$$\rightarrow \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2 \frac{1}{1+\frac{1}{E_c \cdot L}(V_{GS}-V_{th})}$$ (*)

MOS I-V characteristics

$$= \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2 \frac{1}{1+\theta(V_{GS}-V_{th})}$$

② Saturation region

$$I_{DS} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2 \frac{E_c \cdot L}{(V_{GS}-V_{th})+E_c \cdot L}(1+\lambda V_{DS})$$

$$\simeq \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2 \frac{E_c \cdot L}{(V_{GS}-V_{th})+E_c \cdot L}$$

$$= \underbrace{\frac{1}{2}\mu_n E_c}_{=v_{sat}} C_{ox} W (V_{GS}-V_{th})^2 \frac{1}{(V_{GS}-V_{th})+E_c \cdot L}$$

$$= v_{sat} \cdot W \cdot C_{ox} (V_{GS}-V_{th})^2 \frac{1}{(V_{GS}-V_{th})+E_c \cdot L}$$

↓ (if) $V_{GS}-V_{th} \gg E_c \cdot L$

$$\simeq v_{sat} \cdot W \cdot C_{ox} (V_{GS}-V_{th})$$

⇒ I_{DS} is linearly dependent on $(V_{GS}-V_{th})$.

⇒ For extreme case, $g_m = \frac{\partial I_{DS}}{\partial V_{GS}} = v_{sat} \cdot W \cdot C_{ox}$

⇒ g_m is constant, not dependent on biasing.

Q) How to determine $V_{DS,sat}$ at short channel case?