Telkom University

Diploma of Telecommunication Engineering

DTG2F3

Sistem Komunikasi

MODULASI ANALOG

By : Dwi Andi Nurmantris

Where We Are?

1. **PENDAHULUAN**
   - Perkenalan dan sosialisasi SAP&syllabus
   - Elemen dasar Sistem Komunikasi
   - Sistem komunikasi Analog Vs Digital
   - Sumber Informasi dalam sistem komunikasi
   - Kanal dalam sistem komunikasi
   - Teorema shanon
   - Modulasi (modulasi analog vs modulasi digital ; CW modulation vs pulse modulation)
2. **MODULASI ANALOG**
   - Modulasi , demodulasi, dan kinerja sistem AM
   - Modulasi, demodulasi, dan kinerja sistem FM
   - Aplikasi sistem AM dan FM (Radio Broadcasting, dan TV analog)
3. **TIPE-TIPE SALTRAN SISKOM DIGITAL → ADC, SOURCE CODING, MULTIPLEXING**
   - Analog to Digital converter (ADC)
   - Source Coding (Shanon faco coding dan huffman coding)
   - Multiplexing (Time Division Multiplexing (TDM) : PCM 30/E1 dan PCM 24/T1)
4. **SISKOM DIGITAL → Baseband Modulation**
   - Binary digit waveform
   - PCM waveform type
5. **SISKOM DIGITAL → Passband Modulation**
   - Modulasi ASK
   - Modulasi FSK
   - Modulasi PSK
   - Modulasi QAM
   - Modulasi GMSK
   - OFDM
6. **NOISE DALAM SISKOM**
   - Sumber Noise (internal dan external)
   - Shot Noise dan Thermal Noise
   - AWGN (Additive White Gaussian Noise)
   - Noise Figure, Noise Temperature, dan Sistem Temperatur
7. **SISKOM DIGITAL → Channel Coding**
   - Linear Block Code
   - Cyclic Code
   - Convolution COde

OUTLINE

MODULASI ANALOG

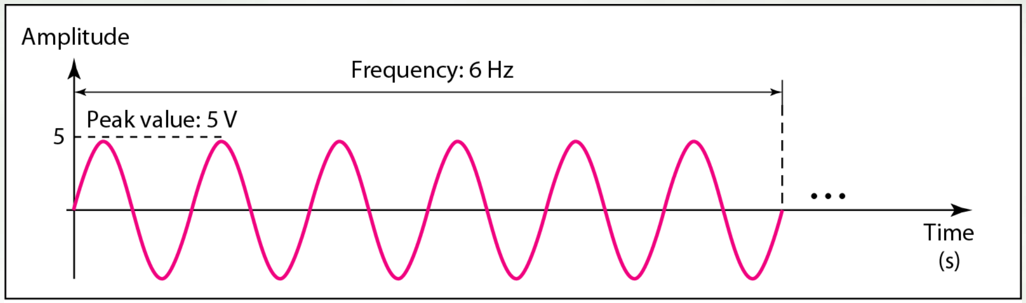
1. Penerapan Tranformasi Fourier dalam Sistem Komunikasi
2. Modulasi, Demodulasi, dan Kinerja Sistem AM
3. Modulasi, Demodulasi, dan Kinerja Sistem FM
4. Radio Broadcasting (AM dan FM) & TV Broadcasting (Analog)

OUTLINE

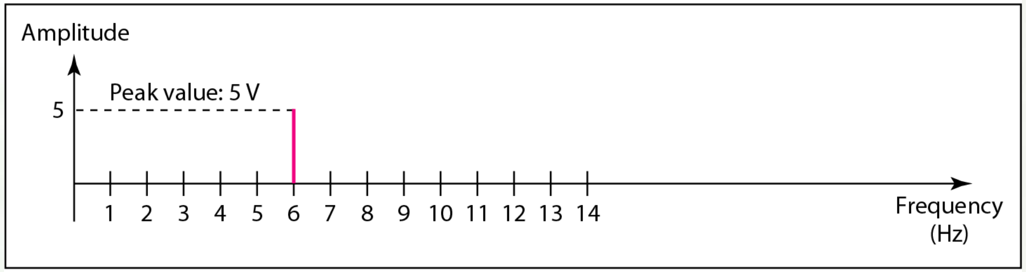
Penerapan Transformasi Fourier dalam Sistem Komunikasi

TRANSFORMASI FOURIER

Time and Frequency Domain



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



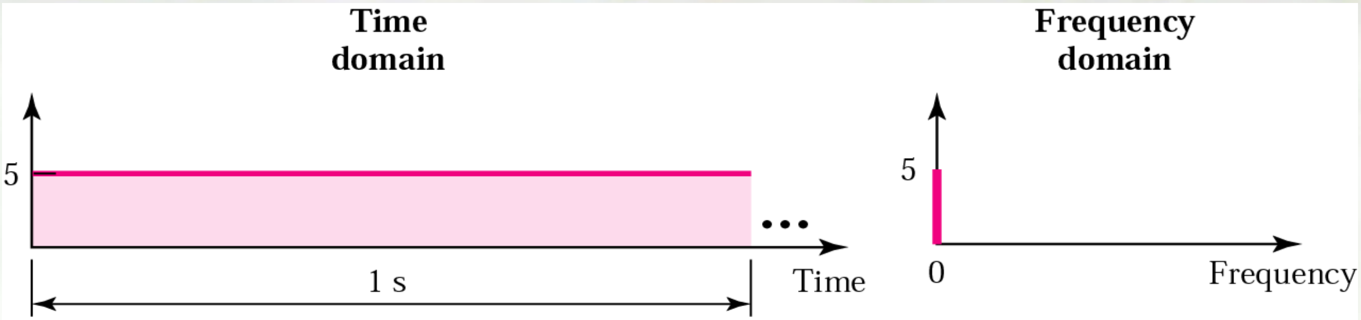
b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

Domain Waktu dan domain Frekuensi dari gelombang sinusoidal

- ❑ Suatu sinyal dapat direpresentasikan dalam domain waktu ataupun frekuensi
- ❑ Dalam domain waktu direpresentasikan dalam bentuk tegangan atau arus dalam fungsi waktu
- ❑ Dalam domain frekuensi direpresentasikan dalam bentuk magnitudo dan fasa dalam fungsi frekuensi
- ❑ Transformasi fourier berfungsi sebagai pengubah representasi sinyal dari domain waktu s(t) kedalam domain frekuensi S(f)
- ❑ Inverse Transformasi Fourier melakukan fungsi sebaliknya

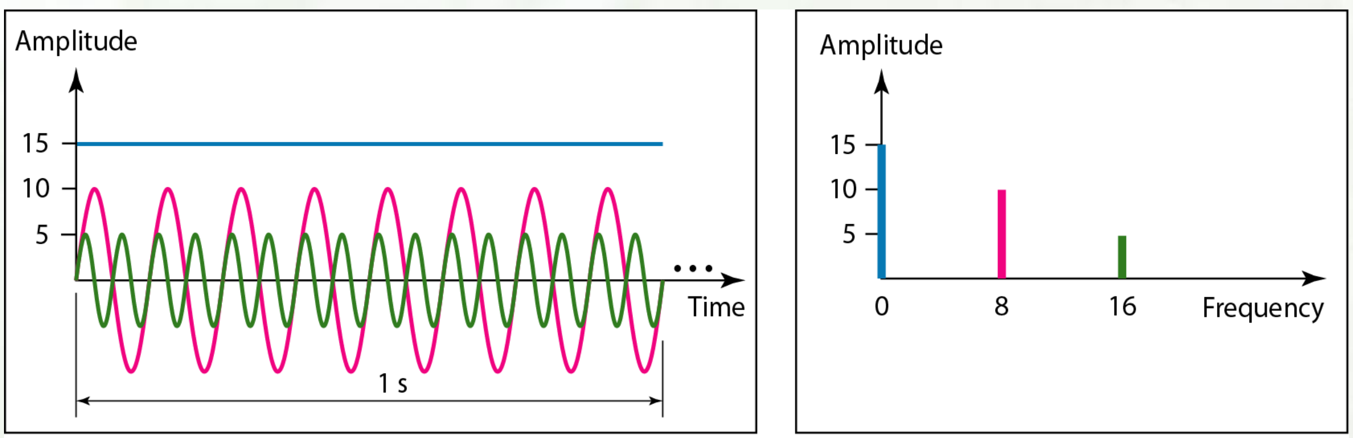
TRANSFORMASI FOURIER

Time and Frequency Domain



a. A signal with frequency 0

The time-domain and frequency-domain plots of a DC Signal



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16

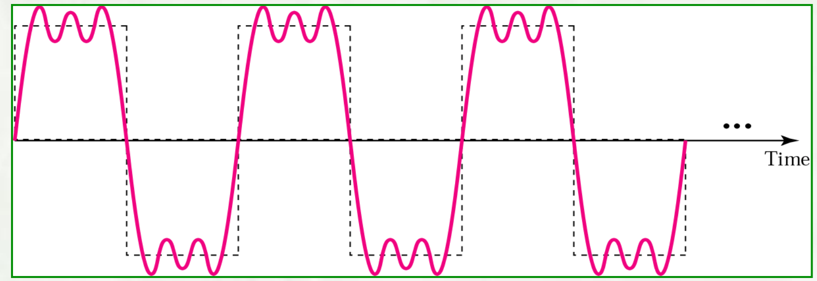
b. Frequency-domain representation of the same three signals

