Analog Transmission System

Summarize: Modulation

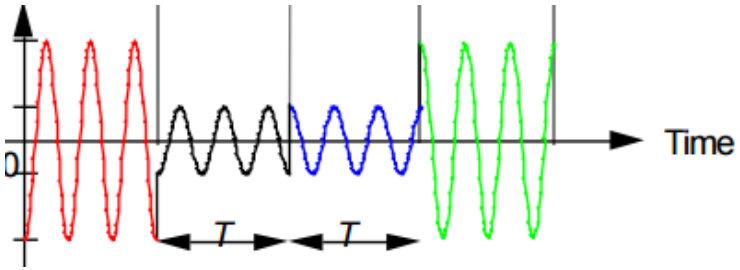
- Digital Modulation
  - Changing sinewave properties based on
    - Digital data
- Analog Modulation
  - Changing sinewave properties based on
    - Analog data

How digital data control sinewave properties?

Digital data '11001001' → Partition bits/baud '11' '00' '10' '01' → Select sinewave properties

↓

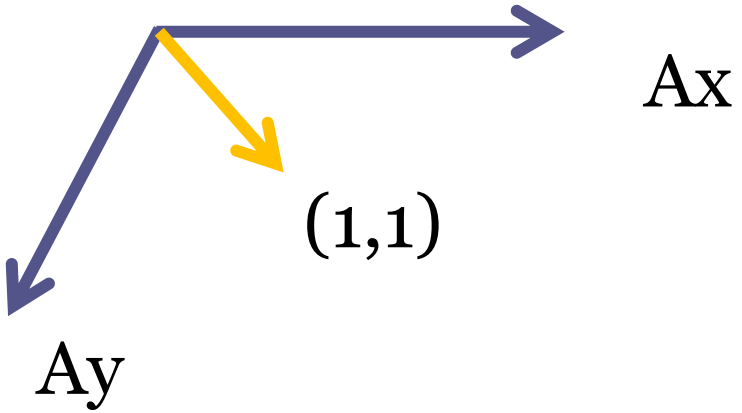
Generate sinewave for each baud ←

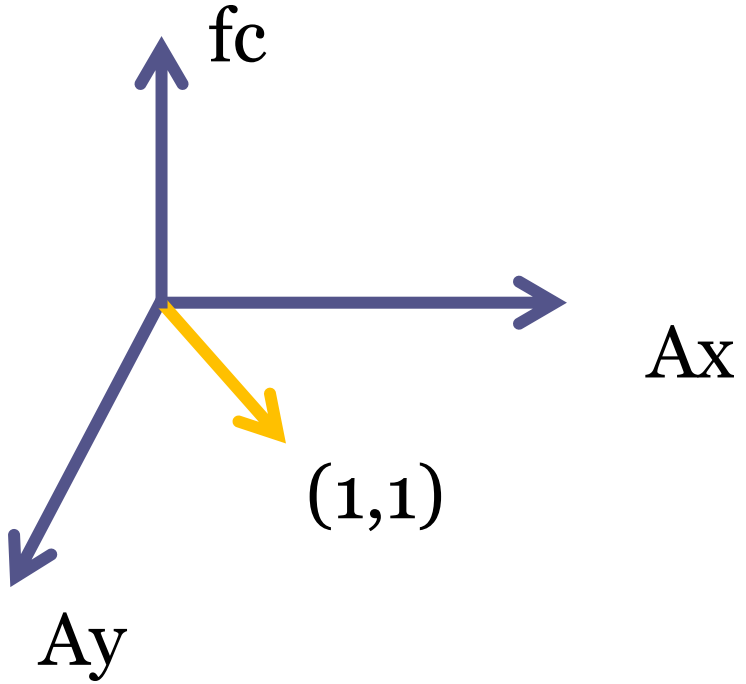


What is the relation between buad_rate vs cycles/baud ?

