UNIT-1
AM GENERATION

BY: PRADEEP KUMAR

pradeep14335@gmail.com

Lecturer, ET DEPT., RCET

SYLLABUS

- **AM Generation:** Methods of AM generation:
- Detailed Analysis of Class - C Tuned Amplifiers
- Linear shunt plate modulation ------SLIDE NO. 9
- Linear series plate modulation -----SLIDE NO. 15
- Grid-bias modulation-------------------SLIDE NO. 17
- Cathode modulation-------------------SLIDE NO. 25
- Suppress grid modulation-------------SLIDE NO. 27
- Screen grid modulation---------------SLIDE NO. 31
- Collector modulation------------------SLIDE NO. 13

AMPLITUDE MODULATION METHOD

Two categories:

1. **Linear Modulation method**: ***Utilizes linear region of the current- voltage characteristic of the amplifying device such as transistor or electron tube.***

2. **Square law modulation method**: ***utilizes non linear region.***

Classification of Linear Modulation method:

1. Linear shunt plate modulation method or Anode choke modulation or Heising modulation.
2. Linear series Plate Modulation.
3. Grid bias Modulation.
4. Cathode modulation.
5. Suppressor Modulation.
6. Screen grid Modulation.
7. Collector Modulation.

AM Generation:

It is done in two parts

part 1:modulated class c amplifier

part 2: tuned Circuits

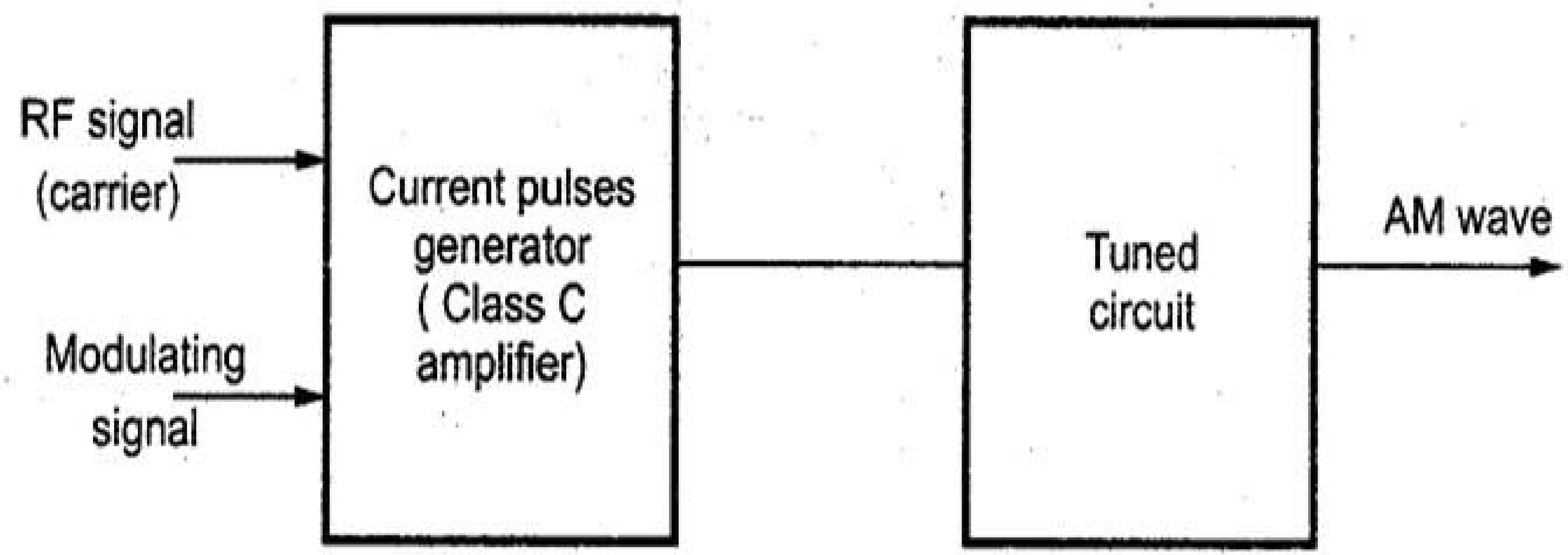


Fig. 2.10 Block schematic of AM generator

Class C Amplifier

It is possible to make the output current of a class C amplifier proportional to the modulating voltage by applying modulating voltage in series with the dc power supply voltage for the amplifier. Fig. 2.11 shows the modulating signal and the output current waveform of the class C amplifier.

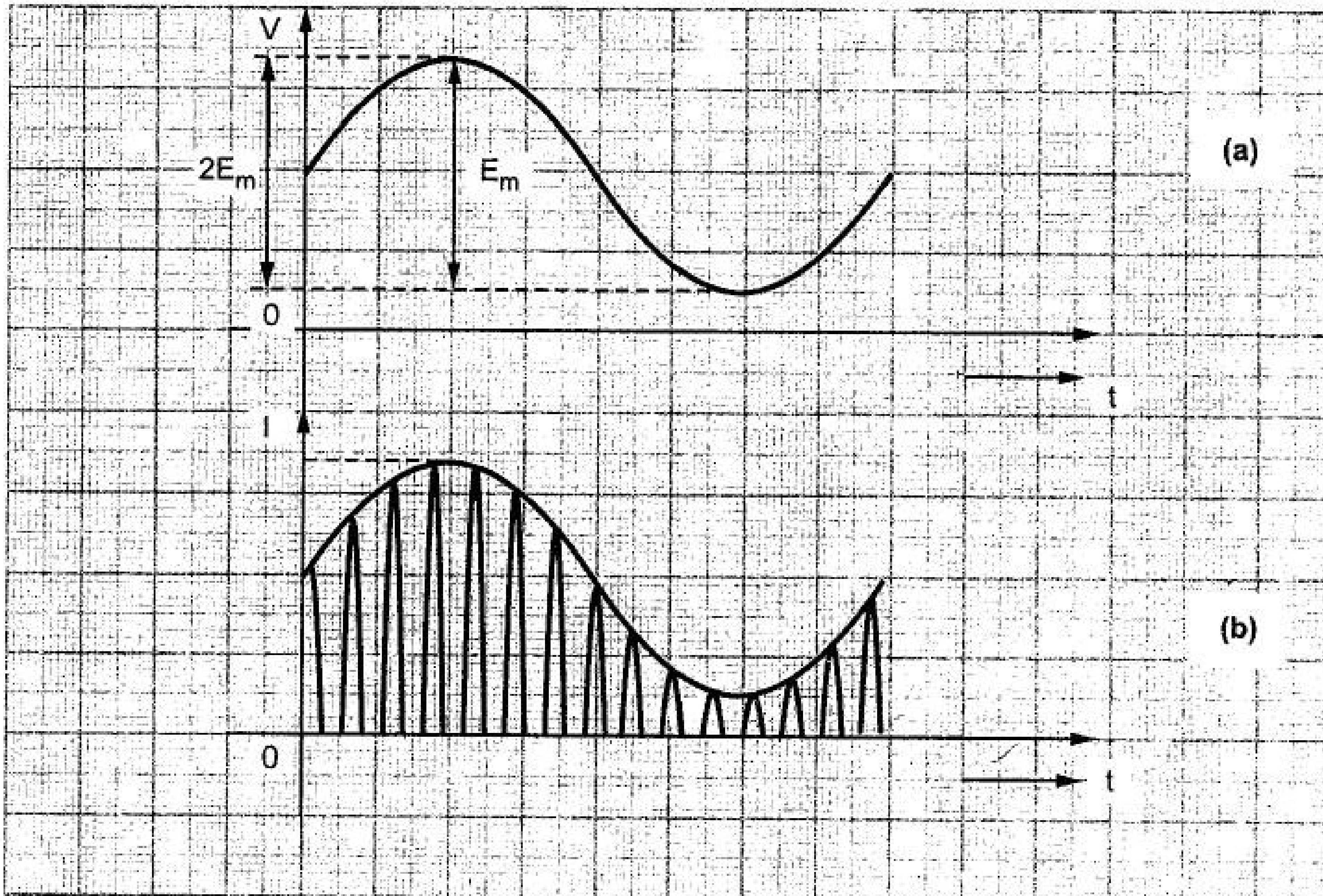


Fig. 2.11 (a) Modulating Signal (b) Current pulses

Tuned Circuit

Each current pulse applied to the tuned circuit initiates a damped oscillation in it. The amplitude of the oscillation is proportional to the size of the current pulse and decay rate is proportional to the time constant of the circuit. Since series of pulses are fed to the tuned circuit, each pulse will generate a complete sine wave proportional in amplitude to the size of applied pulse. This will be followed by the next sine wave, proportional to the size of the output signal is coupled through modulating transformer T_1 to the class C amplifier. The secondary winding of the modulation transformer is connected in series with the collector supply voltage V_{CC} of the class C amplifier. This means that modulating signal is applied in series with the collector power supply voltage of the class C amplifier applying collector modulation.

