Telkom University

Diploma of Telecommunication Engineering

DTG2F3

Sistem Komunikasi

MODULASI ANALOG

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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

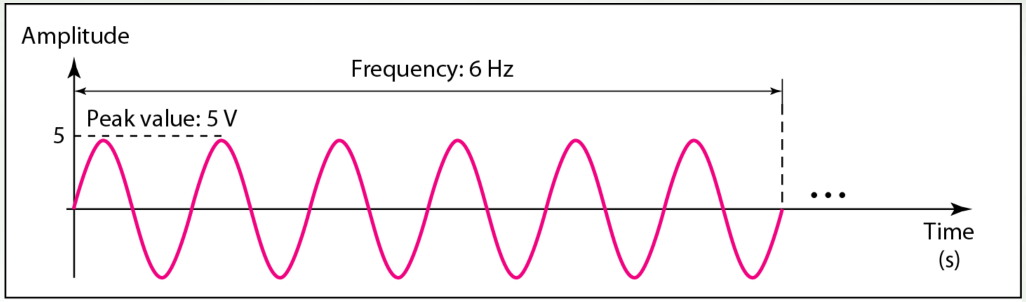
1. Penerapan Tranformasi Fourier dalam Sistem Komunikasi
2. Modulasi, Demodulasi, dan Kinerja Sistem AM
3. Modulasi, Demodulasi, dan Kinerja Sistem FM
4. Radio Broadcasting (AM dan FM) & TV Broadcasting (Analog)

OUTLINE

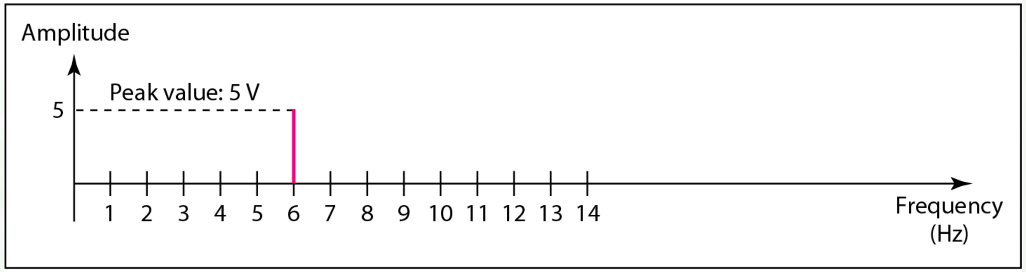
Penerapan Transformasi Fourier dalam Sistem Komunikasi

TRANSFORMASI FOURIER

Time and Frequency Domain



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



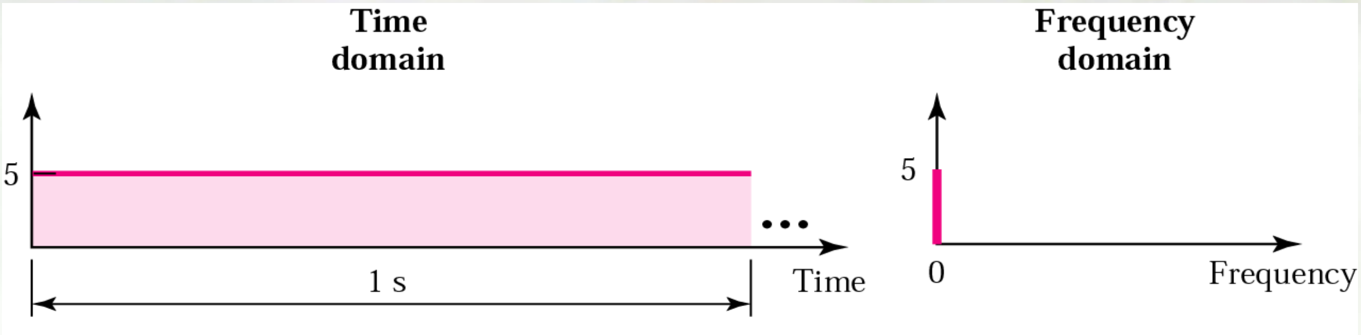
b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

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

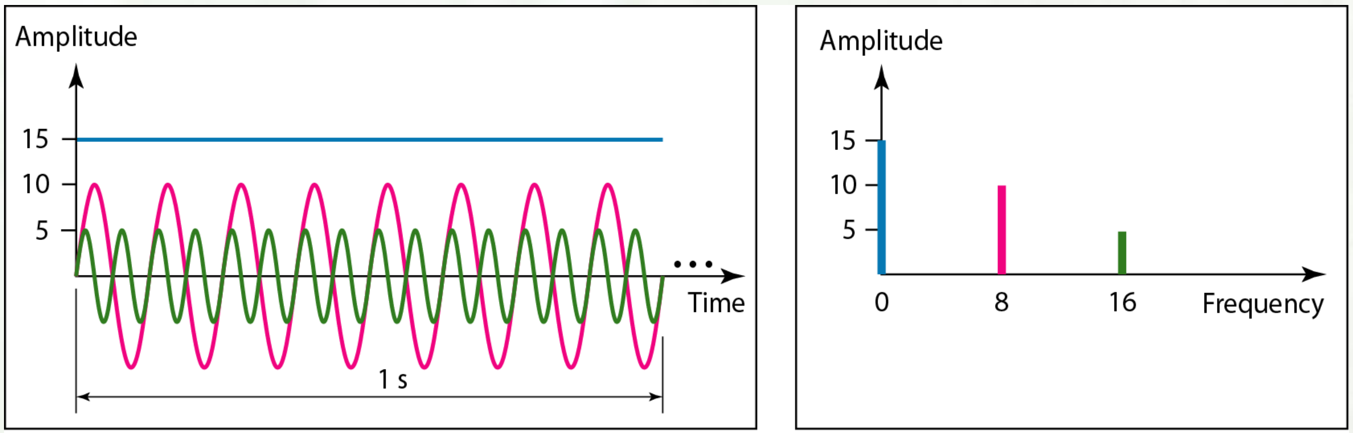
TRANSFORMASI FOURIER

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

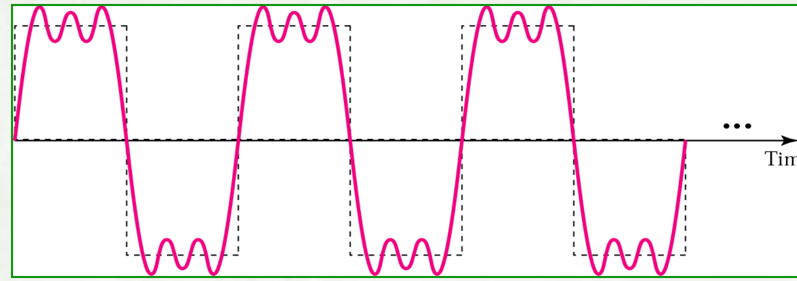
b. Frequency-domain representation of the same three signals

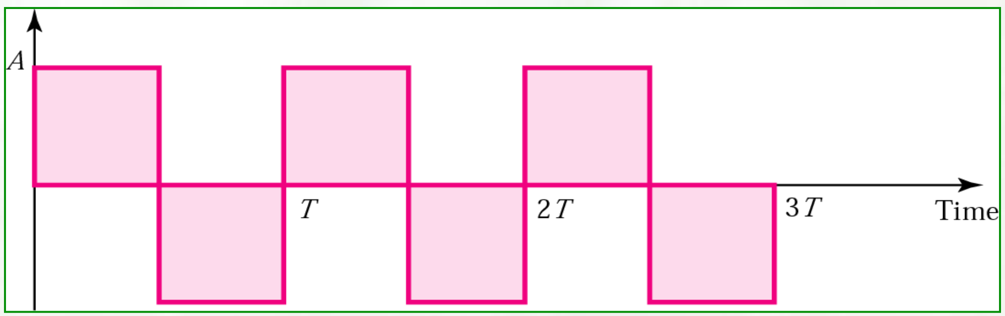
The time domain and frequency domain of three sine waves

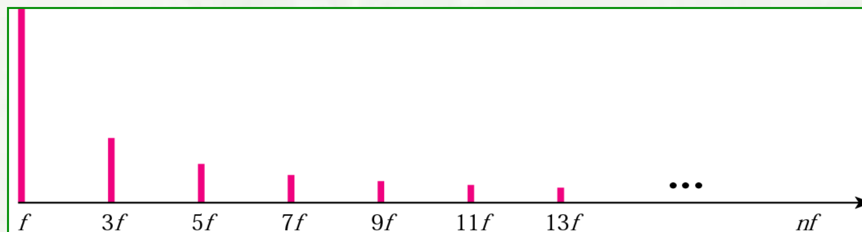
TRANSFORMASI FOURIER

Fourier Analysis

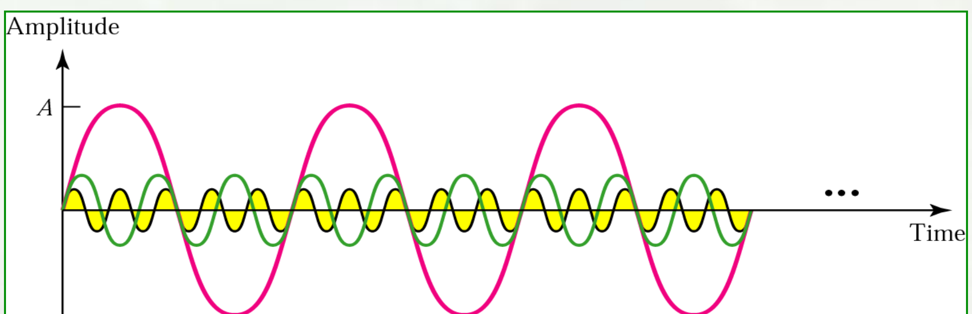
According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

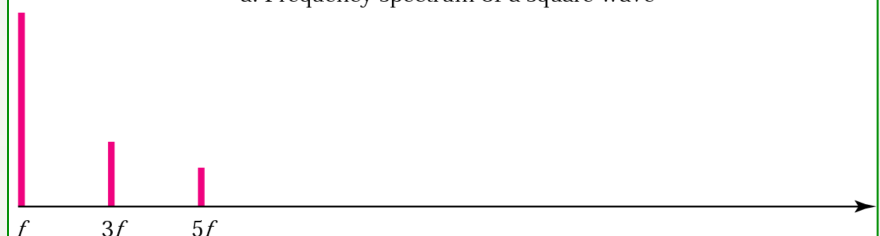






a. Frequency spectrum of a square wave

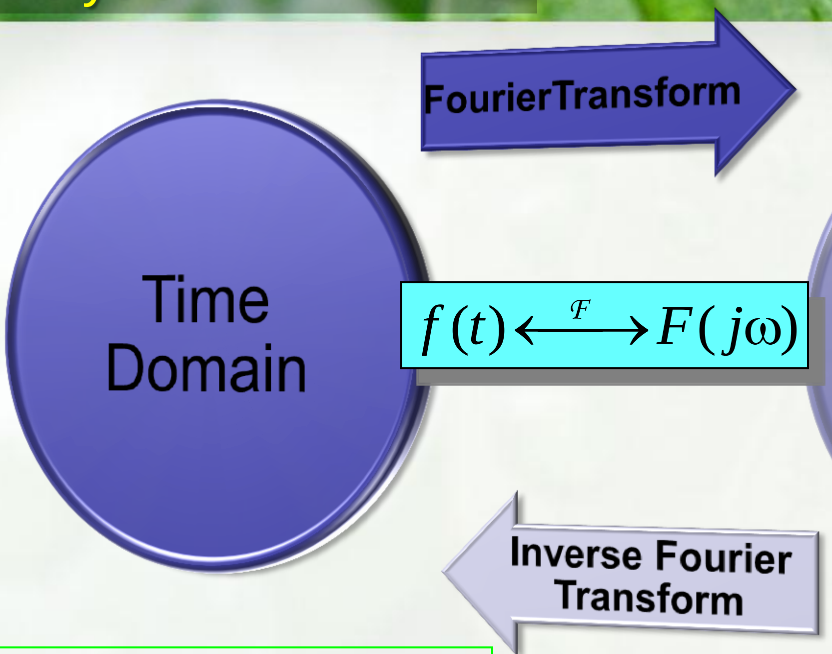




b. Frequency spectrum of an approximation with only three harmonics

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

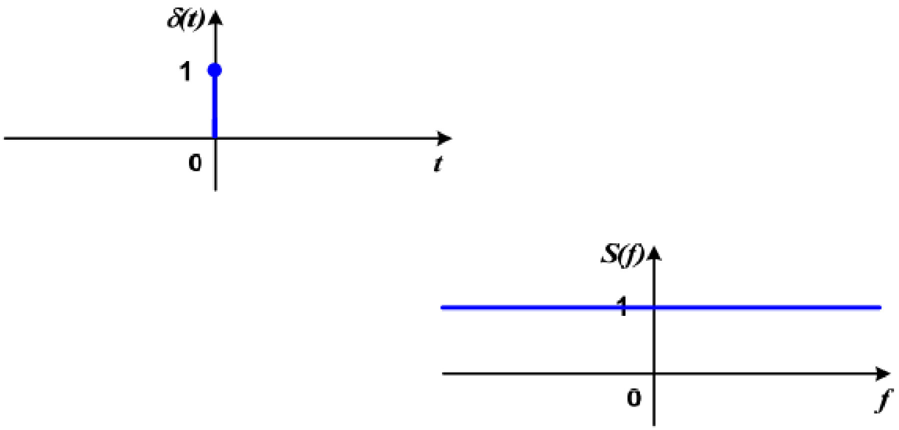
Inverse Fourier Transform
Frequency domain → Time Domain

TRANSFORMASI FOURIER

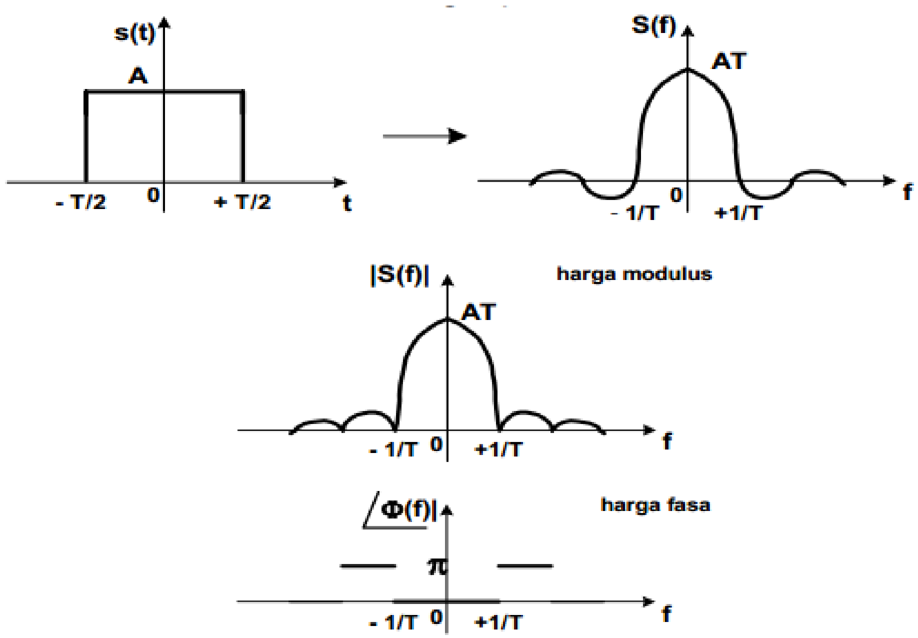
Beberapa Transformasi Penting

Signal Delta Dirac (Impulse)