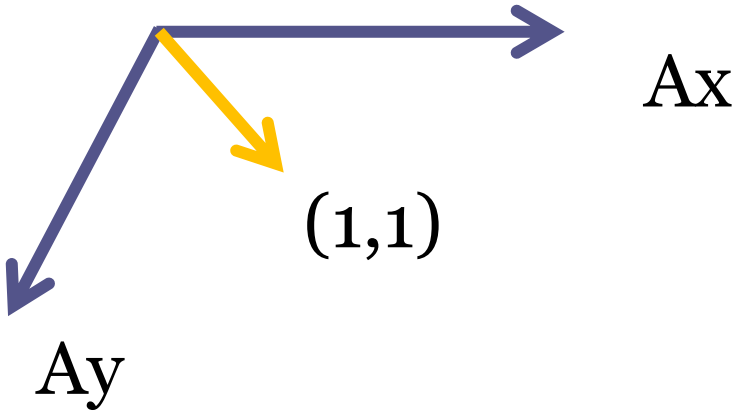
- Buad rate = signal units/s (Hz, baud)
- fc = carrier frequency (Hz)
- Cycles/baud = fc / baud_rate
  = Tbaud - Tfc
- Ex. Baud rate = 5 Hz, T = 0.2 s
  - fc = 10 Hz -> T = 0.1 s
  - cycles/baud = (10/5) = (0.2/0.1) = 2