SEE next slide for:-

1. Input waveform of tank by collector
2. Output waveform to the load

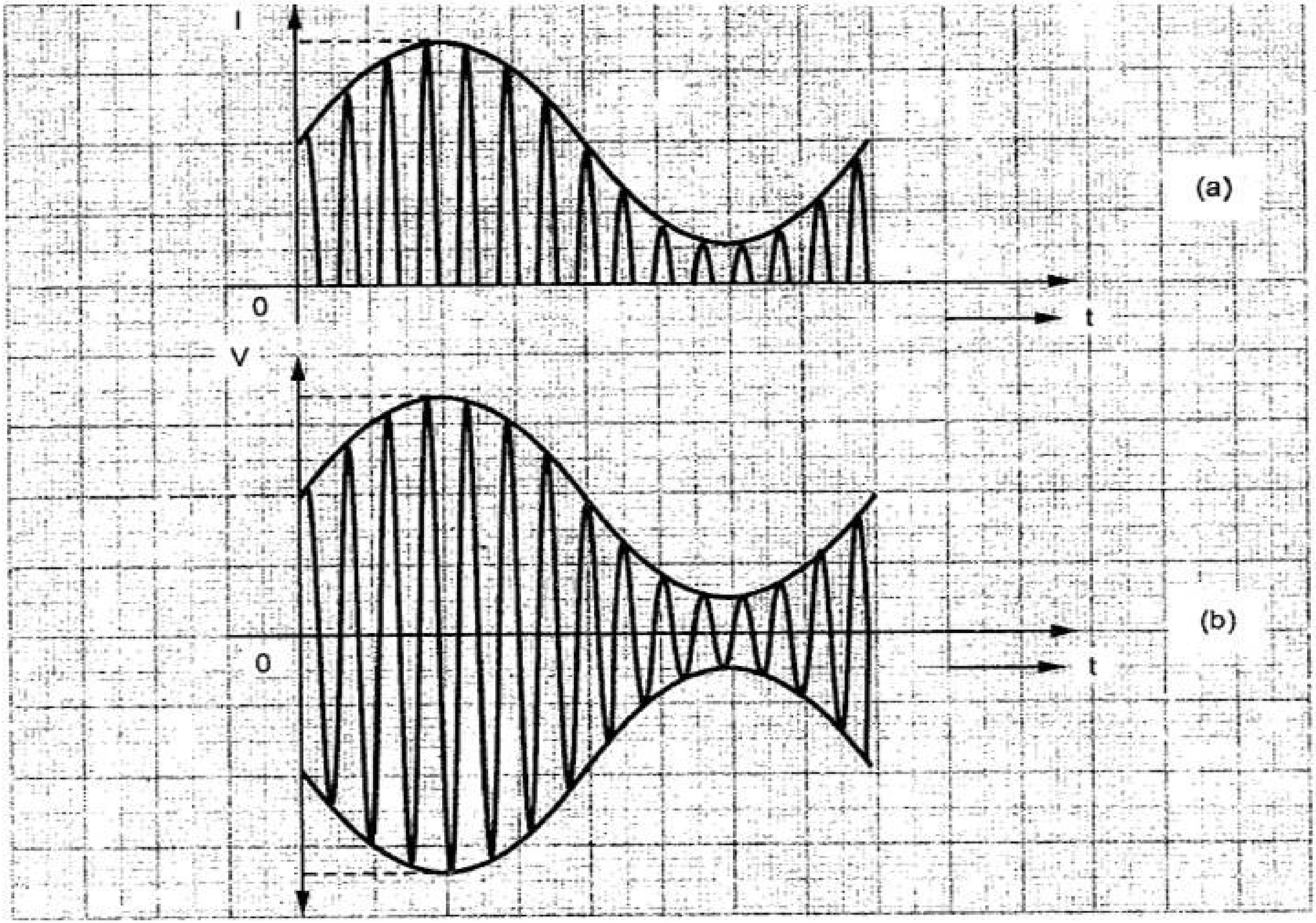


Fig. 2.12 (a) Current pulses (b) Tuned circuit output (AM wave)

1.Linear shunt plate modulation method or Anode choke modulation or Heising modulation.

- Circuit diagram (see next slide)
- Input and output Waveform (see next slide)

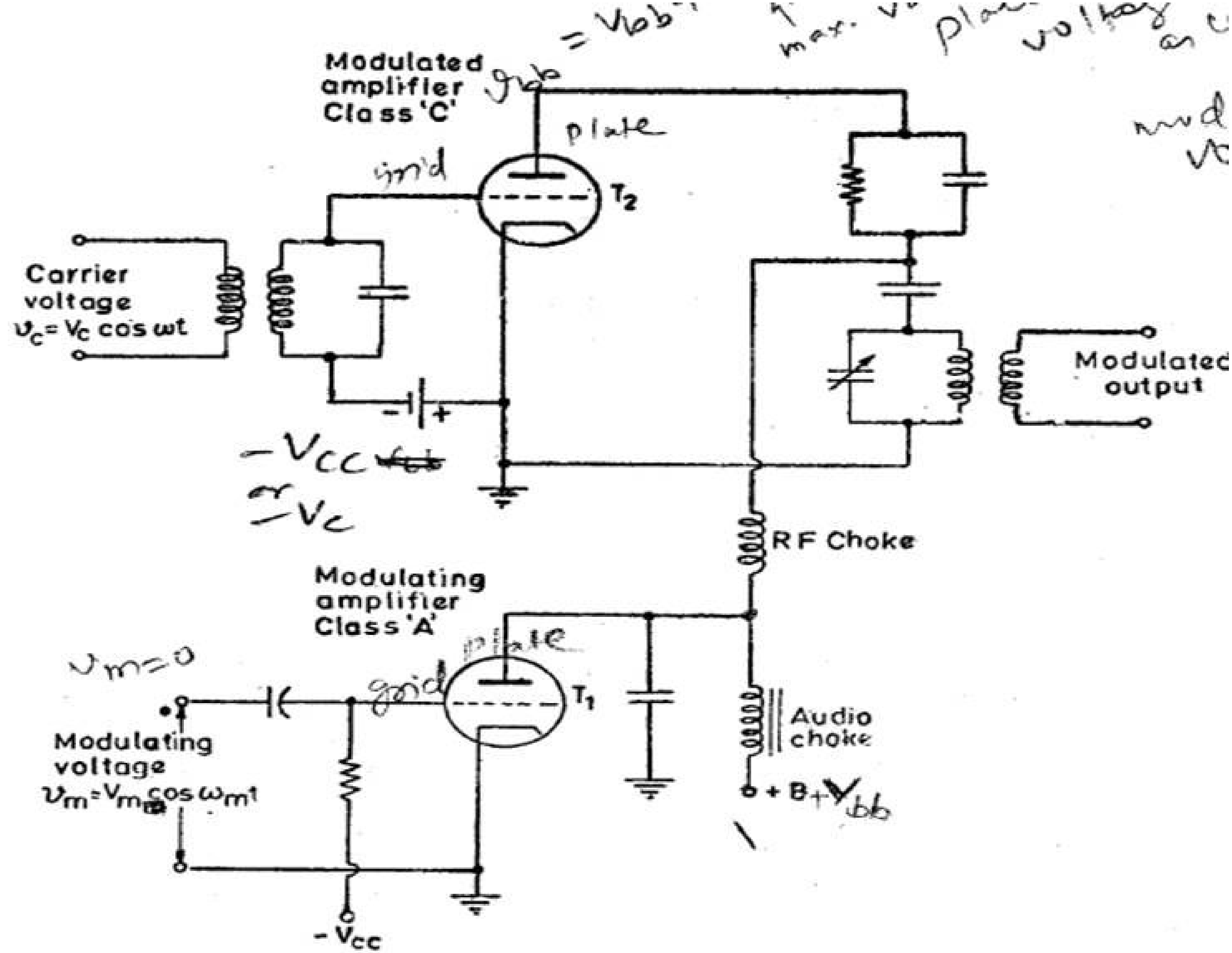


Fig. 4.1. Basic circuit of shunt plate modulation or Heising modulation.