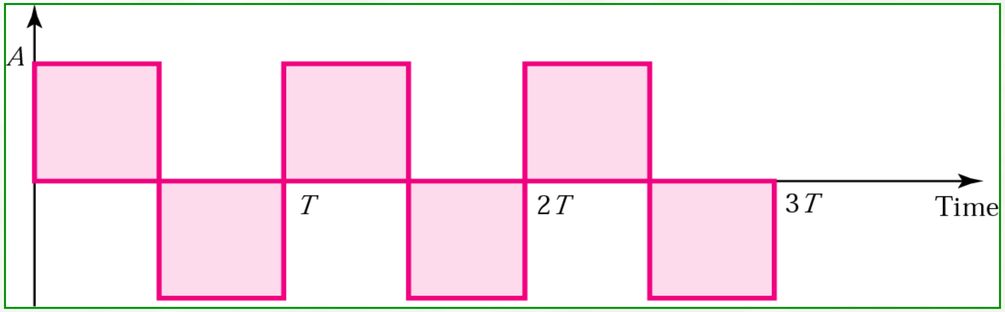
The time domain and frequency domain of three sine waves

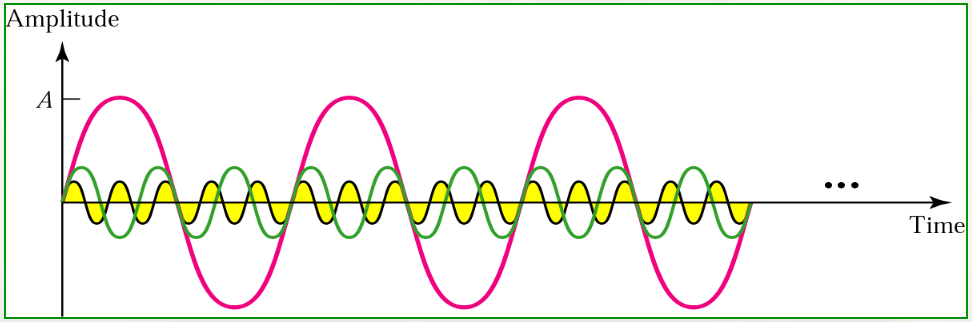
TRANSFORMASI FOURIER

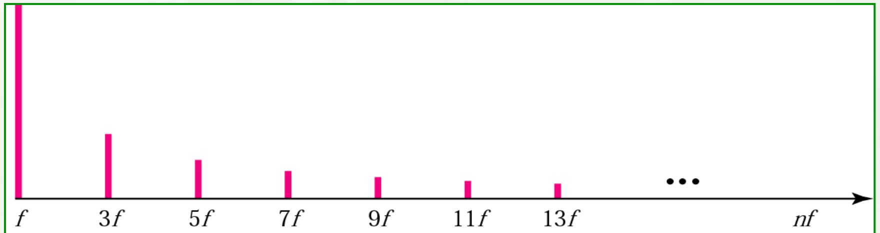
Fourier Analysis

According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

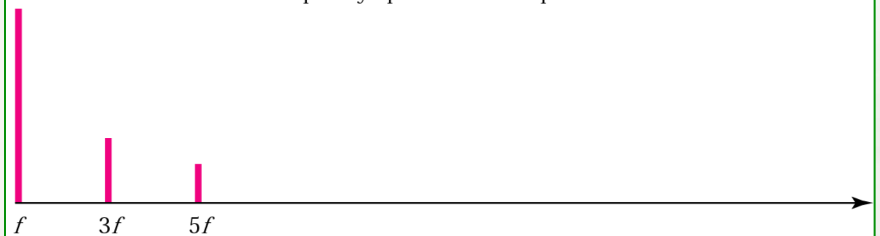








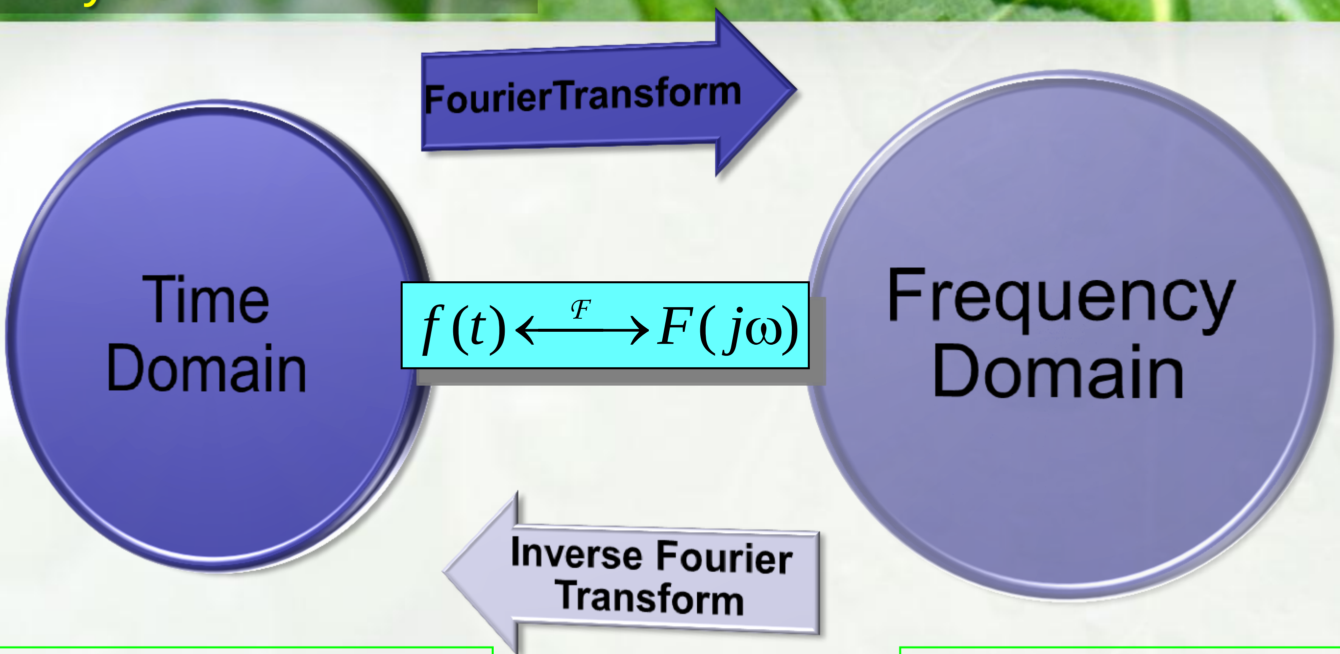
a. Frequency spectrum of a square wave



b. Frequency spectrum of an approximation with only three harmonics

TRANSFORMASI FOURIER

Fourier Analysis



$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-j2\pi ft} dt$$

$$x(t) = \int_{-\infty}^{\infty} X(f) e^{j2\pi ft} df$$

Fourier Transform
Time domain → Frequency Domain

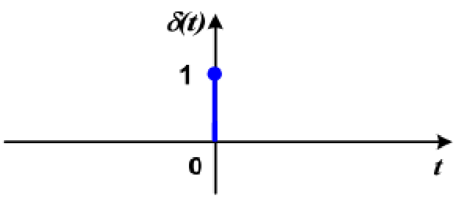
Inverse Fourier Transform
Frequency domain → Time Domain

