad (5.5.16)$$

where $m_a = \dfrac{2a_2\,E_m}{a_1}$ is the modulation index.

Advantages of balanced modulator

- In simple non-linear circuits ,the undesired non-linear terms are eliminated by bandpass filter. Hence bandpass filter must be carefully designed.
- In balanced modulator ,the undesired non-linear terms are automatically eliminated. The output will have only desired terms.

Demodulation of AM Wave-Linear diode detector

- A diode operates in the linear region ,can extract the envelope of an AM wave. Such a detector is called envelope detector.
- This detector is popular in commercial radio receivers circuits ,it is very simple and less expensive.
- Tuned transformer provides perfect tuning at desired carrier frequency.
- R-C forms the time constant network.
- When modulated carrier at the input of diode is 1v,the operation takes place in the linear region

Linear diode detector (a)circuit (b)Characteristics (c)Detected output

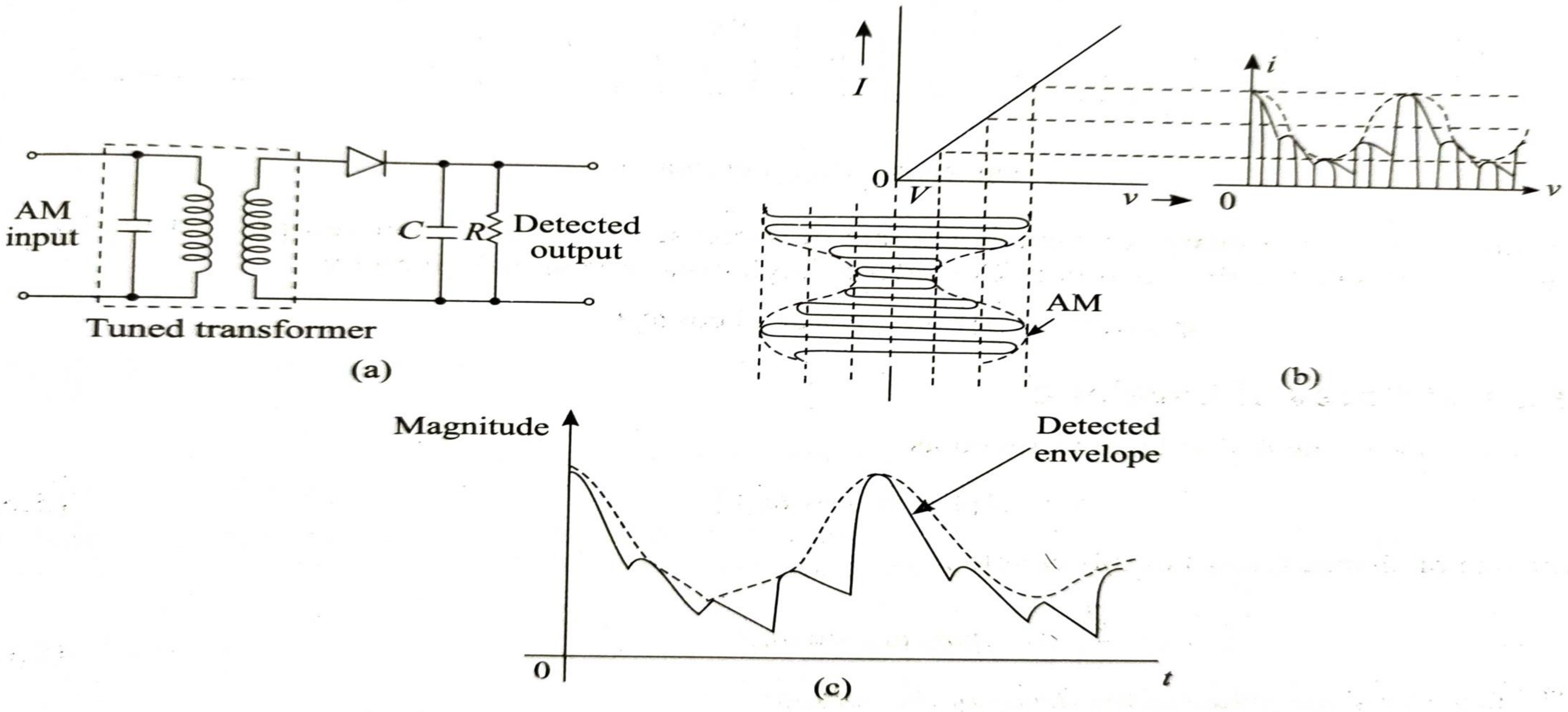
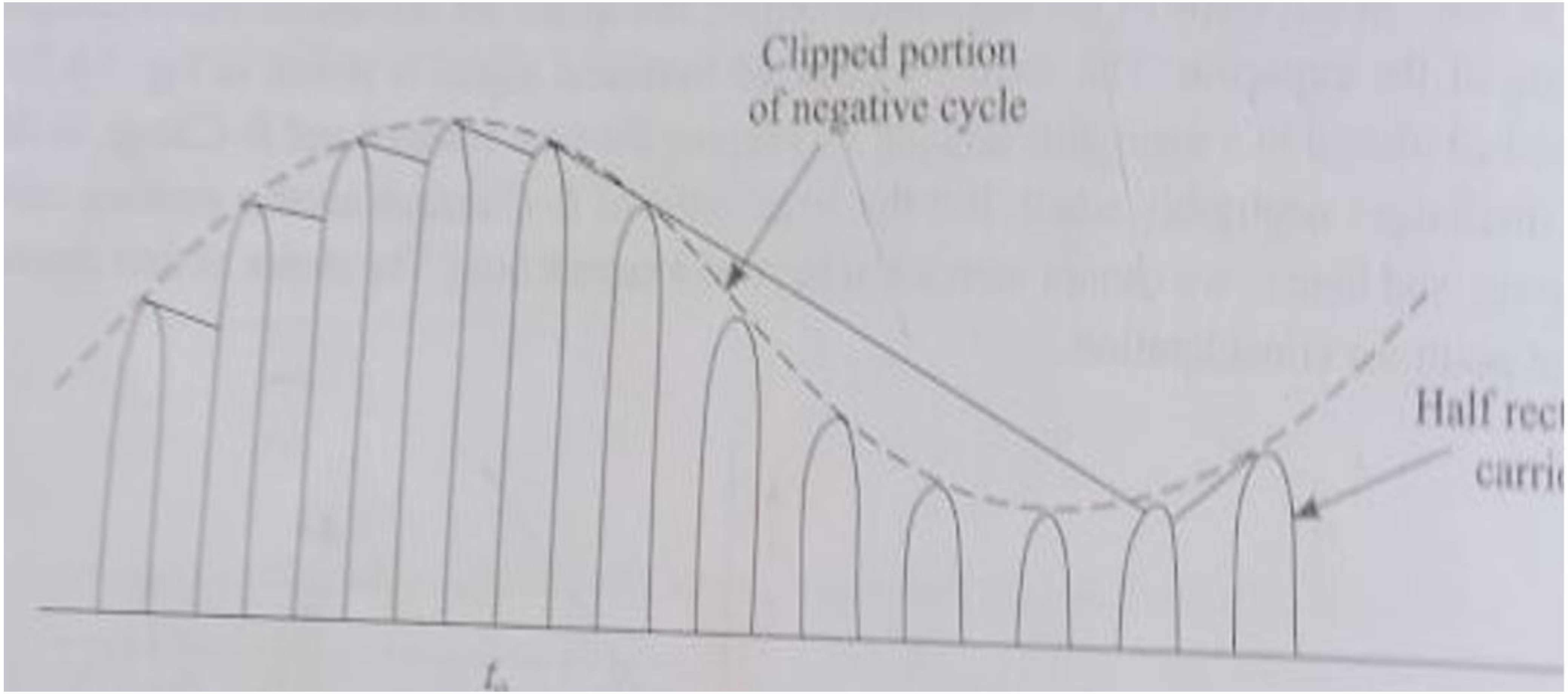