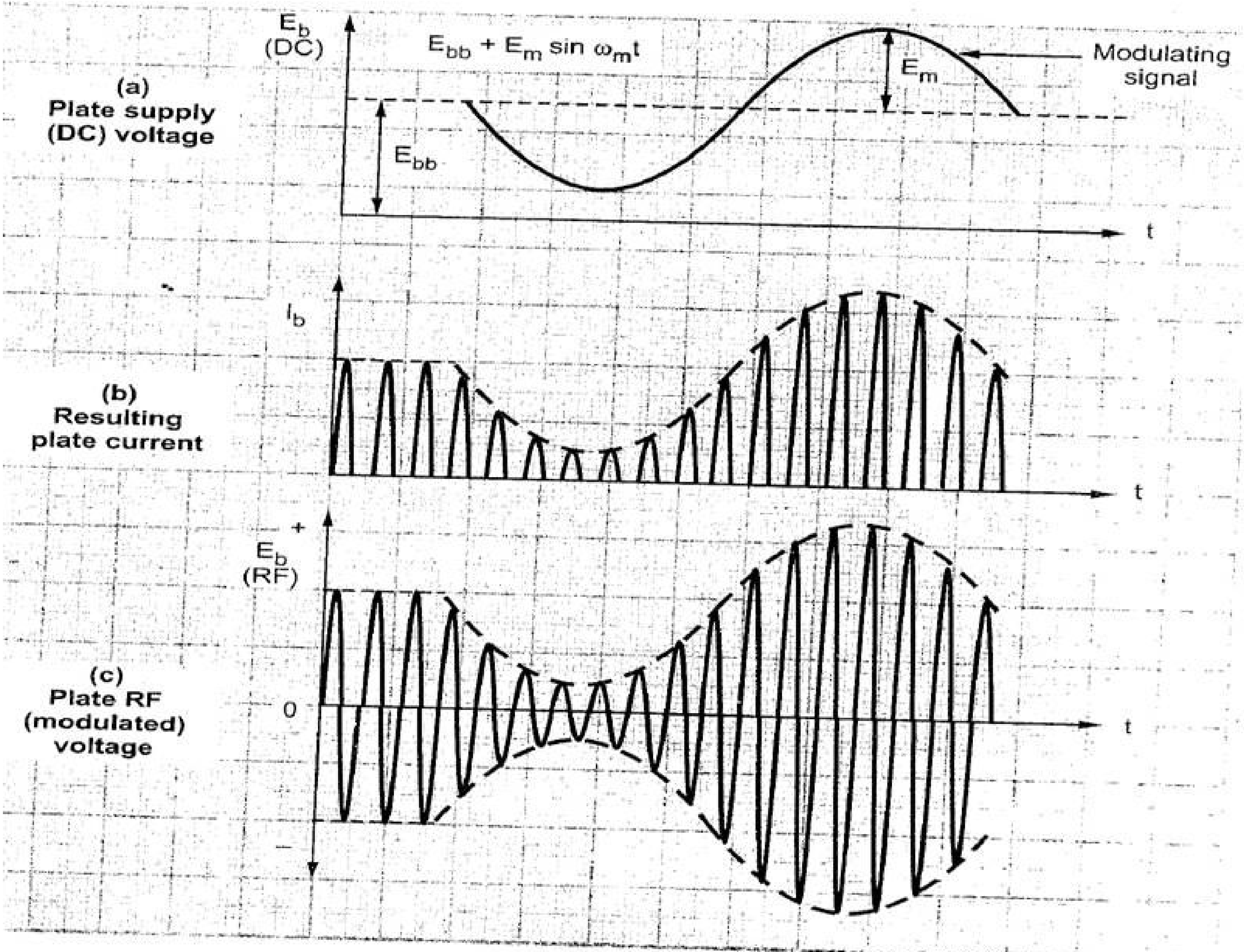


Fig. 2.19 Waveforms of plate modulation

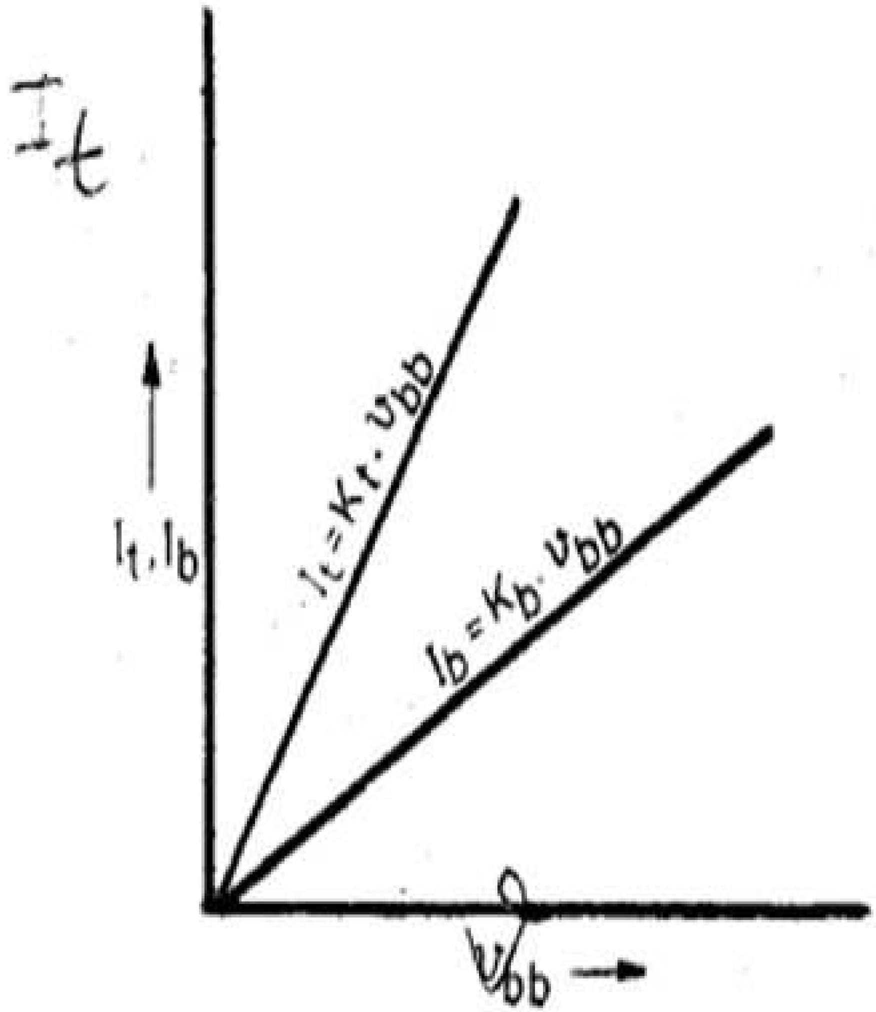


Fig. 4.2. Ideal modulation characteristic for linear plate modulation.

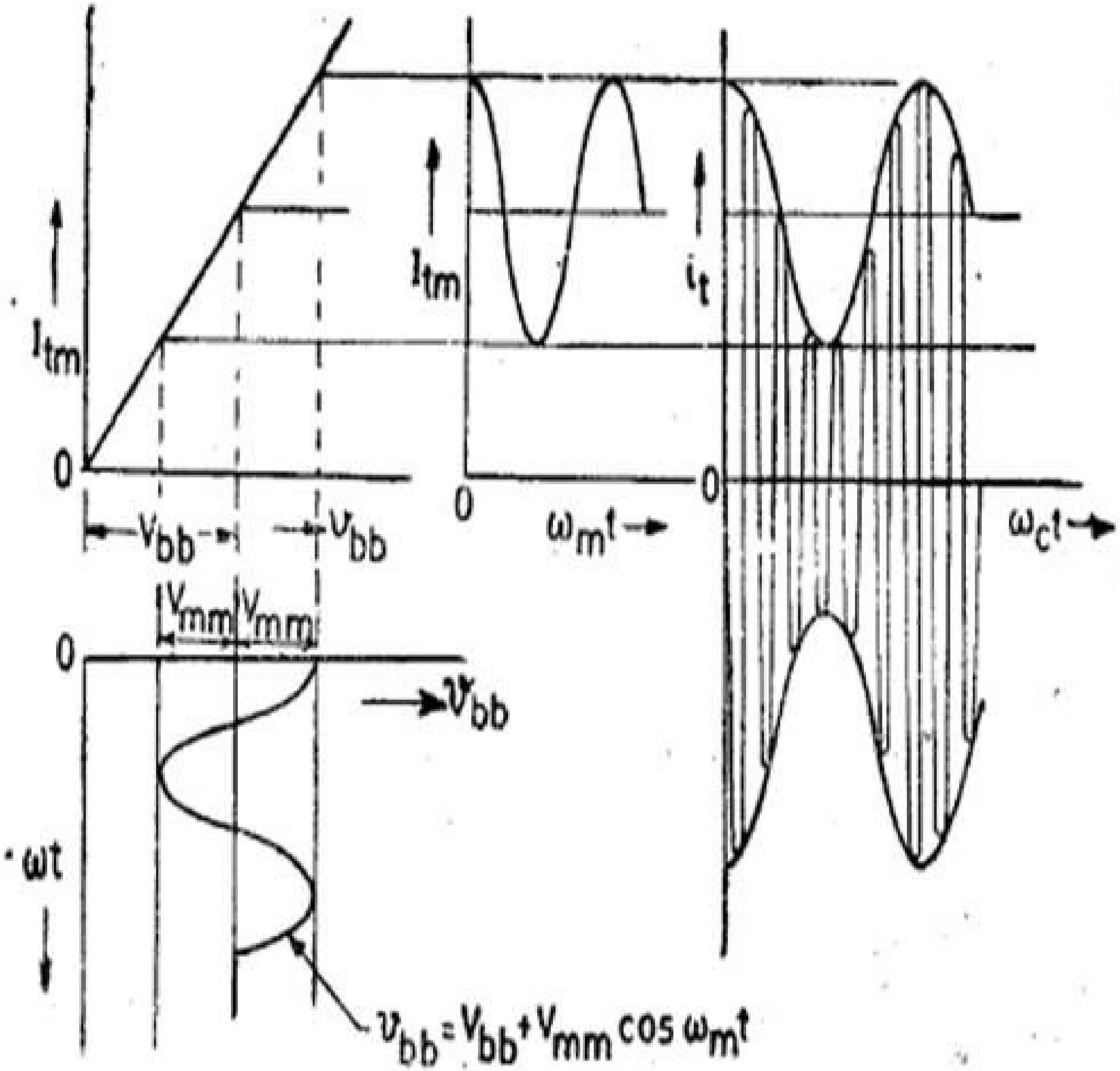


Fig. 4.3. Variation of plate tank current in linear plate modulation.

7.Collector Modulation

The Fig. 2.13 shows the basic circuit for a BJT modulator.

