Huazhong University
of Science & Technology

Electronic Circuit of Communications

School of Electronic Information
and Commnications

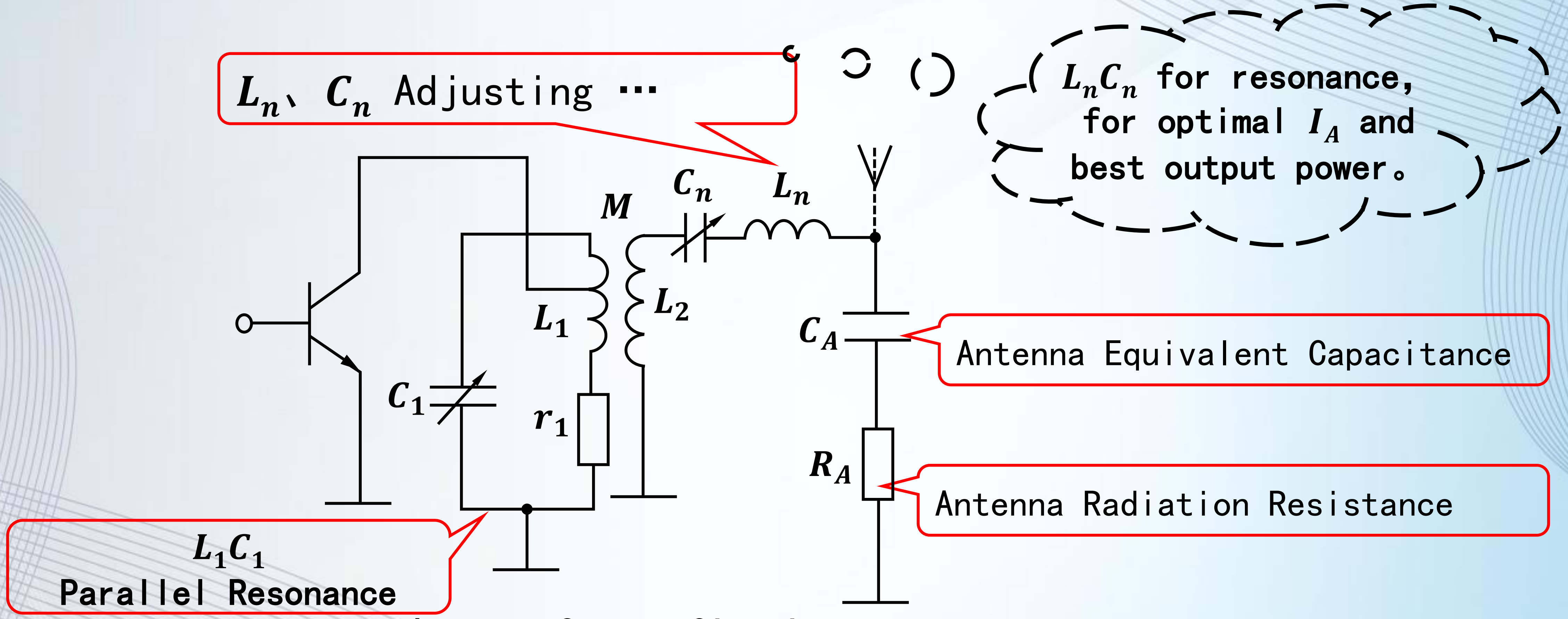
Jiaqing Huang

Power Amplifier Circuit

◆ Antenna Output Circuit