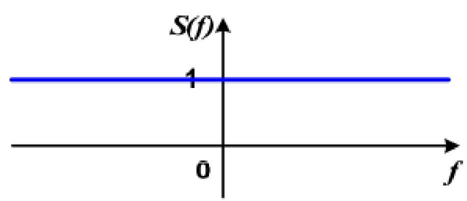
TRANSFORMASI FOURIER

Beberapa Transformasi Penting

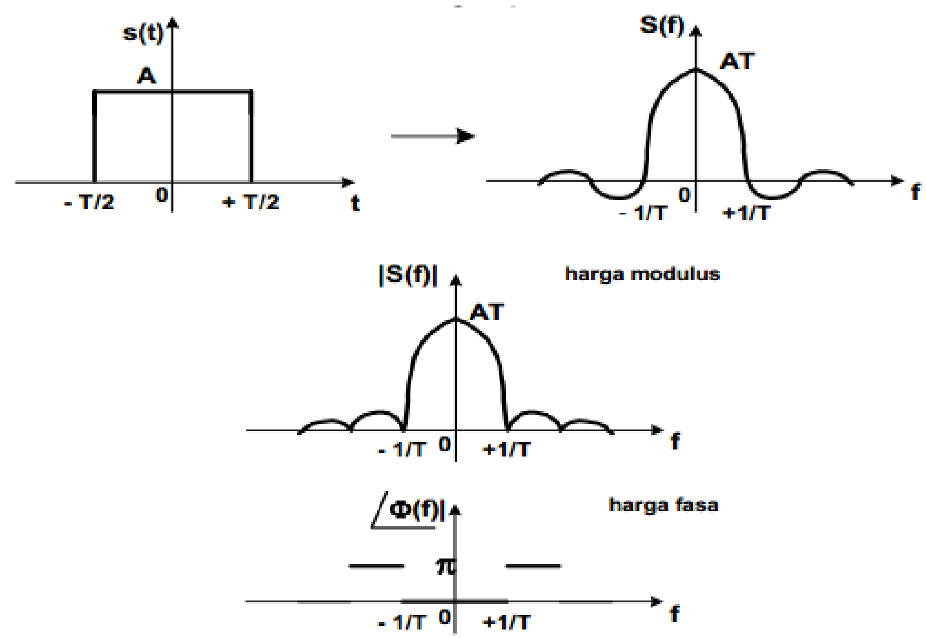
Signal Delta Dirac (Impulse)

$$S(f) = \int_{-\infty}^{+\infty} \delta(t).e^{-j2\pi ft}\,dt = 1$$





Signal Pulsa



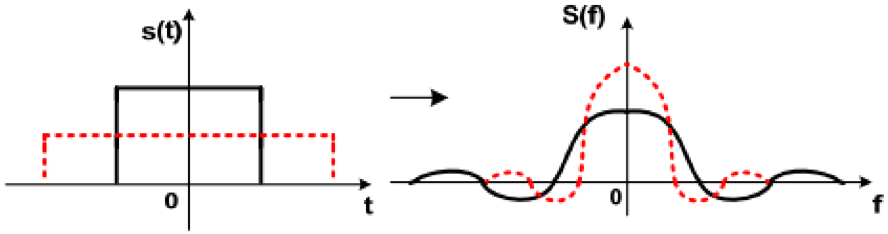
TRANSFORMASI FOURIER

Sifat Penting Transformasi Fourier

Time Scaling

$$s(t) \Leftrightarrow S(f)$$

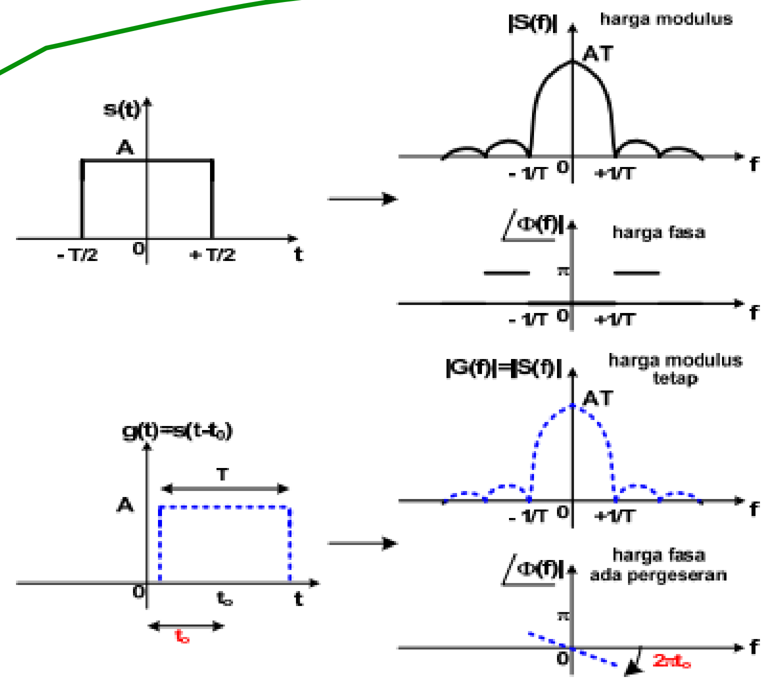
$$s(at) \Leftrightarrow \frac{1}{|a|} S\left(\frac{f}{a}\right)$$



Time Shifting

$$x(t) \Leftrightarrow X(f)$$

$$x(t - t_0) \Leftrightarrow X(f) e^{-j2\pi f t_0}$$



TRANSFORMASI FOURIER

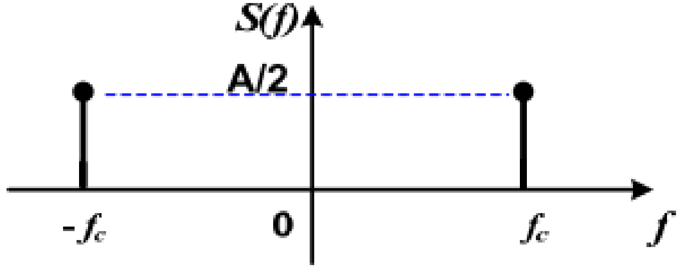
Sifat Penting Transformasi Fourier

Frequency Shifting

Bila $s(t) \leftrightarrow S(f)$ maka $S(f-f_o) \leftrightarrow s(t).e^{-j2\pi f_o t}$

Contoh : $s(t) = A \cos 2\pi f_c t = \frac{A}{2}\left(e^{j2\pi f_c t} + e^{-j2\pi f_c t}\right)$

maka $S(f) = \frac{A}{2}\delta(f+f_c) + \frac{A}{2}\delta(f-f_c)$



→ **spektrum amplitudo PADA PITA DUA SISI**

TRANSFORMASI FOURIER

Sifat Penting Transformasi Fourier

Konvolusi di kawasan waktu

Bila $s_1(t) \leftrightarrow S_1(f)$ dan $s_2(t) \leftrightarrow S_2(f)$,

maka :

$$\int_{-\infty}^{\infty} s_1(t).s_2(t-\tau)d\tau \Leftrightarrow S_1(f).S_2(f)$$

Perkalian di kawasan waktu

Bila $s_1(t) \leftrightarrow S_1(f)$ dan $s_2(t) \leftrightarrow S_2(f)$,

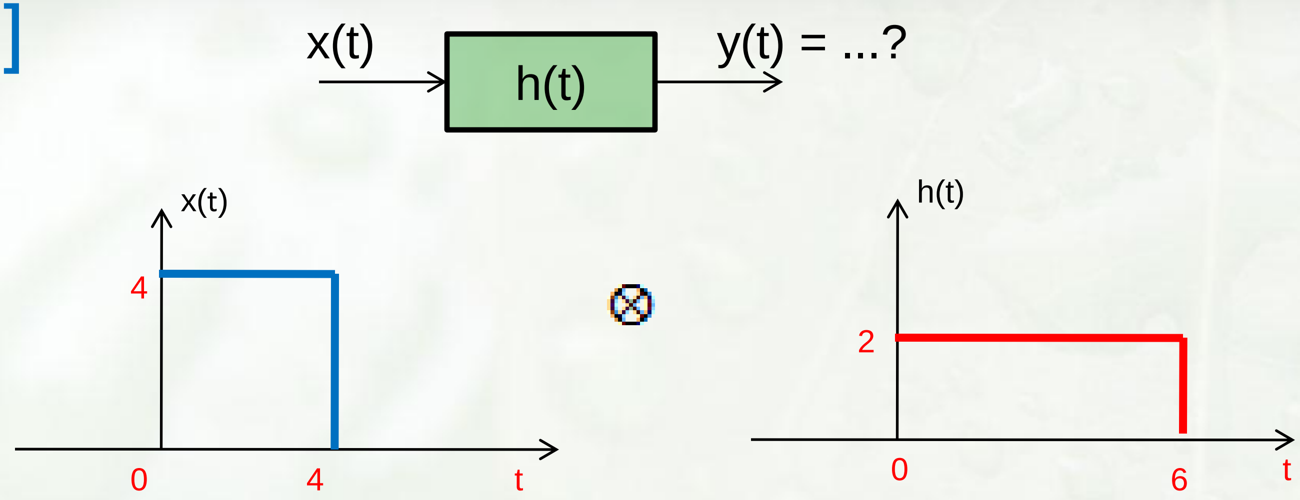
maka :

$$s_1(t).s_2(t) \Leftrightarrow \int_{-\infty}^{\infty} S_1(\lambda).S_2(f-\lambda)d\lambda$$

TRANSFORMASI FOURIER

TUGAS 2 (Review PSTM)

[1]