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



Signal Pulsa



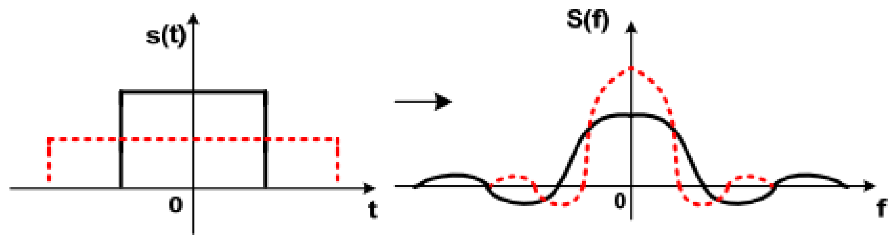
TRANSFORMASI FOURIER

Sifat Penting Transformasi Fourier

Time Scaling

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

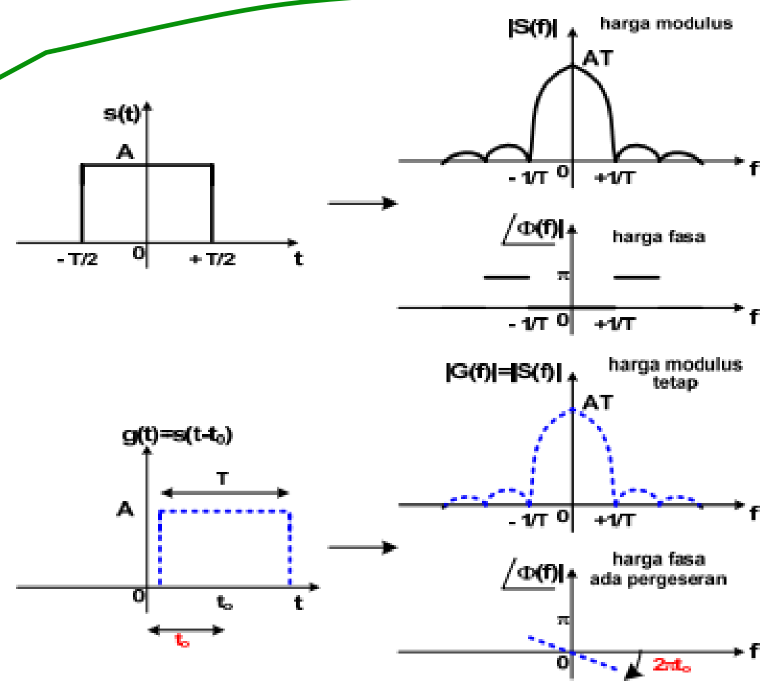
$$s(at) \Leftrightarrow \frac{1}{|a|} S\left(\frac{f}{a}\right)$$



Time Shifting

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

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



TRANSFORMASI FOURIER

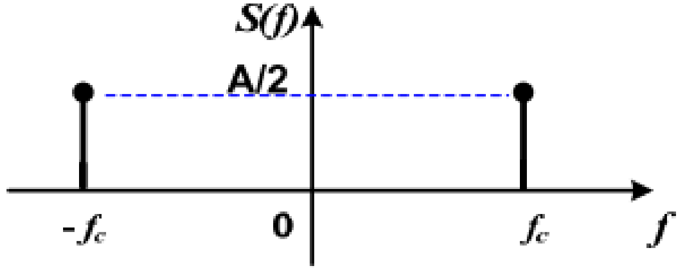
Sifat Penting Transformasi Fourier

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 $s_2(t) \leftrightarrow S_2(f)$,

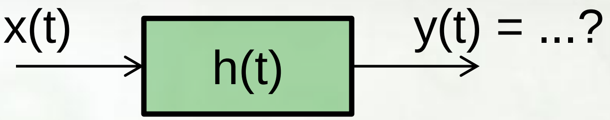
maka :

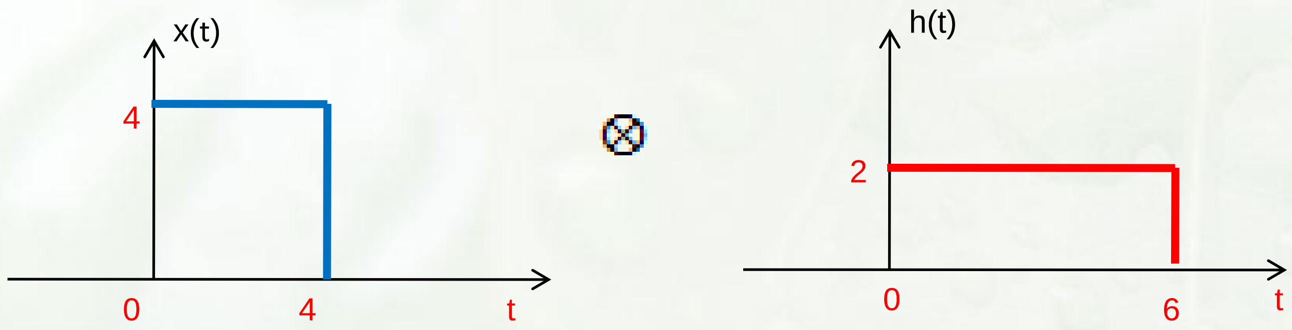
$$s_1(t).s_2(t) \Leftrightarrow \int_{-\infty}^{\infty} S_1(\lambda).S_2(f-\lambda)d\lambda$$

TRANSFORMASI FOURIER

TUGAS 2 (Review PSTM)

[1]





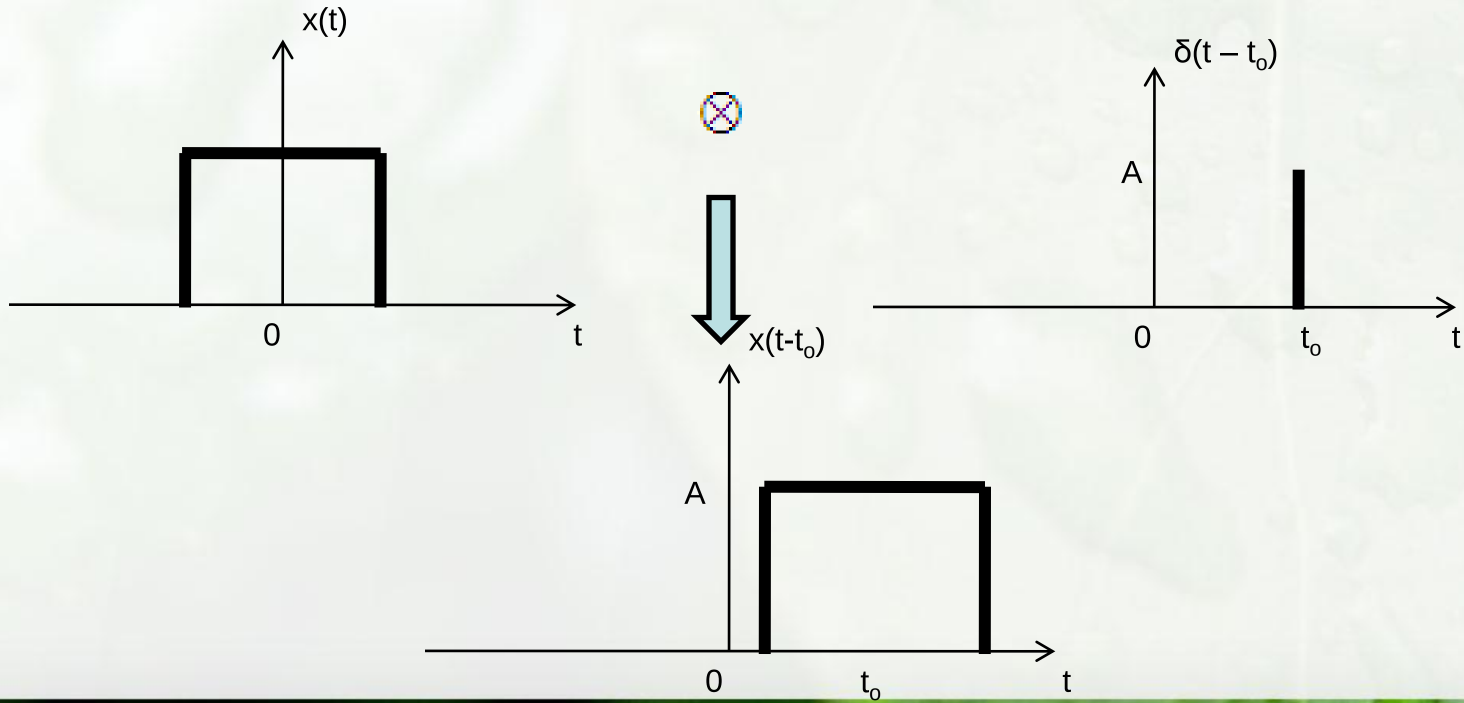
TRANSFORMASI FOURIER

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)

$(\omega_c t + \theta)$

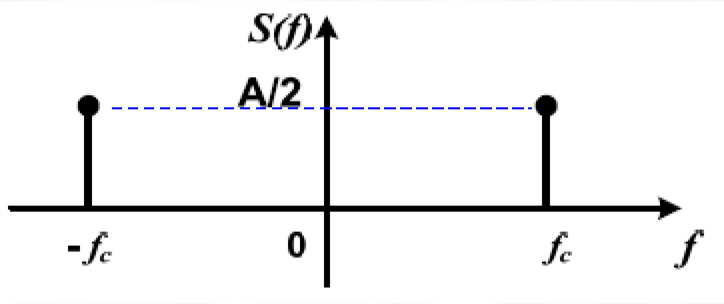
Frequency Modulation (FM)

Phase Modulation (PM)

AMPLITUDE MODULATION (AM)

Review Kawasan Waktu ↔Frekuensi?

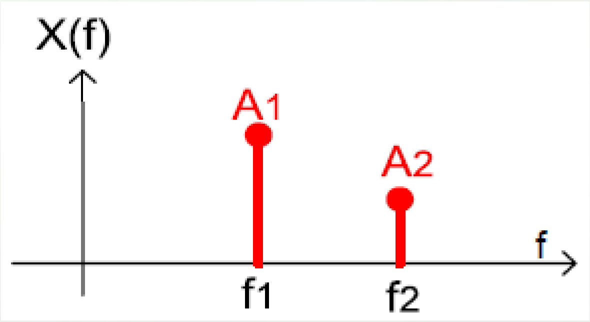
$s(t) = A \text{ Cos } 2\pi f_c t$



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

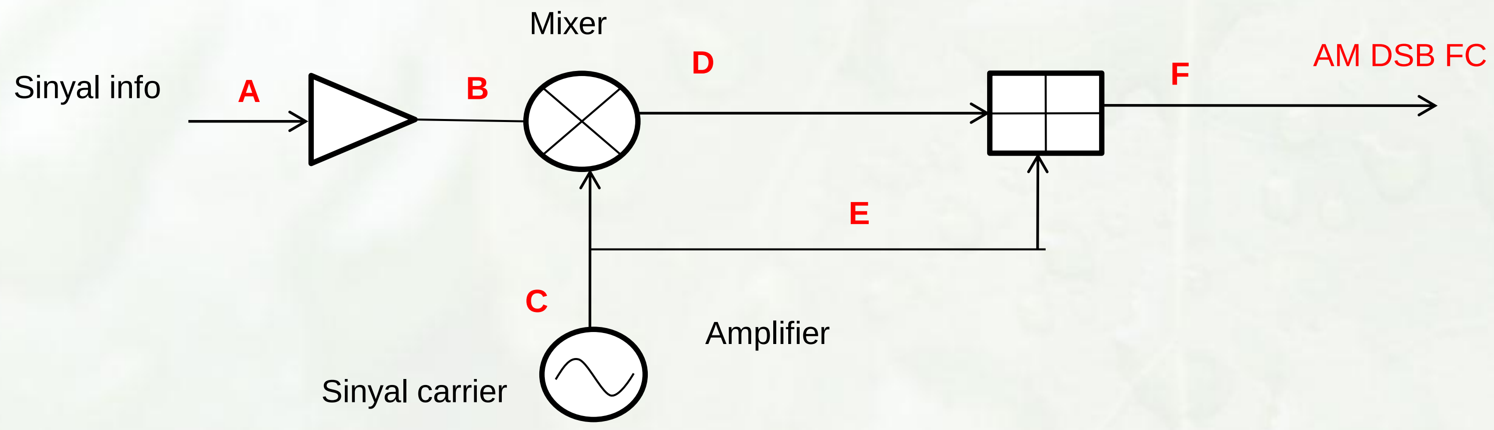
1. Double Side Band **Full Carrier (DSB-FC)**
2. Double Side Band **Suppressed Carrier (DSB-SC)**
3. Single Side Band (SSB)
4. Vestigial Side Band (VSB)

AM-DSB-FC

AMPLITUDE MODULATION (AM)

AM-DSB-FC

"Diagram Blok Modulasi AM-DSB-FC"



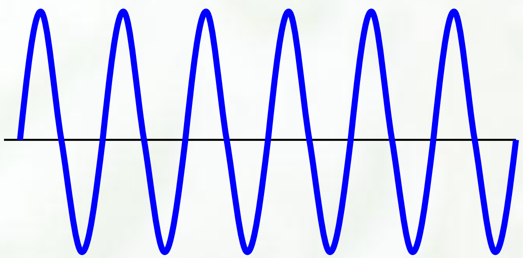
$$S_c(t) = V_c \cos(\omega_c t)$$

AMPLITUDE MODULATION (AM)

AM-DSB-FC

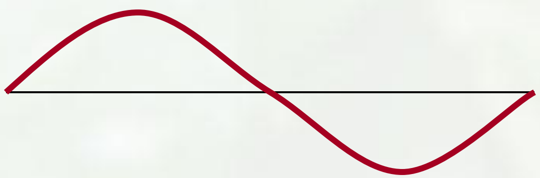
Pembawa : $S_c(t) = V_c \cos(\omega_c t)$

$S_c(t)$



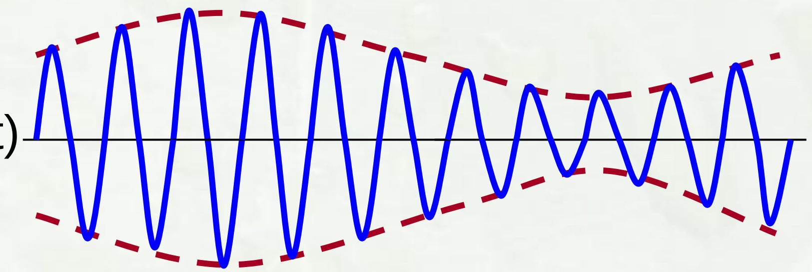
Pemodulasi : m(t)

m(t)