RF Power Amplifier—Antenna Output Circuit

➤ Aim: Antenna Circuit Coupling with Parallel Resonance by M

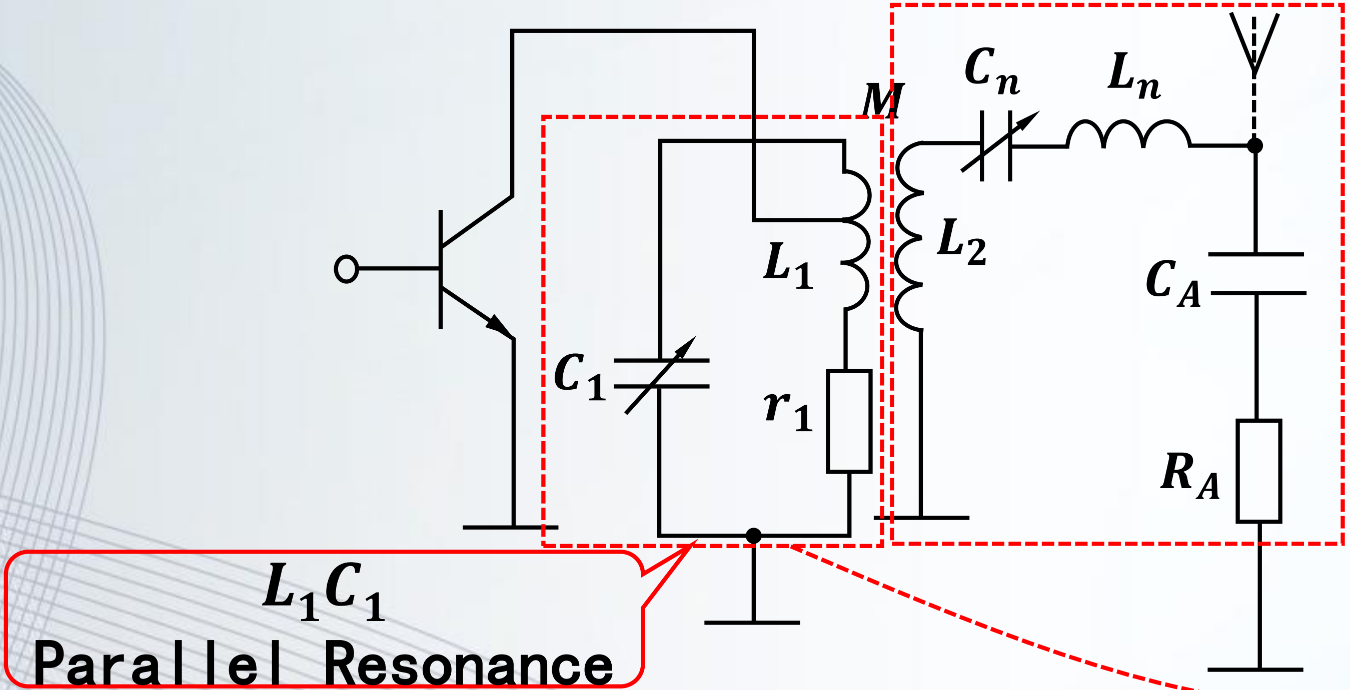


Antenna Output Circuit

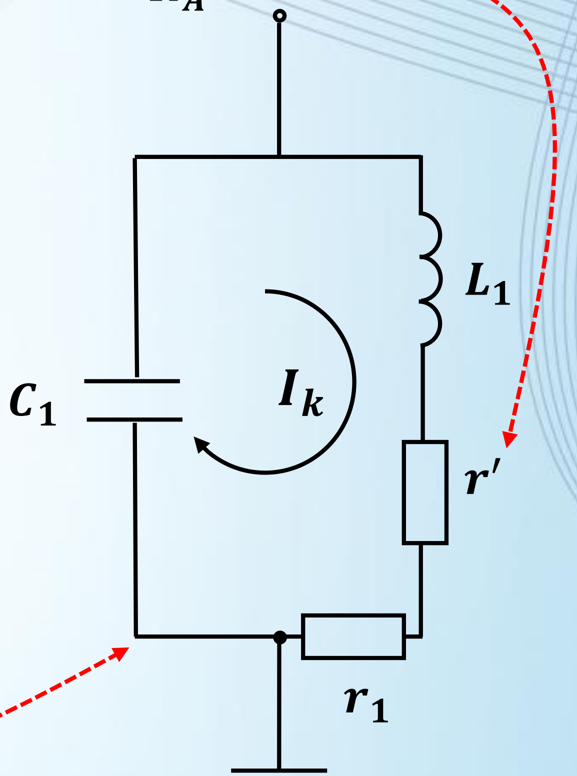
RF Power Amplifier—Antenna Output Circuit