Fig. 5.6.2 *Linear Diode Detector: (a) Circuit, (b) Characteristics, (c) Detected Output*

operation

- Assume Capacitor is absent in the circuit,then output will be like half-rectified as shown in fig b.
- The diode will provide low resistance rd.
- The total resistance will be rd+R.
- For positive half cycle ,the capacitor is charged to peak.
- For negative half cycle ,the diode is reverse biased and carrier voltage is disconnected from R-C circuit.
- capacitor starts discharging through resistor with time constant.
- If time constant is choosen properly,the voltage across the capacitor doesnot falls below
- The voltage across the capacitor will be like spiky base band as shown in figure c.

Diagonal clipping



Choosing time constant RC

- IF RC is too high-cause diagonal clipping
- The optimum value of time constant has to be chosen which provides a compromise between the following two facts

(i) The spike, or fluctuation in a detected envelope should be minimum.

(ii) Negative peaks of detected envelope should not be missed even partially (diagonal clipping).

For this, the rate of discharge of capacitor ≥ rate of decrease of modulation envelope. Let us derive a relation which satisfies this condition. Consider a single-tone AM signal given by

$$\varphi_{\mathrm{AM}}(t) = A[1 + m_a \cos \omega_m t] \cos \omega_c t$$

SRM INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

$$\varphi_{AM}(t) = A[1 + m_a \cos \omega_m t] \cos \omega_c t$$

- ## Rate of Decay of Envelope

The envelope of the AM voltage is, given as

$$e = A[1 + m_a \cos \omega_m t]$$

The rate of change (slope) of this envelope is

$$-\frac{de}{dt} = A\, m_a\, \omega_m \sin \omega_m t$$

The negative slope indicates the *decay of the voltage.*

The slope at an instant t_o will be

$$-\left(\frac{de}{dt}\right)_{t=t_o} = A\, m_a\, \omega_m \sin \omega_m t_o$$

This is the rate of decay of the envelope at an instant $t = t_o$.

