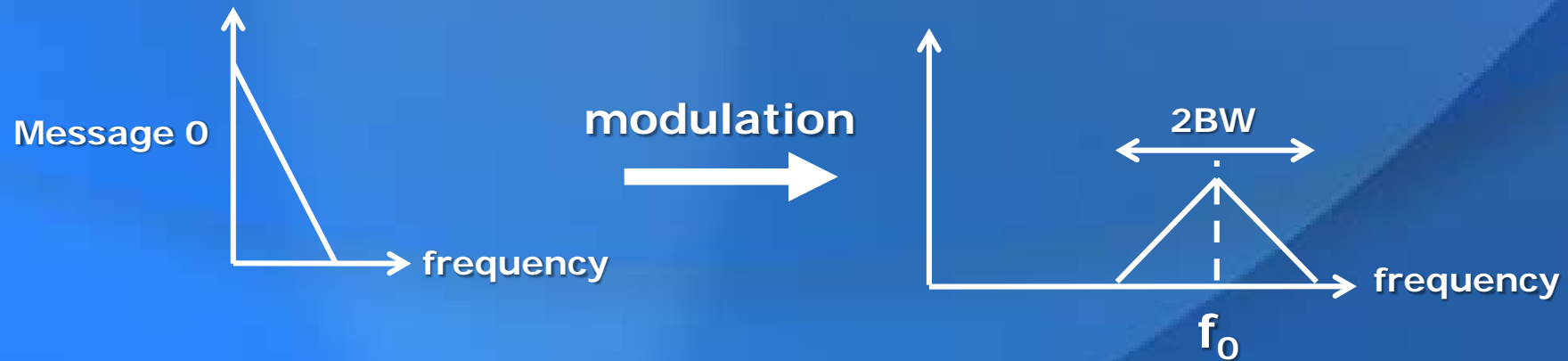
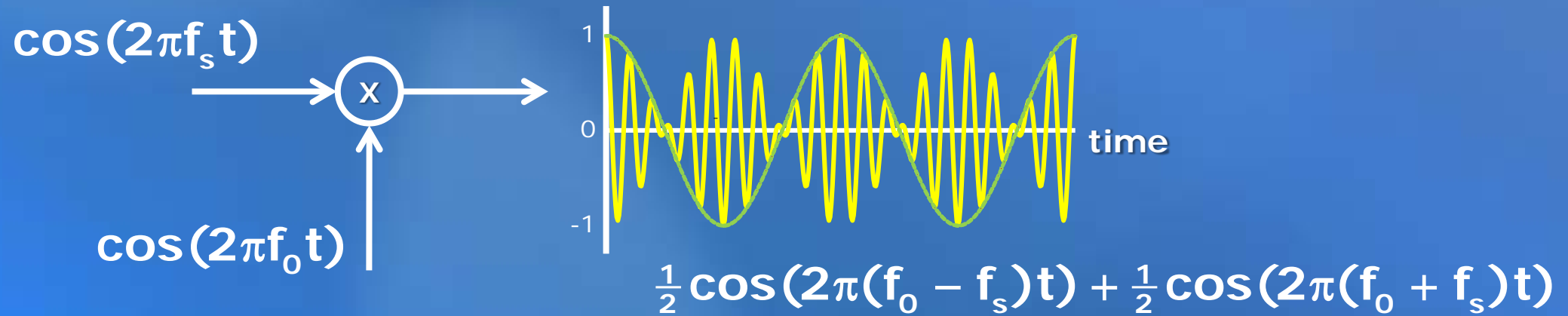


# Modulation with Complex Exponentials

# Modulation



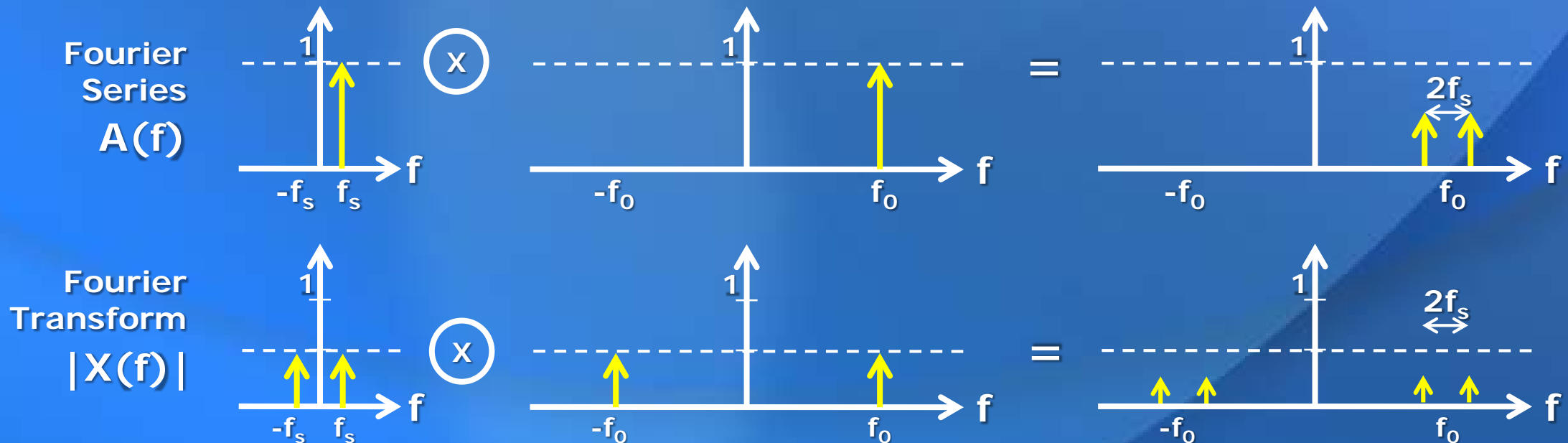
# Modulation with exponentials

signal:  $\cos(2\pi f_s t) = \frac{1}{2} e^{j2\pi f_s t} + \frac{1}{2} e^{-j2\pi f_s t}$

carrier:  $\cos(2\pi f_0 t) = \frac{1}{2} e^{j2\pi f_0 t} + \frac{1}{2} e^{-j2\pi f_0 t}$

The signals are multiplied (indicated by the 'X' in a circle):
 
$$\left( \frac{1}{2} e^{j2\pi f_s t} + \frac{1}{2} e^{-j2\pi f_s t} \right) \left( \frac{1}{2} e^{j2\pi f_0 t} + \frac{1}{2} e^{-j2\pi f_0 t} \right)$$

$$= \frac{1}{4} e^{j2\pi(f_0+f_s)t} + \frac{1}{4} e^{j2\pi(f_0-f_s)t} + \frac{1}{4} e^{j2\pi(-f_0+f_s)t} + \frac{1}{4} e^{j2\pi(-f_0-f_s)t}$$



# Frequency Division Multiplexing

Translate two baseband messages to frequency bands centered at  $f_0$  and  $f_1$