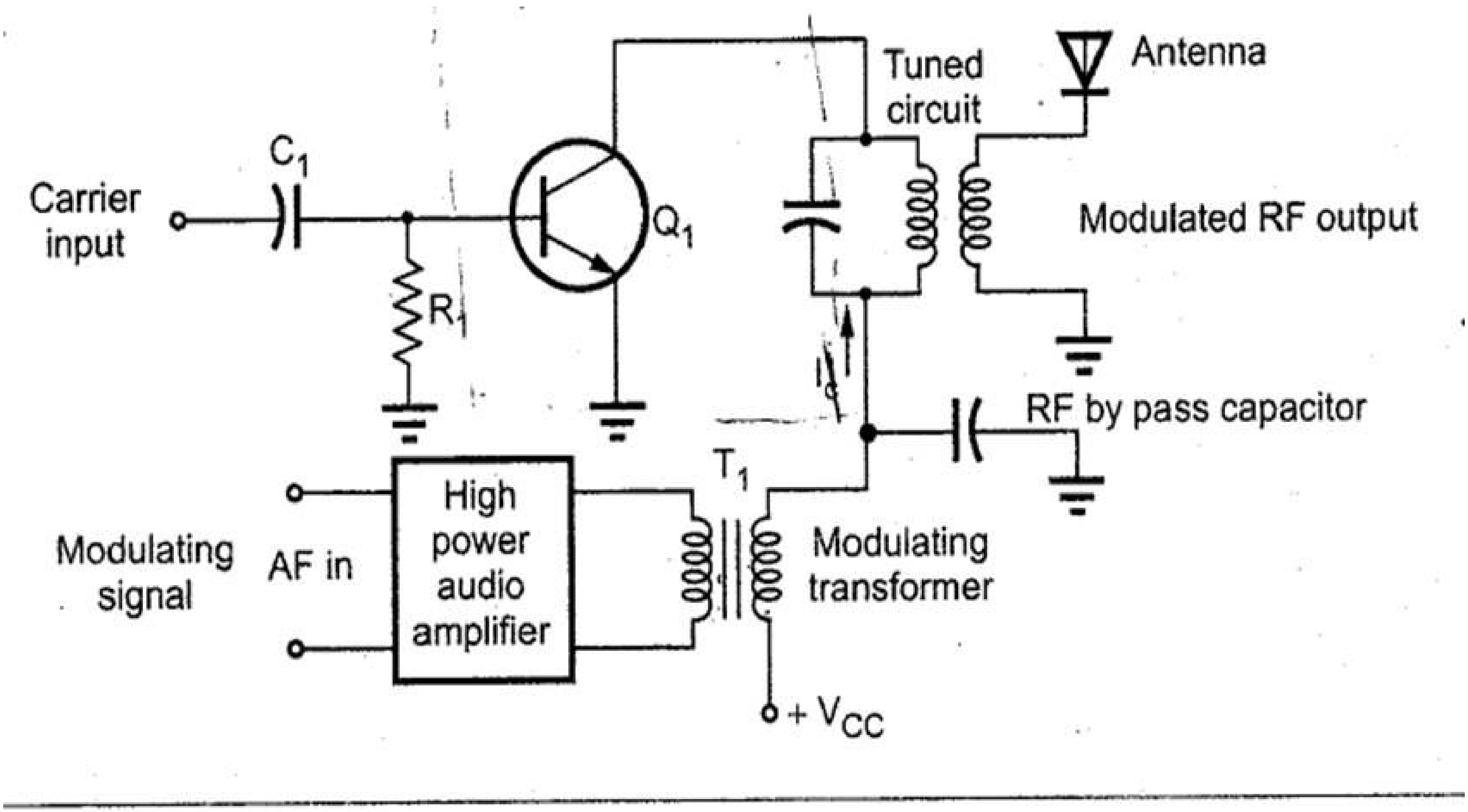


Fig. 2.13

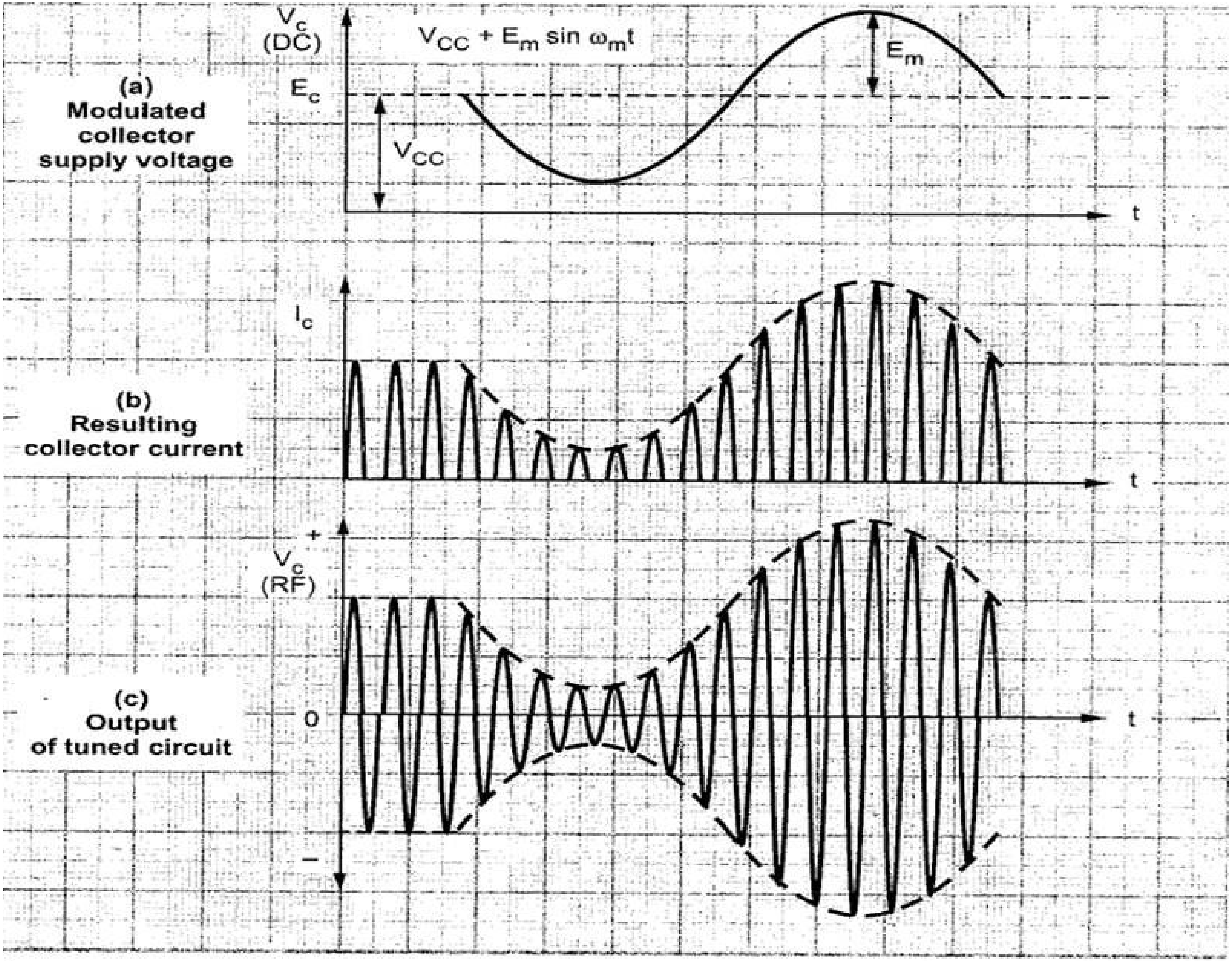


Fig. 2.14 Waveforms of collector modulation

2.Linear series Plate Modulation.

4.4. Linear Series Plate Modulation

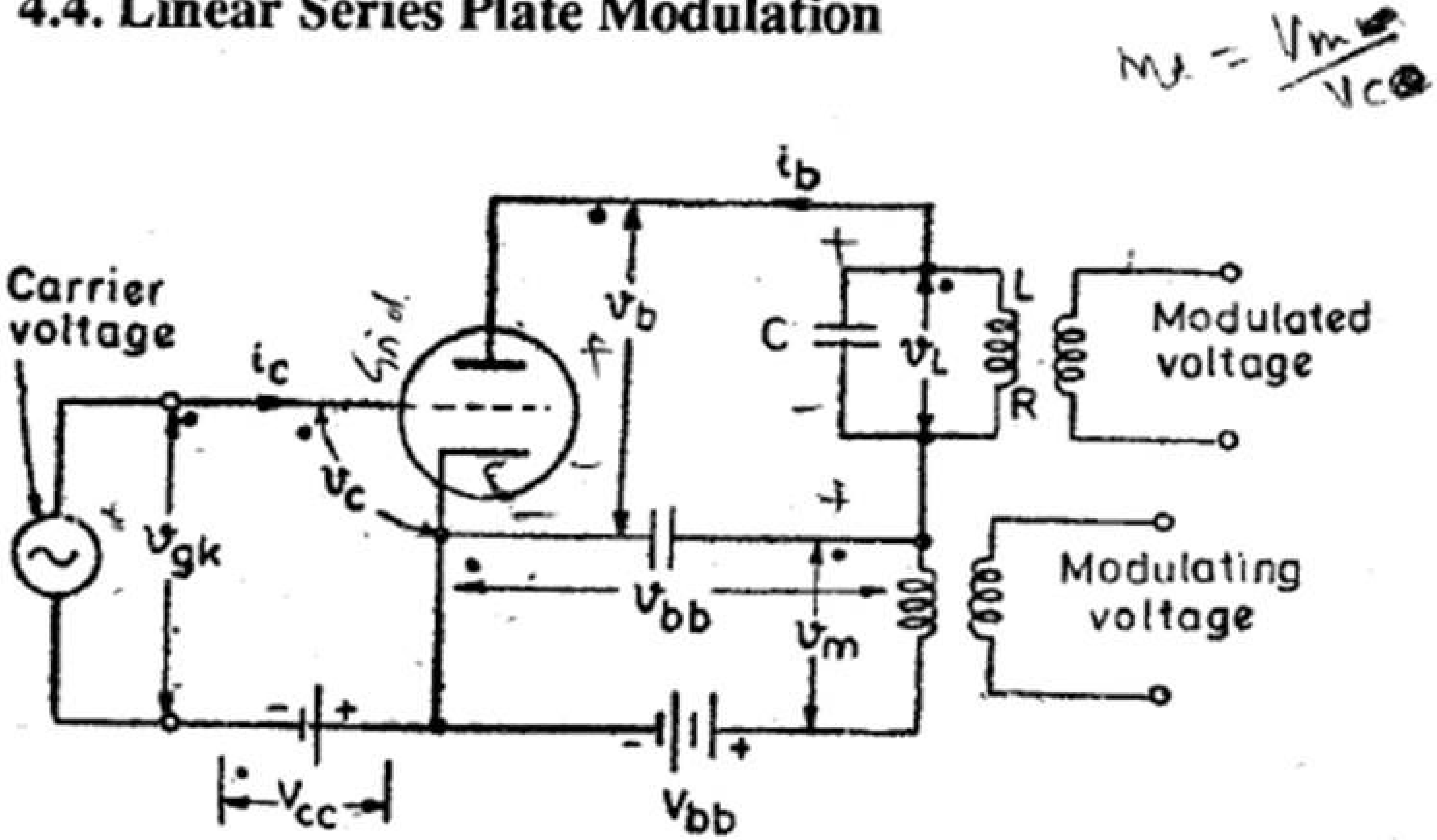


Fig. 4.4. Basic circuit of linear series modulated class C amplifier.