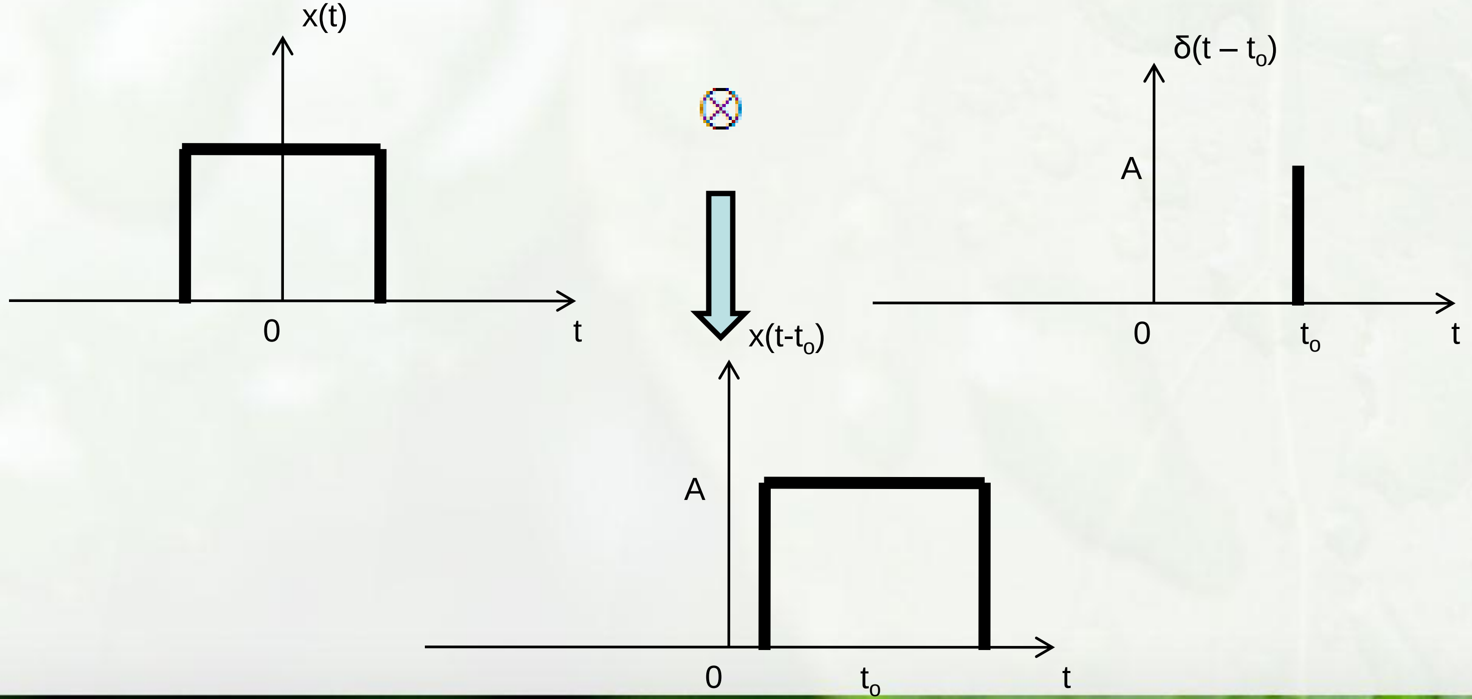
TRANSFORMASI FOURIER

Contoh Perhitungan Konvolusi dengan Metoda Grafis

[2] Konvolusi dengan fungsi δ $(t\text{-}t_o)$

$$x(t) \otimes \delta(t-t_o) = \int_{-\infty}^{\infty} x(t-\lambda).\delta(t-t_o)\, d\lambda = x(t-t_o)$$

$$x(t) \otimes A\delta(t-t_o) = A.x(t-t_o)$$



OUTLINE

Modulasi, Demodulasi, Kinerja Sistem Amplitude Modulation (AM)

AMPLITUDE MODULATION (AM)

Mengapa Perlu Modulasi?

- Meminimalisasi interferensi sinyal pada pengiriman informasi yang menggunakan frequency sama atau berdekatan
- Dimensi antenna menjadi lebih mudah diwujudkan
- Sinyal termodulasi dapat dimultiplexing dan ditransmisikan via sebuah saluran transmisi

Modulasi adalah pengaturan parameter dari sinyal pembawa (carrier) yang berfrekuensi tinggi sesuai sinyal informasi (pemodulasi) yang frequensinya lebih rendah, sehingga informasi tadi dapat disampaikan.

AMPLITUDE MODULATION (AM)

Persamaa Sinyal Pembawa/Carrier

Persamaan Sinyal Pembawa/ Carrier:

$$V_c(t) = V_c \sin(\omega_c t + \theta)$$

Amplitude modulation (AM)

Modulasi Sudut (Angle Modulation)

$(\omega_c t + \theta)$

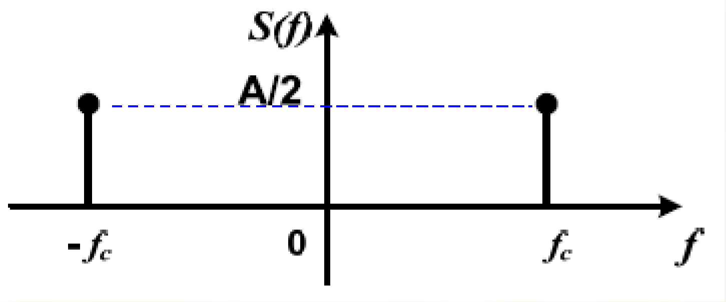
Frequency Modulation (FM)

Phase Modulation (PM)

AMPLITUDE MODULATION (AM)

Review Kawasan Waktu ↔Frekuensi?

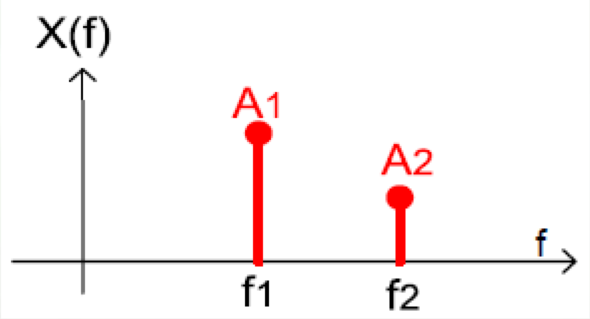
$s(t) = A \cos 2\pi f_c t$



Gambar spektrum sinyal diturunkan dari persamaan sinyal kawasan frekuensi → **spektrum amplitudo PADA PITA DUA SISI**

$x(t) = A_1 \cos(2\pi f_1 t) + A_2 \cos(2\pi f_2 t)$

$X(f) = A_1 \delta(f-f_1) + A2\ \delta(f-f2)$



Gambar spektrum sinyal diturunkan dari persamaan sinyal kawasan frekuensi → **spektrum amplitudo PADA FREKUENSI POSITIF / PITA SATU SISI**

AMPLITUDE MODULATION (AM)

Modulasi Amplituda (AM)

Pada AM, amplitudo dibuat berubah sesuai sinyal informasi, sedang phasanya dibuat nol.

sehingga persamaan sinyal termodulasi secara umum adalah:

$$S_{AM}(t) = m(t)\ \cos \omega_c t$$

$m(t)$ = sinyal informasi / pemodulasi

AMPLITUDE MODULATION (AM)

Varian dari Modulasi Amplitudo

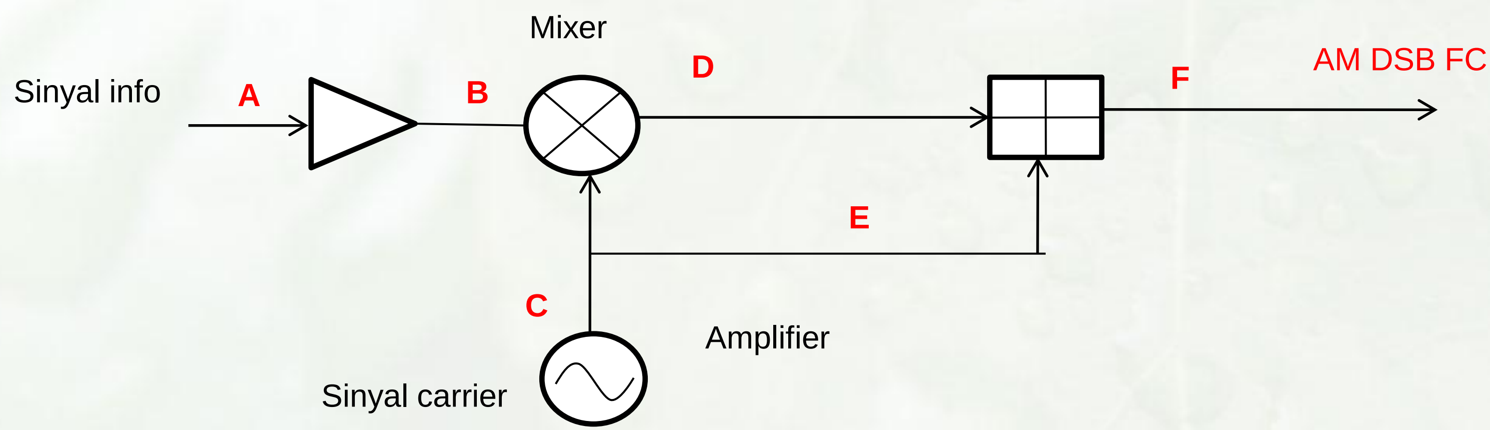
1. Double Side Band **Full Carrier (DSB-FC)**
2. Double Side Band **Suppressed Carrier (DSB-SC)**
3. Single Side Band (SSB)
4. Vestigial Side Band (VSB)