Constellation Diagram

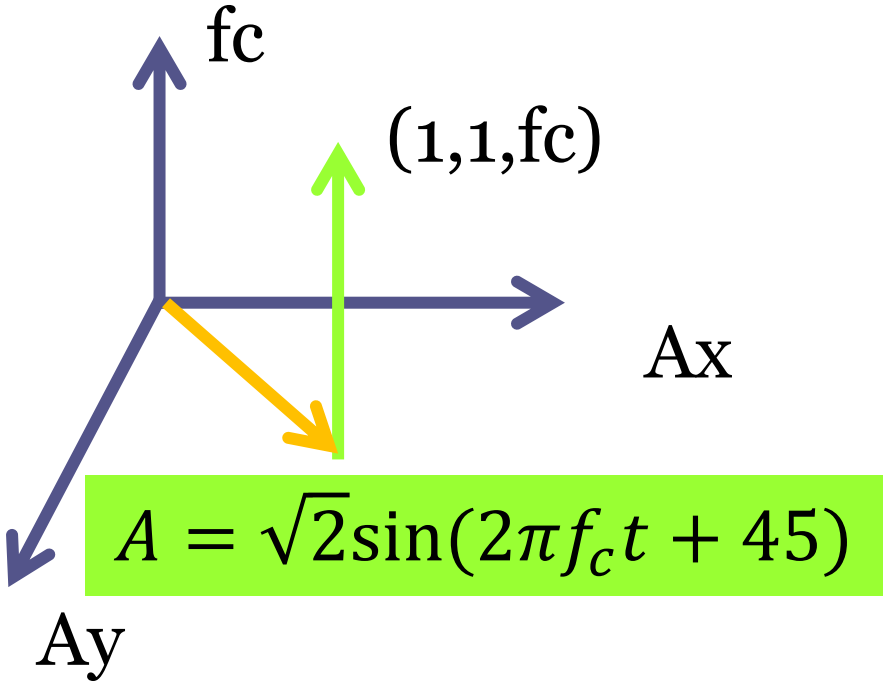




Adding frequency point of view to constellation diagram

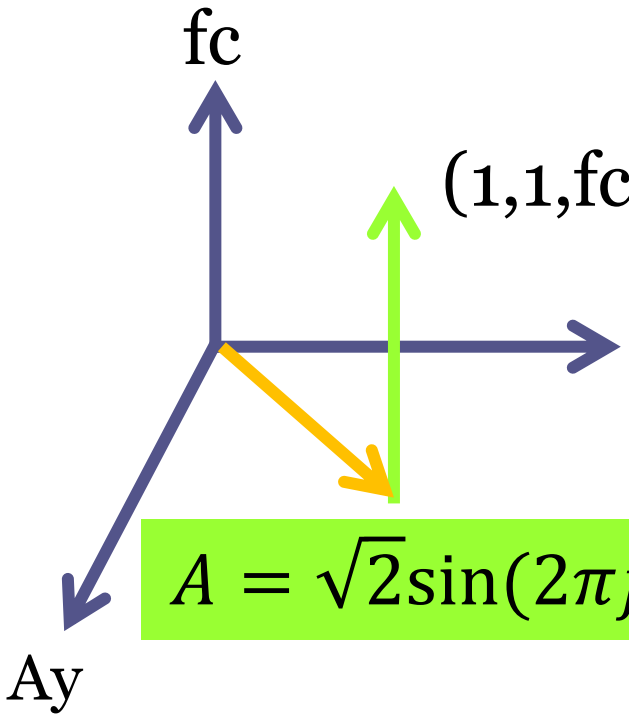


2D Constellation diagram



Adding frequency
Point of view

Adding frequency point of view to constellation diagram



$$A = \sqrt{2}\sin(2\pi f_c t + 45)$$

$$= \sqrt{2}((\sin(45) * \cos(2\pi f_c t)) + (\cos(45) * \sin(2\pi f_c t))$$

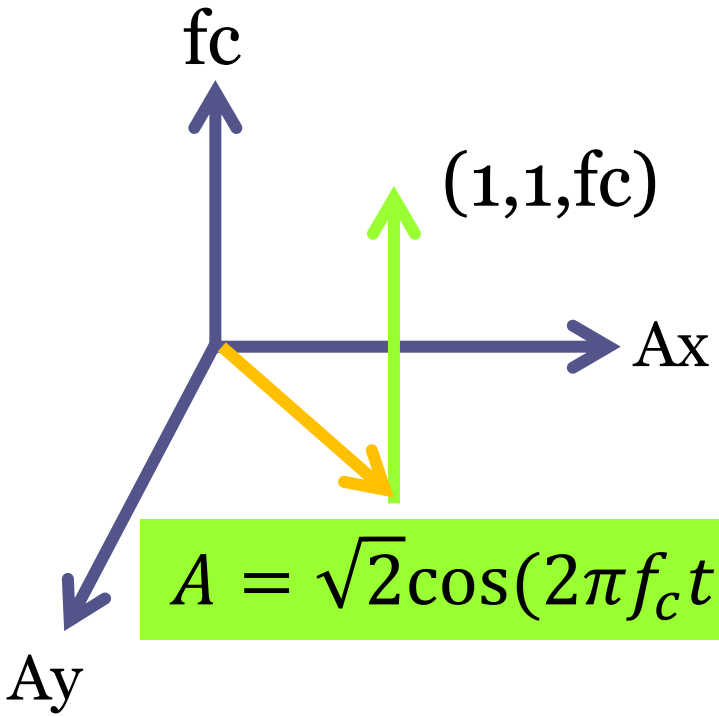
$$= \sqrt{2}((\mathrm{Ay} * \cos(2\pi f_c t)) + (\mathrm{Ax} * \sin(2\pi f_c t))$$

$$A = \sqrt{2}\sin(2\pi f_c t + 45)$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$
$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$
$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$
$$\cot A \pm B = \frac{\cot A \cot B \mp 1}{\cot B \pm \cot A}$$

Adding frequency
Point of view

Adding frequency point of view to constellation diagram



$$A = \sqrt{2}\cos(2\pi f_c t + 45)$$

$$= (\sin(45) * \cos(2\pi f_c t)) + (\sin(45) * \sin(2\pi f_c t)$$

$$= (\mathrm{Ax} * \cos(2\pi f_c t)) + (\mathrm{Ay} * \sin(2\pi f_c t)$$

$$A = \sqrt{2}\cos(2\pi f_c t + 45)$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$
$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$
$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$
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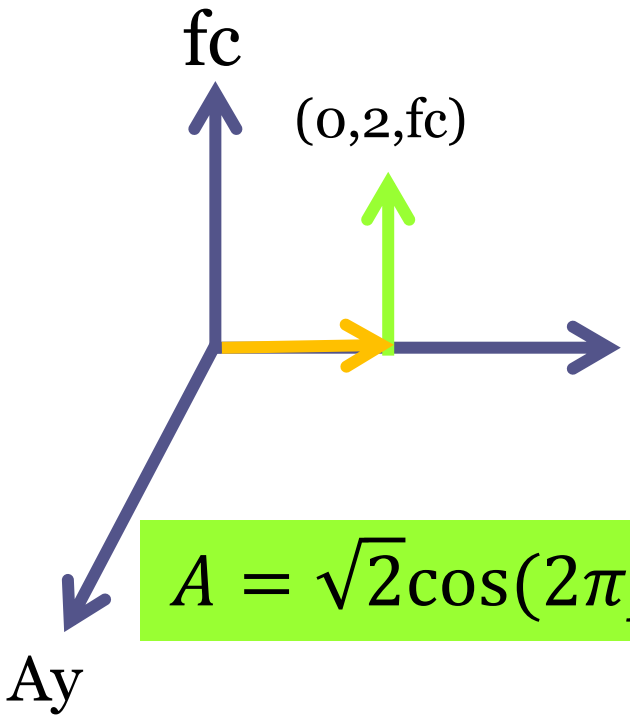
Adding frequency
Point of view