- Reflected Impedance of Coupling Circuits
  - Reflected impedance r' from antenna to L_1C_1 :

$$r' = \frac{\omega^2 M^2}{R_A}$$



Antenna Output Circuit



L_1C_1 Equivalent Circuit

RF Power Amplifier—Antenna Output Circuit

- Reflected Impedance of Coupling Circuits
  - Reflected impedance r' from antenna to L_1C_1 :

$$r' = \frac{\omega^2 M^2}{R_A}$$

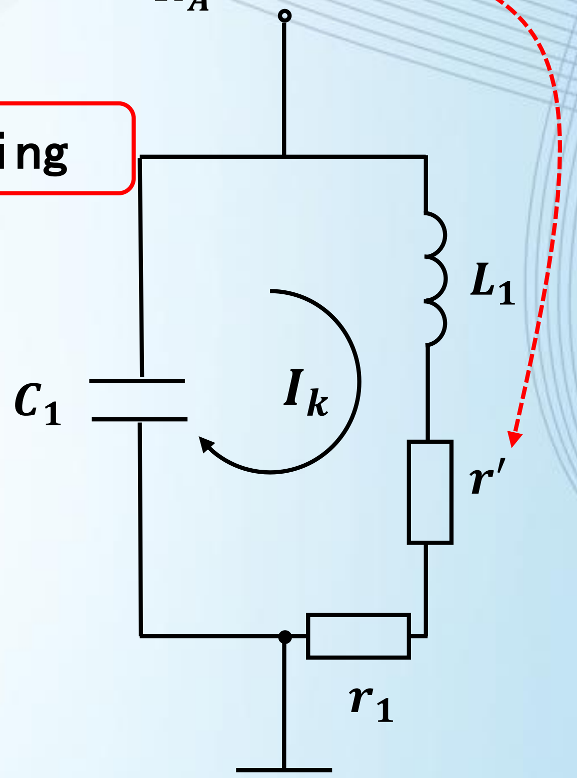
$$\boxed{R_p = \frac{L}{C}\frac{1}{R}} \qquad R'_p = \frac{L_1}{C_1(r_1 + r')} = \frac{L_1}{C_1\left(r_1 + \frac{\omega^2 M^2}{R_A}\right)}$$

M helps matching

  - For optimal power transmission to antenna R_A, Reflected Resistance $r' \gg$ Loss Resistance r_1