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

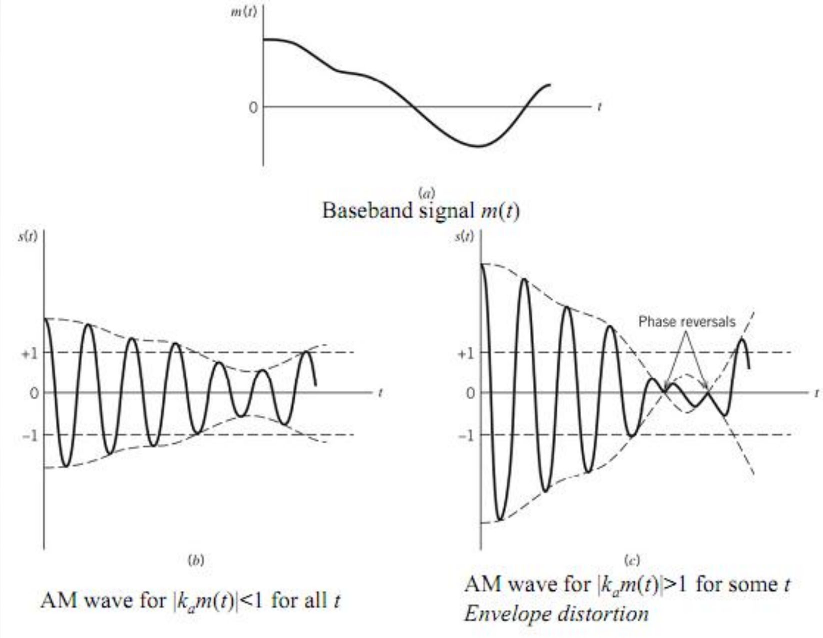
$S_{AM}(t)$



k_a = sensitivitas Amplituda [per volt]

AMPLITUDE MODULATION (AM)

AM-DSB-FC



Syarat Modulasi AM :

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

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

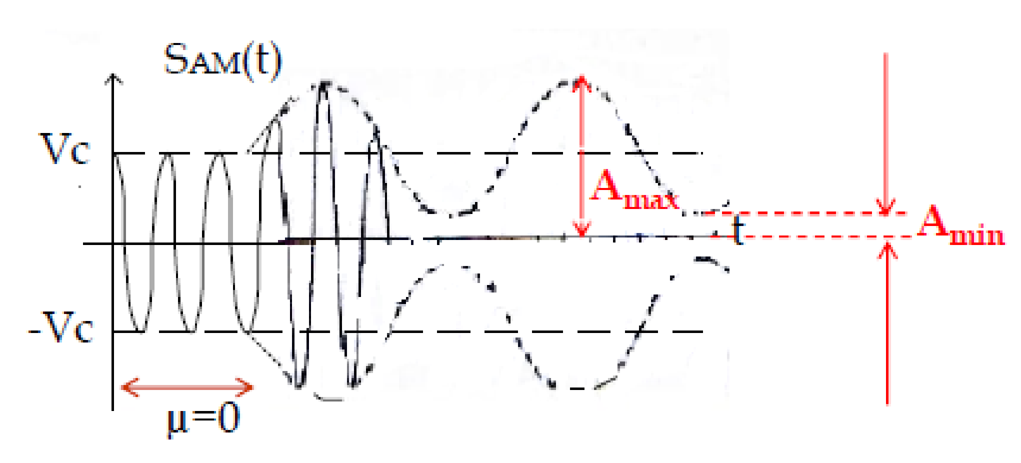
AMPLITUDE MODULATION (AM)

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 = $K_a V_m$



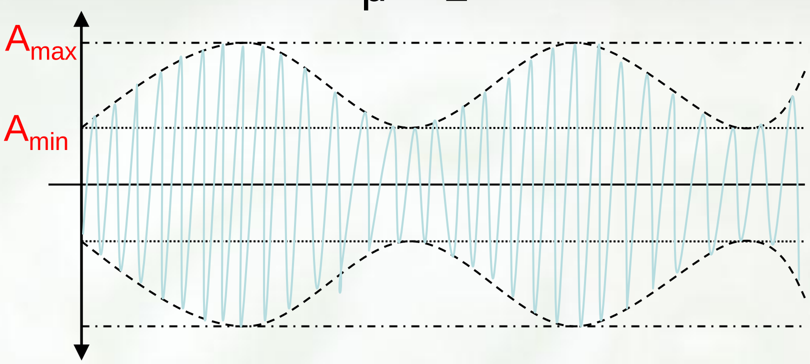
$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

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

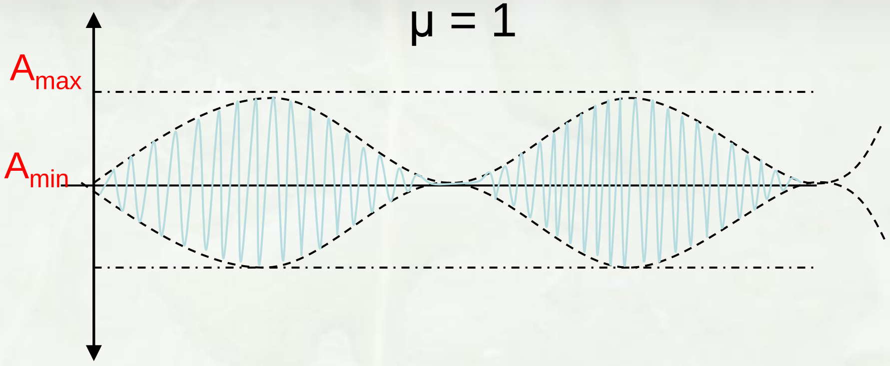
AMPLITUDE MODULATION (AM)

Indeks Modulasi AM-DSB-FC

μ < 1

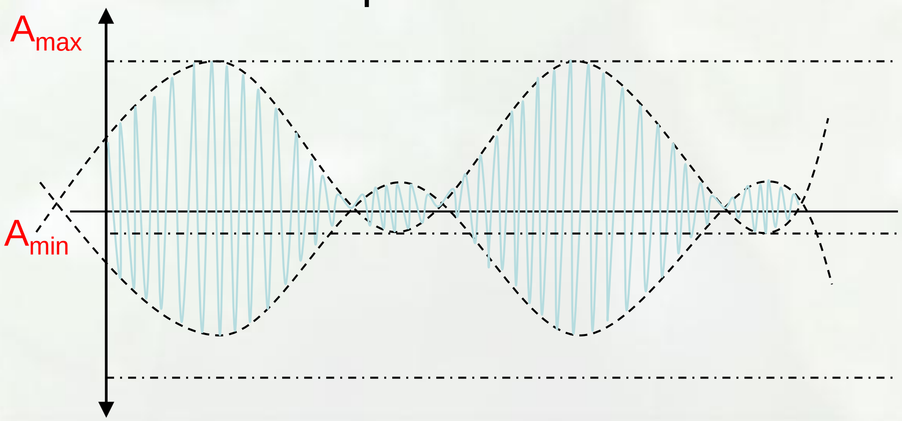


μ = 1



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

μ > 1



⇨ **OVER MODULATION**

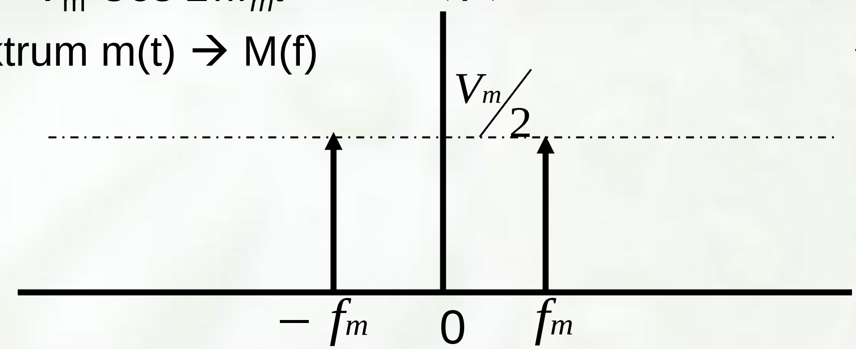
AMPLITUDE MODULATION (AM)

Spektrum AM DSB FC

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

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

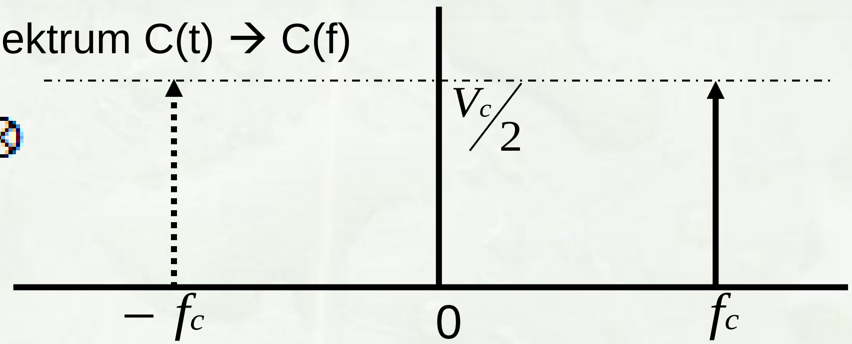
Spektrum m(t) → M(f)



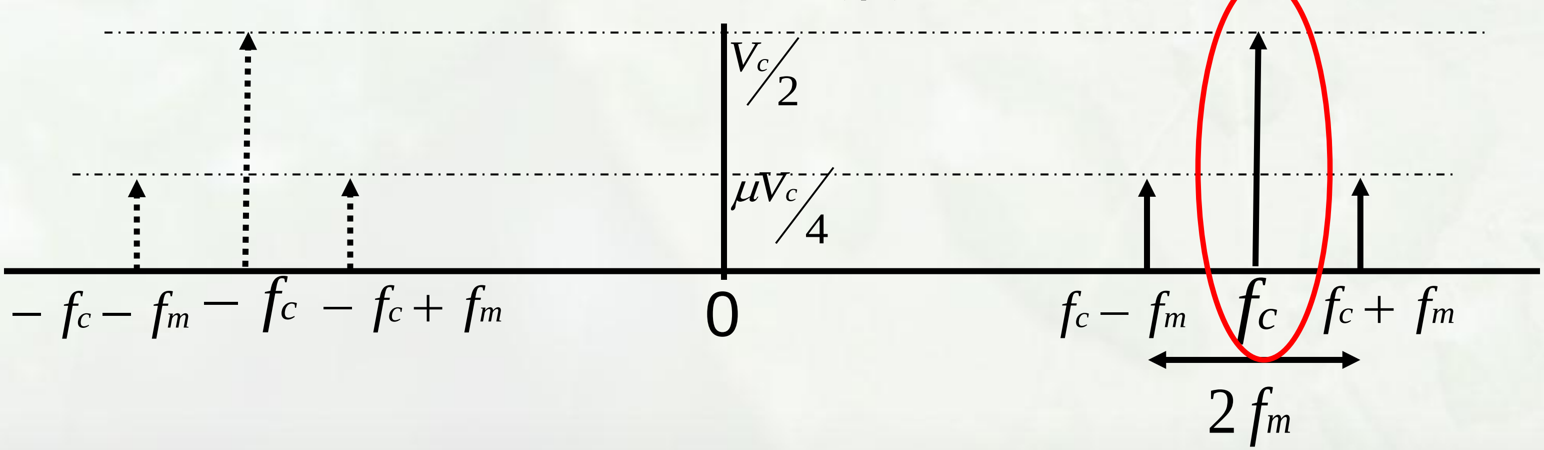
⊗

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

Spektrum C(t) → C(f)



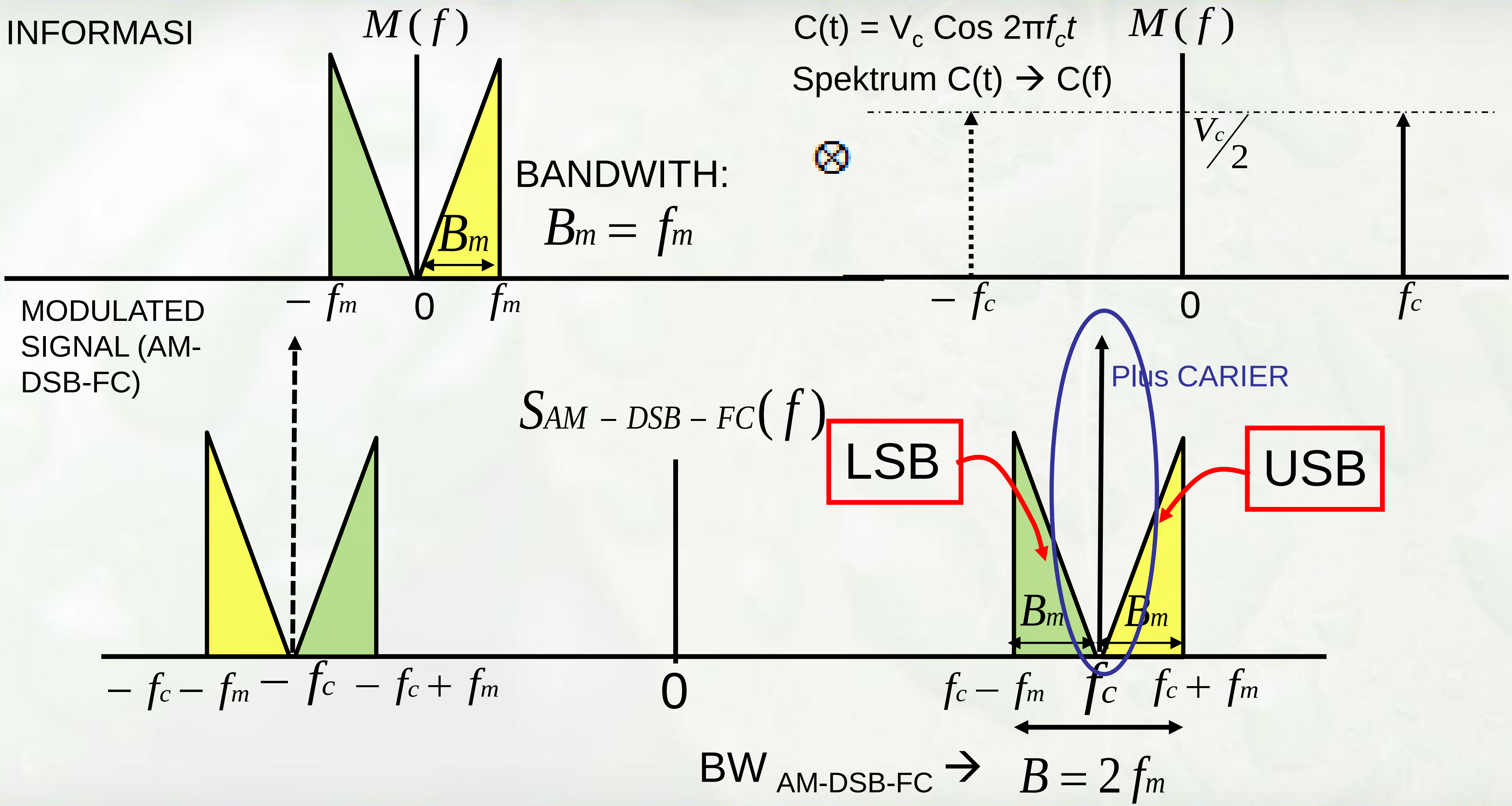
Gambar Spektrum
Sinyal DSB-FC



AMPLITUDE MODULATION (AM)