Ex: ASK



$$A = 2sin(2\pi f_c t + 0)$$

$$= 2((\sin(0) * \cos(2\pi f_c t)) + (\cos(0) * \sin(2\pi f_c t))$$

$$= 2((0 * \cos(2\pi f_c t)) + (1 * \sin(2\pi f_c t))$$

$$= 2\ \sin(2\pi f_c t)$$

$$A = \sqrt{2}\cos(2\pi f_c t + 45)$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

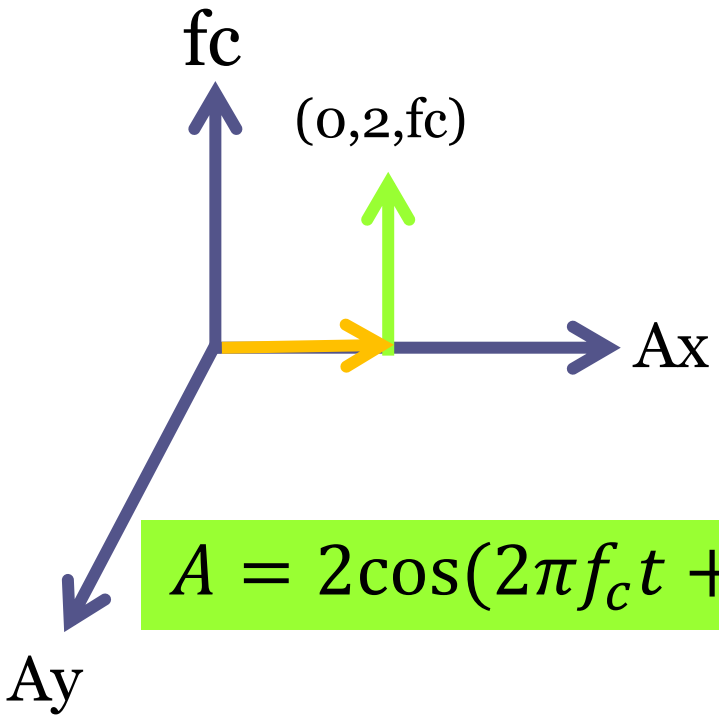
$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