  - L_1C_1 **Efficiency η_k**: $= P_A / P_o$

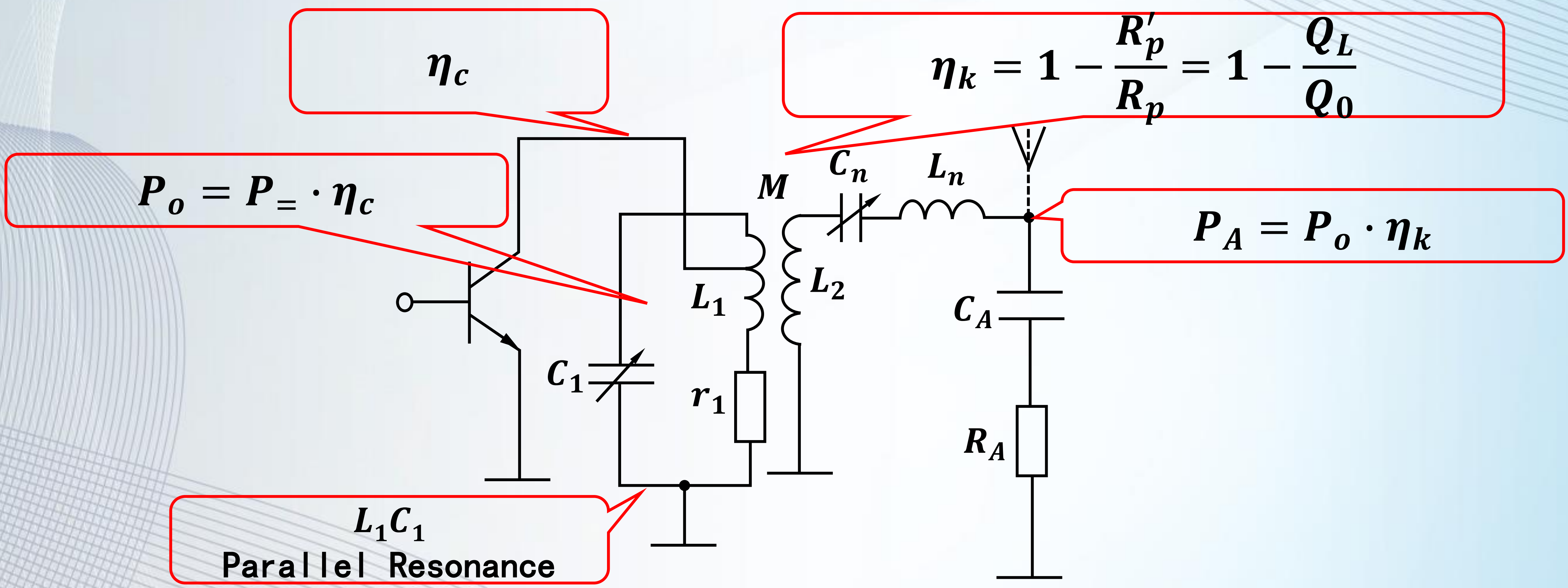
$$\eta_k = \frac{r'}{r_1 + r'} = 1 - \frac{r_1}{r_1 + r'} = 1 - \frac{R'_p}{R_p} = 1 - \frac{Q_L}{Q_0}$$



L_1C_1 Equivalent Circuit

RF Power Amplifier—Antenna Output Circuit

- Total Efficiency: $\eta = \dfrac{P_A}{P_=} = \dfrac{P_o}{P_=}\dfrac{P_A}{P_o} = \eta_c \cdot \eta_k$