AM-DSB-FC

AMPLITUDE MODULATION (AM)

AM-DSB-FC

"Diagram Blok Modulasi AM-DSB-FC"



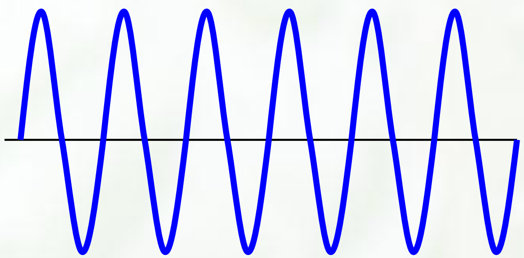
$$S_c(t) = V_c \cos(\omega_c t)$$

AMPLITUDE MODULATION (AM)

AM-DSB-FC

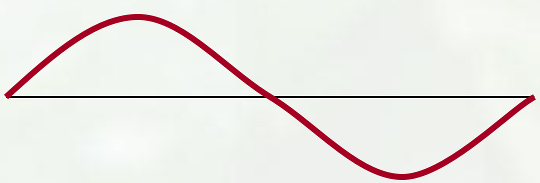
Pembawa : $S_c(t) = V_c \cos(\omega_c t)$

$S_c(t)$



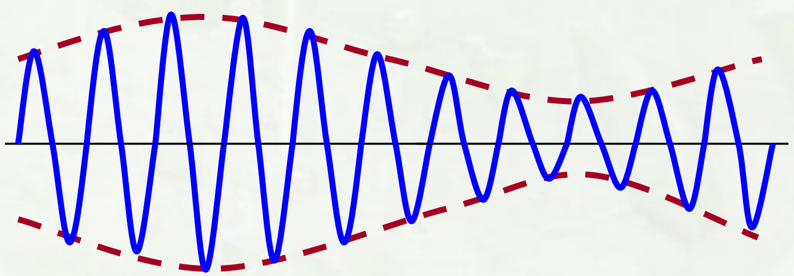
Pemodulasi : m(t)

m(t)



$$S_{AM}(t) = V_c\left[1 + k_a m(t)\right]\cos\left(2\pi f_c t\right)$$

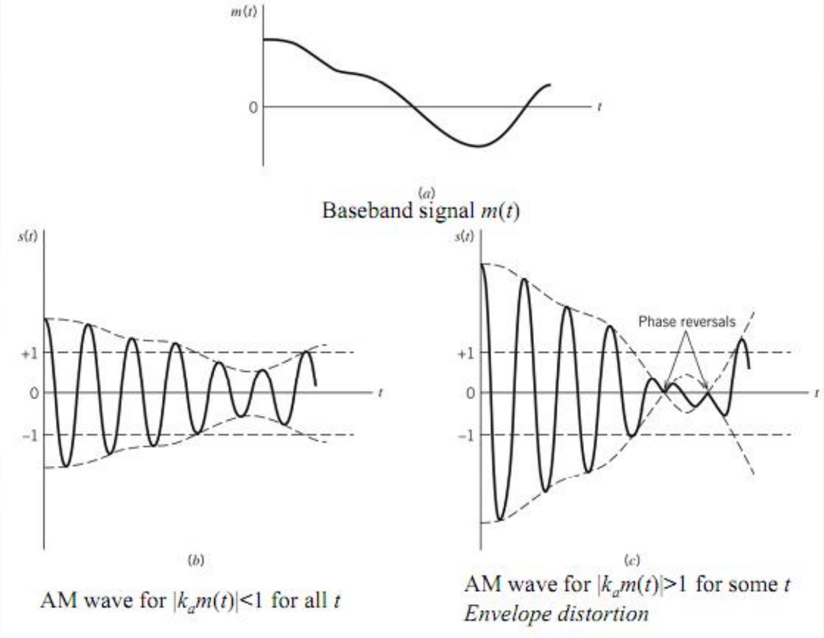
$S_{AM}(t)$



k_a = sensitivitas Amplituda [per volt]

AMPLITUDE MODULATION (AM)

AM-DSB-FC



Syarat Modulasi AM :

$$S_{AM}(t) = V_c[1 + k_a m(t)]\cos(2\pi f_c t)$$

- $|k_a m(t)| \leq 1 \rightarrow$ tidak terjadi 'over modulasi'→ menghindari Envelope Distortion
- $f_c >> f_m$ → agar bentuk envelope bisa dilihat (fm adalah komponen frekuensi tertinggi dari informasi)

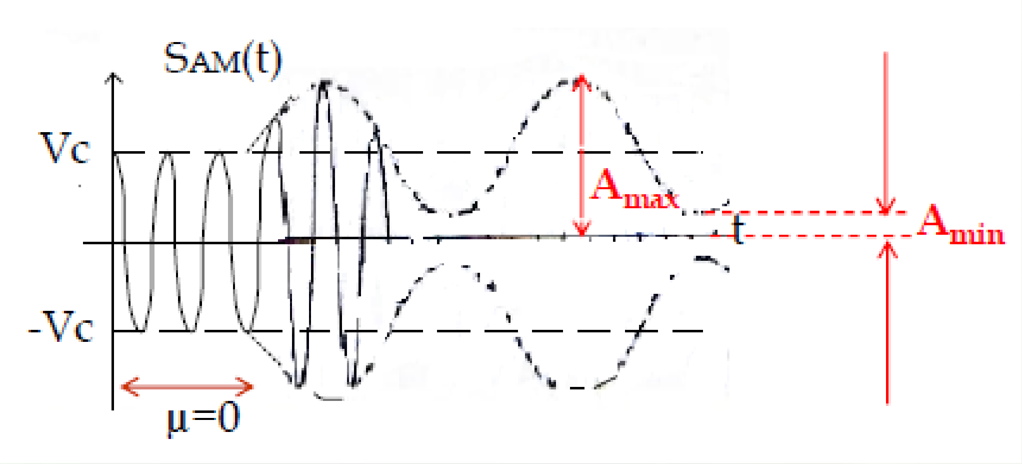
AMPLITUDE MODULATION (AM)

AM-DSB-FC→ Pemodulasi Sinusoidal Tunggal

$$m(t) = V_m \cos(2\pi f_m t)$$
$$S_c(t) = V_c \cos(2\pi f_c t)$$

$$S_{AM}(t) = V_c[1 + k_a m(t)]\cos(2\pi f_c t)$$
$$= V_c[1 + k_a V_m \cos(2\pi f_m t)]\cos(2\pi f_c t)$$
$$= V_c[1 + \mu \cos(2\pi f_m t)]\cos(2\pi f_c t)$$

m = μ = indeks modulasi = $K_a V_m$



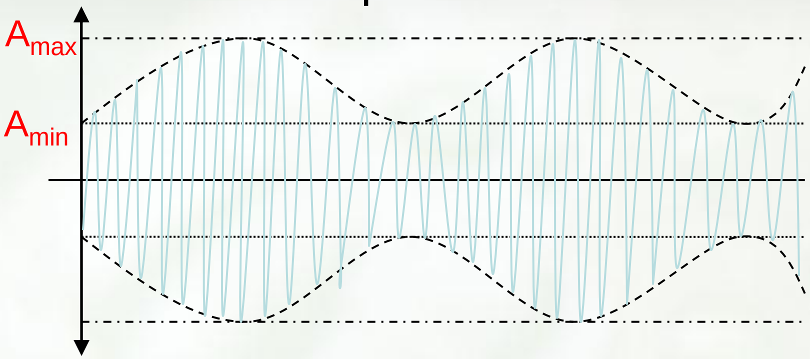
$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

$$V_c = \frac{A_{max} + A_{min}}{2}$$

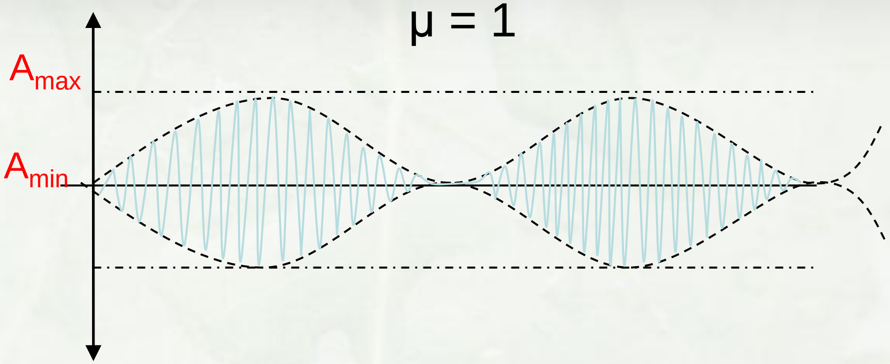
AMPLITUDE MODULATION (AM)

