

## Bab 7. Modulasi

Dr. Ir. Yeffry Handoko, M.T

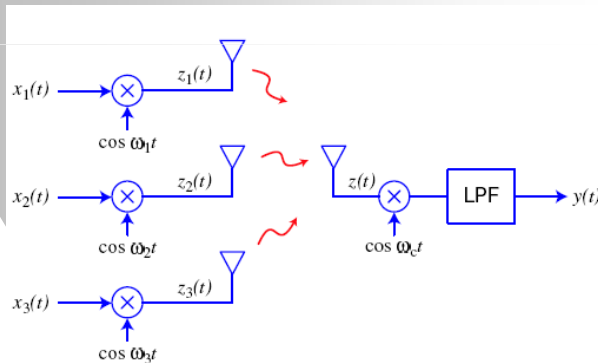
## Sistem Komunikasi

- ❖ Sinyal tidak selalu matching dengan media pengirim

Sinyal	Aplikasi
Audio	telepon, radio, phonograph, CD, Ponsel, MP3
Video	Televisi, sinema, HDTV, DVD
Internet	Coaxial, Twisted pair, cable TV, ADSL, Optical Fiber, E/M

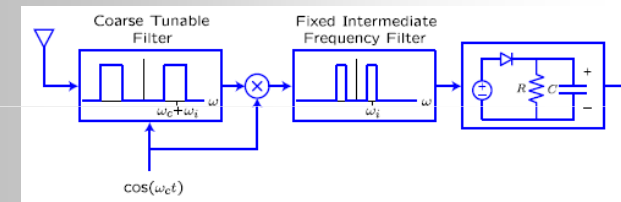
## Amplitude Modulation

- ❖ Amplitude Modulation dapat digunakan untuk menyelaraskan (match) frekuensi audio dengan frekuensi radio.
- ❖ AM juga dapat digunakan untuk transmisi paralel dari multi channel



## Superheterodyne Receiver

- ❖ Edwin Howard Armstrong menemukan penerima superheterodyne, yang membuat broadcast AM lebih praktis



- ❖ Edwin Howard Armstrong juga menemukan paten untuk rangkaian regeneratif (positive feedback) yang mengamplifikasi sinyal radio (saat ia masih junior di Universitas Columbia) Ia juga menemukan wideband FM



## Amplitude, Phase, and Frequency Modulation



- ❖ Cara-cara memasukan pesan pada gelombang pembawa (carrier), Tiga diantaranya

Amplitude Modulation (AM):  $y_1(t) = x(t) \cos(\omega_c t)$

Phase Modulation (PM):  $y_2(t) = \cos(\omega_c t + kx(t))$

Frequency Modulation (FM):  $y_3(t) = \cos\left(\omega_c t + k \int_{-\infty}^t x(\tau) d\tau\right)$

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## Frequency Modulation



- ❖ Pada FM, sinyal memodulasi frekuensi sinyal pembawa sesaat

$$y_3(t) = \cos\left(\omega_c t + \underbrace{k \int_{-\infty}^t x(\tau) d\tau}_{\phi(t)}\right)$$

$$\omega_i(t) = \omega_c + \frac{d}{dt}\phi(t) = \omega_c + kx(t)$$

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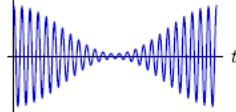


## Frequency Modulation

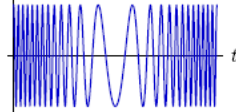


- ❖ Bandingkan AM dan FM

AM:  $y_1(t) = (\cos(\omega_m t) + 1.1) \cos(\omega_c t)$



FM:  $y_3(t) = \cos(\omega_c t + m \sin(\omega_m t))$



- ❖ Keuntungan FM:

- Daya konstan
- Tidak perlu mentransmitkan gelombang pembawa (kecuali DC)
- Bandwidth?