Analysis of Linear Series Plate Modulation

It is assumed that carrier frequency $\omega_c \gg \omega_m$. At the grid of class C modulated amplifier,

$$v_{gk} = V_{gm} \cos \omega_c t \qquad \ldots(4.2)$$

and

$$v_c = V_{cc} + v_{gk} = V_{cc} + V_{gm} \cos \omega_c t \qquad \ldots(4.3)$$

The modulating voltage in the modulated amplifier plate circuit is given by,

$$v_m = V_{mm} \cos \omega_m t \qquad \ldots(4.4)$$

Instantaneous plate supply voltage in modulated amplifiers is given by,

$$v_{bb} = V_{bb} + v_m = V_{bb} + V_{mm} \cos \omega_m t \qquad \ldots(4.5)$$

$$= V_{bb} [1 + m_a \cos \omega_m t] \qquad \ldots(4.6)$$

To be contd.(work out in class notes)

3. Grid bias Modulation

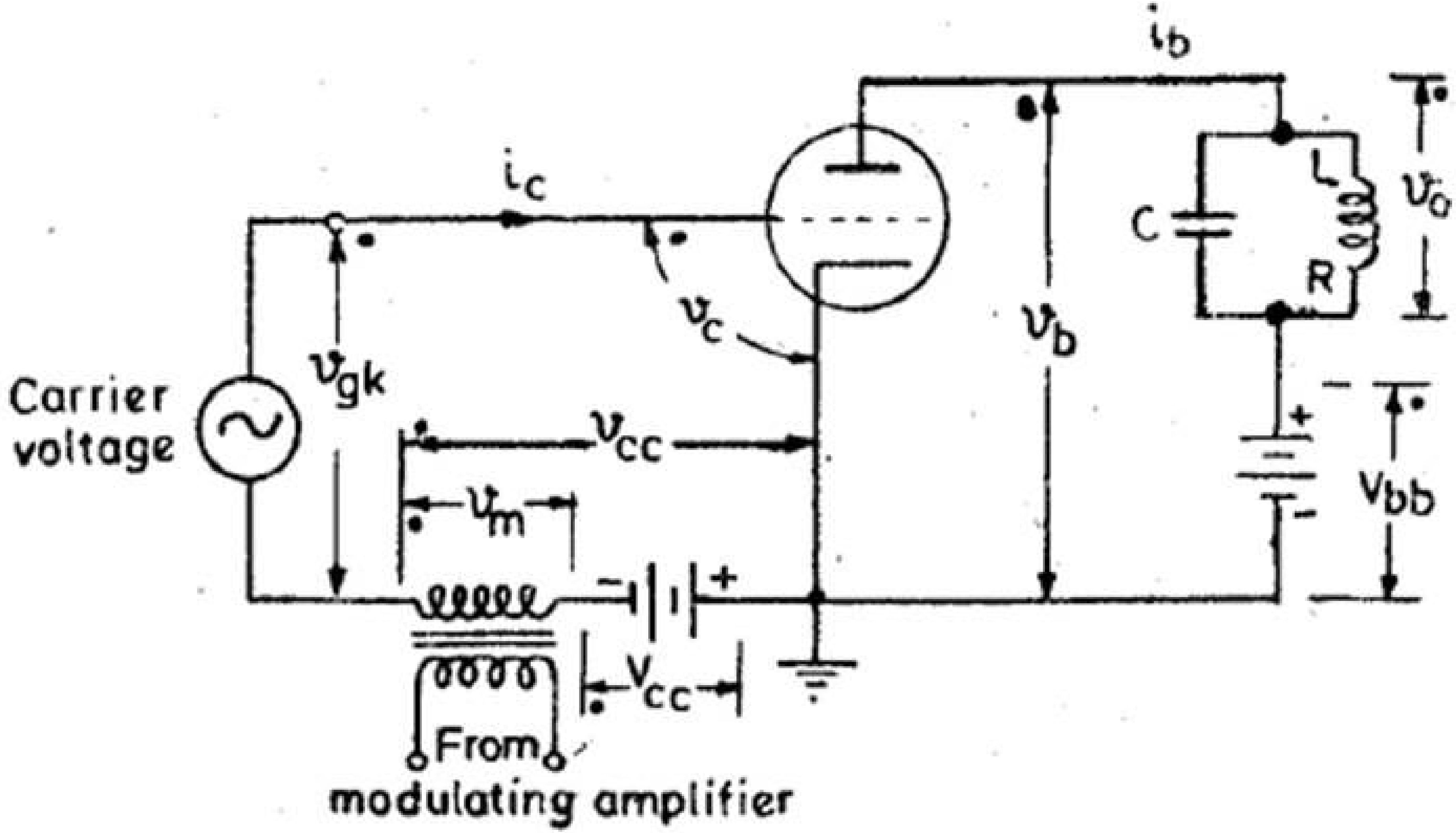


Fig. 4.7. Basic circuit of grid bias modulation.

4.6.1. Analysis of Grid Bias Modulation System. Analysis of grid bias modulated amplifier may be done in a way similar to that for linear series plate modulation.

Let the carrier voltage be given by, $v_{gk} = V_{gm} \sin \omega_c t$ ...(4.36)

The modulating voltage is, $v_m = V_{mm} \cos \omega_m t$ ...(4.37)

Total varying grid bias v_{cc} is given by, $v_{cc} = V_{cc} + V_{mm} \cos \omega_m t$ ...(4.38)

Total grid-to-cathode voltage v_c is given by,

$$v_c = v_{gk} + v_{cc} = V_{gm} \sin \omega_c t + V_{mm} \cos \omega_m t + V_{cc} \quad ...(4.39)$$

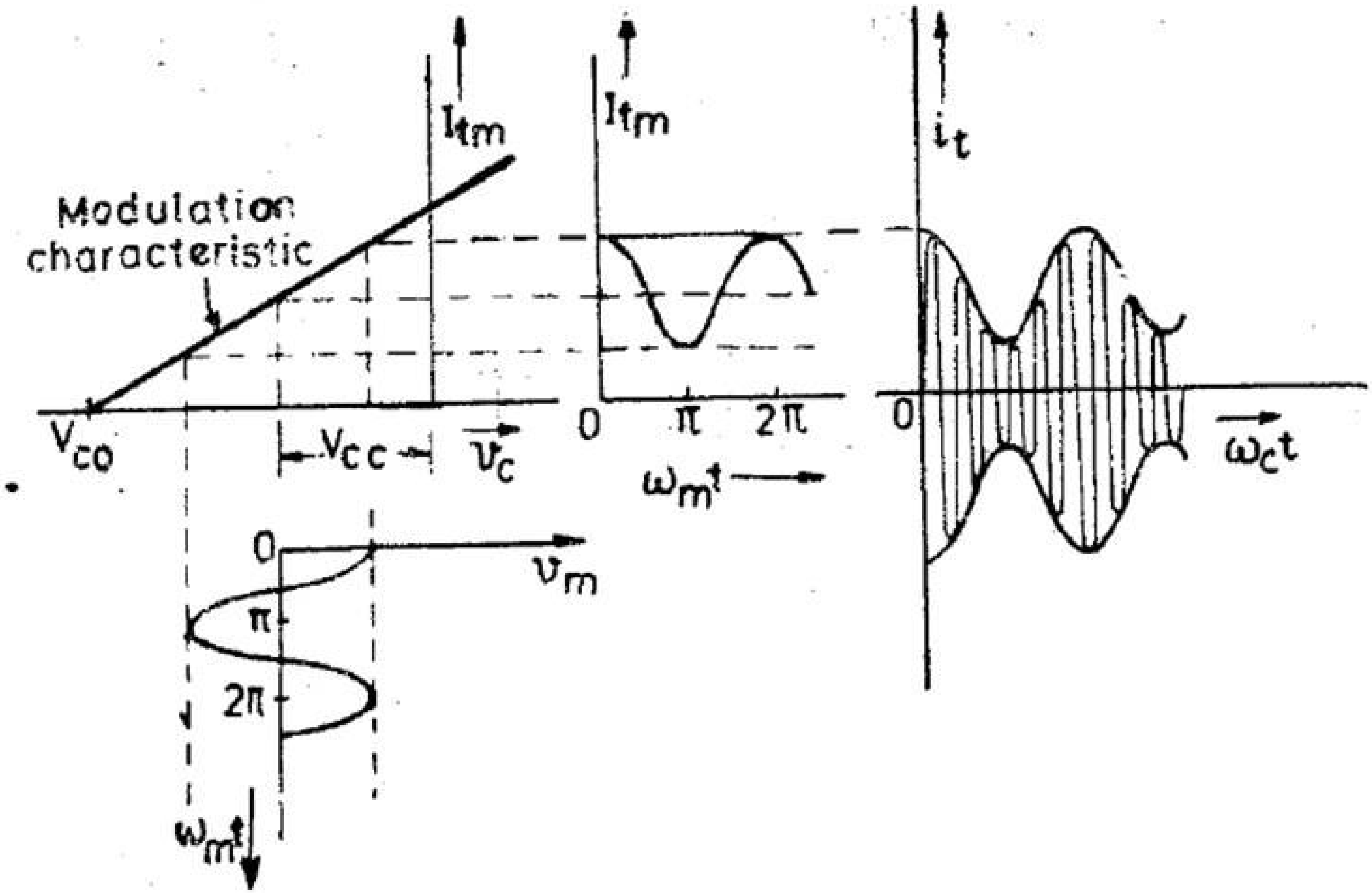


Fig. 4.8. Variation of tank current in grid bias modulation.

Let the R.M.S. value of tank current for linear modulation characteristic be given by,

$$I_t = k_t \cdot (v_{cc} - V_{co}) \quad \ldots(4.40)$$

where V_{co} is grid-to-cathode voltage for zero tank current.

But the instantaneous tank current varies at frequency ω_c and is given by,

$$i_t = I_{tm} \sin \omega_c t \quad \ldots(4.41)$$

where I_{tm} is the amplitude of the tank current.