Indeks Modulasi AM-DSB-FC

$\mu < 1$

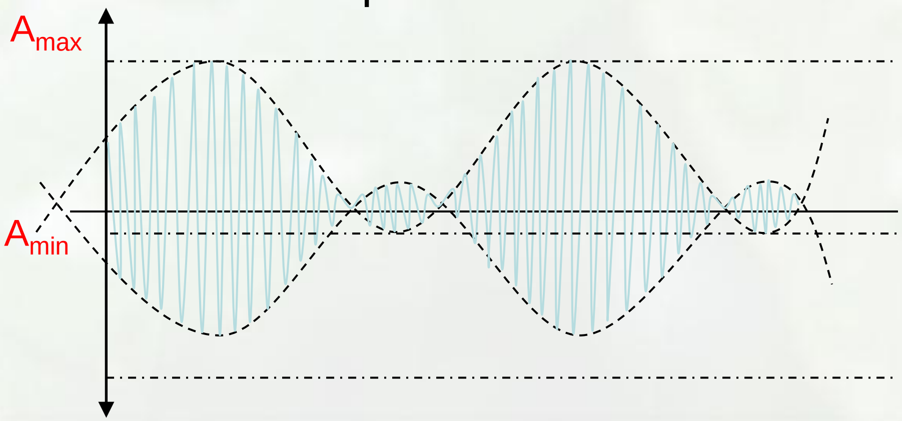


$\mu = 1$



$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

$\mu > 1$



OVER MODULATION

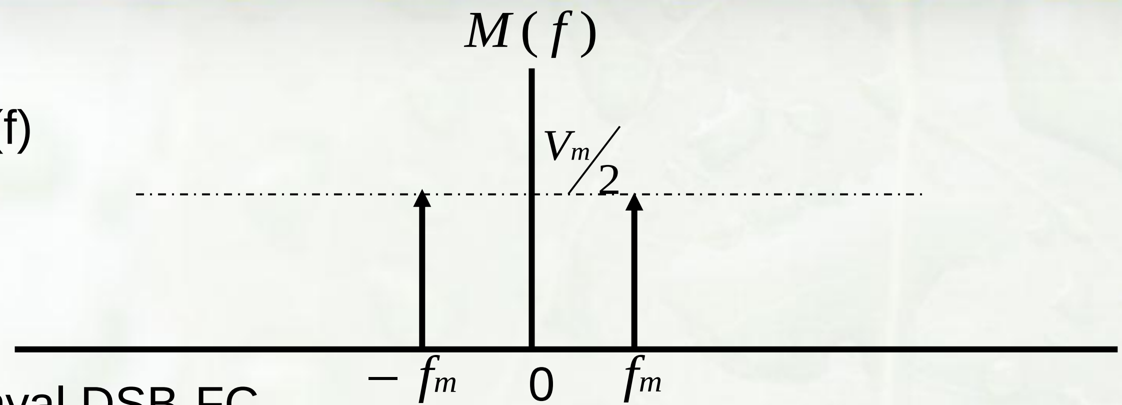
AMPLITUDE MODULATION (AM)

Spektrum AM DSB FC

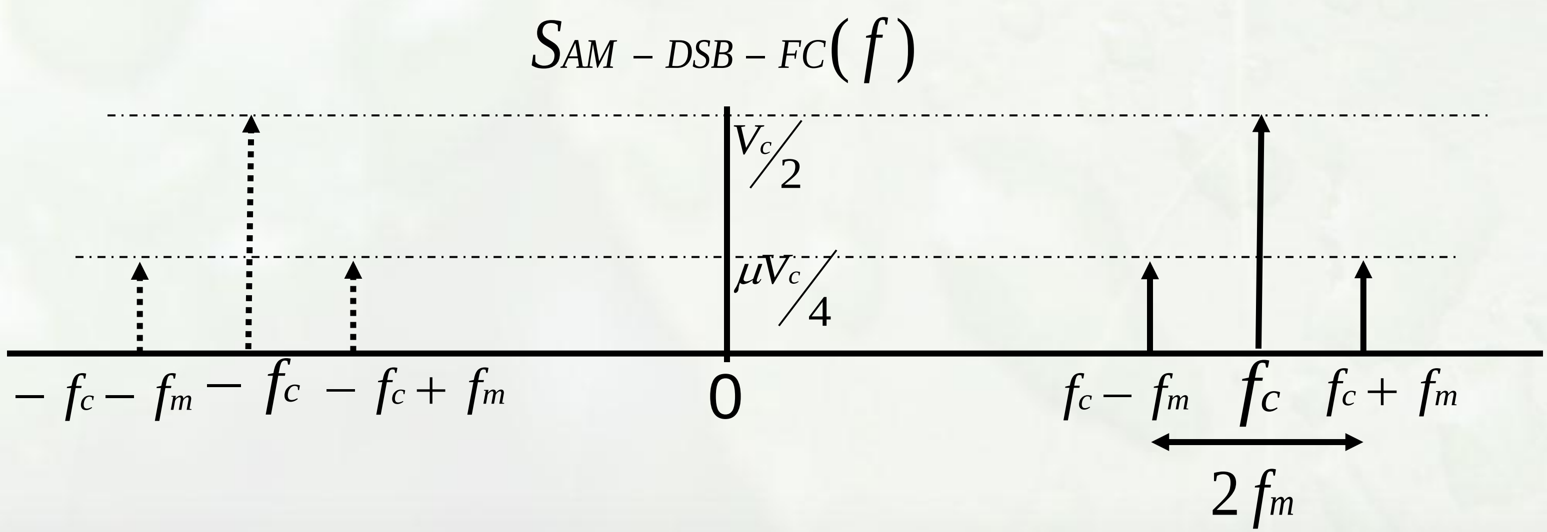
dengan informasi sinyal sinusoidal tunggal m(t) ↔ M(f)

$m(t) = V_m \cos 2\pi f_m t$

Spektrum m(t) → M(f)