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## Frequency Modulation



- ❖ Peneliti dahulu berpikir narrowband FM dapat memiliki narrow band sembarang, membuat lebih banyak channel dari AM. Tapi salah

$$\begin{aligned} y_3(t) &= \cos\left(\omega_c t + k \int_{-\infty}^t x(\tau) d\tau\right) \\ &= \cos(\omega_c t) \times \cos\left(k \int_{-\infty}^t x(\tau) d\tau\right) - \sin(\omega_c t) \times \sin\left(k \int_{-\infty}^t x(\tau) d\tau\right) \end{aligned}$$

If  $k \rightarrow 0$  then

$$\cos\left(k \int_{-\infty}^t x(\tau) d\tau\right) \rightarrow 1$$

$$\sin\left(k \int_{-\infty}^t x(\tau) d\tau\right) \rightarrow k \int_{-\infty}^t x(\tau) d\tau$$

$$y_3(t) \approx \cos(\omega_c t) - \sin(\omega_c t) \times \left(k \int_{-\infty}^t x(\tau) d\tau\right)$$

- ❖ Bandwidth dari Narrowband FM sama dengan AM. (Pengintegralan tidak mengubah bandwidth)

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## Phase/Frequency Modulation



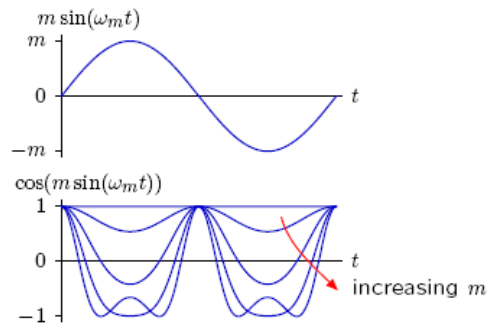
### ❖ Carilah Transformasi dari Sinyal PM

$$x(t) = \sin(\omega_m t)$$

$$y(t) = \cos(\omega_c t + m x(t)) = \cos(\omega_c t + m \sin(\omega_m t))$$

$$= \cos(\omega_c t) \cos(m \sin(\omega_m t)) - \sin(\omega_c t) \sin(m \sin(\omega_m t))$$

$x(t)$  is periodic in  $T = \frac{2\pi}{\omega_m}$ , therefore  $\cos(m \sin(\omega_m t))$  is periodic in  $T$ .



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## Phase/Frequency Modulation



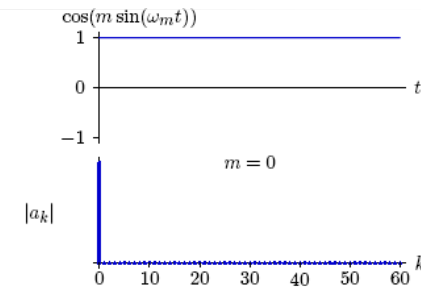
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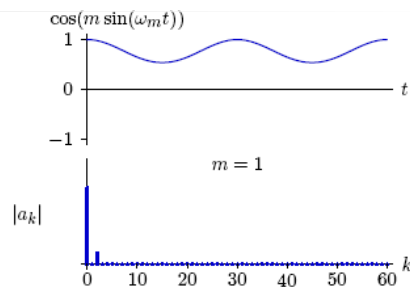
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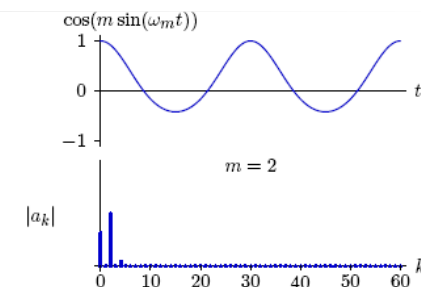
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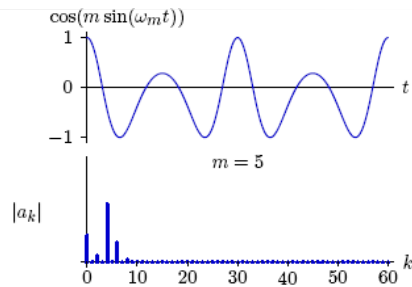
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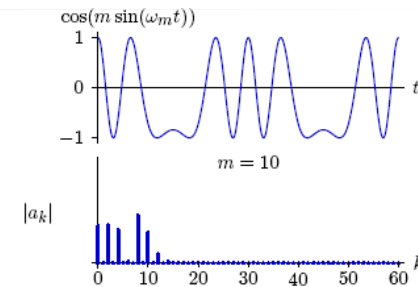
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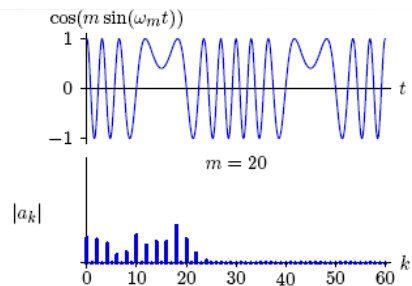
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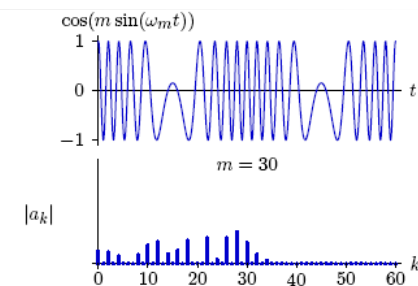
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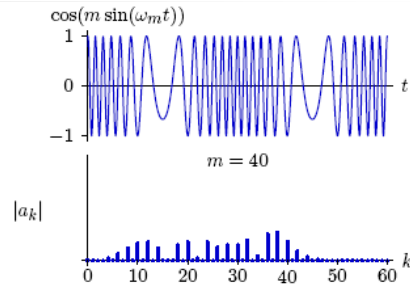
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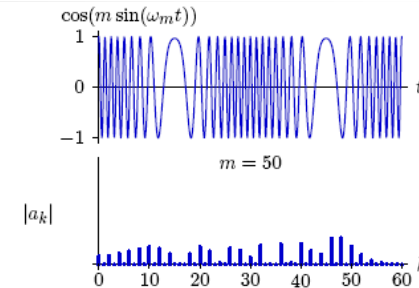
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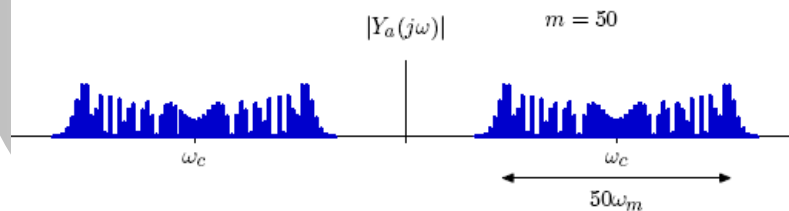