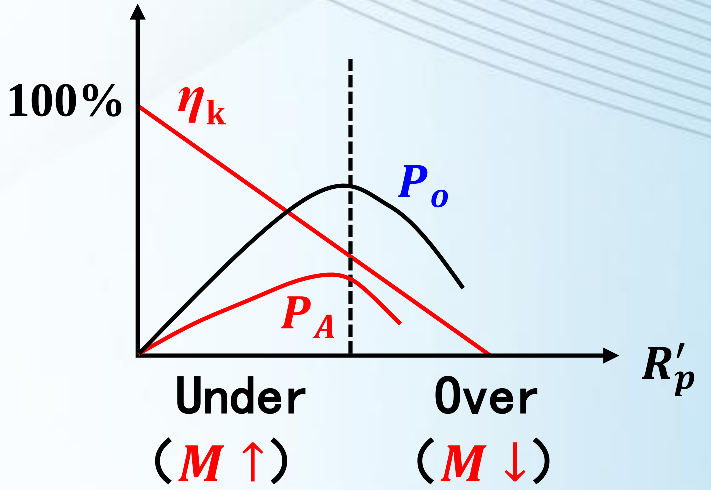


Antenna Output Circuit

RF Power Amplifier—Antenna Output Circuit

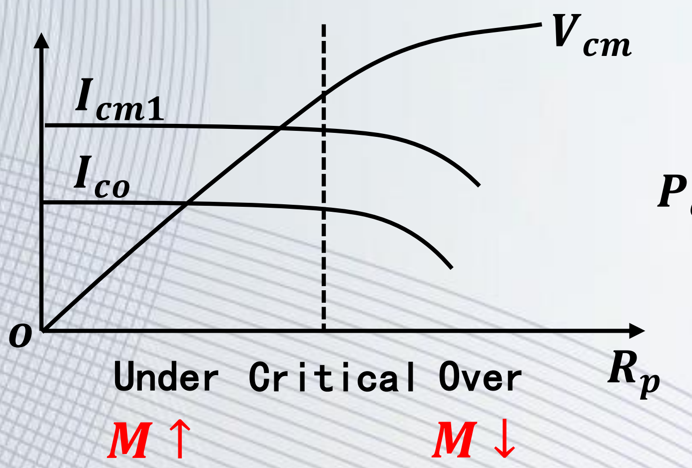
- After considering coupling antenna, L_1C_1 resonance resistance becomes R_p'

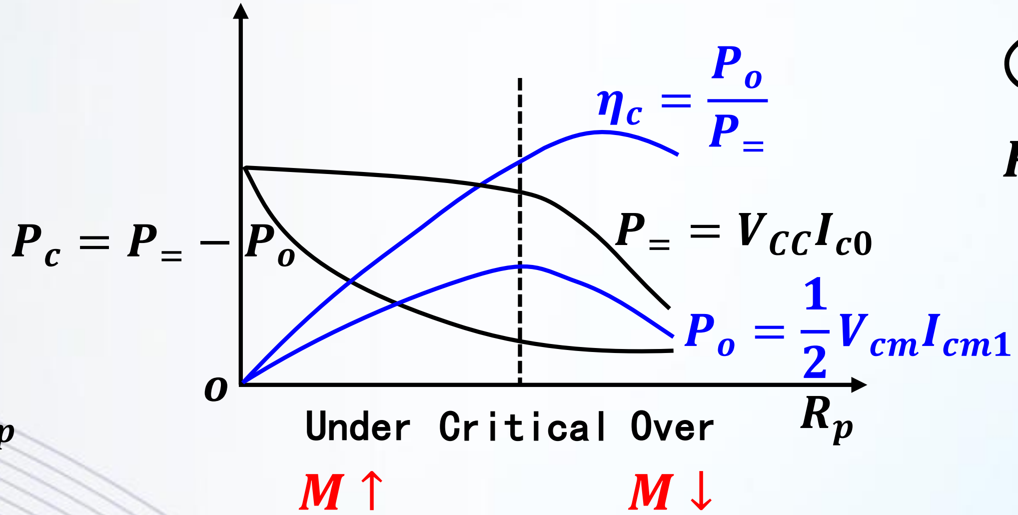
$$R_p' = \frac{L_1}{C_1(r_1 + r')} = \frac{L_1}{C_1\left(r_1 + \frac{\omega^2 M^2}{R_A}\right)}$$