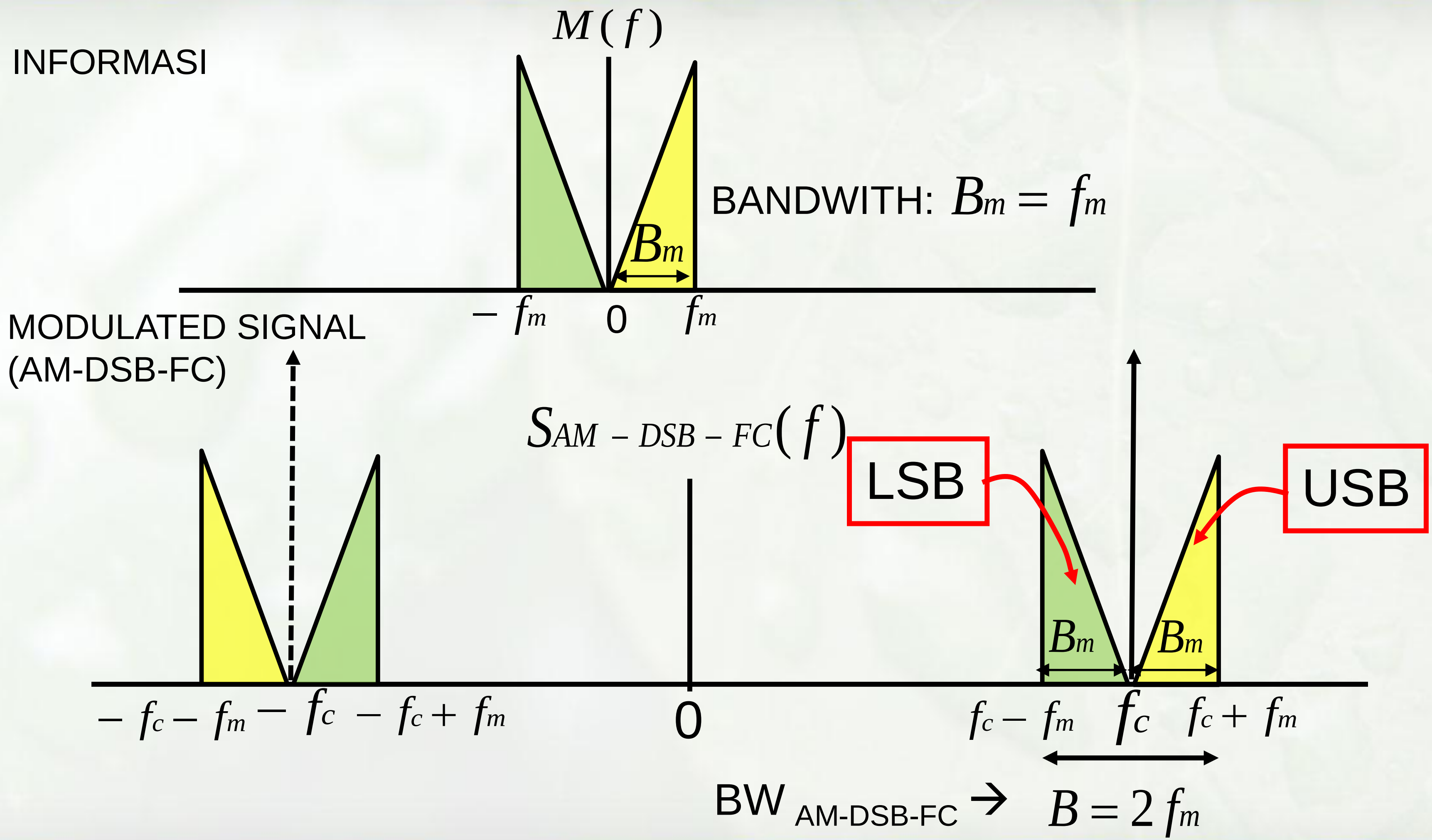
Gambar Spektrum Sinyal DSB-FC



AMPLITUDE MODULATION (AM)

Spektrum AM DSB FC

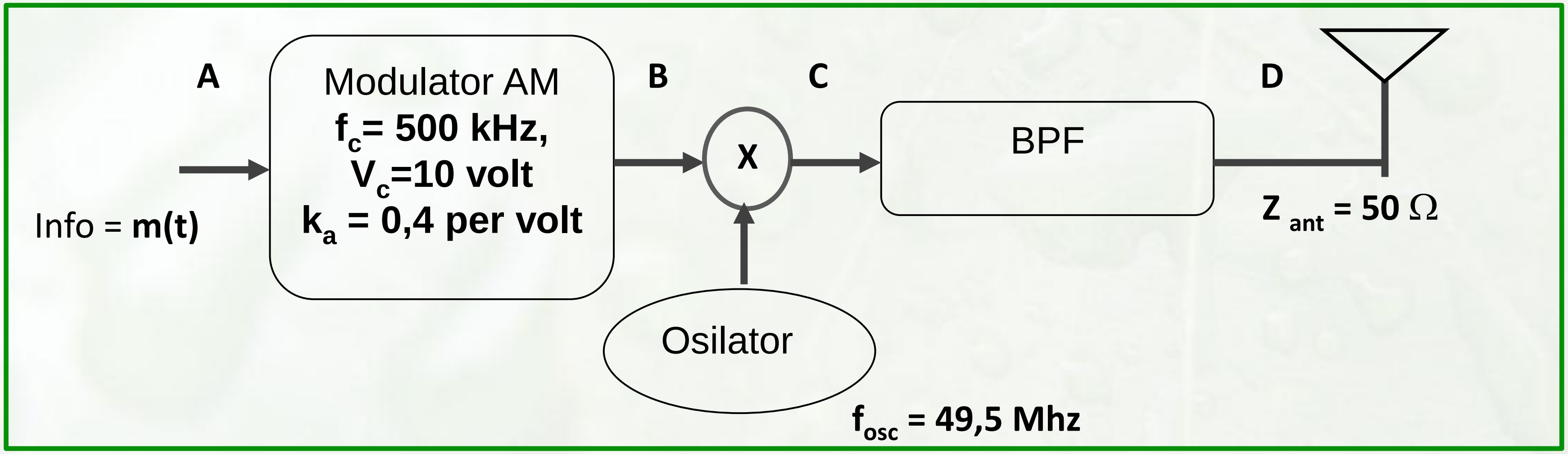
dengan informasi sinyal sembarang $m(t) \leftrightarrow M(f)$



AMPLITUDE MODULATION (AM)

Contoh Soal

Perhatikan **pemancar AM-DSB-FC pada frekuensi radio 50 MHz (di titik D)** dengan diagram blok sbb :



Persamaan umum sinyal AM-DSB-FC (di B atau di D) adalah: $V_{AM}(t) = Vc\ [\ 1 + k_a\ m(t)\ ]\ \cos(2\pi f_c t)$

a) **gambarkan gelombang** sinyal AM DSB-FC **(di B) pada gambar diatas, Jika $m(t) = 1 \cos(2\pi.3400.t)$! Berikan skala amplitudo yang jelas !**

b) **Gambarkan spektrum** sinyal AM DSB-FC **di B, C** dan di **D** !

AMPLITUDE MODULATION (AM)

Daya Pada sinyal AM-DSB-FC

$$S_{AM}(t) = V_c\left[1 + k_a m(t)\right]\cos(2\pi f_c t)$$

$$\begin{aligned} S_{AM}(t) &= V_c\left[1 + k_a m(t)\right]\cos(2\pi f_c t) \\ &= V_c\left[1 + \mu\cos(2\pi f_m t)\right]\cos(2\pi f_c t) \\ &= V_c\cos(2\pi f_c t) + \mu V_c\cos(2\pi f_m t)\cos(2\pi f_c t) \\ &= V_c\cos(2\pi f_c t) + \frac{\mu}{2}V_c\cos(2\pi(f_c + f_m)t) + \frac{\mu}{2}V_c\cos(2\pi(f_c - f_m)t) \end{aligned}$$

Nilai RMS → $\frac{V_c}{\sqrt{2}}$ $\frac{\mu V_c}{2\sqrt{2}}$ $\frac{\mu V_c}{2\sqrt{2}}$

AMPLITUDE MODULATION (AM)

Daya Pada sinyal AM-DSB-FC

$$P_{AM_{DSB-FC}} = P_C + P_{USB} + P_{LSB}$$

$$= \frac{(V_c/\sqrt{2})^2}{R} + \frac{(\mu V_c/2\sqrt{2})^2}{R} + \frac{(\mu V_c/2\sqrt{2})^2}{R}$$

$$= \frac{V_c^{\ 2}}{2R} + \frac{\mu^2 V_c^{\ 2}}{8R} + \frac{\mu^2 V_c^{\ 2}}{8R}$$

Daya pada Referensi Resistansi 1 ohm ⇒

$$P_{AM_{DSB-FC}} = \frac{V_c^{\ 2}}{2R} + \frac{\mu^2 V_c^{\ 2}}{8R} + \frac{\mu^2 V_c^{\ 2}}{8R}$$

$$= \frac{V_c^{\ 2}}{2} + 2\frac{\mu^2 V_c^{\ 2}}{8}$$

$$= \frac{V_c^{\ 2}}{2} + \frac{\mu^2 V_c^{\ 2}}{4} = \frac{V_c^{\ 2}}{2}\left(1 + \frac{\mu^2}{2}\right)$$

$$= \frac{V_c^{\ 2}\left(2 + \mu^2\right)}{4}$$

AMPLITUDE MODULATION (AM)

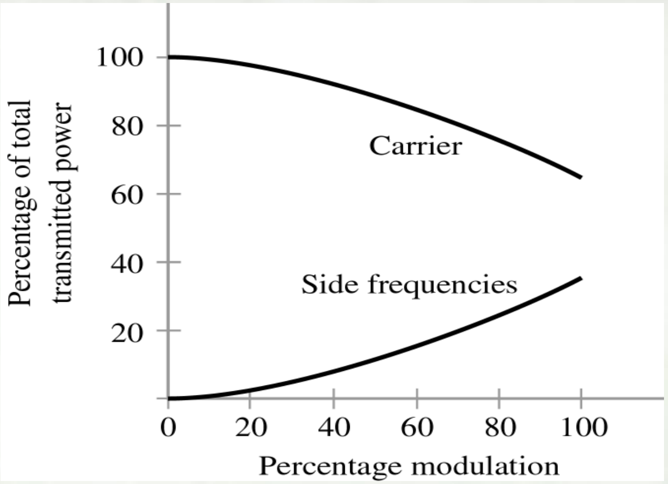
Power Transmission Efficiency of AM-DSB-FC

$$\eta = \frac{total\ sidaband\ power}{Total\ power}$$

$$= \frac{P_{USB} + P_{LSB}}{P_C + P_{USB} + P_{LSB}}$$

$$= \frac{\frac{\mu^2 V_c^{\ 2}}{4}}{\frac{V_c^{\ 2}\left(2+\mu^2\right)}{4}} = \frac{\mu^2}{2+\mu^2}$$