Hence

$$i_t = \sqrt{2} I_t \sin \omega_c t \quad \ldots(4.42)$$

or

$$i_t = \sqrt{2} k_t \cdot (v_{cc} - V_{co}) \sin \omega_c t \quad \ldots(4.43)$$

$$= \sqrt{2} k_t [V_{mm} \cos \omega_{mt} + V_{cc} - V_{co}] \sin \omega_c t \quad \ldots(4.44)$$

When modulating voltage v_m is zero, tank current is given by,

$$i_{to} = \sqrt{2} k_t [V_{cc} - V_{co}] \sin \omega_c t \quad \ldots(4.45)$$

or

$$i_{to} = I_{tmo} \sin \omega_c t \quad \ldots(4.46)$$

where I_{tmo} is the amplitude of the tank current with zero modulating voltage and is given by,

$$I_{tmo} = \sqrt{2} k_t [V_{cc} - V_{co}] \quad \ldots(4.47)$$

Eq. (4.44) may be written as,

$$i_t = \sqrt{2} k_t (V_{cc} - V_{co}) \left[1 + \frac{V_{mm} \cos \omega_m t}{V_{cc} - V_{co}} \right] \sin \omega_c t \quad \ldots(4.48)$$

or $$i_t = I_{tmo}\left[1 + \frac{V_{mm}}{V_{cc} - V_{co}} \cos \omega_m t\right] \sin \omega_c t \quad \ldots(4.49)$$

or $$i_t = I_{tmo}\,[1 + m_a \cos \omega_m t] \sin \omega_c t \quad \ldots(4.50)$$

where m_a is the modulation index and is given by,

$$m_a = \frac{V_{mm}}{V_{cc} - V_{co}} \quad \ldots(4.51)$$

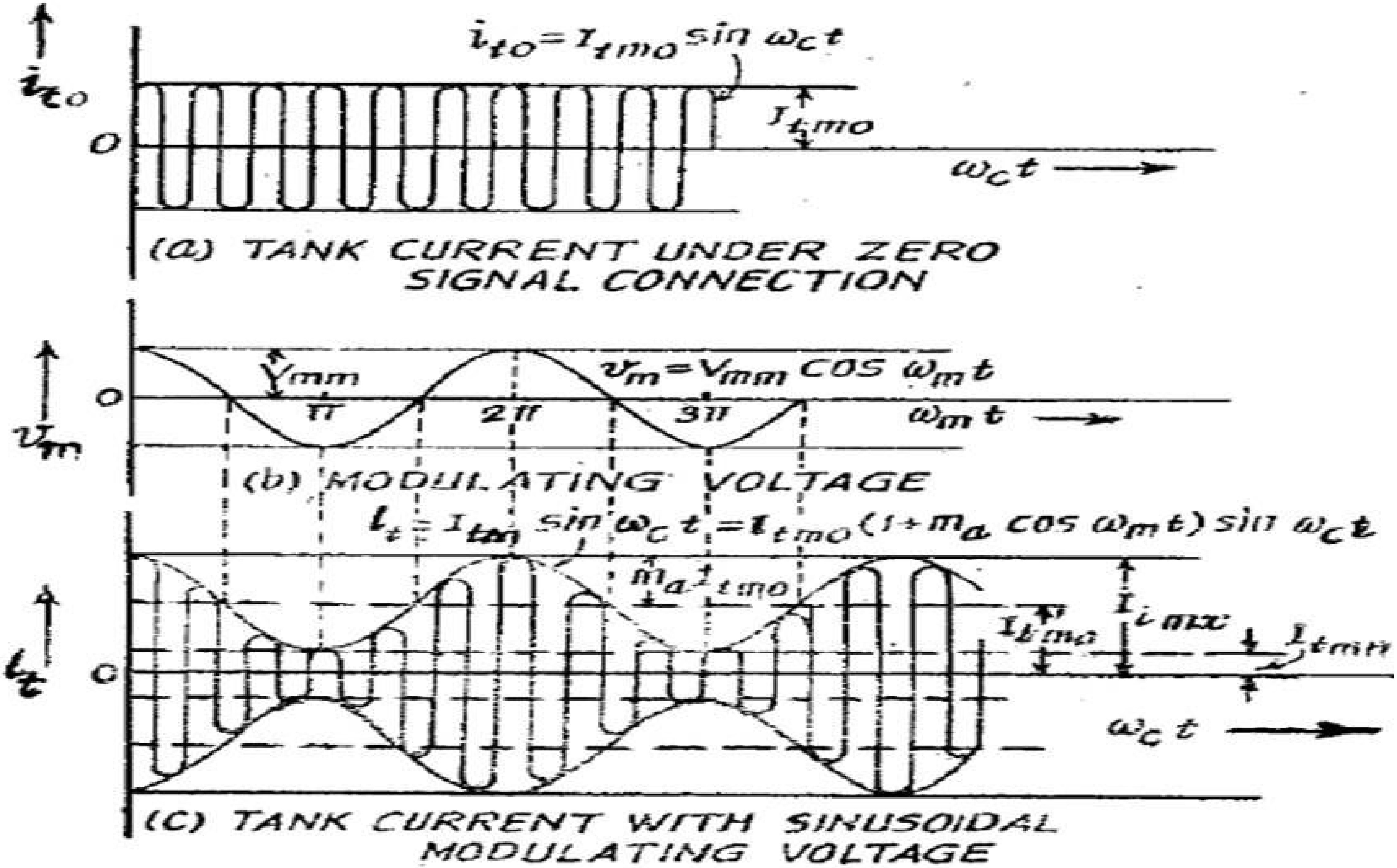
Fig. 4.9 shows the waveform of carrier voltage, modulating voltage and modulated voltage.

Now since the grid bias is no longer constant but consists of a steady component V_{cc} and variable component v_m, the D.C. plate current I_b is no longer constant but varies in accordance with the variation of variable grid bias v_{cc} as given by the relation,

$$I_b = k_b\,(V_{cc} - V_{co}) \quad \ldots(4.52)$$

The steady value of D.C. plate current is then given by,

$$I_{bb} = k_b\,(V_{cc} - V_{co}) \quad \ldots(4.53)$$



I_{tmx} — maximum value of I_{tm}.
I_{tmn} — minimum value of I_{tm}.

Fig. 4.9. Waveforms of modulating voltage and tank current in grid bias modulation.

Substituting the value of v_{cc} as given by Eq. (4.38) into Eq. (4.52), we get

$$I_b = k_b (V_{cc} + V_{mm} \cos \omega_m t - V_{co})$$

$$= k_b (V_{cc} - V_{co}) \left[1 + \frac{V_{mm} \cos \omega_m t}{V_{cc} - V_{co}}\right] \quad \ldots(4.54)$$

$$= k_b (V_{cc} - V_{co}) (1 + m_a \cos \omega_m t) \quad \ldots(4.55)$$

$$= I_{bb} (1 + m_a \cos \omega_m t) \quad \ldots(4.56)$$

Tank circuit voltage is the desired A.C. output voltage and is given by,

$$V_o = j X I_t \quad \ldots(4.57)$$

where X is the reactance of either the inductor or capacitor at the resonant frequency ω_c.

Eq. (4.57) may be put as,

$$V_o = j X k_t (V_{cc} - V_{co}) (1 + m_a \cos \omega_m t) \quad \ldots(4.58)$$

The instantaneous output voltage is then given by,

$$v_o = \sqrt{2} X k_t (V_{cc} - V_{co}) (1 + m_a \cos \omega_m t) \sin (\omega_c t + 90°)$$

$$= \sqrt{2} X k_t (V_{cc} - V_{co}) (1 + m_a \cos \omega_m t) \cos \omega_c t \qquad \ldots(4.59)$$

DC Input power=?

AC output power=?

Plate circuit Efficiency=?

Plate dissipation=?

CONCLUSION: ?????

4. Cathode modulation

4.9. Cathode Modulation

In cathode modulation, the modulation voltage is introduced in the cathode circuit of the modulated amplifier as shown in Fig. 4.11.

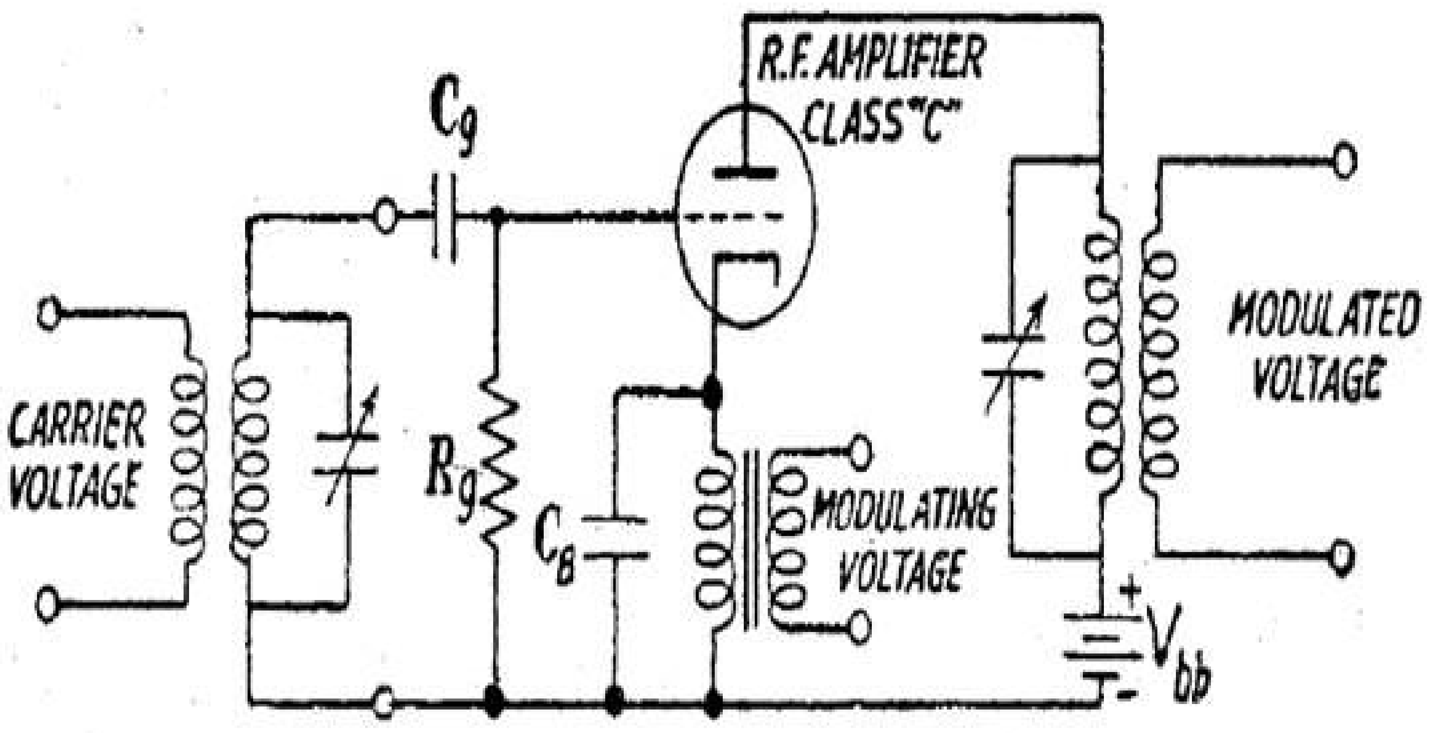


Fig. 4.11. Basic circuit of cathode modulation.