### ❖ Transformasi Fourier dari bag. pertama

$$x(t) = \sin(\omega_m t)$$

$$y(t) = \cos(\omega_c t + m x(t)) = \cos(\omega_c t + m \sin(\omega_m t))$$

$$= \underbrace{\cos(\omega_c t) \cos(m \sin(\omega_m t))}_{y_a(t)} - \sin(\omega_c t) \sin(m \sin(\omega_m t))$$



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## Phase/Frequency Modulation

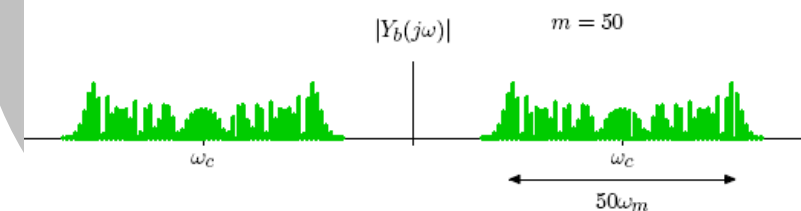


### ❖ Transformasi Fourier dari bag. kedua

$$x(t) = \sin(\omega_m t)$$

$$y(t) = \cos(\omega_c t + m x(t)) = \cos(\omega_c t + m \sin(\omega_m t))$$

$$= \cos(\omega_c t) \cos(m \sin(\omega_m t)) - \underbrace{\sin(\omega_c t) \sin(m \sin(\omega_m t))}_{y_b(t)}$$



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## Phase/Frequency Modulation

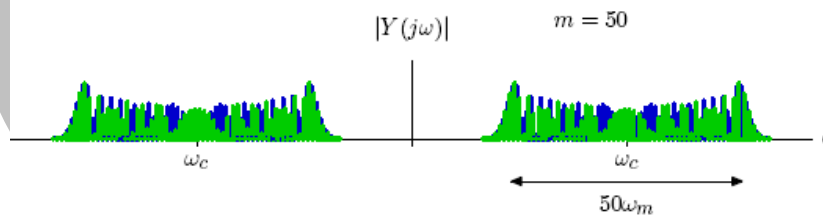


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## Frequency Modulation

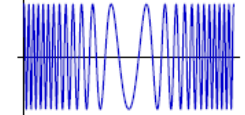


### ❖ Wideband FM sangat berguna karena tegar (robust) terhadap noise

$$\text{AM: } y_1(t) = (\cos(\omega_m t) + 1.1) \cos(\omega_c t)$$



$$\text{FM: } y_3(t) = \cos(\omega_c t + m \sin(\omega_m t))$$



### ❖ FM membangkitkan sinyal yg sangat redundan (berulang), yang mengurangi keberadaan noise

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