$$\cot A \pm B = \frac{\cot A \cot B \mp 1}{\cot B \pm \cot A}$$

Adding frequency
Point of view

Ex: ASK



$$A = 2\cos(2\pi f_c t + 0)$$

$$= 2((\cos(0) * \cos(2\pi f_c t)) + (\sin(0) * \sin(2\pi f_c t))$$

$$= 2((1 * \cos(2\pi f_c t)) + (0 * \sin(2\pi f_c t))$$

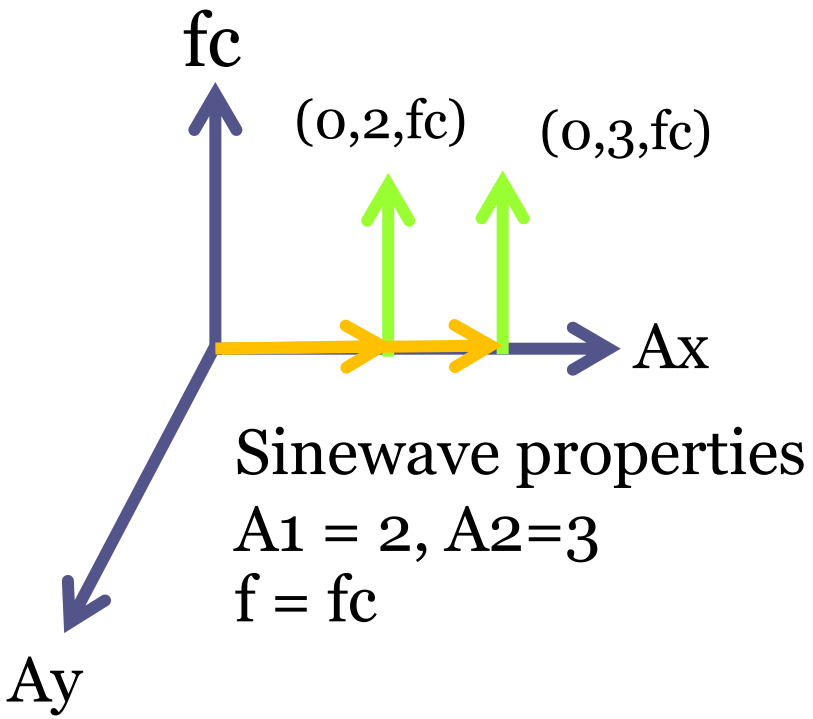
$$= 2\cos(2\pi f_c t))$$

$$A = 2\cos(2\pi f_c t + 0)$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$
$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$
$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$
$$\cot A \pm B = \frac{\cot A \cot B \mp 1}{\cot B \pm \cot A}$$