Spektrum AM DSB FC

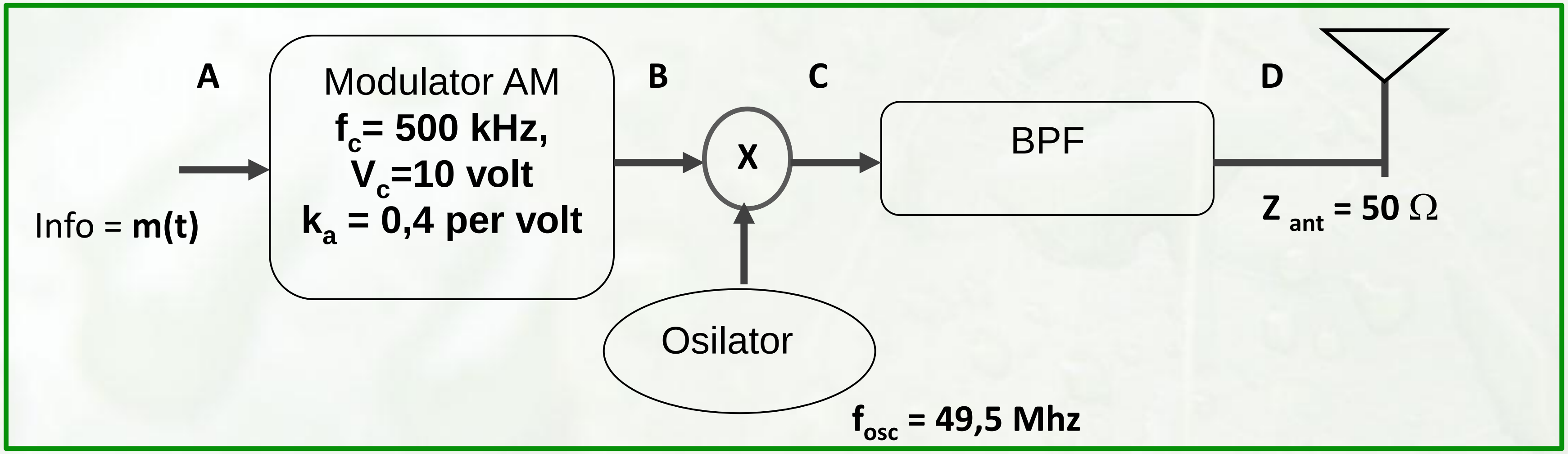
dengan informasi sinyal sembarang m(t) ↔ M(f)



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: $\mathbf{V_{AM}(t) = Vc\,[\,1+ k_a\, m(t)\,]\cos(2\pi f_c t)}$

a) **gambarkan gelombang** sinyal AM DSB-FC **(di B) pada gambar diatas, Jika m(t) = 1 cos(2π.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

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

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

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

CARIER USB LSB

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)

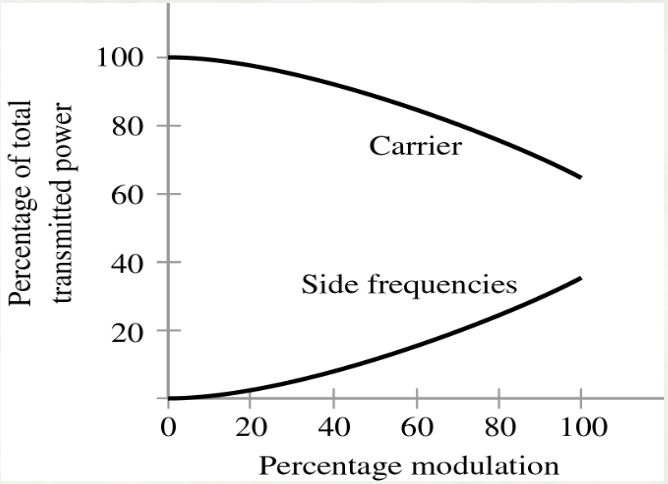
Power Transmission Efficiency of AM-DSB-FC

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

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

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

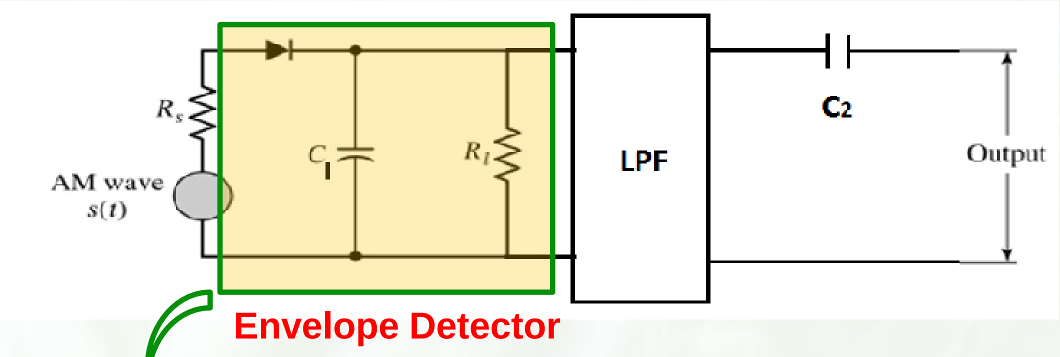
μ	η
0,25	0,03
0,5	0,11
0,75	0,22
1	0,33



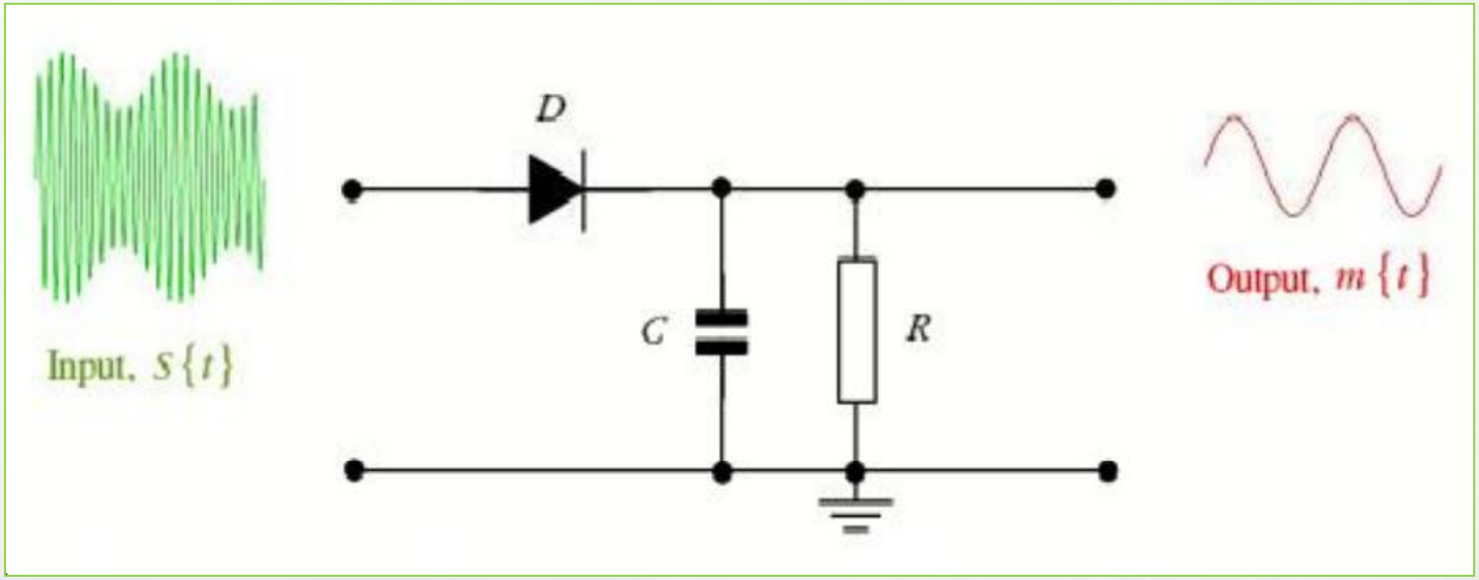
Dari Tabel Diatas bisa disimpulkan bahwa Efisiensi Power transmisi dari AM-DSB-FC meningkat jika index modulasinya **μ** dinaikkan, Tetapi meskipun index modulasinya sudah maksimal **μ = 1**, hanya 1/3 dayanya berada pada sideband, sedangkan 2/3 berada pada carier

AMPLITUDE MODULATION (AM)

Demodulasi Sinyal AM-DSB-FC – Detector Selubung

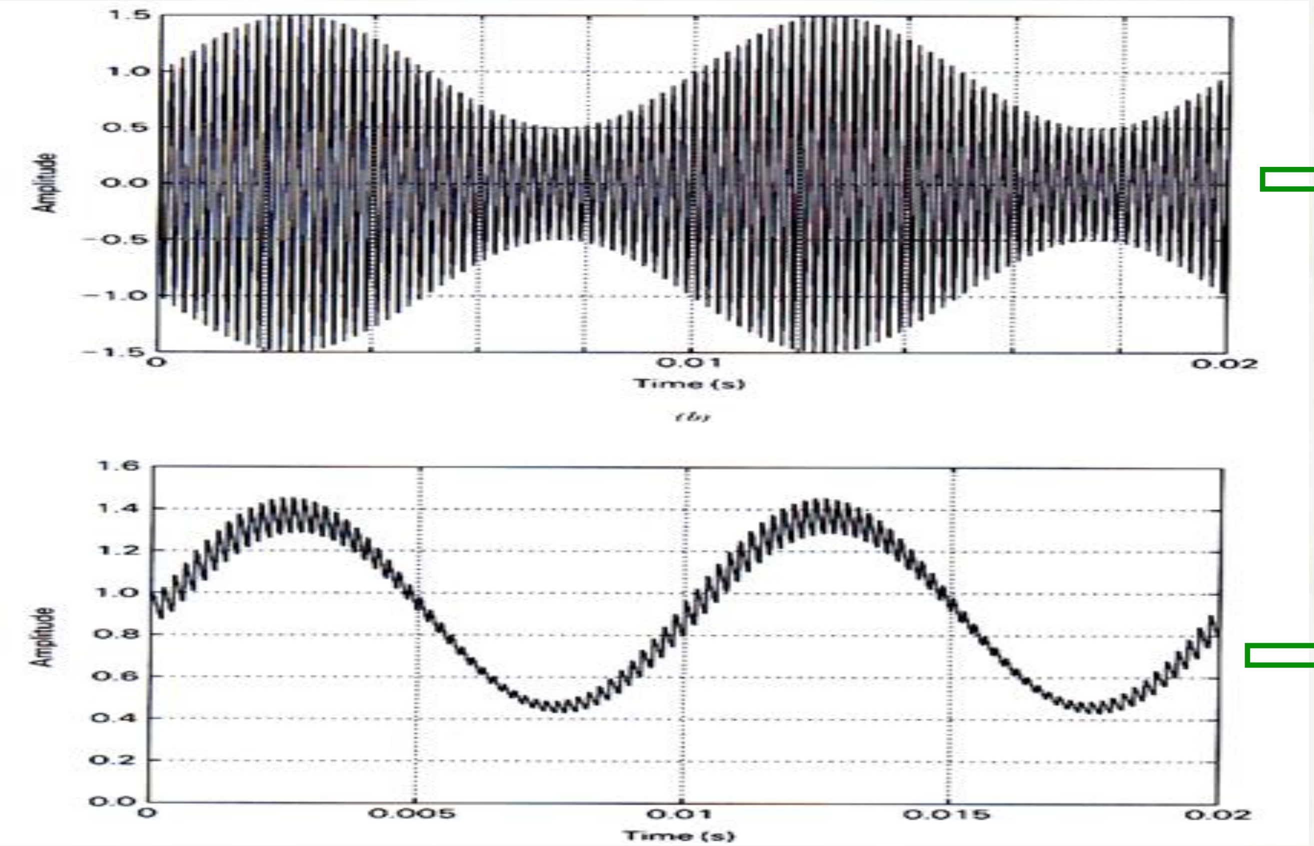


Dilakukan dengan mendeteksi selubung (envelope) sinyal termodulasinya. Alat yang digunakan disebut **Detektor Selubung (Envelope Detector**)



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

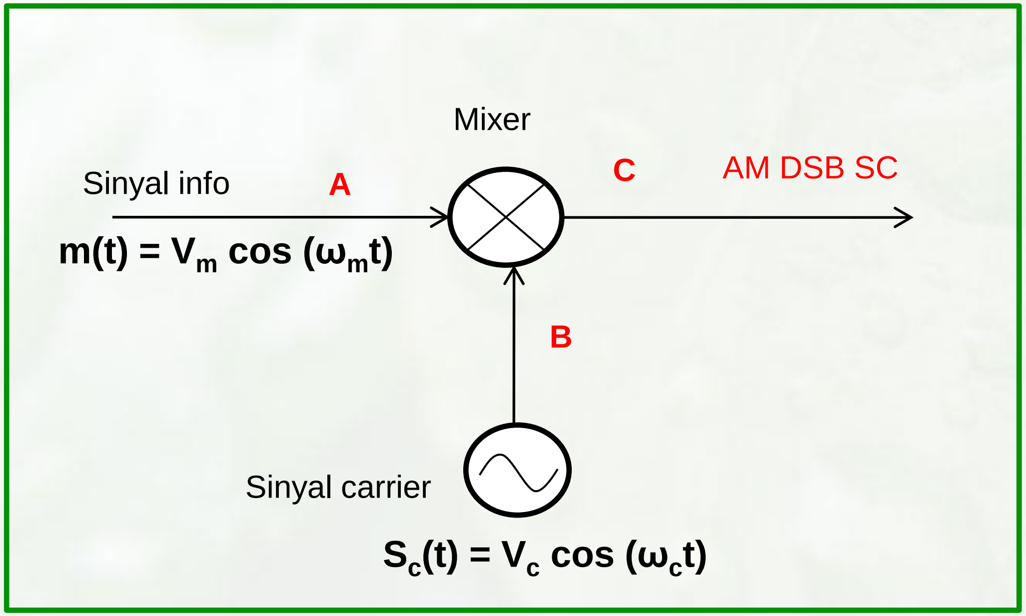
- Pada AM-DSB-FC, sinyal sideband di transmisikan bersama dengan cariernya
- Sederhana dalam mendeteksi / Demodulasi → detektor selubung
- Efisiensi Power transmisi rendah
- Bandwidth yang dibutuhkan besar (2 x BW informasi)

AM-DSB-SC

AMPLITUDE MODULATION (AM)

AM-DSB-SC

"Diagram Blok Modulasi AM-DSB-SC"