μ	η
0,25	0,03
0,5	0,11
0,75	0,22
1	0,33

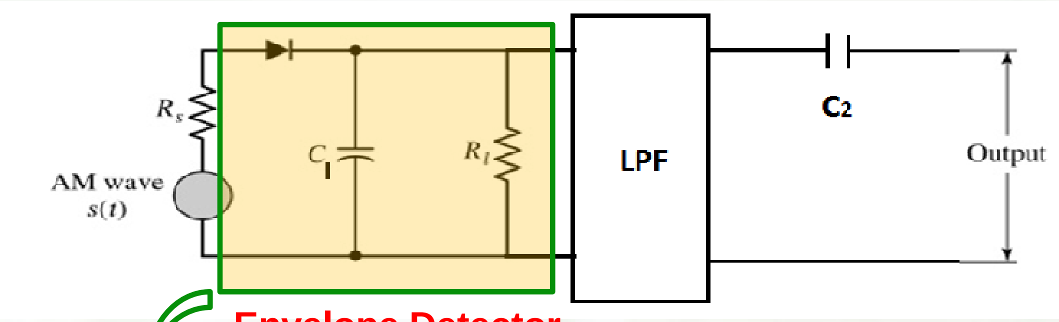


⇩

Dari Tabel Diatas bisa disimpulkan bahwa Efisiensi Power transmisi dari AM-DSB-FC meningkat jika index modulasinya **μ** dinaikkan, Tetapi meskipun index modulasinya sudah maksimal **μ = 1**, hanya 1/3 dayanya berada pada sideband, sedangkan 2/3 berada pada carier

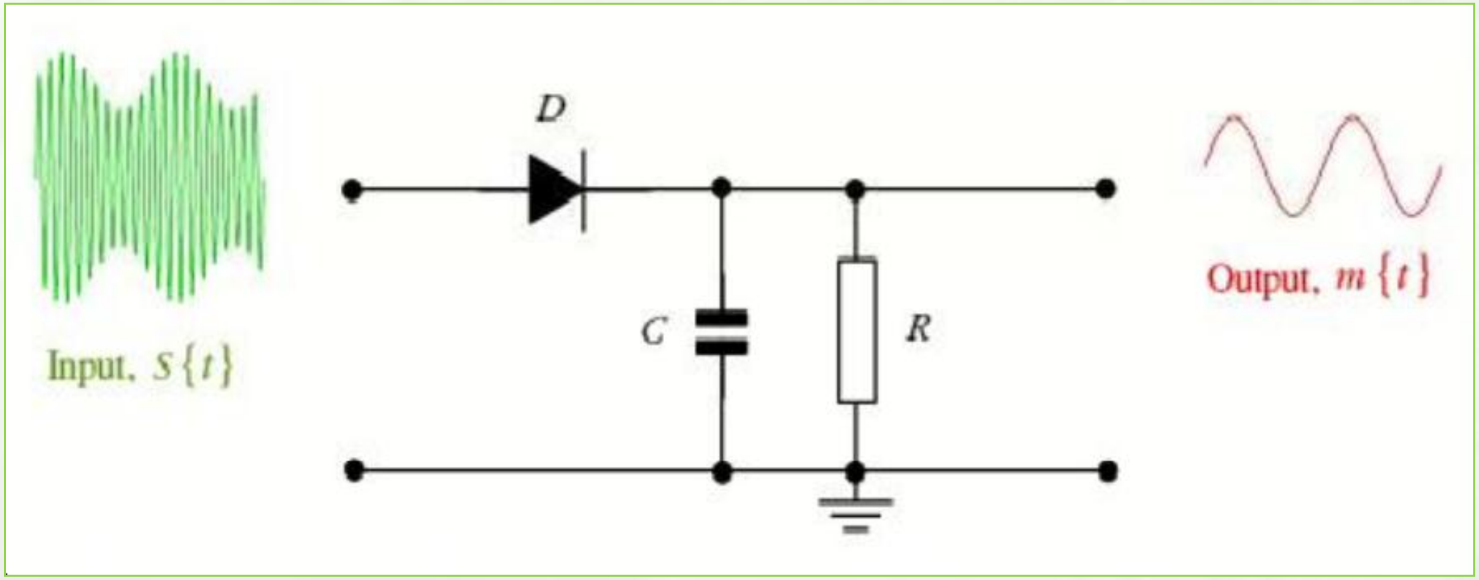
AMPLITUDE MODULATION (AM)

Demodulasi Sinyal AM-DSB-FC – Detector Selubung



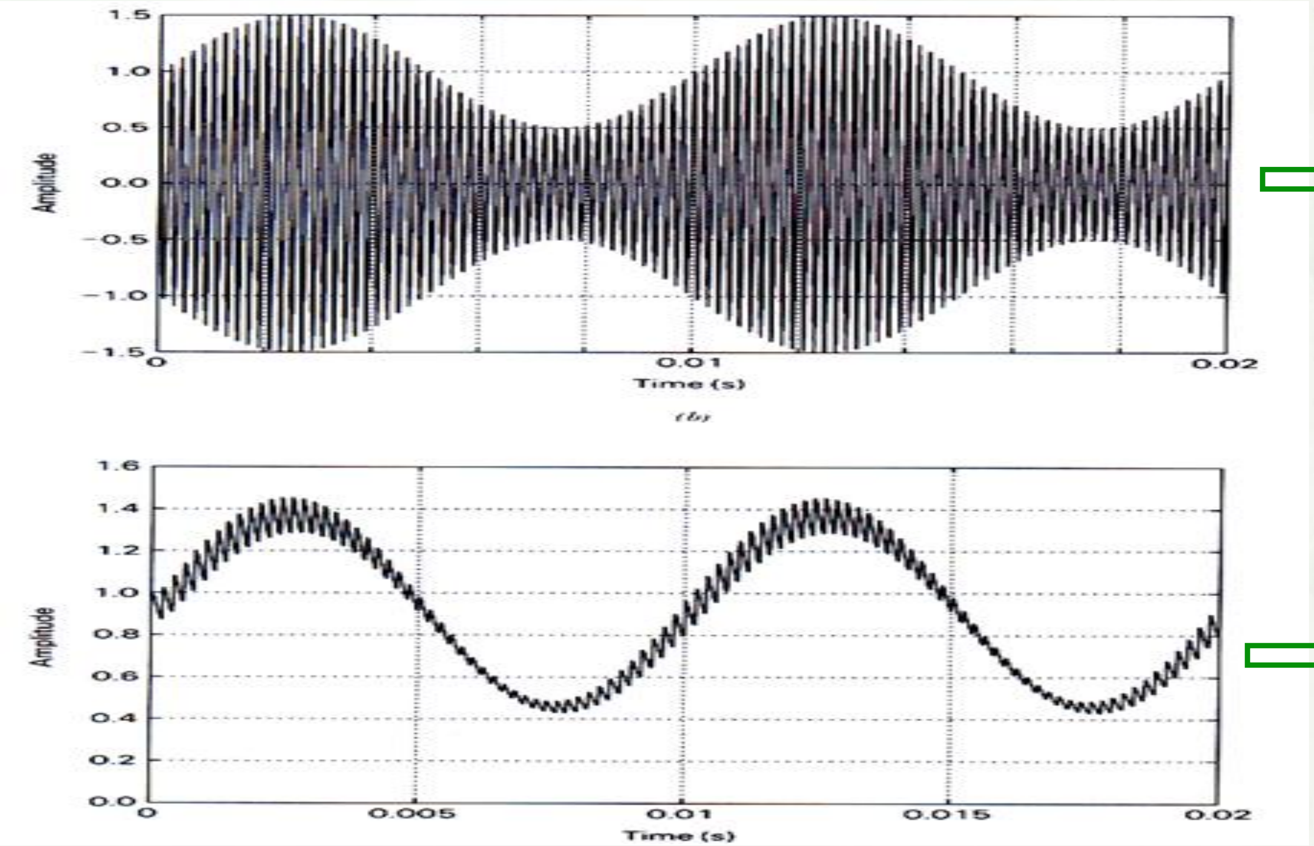
Envelope Detector

Dilakukan dengan mendeteksi selubung (envelope) sinyal termodulasinya. Alat yang digunakan disebut **Detektor Selubung (Envelope Detector**)



AMPLITUDE MODULATION (AM)

Demodulasi Sinyal AM-DSB-FC – Detector Selubung



Sinyal AM-DSB-FC dengan index modulasi 1/2

Output dari detektor selubung → terlihat masih ada ripple → bisa dihilangkan dengan LPF

AMPLITUDE MODULATION (AM)

Kesimpulan AM-DSB-FC

- Pada AM-DSB-FC, sinyal sideband di transmisikan bersama dengan cariernya
- Sederhana dalam mendeteksi / Demodulasi → detektor selubung
- Efisiensi Power transmisi rendah
- Bandwidth yang dibutuhkan besar (2 x BW informasi)


THANK
YOU