R_p' vs. State

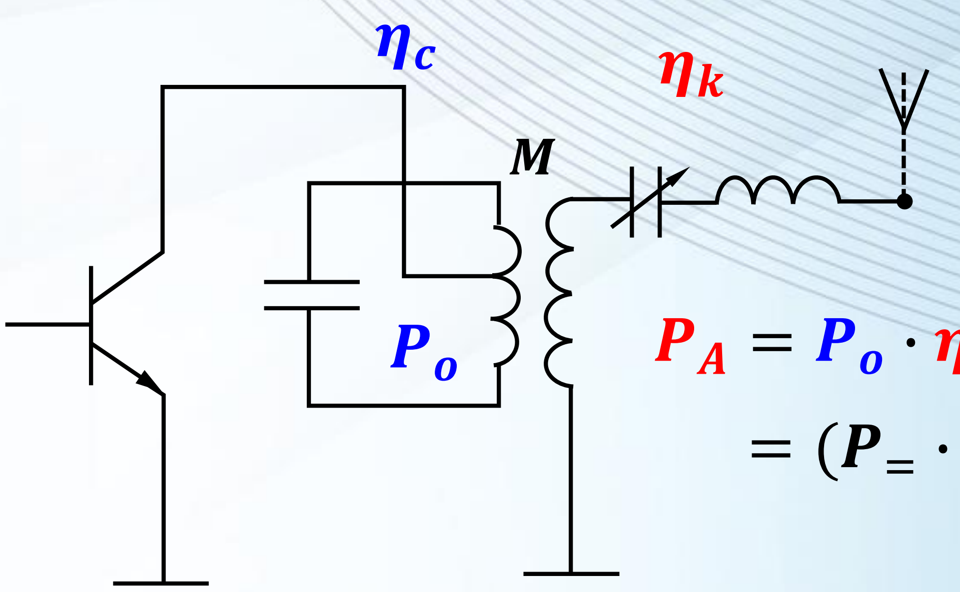
- State for $M\downarrow R_p'\uparrow$





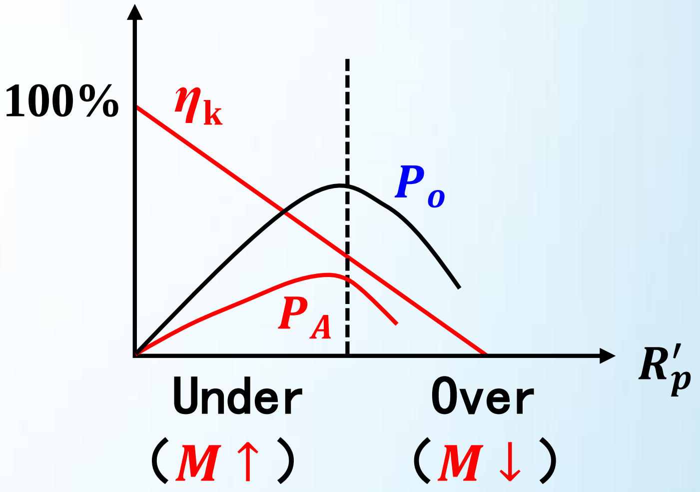
Summary

- Antenna Output Circuit
  - η_k and P_A

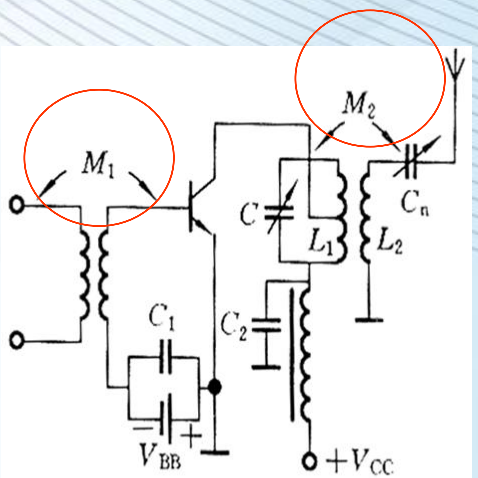


$$P_A = P_o \cdot \eta_k$$
$$= (P_= \cdot \eta_c) \cdot \eta_k$$

- R_p' vs. M with Operating State



Example 4-4 A resonant power amplifier is shown in Figure. The LC circuit and the load circuit have operated at resonance. And the amplifier is operating at critical state.



1. If M_2 is increased and V_{CC}, V_{BB}, M_1 are unchanged, how will the operating state of the amplifier change? Why?

2. If M_2 is increased, how should M_1 change such that the amplifier could still operate at critical state (V_{CC} and V_{BB} are unchanged)? Why?