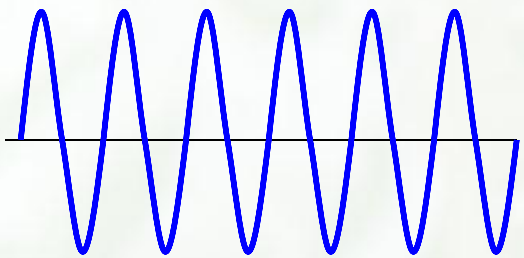


AMPLITUDE MODULATION (AM)

AM-DSB-SC

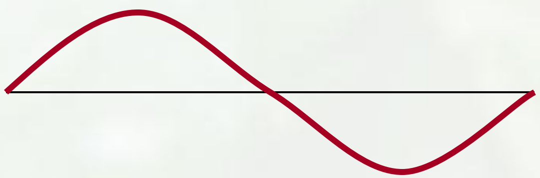
Pembawa : $S_c(t) = V_c \cos(\omega_c t)$

$S_c(t)$



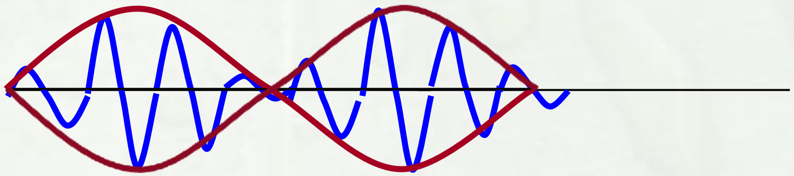
Pemodulasi : $m(t)$

$m(t)$



$$S_{AM_{DSB-SC}}(t) = V_c V_m \cos(2\pi f_c t)\cos(2\pi f_m t)$$

$S_{AM}(t)$

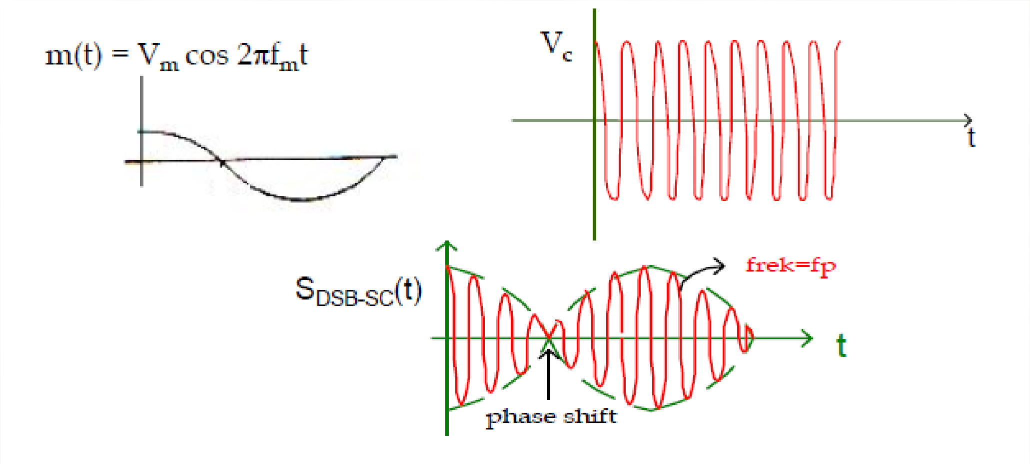


AMPLITUDE MODULATION (AM)

AM-DSB-SC→ Pemodulasi Sinusoidal Tunggal

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

$$S_{AM_{DSB-SC}}(t) = V_c V_m \cos(2\pi f_m t)\cos(2\pi f_c t)$$
$$= \left(\frac{V_c V_m}{2}\right)\{\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t\}$$



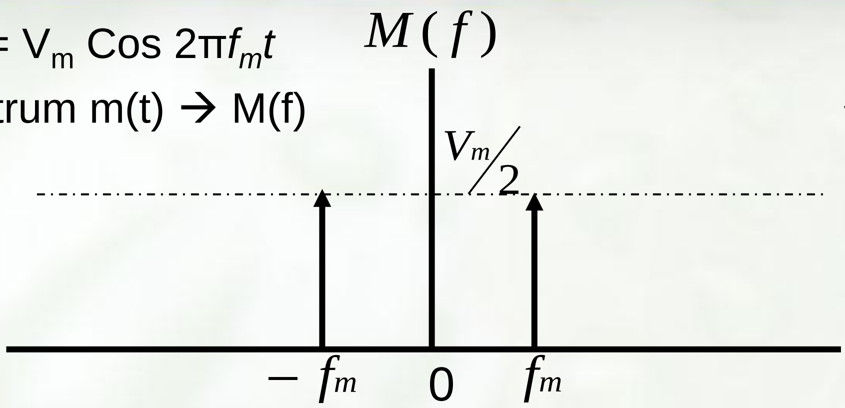
AMPLITUDE MODULATION (AM)

Spektrum AM DSB SC

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

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

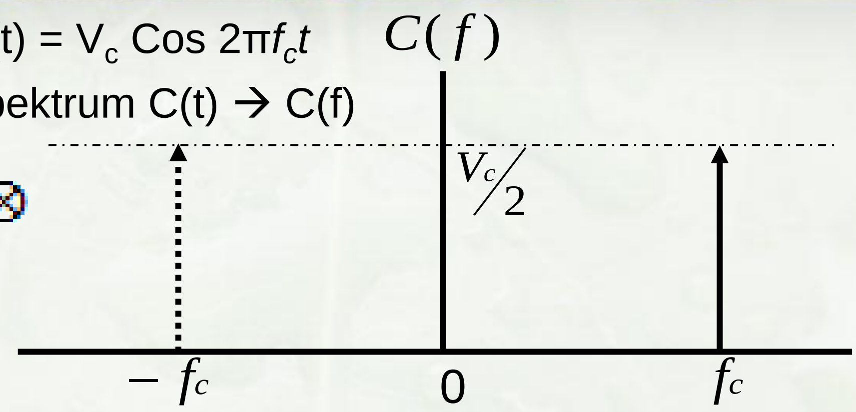
Spektrum m(t) → M(f)



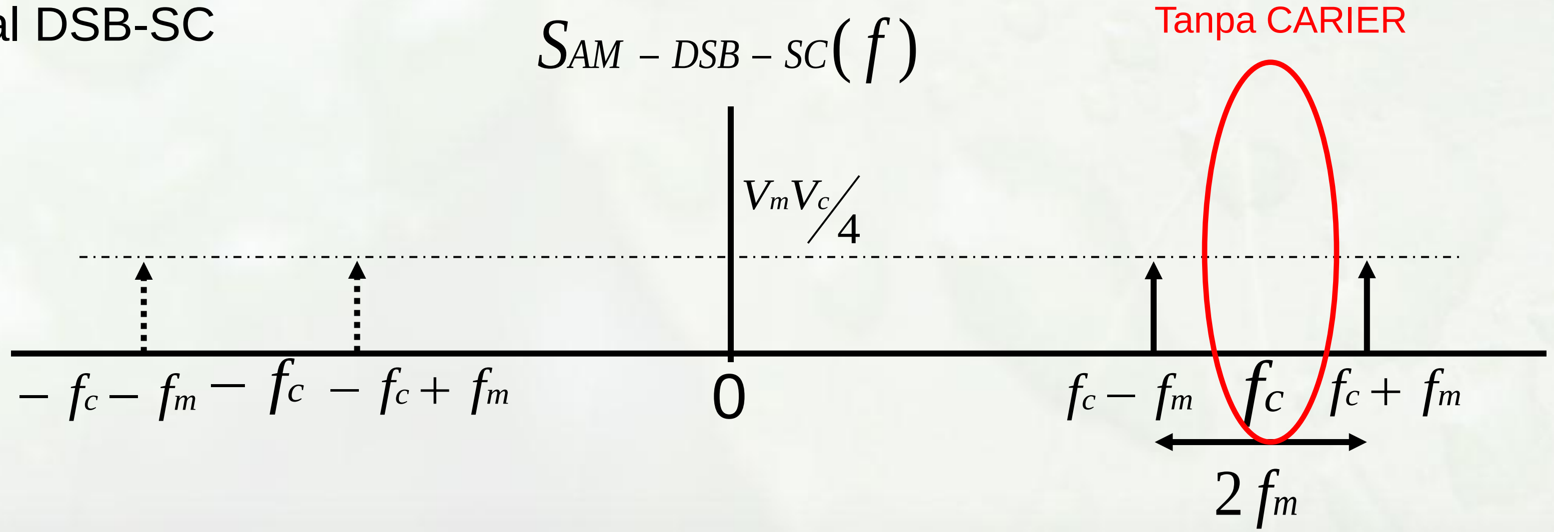
$\otimes$

C(t) = V_c Cos $2\pi f_c t$

Spektrum C(t) → C(f)



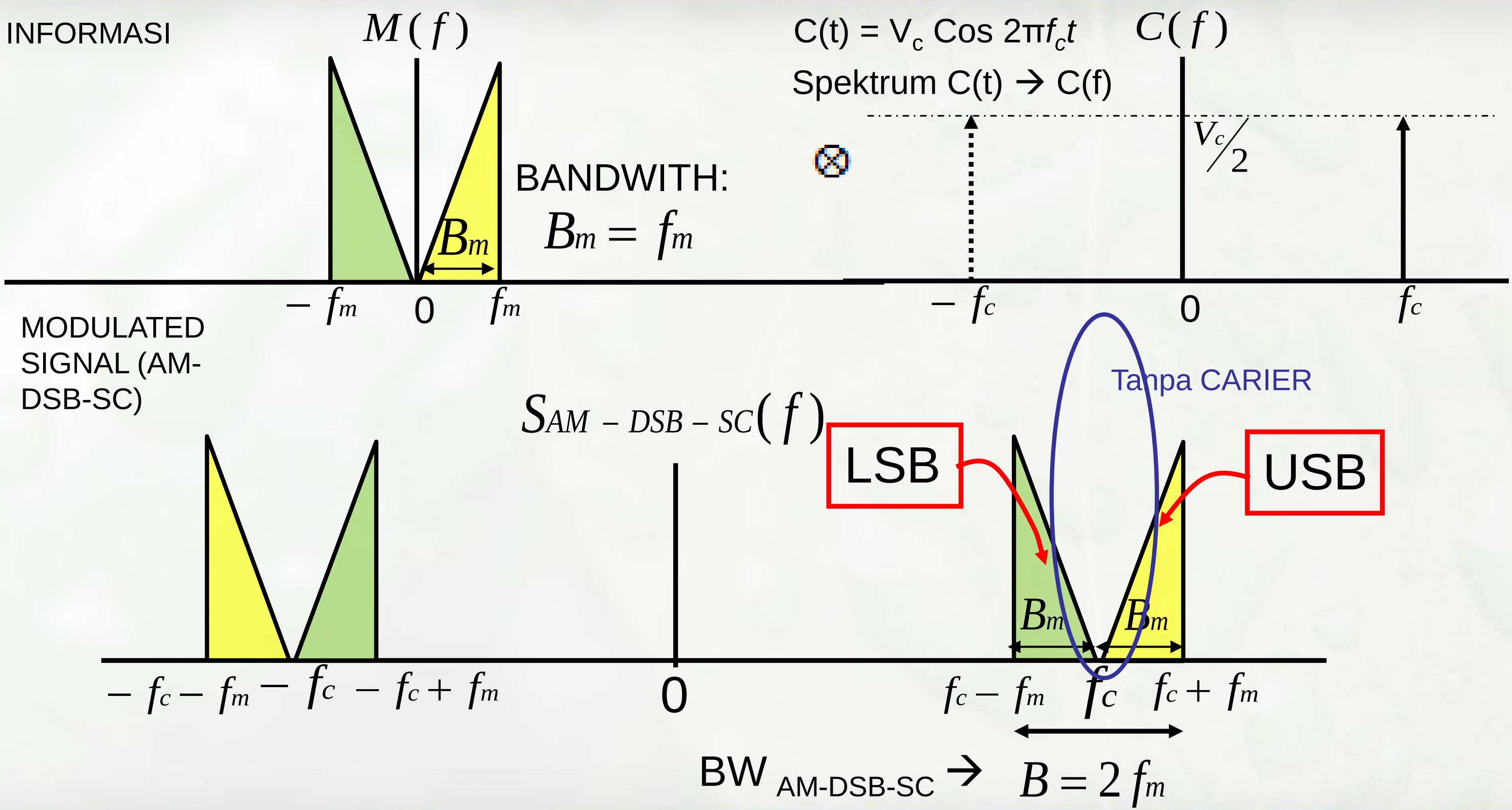
Gambar Spektrum
Sinyal DSB-SC



AMPLITUDE MODULATION (AM)

Spektrum AM DSB SC

dengan informasi sinyal sembarang m(t) ↔ M(f)



AMPLITUDE MODULATION (AM)

Daya Pada sinyal AM-DSB-SC

$$S_{AM\ DSB-SC}(t) = V_m V_c \cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$S_{AM}(t) = V_m V_c \cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$= \frac{V_m V_c}{2}\cos(2\pi(f_c + f_m)t) + \frac{V_m V_c}{2}\cos(2\pi(f_c - f_m)t)$$

Nilai RMS → $\frac{V_m V_c}{2\sqrt{2}}$ (USB) $\frac{V_m V_c}{2\sqrt{2}}$ (LSB)

USB

LSB

AMPLITUDE MODULATION (AM)

Daya Pada sinyal AM-DSB-SC

$$P_{AM_{DSB-SC}} = P_{USB} + P_{LSB}$$

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

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

Daya pada Referensi Resistansi 1 ohm ⇒

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

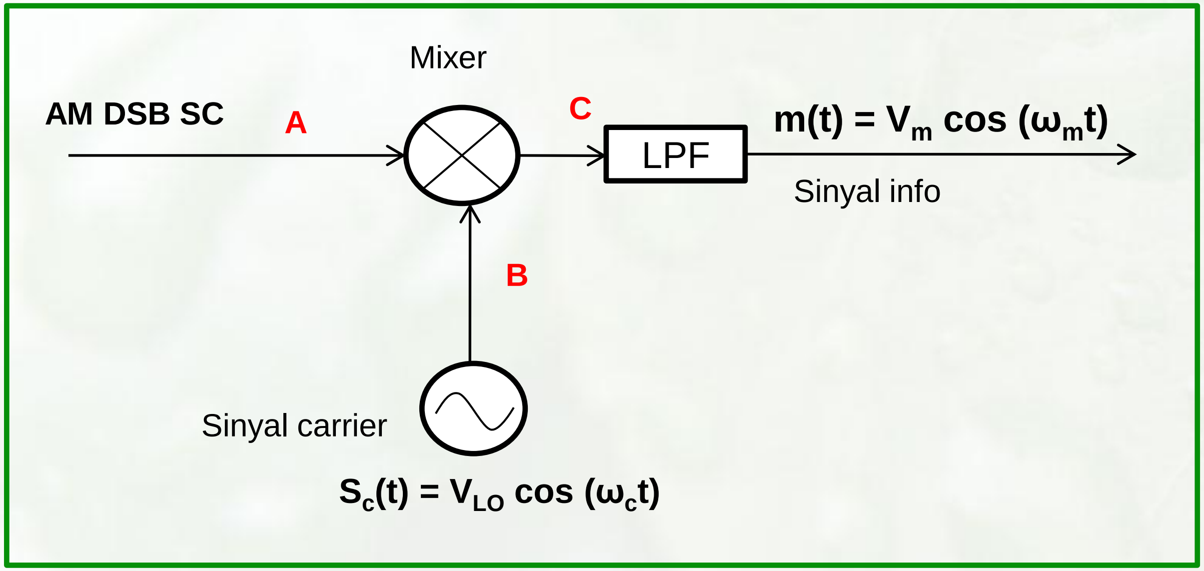
$$= 2\frac{V_m{}^2 V_c{}^2}{8R} = 2\frac{V_m{}^2 V_c{}^2}{8}$$

$$= \frac{V_m{}^2 V_c{}^2}{4}$$

AMPLITUDE MODULATION (AM)