Working:- of cathode modulation

The cathode circuit is common to both the grid circuit and the plate circuit and hence the modulating voltage appears in both the grid and the plate circuits. Both the grid bias modulation and plate modulation of the carrier, therefore, take place. Cathode modulation, therefore, has characteristics intermediate between those of plate modulation and grid bias modulation. Thus the plate circuit efficiency, power output and modulation power requirement are less than those for plate modulation but more than those for grid bias modulation.

The proportion of grid bias modulation and plate modulation depends upon the circuit adjustments. Thus the proportion of plate modulation may be increased by (*i*) increasing the grid bias and (*ii*) by increasing the modulating voltage amplitude. With grid leak biasing arrangement, grid bias may be increased by increasing the value of grid leak resistance R_g.

5. Suppressor Grid modulation

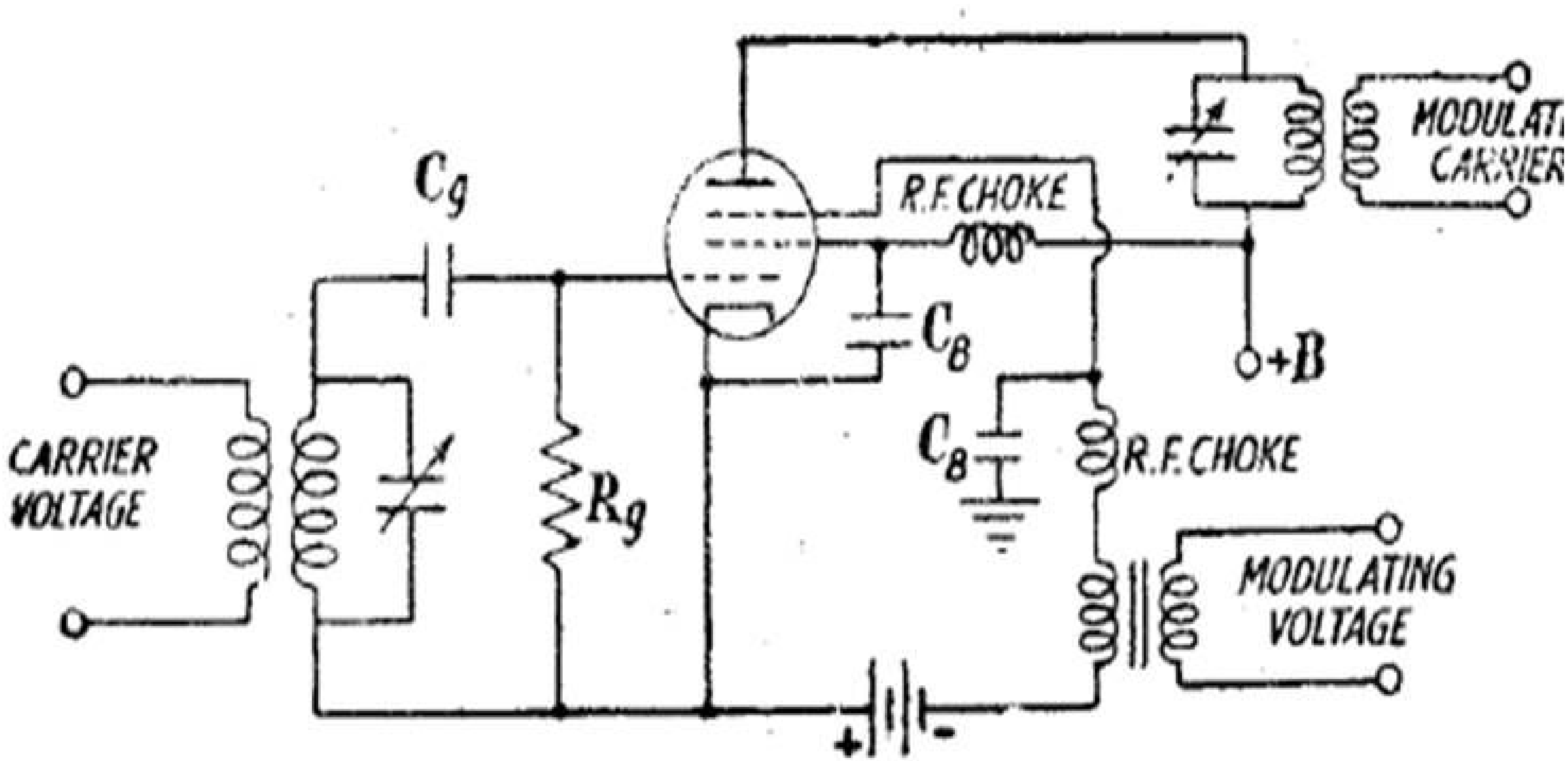
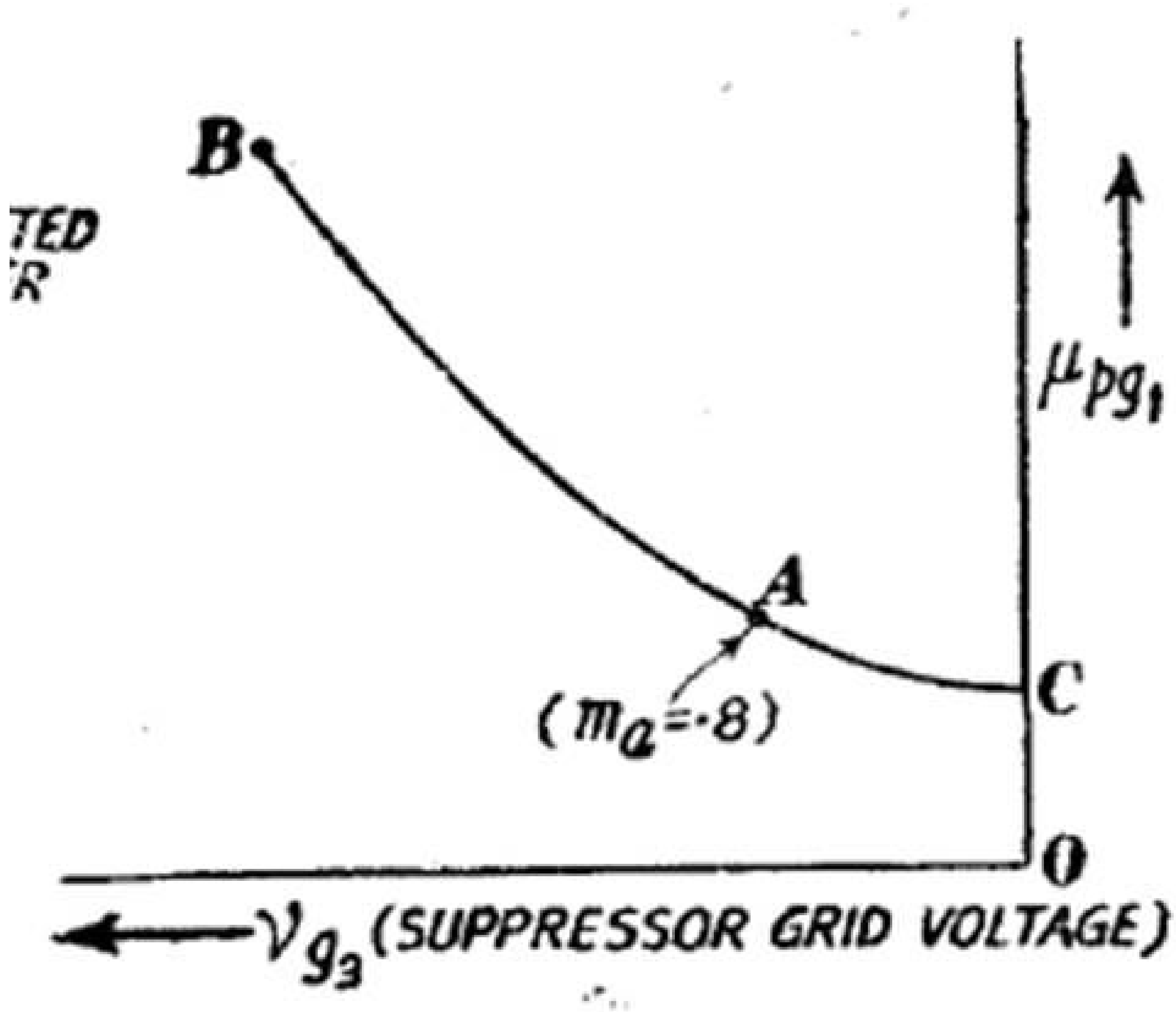


Fig. 4.12. Basic circuit of suppressor grid modulated amplifier.