Adding frequency
Point of view

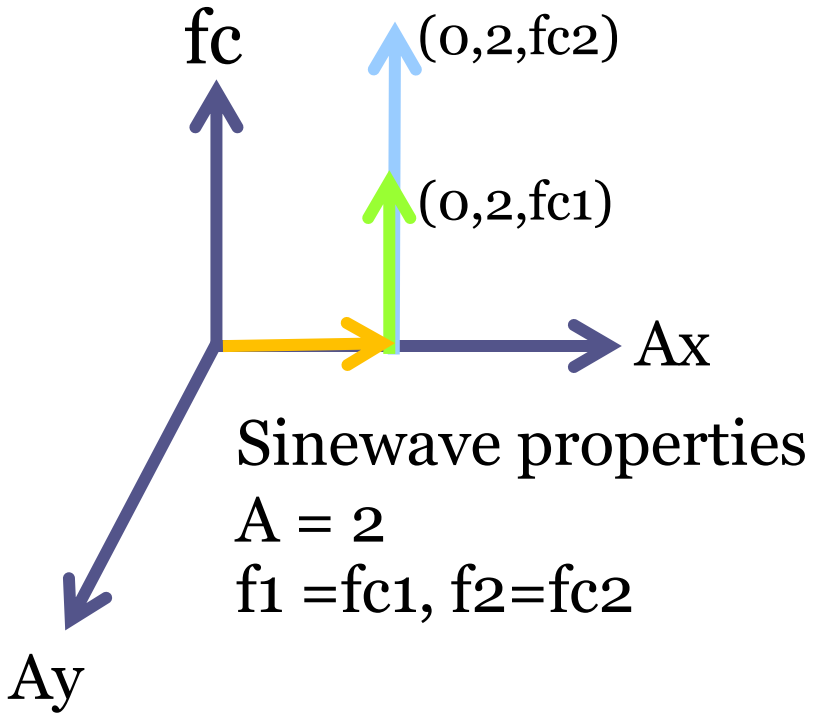
Ex: 2-ASK vs 2-FSK



Sinewave properties

A1 = 2, A2=3

f = fc



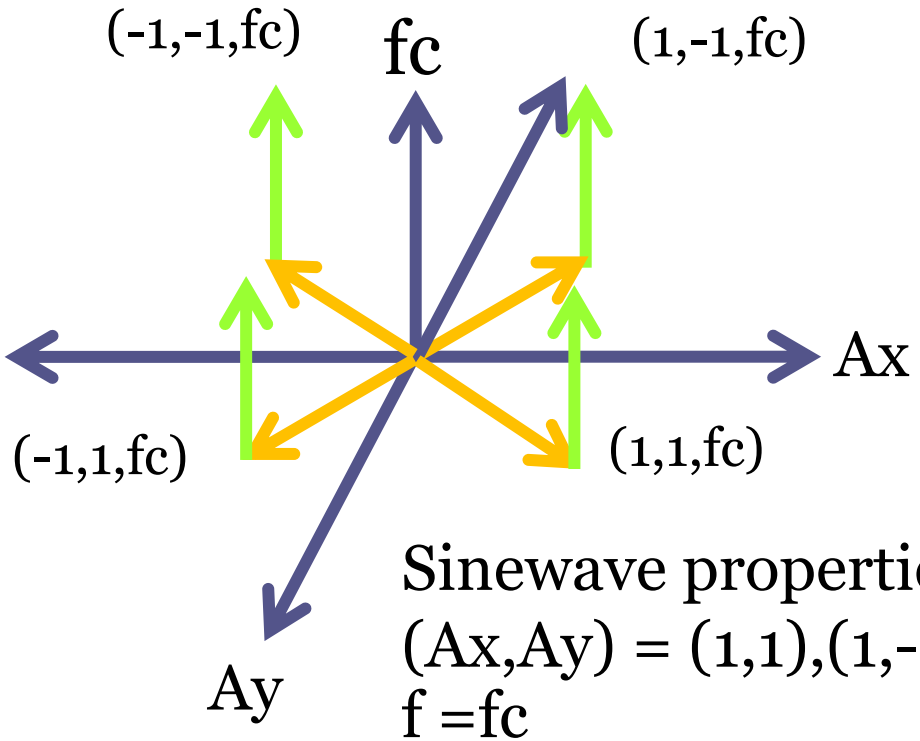
Sinewave properties

A = 2

f1 =fc1, f2=fc2

Adding frequency
Point of view

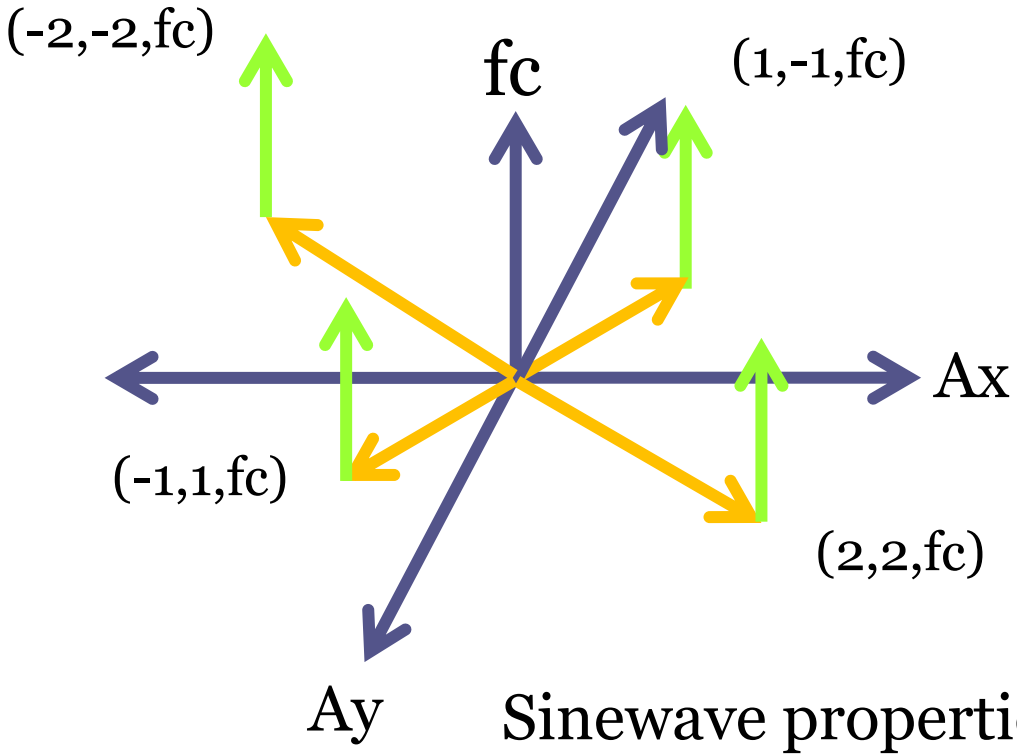
Ex: 4-PSK



Sinewave properties
(Ax,Ay) = (1,1),(1,-1),(-1,1),(-1,-1)
f =fc

Adding frequency
Point of view

Ex: 4-QAM



Sinewave properties

(Ax,Ay) = (2,2),(1,-1),(-1,1),(-2,-2)

f =fc

Adding frequency

Point of view

Bandwidth (BW) vs Baud rate (S)

- ASK & PSK & QAM (1 fc)
  - $BW = (1+d)\,S$ -> $S = BW/(1+d)$
  - $S <= BW <= 2S$ -> $(BW/2) <= S <= BW$
- FSK (multiple fc)
  - $BW = (f_{max} - f_{min}) + (1+d)\,S$
    - -> $S = BW-(f_{max} - f_{min})/(1+d)$
  - $(f_{max} - f_{min}) + S <= BW <= (f_{max} - f_{min}) + 2S$
    - -> $(BW-(f_{max} - f_{min})/2) <= S <= BW-(f_{max} - f_{min})$