Demodulasi/Deteksi Sinyal DSB-SC

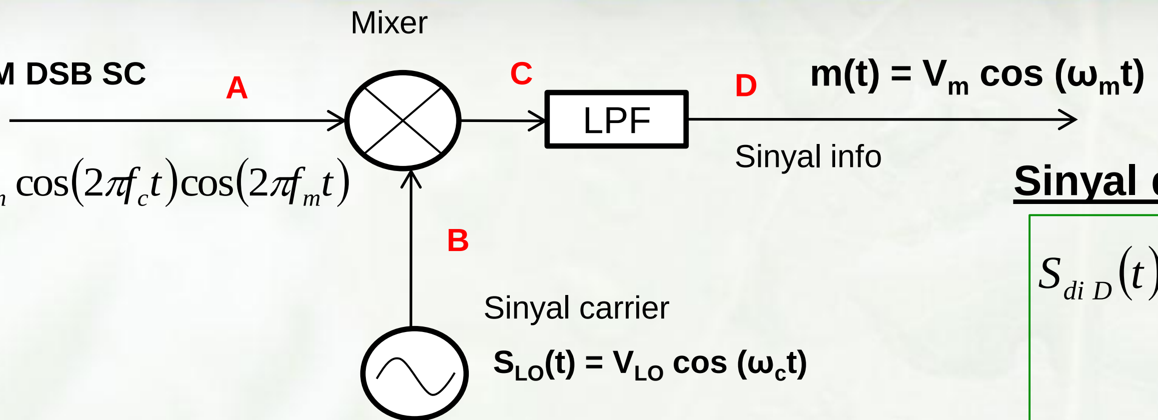
- Proses demodulasi dilakukan dengan mengalikan sinyal carrier termodulasi dengan sinyal local oscillator (pada penerima) yang sama persis dengan sinyal oscillator pada pemancar, kemudian memasukan hasilnya ke sebuah low pass filter (LPF)



- Syarat penting :Local Oscillator harus menghasilkan sinyal cos $\omega_c t$ yang frequency dan phasa nya sama dengan yang dihasilkan oleh oscillator pada pemancar
  - Synchronous Demodulation/Detection
  - Coherent detection

AMPLITUDE MODULATION (AM)

Demodulasi/Deteksi Sinyal DSB-SC



$$S_{AM_{DSB-SC}}(t) = V_c V_m \cos(2\pi f_c t)\cos(2\pi f_m t)$$

Sinyal di C

$$S_{di\ C}(t) = V_m V_c \cos(2\pi f_m t)\cos(2\pi f_c t) V_{LO}\cos(2\pi f_c t)$$

$$= \left(\frac{V_m V_c}{2}\cos(2\pi(f_c + f_m)t) + \frac{V_m V_c}{2}\cos(2\pi(f_c - f_m)t)\right) V_{LO}\cos(2\pi f_c t)$$

$$= \frac{V_m V_c V_{LO}}{2}\cos(2\pi(f_c + f_m)t)\cos(2\pi f_c t) + \frac{V_m V_c V_{LO}}{2}\cos(2\pi(f_c - f_m)t)\cos(2\pi f_c t)$$

$$= \frac{V_m V_c V_{LO}}{4}\cos(2\pi(2f_c + f_m)t) + \frac{V_m V_c V_{LO}}{4}\cos(2\pi(f_m)t) +$$

$$\frac{V_m V_c V_{LO}}{4}\cos(2\pi(2f_c - f_m)t) + \frac{V_m V_c V_{LO}}{4}\cos(2\pi(-f_m)t)$$

Yang Lolos dari LPF

Sinyal di D

$$S_{di\ D}(t) = \frac{V_m V_c V_{LO}}{4}\cos(2\pi f_m t) +$$

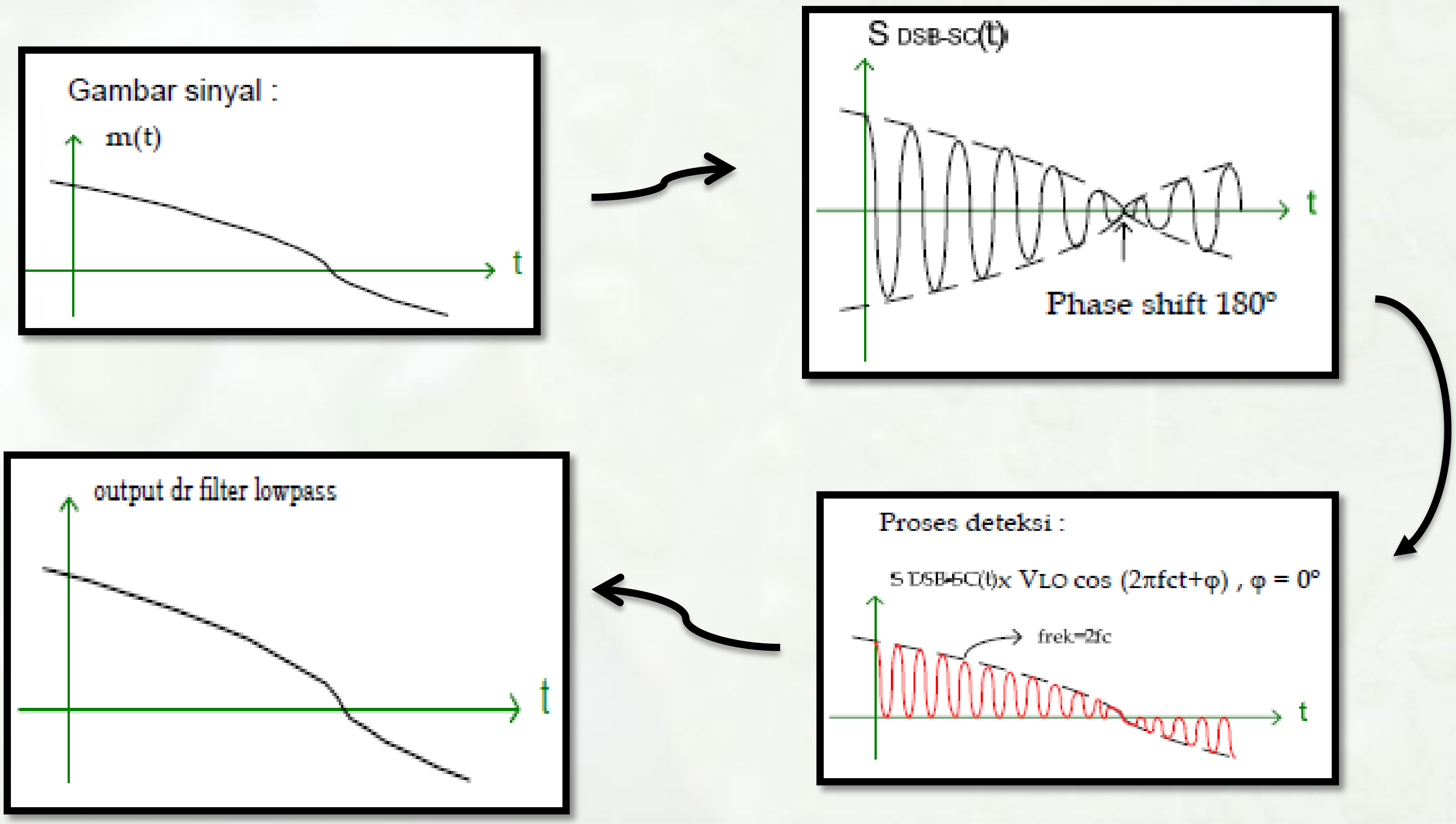
$$\frac{V_m V_c V_{LO}}{4}\cos(2\pi f_m t)$$

$$= \frac{V_m V_c V_{LO}}{2}\cos(2\pi f_m t)$$

AMPLITUDE MODULATION (AM)

Modulasi AM-DSB-SC

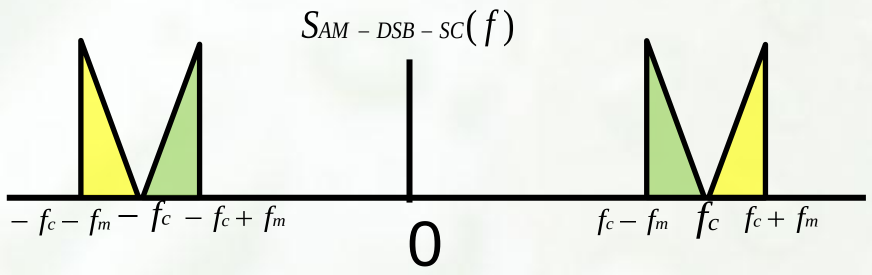
(informasi/pemodulasi sembarang m(t) – analisa kawasan waktu)



AMPLITUDE MODULATION (AM)

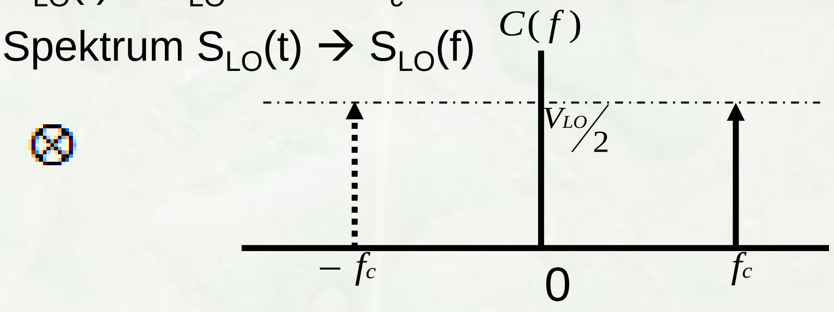
Modulasi AM-DSB-SC
(informasi/pemodulasi sembarang m(t) – analisa kawasan frekuensi)

MODULATED SIGNAL (AM-DSB-SC)

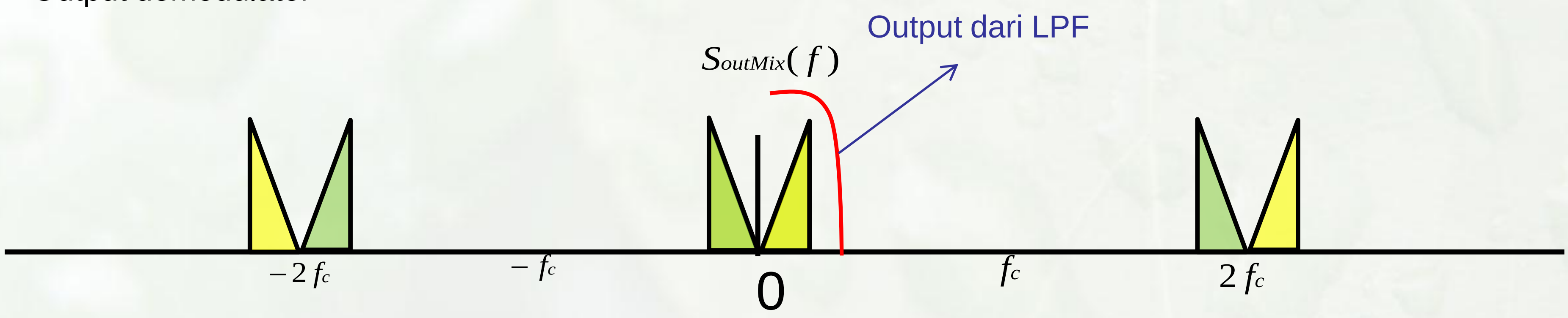


$S_{LO}(t) = V_{LO} \cos 2\pi f_c t$

Spektrum $S_{LO}(t) \rightarrow S_{LO}(f)$



Output demodulator



AMPLITUDE MODULATION (AM)

Kesimpulan AM-DSB-SC

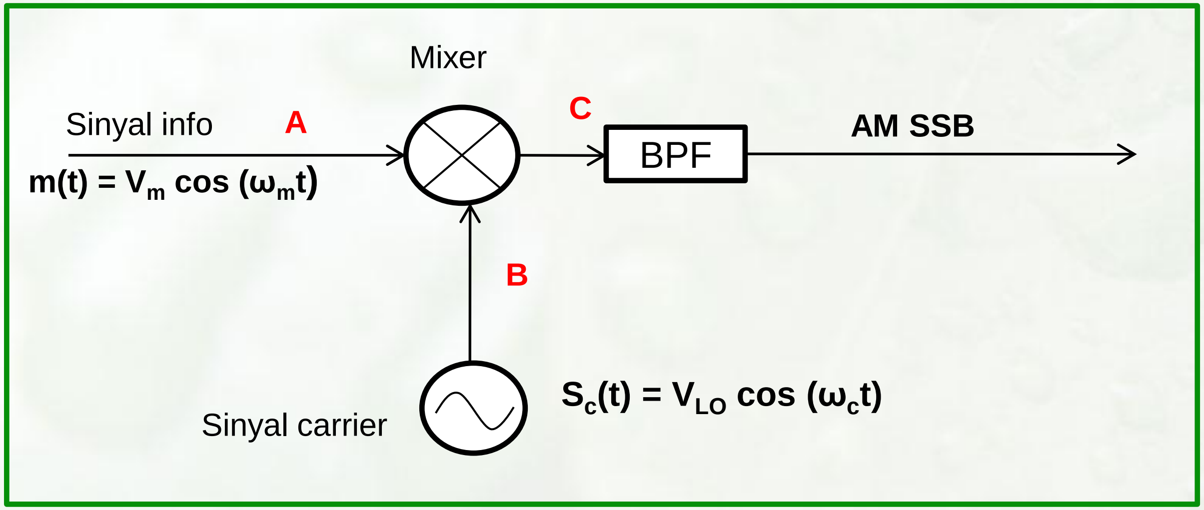
- Less transmitted power than AM-DSB-FC and all the transmitted power is useful.
- Requires a coherent carrier at the receiver; This results in increased complexity in the detector(i.e. synchroniser)

AM-SSB

AMPLITUDE MODULATION (AM)

AM-SSB (Single Side Band)

“Diagram Blok Modulasi AM-SSB”



- Dikembangkan karena DSB-SC membutuhkan Bandwith yang besar (2 kali bandwith sinyal informasi)
- Ternyata USB atau LSB mengandung informasi yang lengkap, sehingga dirasa cukup mentransmisikan salah satu side band saja
- Dua tipe AM-SSB → AM-SSB-USB dan AM-SSB-LSB