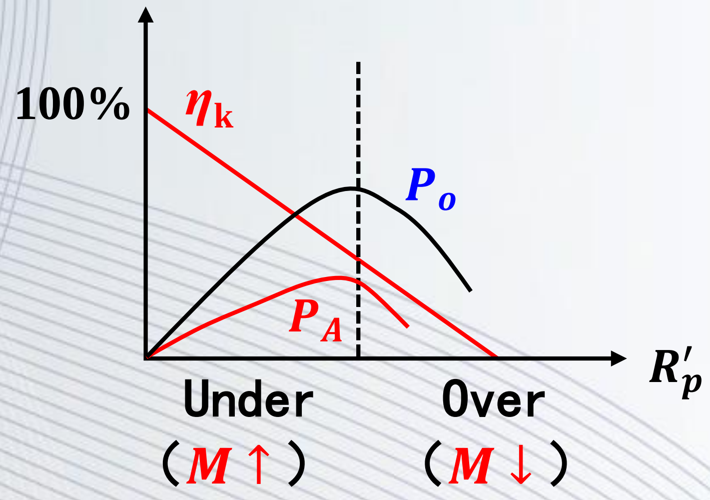
3. The resonant circuit operates at critical state. The transistor has the following operating conditions: the slope of the transfer characteristic curve $g_c = 0.8A/V$, $V_{BZ} = 0.6V$, $|V_{BB}| = 1V$, $\theta_c = 70°$, $V_{CC} = 24V$, and collector voltage utilization factor $\xi = 0.9$. And L_1C circuit has $Q_0 = 100$ and $Q_L = 10$. Determine the collector output power P_0 and the antenna power P_A.

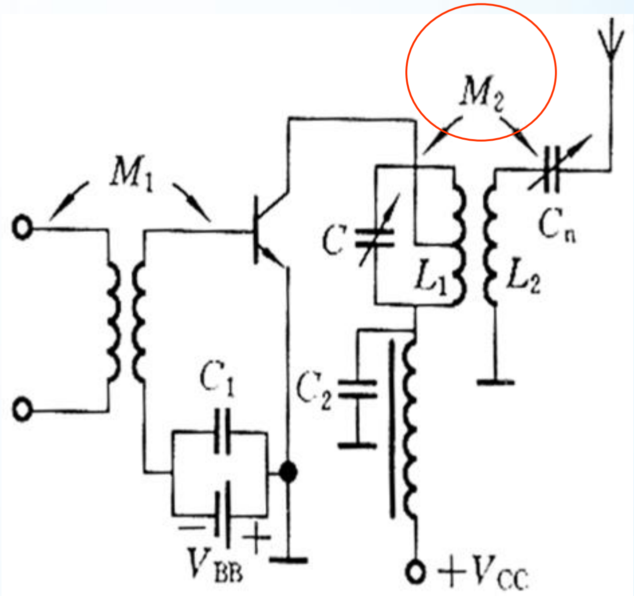
1. If M_2 is increased and V_{CC}, V_{BB}, M_1 are unchanged, how will the operating state of the amplifier change? Why?

Solution: From the equation of equivalent load resistance and M_2, it is known that R_p' will decrease if M_2 increases:

$$R_p' = \frac{L}{C[r_1 + \frac{(\omega M_2)^2}{R_A}]}$$

According to the load characteristic, the operating state of the amplifier tends to change from critical state to undervoltage state as R_p' decreases.



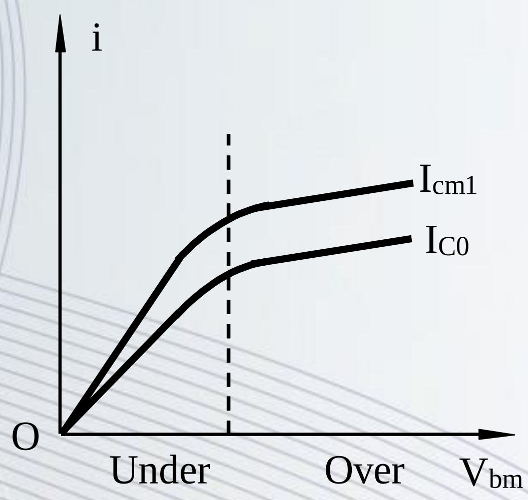


2. If M_2 is increased, how should M_1 change such that the amplifier could still operate at critical state (V_{CC} and V_{BB} are unchanged)? Why?