Fig. 4

Working:-

This method of modulation consists in using a pentode in a class *C* modulated amplifier and applying the modulating voltage to the suppressor grid. The suppressor grid is biased sufficiently negatively and the modulation voltage and this bias are so adjusted that the modulation characteristic lies almost entirely in the region of negative suppressor grid voltage. The suppressor grid current is then zero and hence modulation power required is zero. Fig. 4.12 shows the basic circuit arrangement.



4.13. Modulation characteristic in suppressor grid modulation.

Contd.

This method of modulation is based on the property that μ_{pg1p}, *i.e.* the amplification factor between plate and control grid is a function of the suppressor grid voltage v_{g3}. Thus by varing v_{g3}, the output voltage may be varied. Fig. 4.13 shows the modulation characteristic of a suitably adjusted pentode. It is seen that the modulation curve is substantially linear upto about 80% modulation beyond which curve bends. Hence the system cannot produce linear modulation upto 100%.

6. Screen grid Modulation

This method of modulation is similair to grid bias modulation and suppressor grid modulation

Numericals:

Example 4.1. *In a linear series plate modulated amplifier, the plate supply voltage is 300 volts and the D.C. plate current under unmodulated condition is 20 amperes. The sinusoidal modulating voltage which appears in the plate circuit of modulated amplifier has amplitude of 150 volts. The unmodulated output carrier power is 4.5 kW. Calculate (i) the modulation index (ii) carrier power under modulated condition (iii) plate circuit efficiency and (iv) plate dissipation under unmodulated and modulated conditions.*

Solution: next slide

Solution. Modulation index

$$m_a = \frac{V_{mm}}{V_{bb}} = \frac{150}{300} = 0.5 \quad (1)$$

D.C. power from plate supply source is given by,

$$P_{bb} = V_{bb} \, . \, I_{bb} = 320 \times 20 = 6000 \text{ watts}$$

A.C. output carrier powr 4500 watts

Hence plate circuit efficiency

$$\eta_p = \frac{4500}{6000} \times 100 = 75\% \quad (3)$$

Carrier power under modulated condition is given by

$$P = P_c\left[1 + \frac{m_a^2}{2}\right] = 4500\left[1 + \frac{(0.5)^2}{2}\right] = 5062 \text{ watts} \quad (2)$$

Plate dissipation without modulation is given by

$$P_{PO} = P_{bb} - P_c = (6000 - 4500) = 1500 \text{ watts}$$

Plate dissipation under modulated condition is given by (4)

$$P_p = P_{PO}\left[1 + \frac{m_a^2}{2}\right] = 1500\left[1 + \frac{(0.5)^2}{2}\right] = 1688 \text{ watts.}$$

Example 4.2. *A linear series plate modulated class C amplifier uses plate supply voltage of 1100 volts and has plate circuit efficiency of 70 per cent. The unmodulated carrier power is 7.7 kW. Calculate (i) the power fed from plate supply source. (ii) the d.c. component of plate current under unmodulated condition and (iii) plate dissipation with no modulation. If the carrier is now modulated to a depth of 60 per cent by a sinusoidal voltage from a class A modulating amplifier, calculate (i) amplitude of modulating voltage, (ii) plate dissipation in modulated amplifier with modulation and (iii) audio power fed from modulating amplifier into modulated amplifier. The modulating* A_1 *amplifier has maximum plate circuit efficiency of 25 per cent and it is designed to produce audio output to produce a maximum of 100 per cent modulation. Calculate the overall efficiency of modulating amplifier and modulated amplifier together for modulation of zero and 60 per cent.*

solution: next slide

Solution. Power from plate supply source is modulated amplifier is given

$$P_{bb} = \frac{P_c}{\eta_b}$$

where P_c is the unmodulated carrier power and η_b is the plate circuit efficiency

Hence $$P_{bb} = \frac{7.7 \text{ kW}}{0.7} = 11 \text{ kW}$$

D.C. plate current under unmodulated condition is given by

$$I_{bo} = \frac{P_{bb}}{V_{bb}} = \frac{11,000 \text{ watts}}{1100 \text{ volts}} = 10 \text{ amperes}$$

Plate dissipation with no modulation is given by

$$P_{p1} = P_{bb} - P_c = (11 - 7.7) \text{ kW} = 3.3. \text{ kW}$$

Plate dissipation with modulation is given by

$$P_{p2} = P_{p1}\left[1 + \frac{m_a^2}{2}\right] = 3.3\left[1 + \frac{(0.6)^2}{2}\right] = 3.894 \text{ kilowatts}$$

Solve remaining parts.

Example 4.3. *In a linear series plate modulated amplifier, plate supply voltage V_{bb} = 1000 volts, resistance of coil in tuned circuit is 5 ohms, Q of plate tuned circuit is 50, no modulation d.c. plate current = 10 amperes and r.m.s tank current with zero modulation I_{to} = 38 amperes. On application of sinusoidal modulating voltage from a class A_1 amplifier, carrier power increases to 7.82 kW. Calculate (i) d.c. input power from plate supply source, (ii) plate circuit efficiency (iii) unmodulated carrier power, (iv) r.m.s. plate current with zero modulation, (v) modulation index, (vi) amplitude of modulating voltage, (vii) average power fed from the modulating amplifier (viii) plate dissipation in modulated amplifier with and without modulation.*

Solution:see next slide

Solution. (*i*) D.C. input power from supply source is given by

$$P_{bb} = V_{bb} \cdot I_{bb} = 1000 \text{ volts} \times 10 \text{ amperes} = 10,000 \text{ watts}$$

(*ii*) r.m.s tank current I_t is related to the instantaneous plate supply voltage v_{bb} by the relation.

$$I_t = k_1 \cdot v_{bb}$$

With zero modulation

$$I_{to} = k_{to} V_{bb}$$

or

$$k_t = \frac{I_{to}}{V_{bb}} = \frac{38 \text{ amperes}}{1000 \text{ volts}} = 0.038 \text{ mho}$$

Further d.c. plate curent I_b is related to v_{bb} by the relation.

$$I_b = k_{bb} \cdot V_{bb}$$

With zero modulation

$$I_{bb} = k_b \cdot V_{bb}$$

or

$$k_b = \frac{I_{bb}}{V_{bb}} = \frac{10 \text{ amperes}}{1000 \text{volts}} = 0.01 \text{ mho}$$

But

$$Q^2 = \frac{R_o}{R}$$

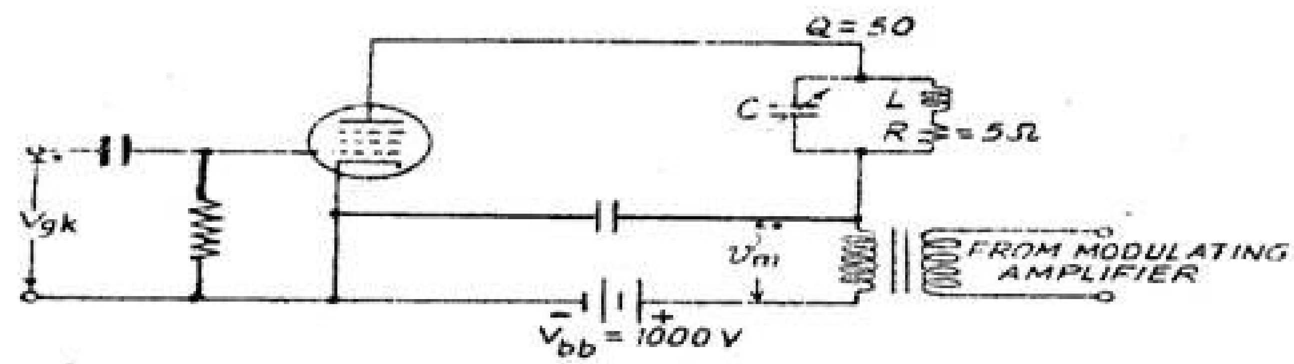


Fig. 4.24.

Where R_0 is the impedance of the tuned circuit at resonance.

Hence $R_0 = Q^2 \cdot R = (50)^2 \cdot 5 = 12,500$ ohms.

Hence plate circuit efficiency of class C modulated amplifier is given by

$$\eta_p = \frac{R_0 K_t^2}{K_t Q^2} = \frac{12,500 \times (0.038)^2}{0.01 \times (50)^2} = 0.724.$$

Percentage plate circuit efficiency = 72.4%

(*iv*) Unmodulated carrier power is given by

$$P_c = P_{bb} \cdot \eta_p = 10,000 \times 0.724$$

$$= 7240 \text{ watts.}$$

Solve remaining parts

Example 4.4. *A linear series plate modulated class C amplifier has plate supply voltage V_{bb} = 1000 volts and has plate circuit efficiency of 75 per cent. The unmodulated carrier power is 8 kilowatts. The carrier is amplitude modulated to a depth of 50 per cent by a sinusoidal voltage from a class B pushpull modulating amplifier which has maximum plate circuit efficiency of 66.66 per cent at 100 per cent modulation and whose plate circuit efficiency is proportional to modulation index. Calculate (i) d.c. input power from plate supply source in modulated amplifier (ii) d.c. current drawn from the supply in modulated amplifier, (iii) plate dissipation with and without modulation, (iv) amplitude of modulating voltage, (v) audio power fed from the modulating amplifier into the modulated amplifier. (vi) overall efficiency of modulated amplifier and modulating amplifier together under unmodulated and modulated conditions.*

Sol: solve as Assignment Question

ASSIGNMENT Questions:

Q1. Draw circuit for Emitter Modulation. Show Input and output waveform?

Q2. Q1. Draw circuit for Base Modulation. Show Input and output waveform?

Any Questions.....????

THANK YOU………….!!!!!!!!!!!

References:

- Radio Engg. :By G K Mithal
- Electronic Communication: By George Kennedy