AMPLITUDE MODULATION (AM)

AM-SSB → Pemodulasi Sinusoidal Tunggal

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

$$S_{AM_{SSB}}(t) = V_c V_m \cos(2\pi f_m t)\cos(2\pi f_c t)$$
$$= \left(\frac{V_c V_m}{2}\right)\left\{\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t\right\}$$
$$= \frac{V_c V_m}{2}\cos 2\pi(f_c + f_m)t \longrightarrow$$ **KASUS AM-SSB-USB**
$$= \frac{V_c V_m}{2}\cos 2\pi(f_c - f_m)t \longrightarrow$$ **KASUS AM-SSB-LSB**

AMPLITUDE MODULATION (AM)

Daya Pada sinyal AM-SSB

$$S_{AM\ SSB}(t) = V_m V_c \cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$S_{AM}(t) = V_m V_c \cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$= \frac{V_m V_c}{2}\cos(2\pi(f_c + f_m)t) + \frac{V_m V_c}{2}\cos(2\pi(f_c - f_m)t)$$

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

USB LSB

AMPLITUDE MODULATION (AM)

Daya Pada sinyal AM-DSB-SC

$$P_{AM_{SSB-USB}} = P_{AM_{SSB-LSB}} = P_{USB} = P_{LSB}$$

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

$$= \frac{V_m{}^2 V_c{}^2}{8R}$$

Daya pada Referensi Resistansi 1 ohm ⇨

$$P_{AM_{SSB-USB}} = P_{AM_{SSB-LSB}} = \frac{V_m{}^2 V_c{}^2}{8R}$$

$$= \frac{V_m{}^2 V_c{}^2}{8}$$

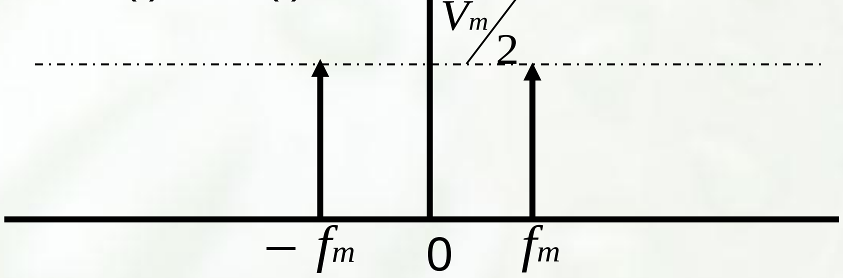
AMPLITUDE MODULATION (AM)

Spektrum AM SSB

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

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

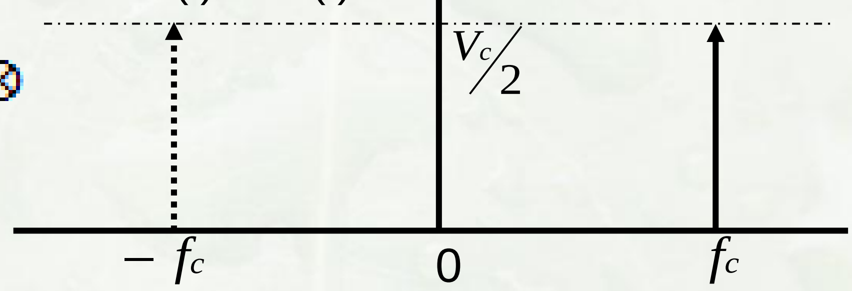
Spektrum m(t) → M(f)



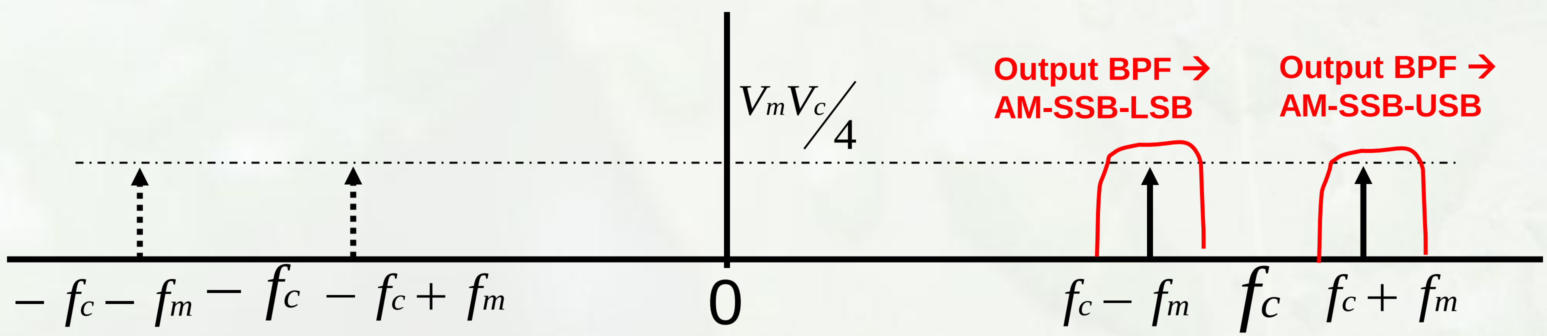
$C(t) = V_c \cos 2\pi f_c t$

Spektrum C(t) → C(f)

⊗

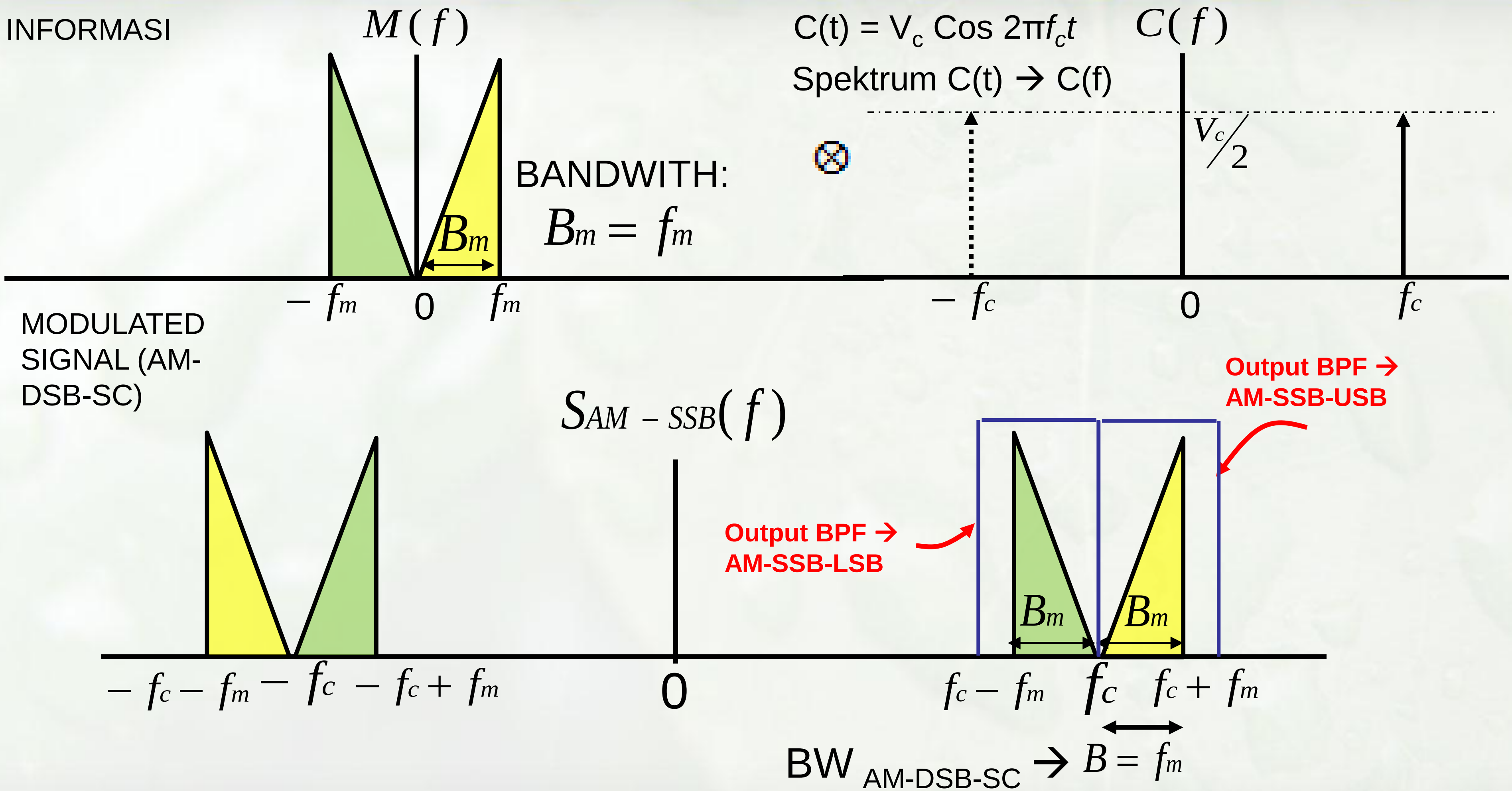


Gambar Spektrum Sinyal DSB-SC



AMPLITUDE MODULATION (AM)

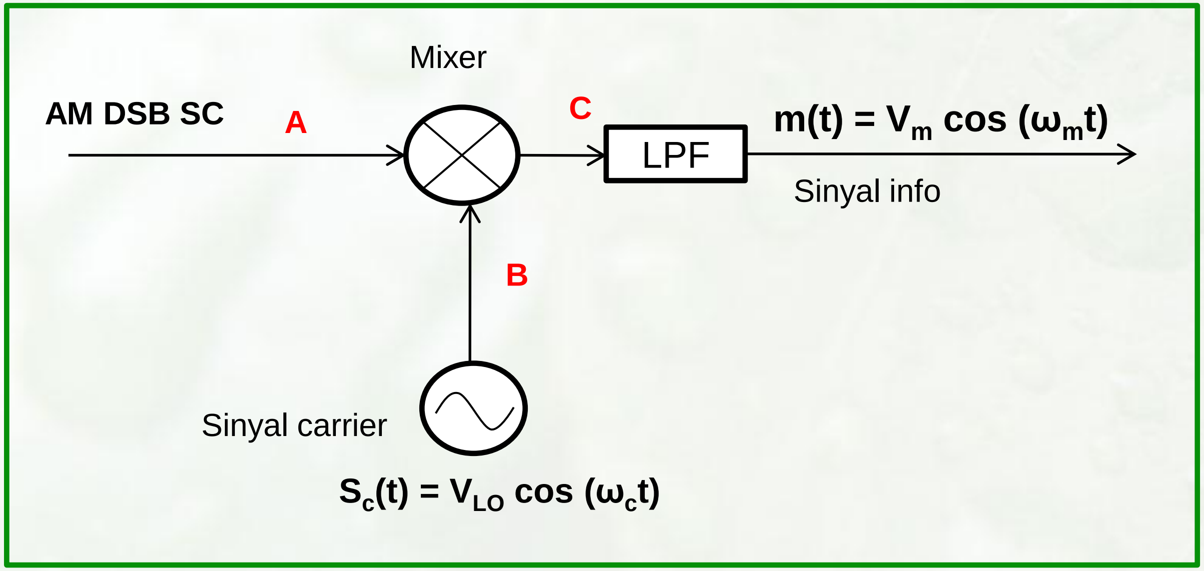
Spektrum AM SSB
dengan informasi sinyal sembarang m(t) ↔ M(f)



AMPLITUDE MODULATION (AM)

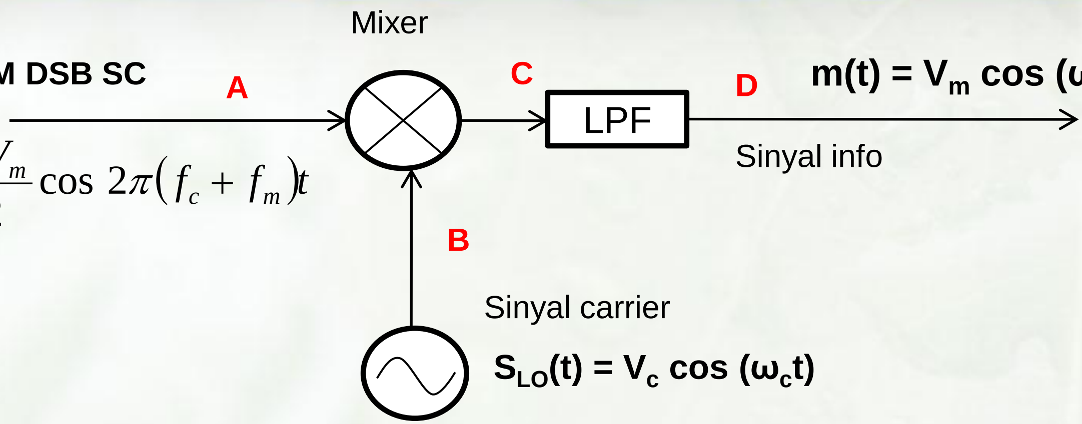
Demodulasi/Deteksi Sinyal AM-SSB

- Proses demodulasi dilakukan dengan Cara yang sama dengan AM-DSB-SC



AMPLITUDE MODULATION (AM)

Demodulasi/Deteksi Sinyal AM-SSB



$$S_{AM_{SSB-USB}}(t)=\frac{V_cV_m}{2}\cos 2\pi\left(f_c+f_m\right)t$$

Sinyal di C

$$S_{di\,C}(t)=\frac{V_mV_c}{2}\cos\left(2\pi\left(f_c+f_m\right)t\right)V_{LO}\cos\left(2\pi f_c t\right)$$

$$=\frac{V_mV_cV_{LO}}{4}\cos\left(2\pi\left(2f_c+f_m\right)t\right)+\frac{V_mV_cV_{LO}}{4}\cos\left(2\pi\left(f_m\right)t\right)$$

Yang Lolos dari LPF

Sinyal di D

$$S_{di\,D}(t)=\frac{V_mV_cV_{LO}}{4}\cos\left(2\pi f_m t\right)$$

AMPLITUDE MODULATION (AM)

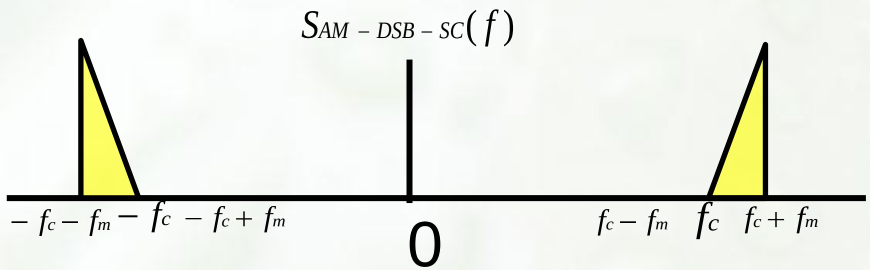
Modulasi AM-SSB

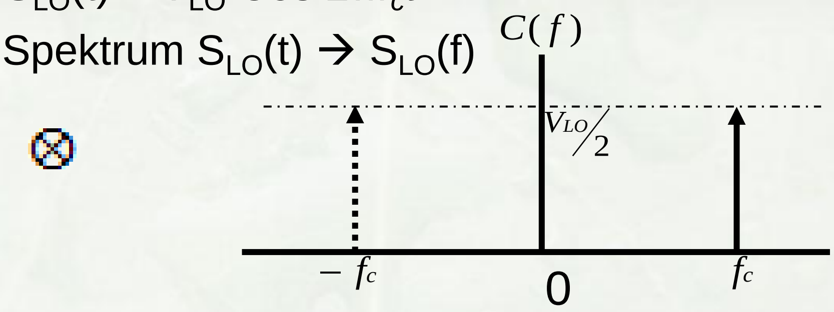
(informasi/pemodulasi sembarang m(t) – analisa kawasan frekuensi)