At t=to

$$e_o = (e)_{t=t_o} = A[1 + m_a \cos \omega_m t_o]$$

The capacitor discharges exponentially from the initial voltage e_o. The capacitor voltage at any instant t is given as

$$e_{\text{cap}} = e_o\, e^{\frac{-(t-t_o)}{RC}}$$

The rate of change of capacitor voltage (slope of the discharge curve) is,

$$-\frac{de_{\text{cap}}}{dt} = -\frac{d}{dt}\left[e_o\, e^{\frac{-(t-t_o)}{RC}}\right]$$

$$= \frac{e_o}{RC} e^{\frac{-(t-t_o)}{RC}}$$

This rate of change at $t = t_o$ is given as

$$-\left(\frac{de_{\text{cap}}}{dt}\right)_{t=t_o} = \frac{e_o}{RC}$$

Substituting e_o from Eq. 5.6.5,

$$-\left(\frac{de_{\text{cap}}}{dt}\right)_{t=t_o} = \frac{A}{RC}[1 + m_a \cos \omega_m t_o]$$

To avoid diagonal clipping, the slope of the discharge curve at $t = t_o$ given by Eq. 5.6.8 must be equal to, or greater than, the envelope-decay rate given in Eq. 5.6.4. Thus,

$$\frac{A}{RC}[1 + m_a \cos \omega_m t_o] \geq A\, m_a \omega_m \sin \omega_m t_o$$

$$\frac{1}{RC} \geq \frac{\omega_m \, m_a \sin \omega_m t_o}{1 + m_a \cos \omega_m t_o}$$

- At an instant t, Eq. 5.6.9(a) can be given as

$$\frac{1}{RC} \geq \frac{\omega_m \, m_a \sin \omega_m t}{1 + m_a \cos \omega_m t}$$

It is desired that $(1/RC)$ is always greater than, or equal to, the right hand side (RHS). This can be achieved by maximizing the RHS. The condition for maximizing the RHS is obtained by equating the derivative of RHS zero.

$$\frac{d}{dt}\left[\frac{\omega_m \, m_a \sin \omega_m t}{1 + m_a \cos \omega_m t}\right] = 0$$

Solution of the above equation yields,

$$\cos \omega_m t = -m_a$$

or

$$\sin \omega_m t = \sqrt{1 - m_a^2}$$

$$\frac{1}{RC} \geq \omega_m \frac{m_a\sqrt{1-m_a^2}}{1-m_a^2}$$

$$\frac{1}{RC} \geq \frac{\omega_m\, m_a}{\sqrt{1-m_a^2}}$$

f $m_a << 1$ (small modulation index), then Eq. reduces to

$$\frac{1}{RC} \geq \omega_m m_a$$

Numericals

- .

An amplitude modulated amplifier has a radio frequency output of 50 W at 100% modulation. The internal loss in the modulator is 10 W:

(a) What is the unmodulated carrier power?

(b) What power output is required from the modulator (baseband signal)?

(c) If the percentage modulation is reduced to 75%, how much output is needed from the modulator (baseband signal)?

Solution

$$P_{\text{out}} = 50 \text{ W}$$

$$P_{\text{in}} = P_{\text{out}} + P_d$$

$$= 50 + 10 = 60 \text{ W}$$

(a) Unmodulated carrier power P_{cc} is related with P_{in} as,

$$P_{\text{in}} = P_{cc}\left(1 + \frac{m_a^2}{2}\right)$$

or

$$60 = P_{cc}\left(1 + \frac{1}{2}\right) = \frac{3}{2} P_{cc}$$

Hence

$$P_{cc} = 60 \times \frac{2}{3} = 40 \text{ W}$$

(b) Power required from the modulator (baseband amplifier) is obtained by subtracting unmodulated power from the total input power:

$$P_m = P_{\text{in}} - P_{cc} = 60 - 40 = 20 \text{ W}$$

(c) Power needed from the modulator (P_m) is given by

$$P_m = P_{cc}\left(\frac{m_a^2}{2}\right) = \frac{40 \times (0.75)^2}{2} = 11.25 \text{ W}$$

SRM INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

An amplitude modulated wave $10[1+0.6\cos 2\pi 10^3 t]\cos 2\pi \cdot 10^6 t$ *is to be detected by a linear diode detector. Find (a) the time constant* τ*, (b) the value of resistance R if the capacitor used is 100 pF.*

(a)

$$\frac{1}{RC} \geq \frac{\omega_m m_a}{\sqrt{1-m_a^2}}$$

Here

$$\omega_m \geq 2\pi \cdot 10^3,\ m_a = 0.6$$

Hence

$$\frac{1}{RC} \geq \frac{2\pi \cdot 10^3 \times 0.6}{\sqrt{1-0.6^2}} = 5.886 \times 10^3$$

In the limiting case,

$$\tau = RC = \frac{10^{-3}}{5.886} = 0.17 \text{ ms}$$

(b)

$$R = \frac{\tau}{C} = 0.17 \times 10^3/100 \times 10^{-12} = 0.17 \times 10^{13}\ \Omega$$