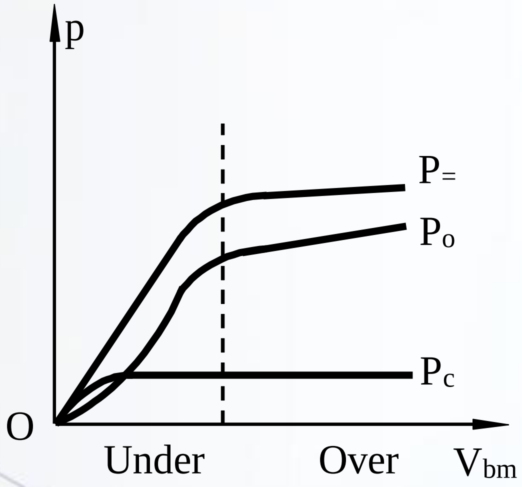
Solution:

If M_2 is increased and V_{CC}, V_{BB} are unchanged, M_1 must be increased in order to keep the amplifier still operating at critical state.

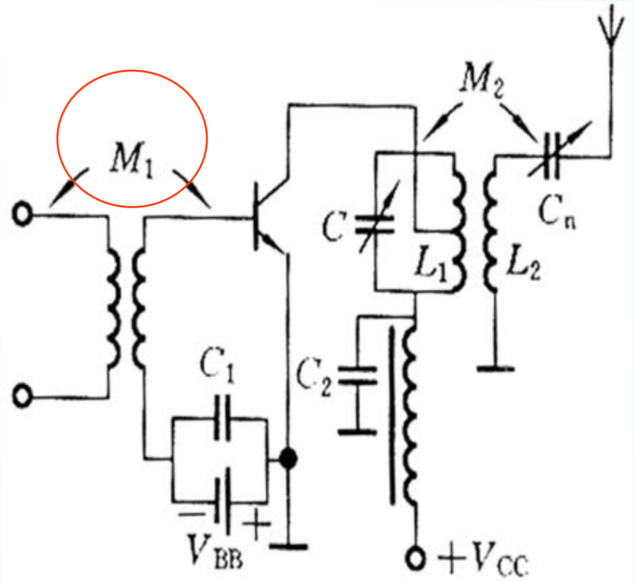
Because the input voltage V_{bm} will increase if M_1 is increased. And the operating state of the amplifier tends to change from undervoltage state to critical state as V_{bm} increases.



(a)



(b)



3. The resonant circuit operates at critical state. The transistor has the following operating conditions: slope of the transfer characteristic curve $g_c = 0.8A/V$, $V_{BZ} = 0.6V$, $|V_{BB}| = 1V$, $\theta_c = 70°$, $V_{CC} = 24V$, and collector voltage utilization factor $\xi = 0.9$. And L_1C circuit has $Q_0 = 100$ and $Q_L = 10$. Determine the collector output power P_0 and the antenna power P_A.

Solution: The maximum collector current is $i_{Cmax} = g_c V_{bm}(1 - cos\theta_c)$ ①

From the transfer characteristic, $V_{bm} cos\theta_c = V_{BB} + V_{BZ}$ ②

From simultaneous equations ① and ②, $V_{bm} = \frac{|V_{BB}| + V_{BZ}}{cos\theta_c} = \frac{1 + 0.6}{cos70°} = 4.71V$

$$i_{Cmax} = g_c V_{bm}(1 - cos70°) = 0.8 \times 4.71 \times (1 - 0.34)A = 2.49A$$

$$I_{cm1} = i_{Cmax} \cdot \alpha_1(70°) = 1.084A$$

$$V_{cm} = \xi V_{CC} = 0.9 \times 24V = 21.6V$$

Therefore, the collector output power P_0 is $P_0 = \frac{1}{2} I_{cm1} \cdot V_{cm} = \frac{1}{2} \times 1.084 \times 21.6W = 11.7W$

The antenna power P_A is $P_A = \eta_k \cdot P_0 = \left(1 - \frac{Q_L}{Q_0}\right) \cdot P_0 = 0.9 \times 11.7W = 10.54W$