MODULATED SIGNAL (AM-SSB-USB)

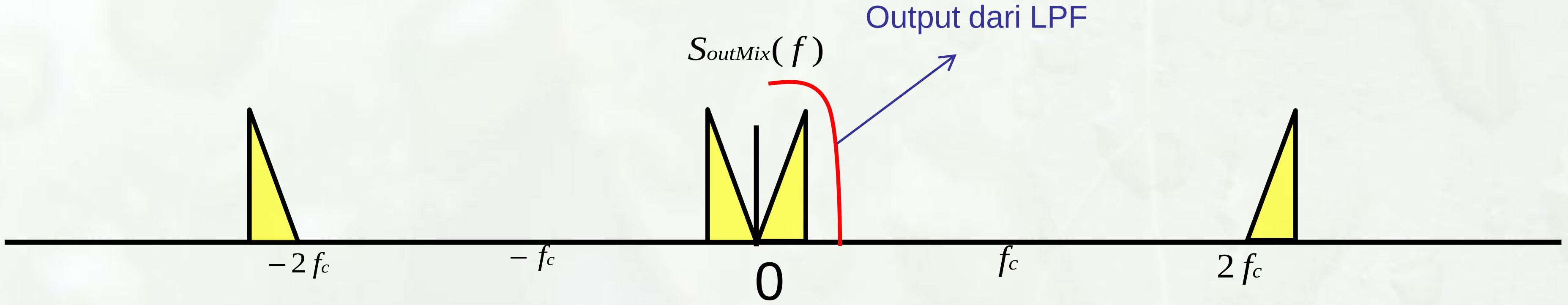
$S_{LO}(t) = V_{LO} \text{ Cos } 2\pi f_c t$

Spektrum $S_{LO}(t) \rightarrow S_{LO}(f)$





Output demodulator



AMPLITUDE MODULATION (AM)

Kesimpulan AM-SSB

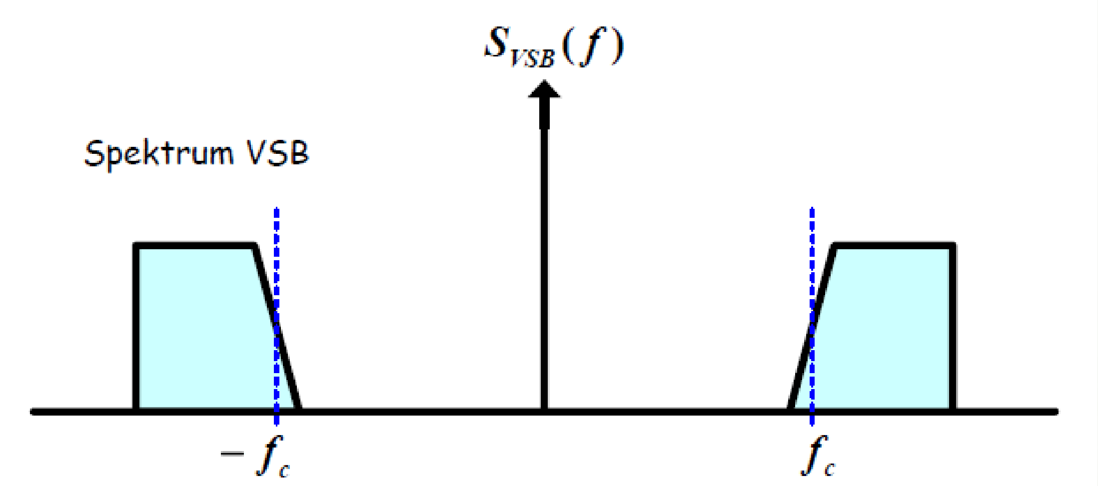
- Good bandwidth utilization (message signal bandwidth = modulated signal bandwidth)
- Good power efficiency
- Demodulation is harder as compares to AM-DSB-FC; Exact filter design and coherent demodulation are required

AM-VSB

AMPLITUDE MODULATION (AM)

AM-VSB (Vestigial Side Band)

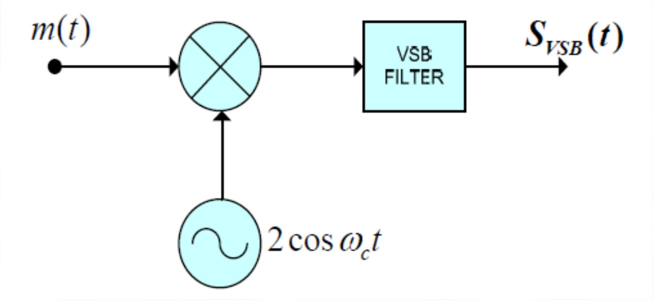
- DSB memiliki kelemahan karena membuang-buang bandwidth dan power, sedangkan SSB meskipun lebih efisien (BW dan Power) tetapi sulit dalam praktek karena butuh filter yang sangat ideal dan biasanya low frekuensi mengandung informasi yang penting
- VSB Merupakan kompromi (jalan tengah) antara SSB dan DSB
- Biasanya digunakan dalam transmisi sinyal video pada televisi

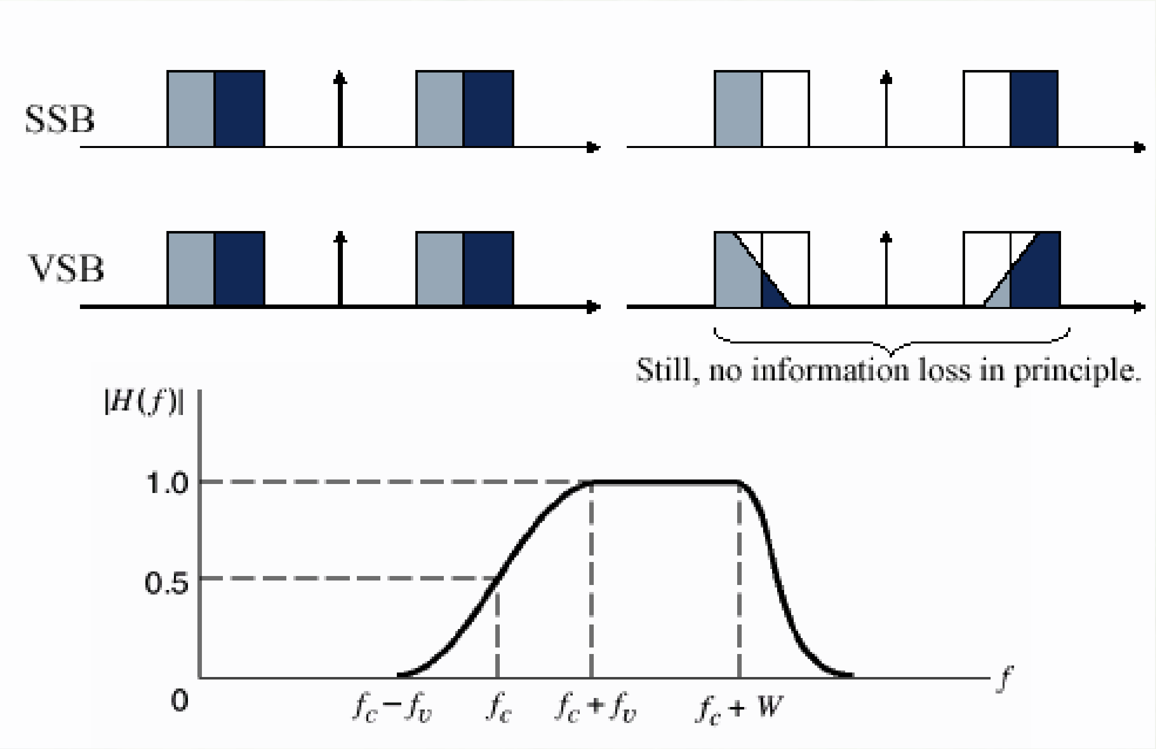


AMPLITUDE MODULATION (AM)

Pembangkitan Sinyal VSB

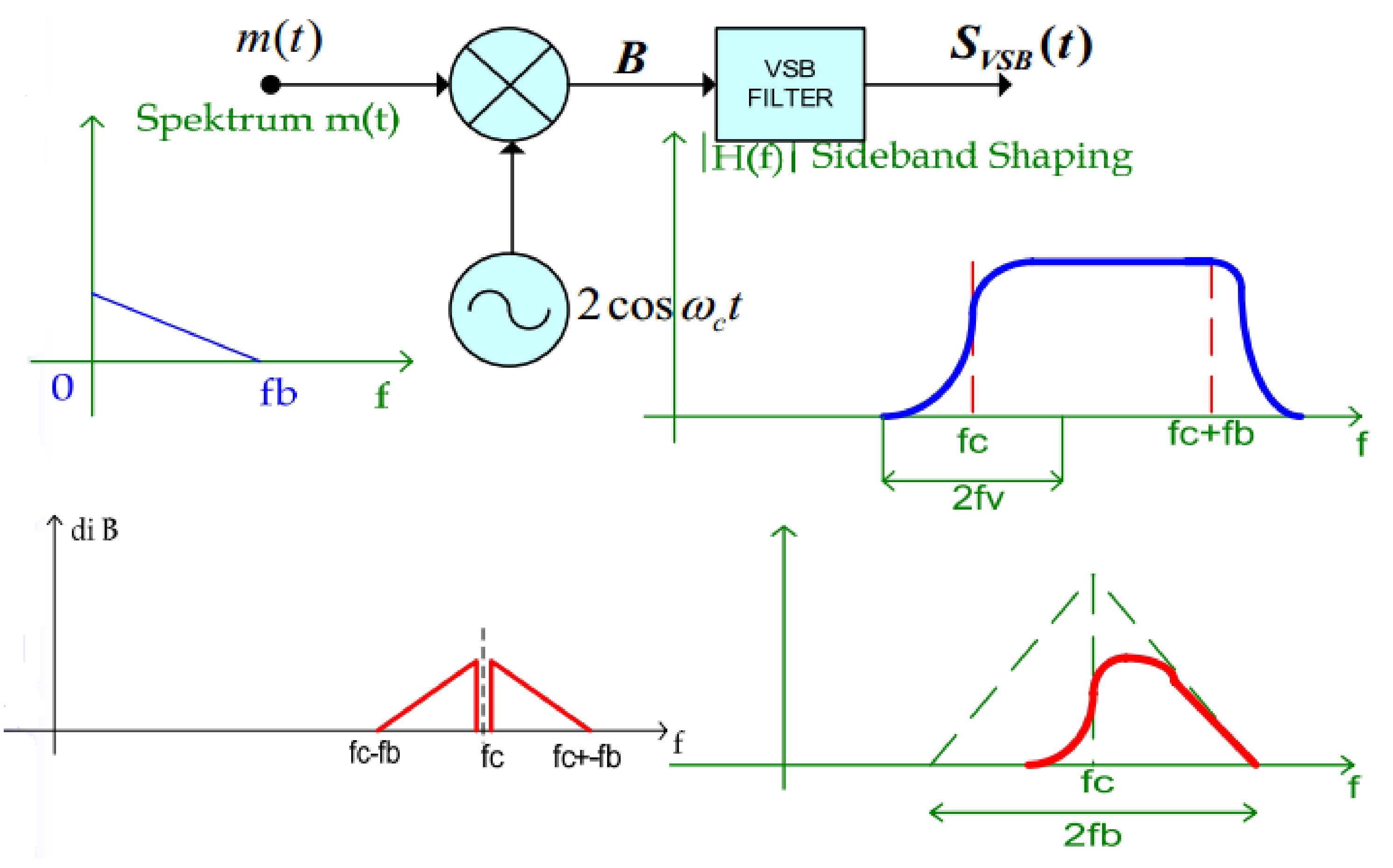
- Sinyal VSB dapat dibangkitkan dengan proses seperti terlihat pada diagram blok berikut





AMPLITUDE MODULATION (AM)

Pembangkitan Sinyal VSB



AMPLITUDE MODULATION (AM)

Kesimpulan AM-VSB

- Offers a compromise between SSB and DSB-SC
- VSB is standard for transmission of TV and similar signals
- Bandwidth saving can be significant if modulating signals are of large bandwidth as in TV and wide band data signals.

  For example with TV the bandwidth of the modulating signal can extend up to 5.5MHz; with full AM the bandwidth required is 11MHz

OUTLINE

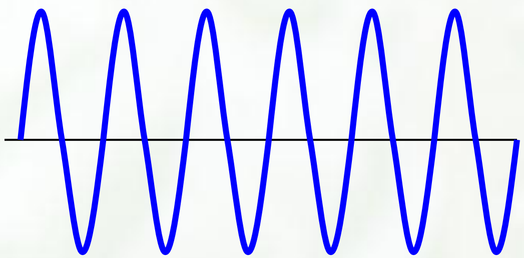
Modulasi, Demodulasi, Kinerja Sistem Frequency Modulation (FM)

FREQUNCY MODULATION (FM)

Pembentukan sinyal FM

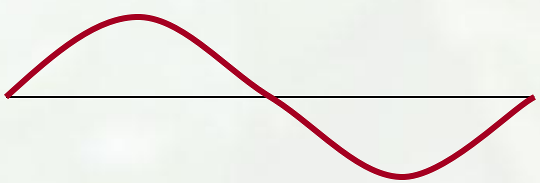
Pembawa : $S_c(t) = V_c \cos(\omega_c t)$

$S_c(t)$



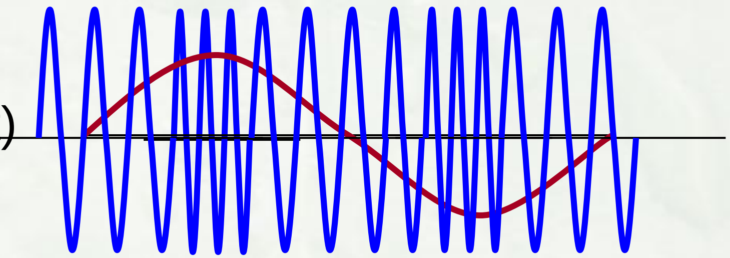
Pemodulasi : m(t)

m(t)



$$S_{FM}(t) = V_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(t)\,dt\right]$$

$S_{FM}(t)$



k_f = sensitivitas Frekuensi [Hz/volt]

FREQUENCY MODULATION

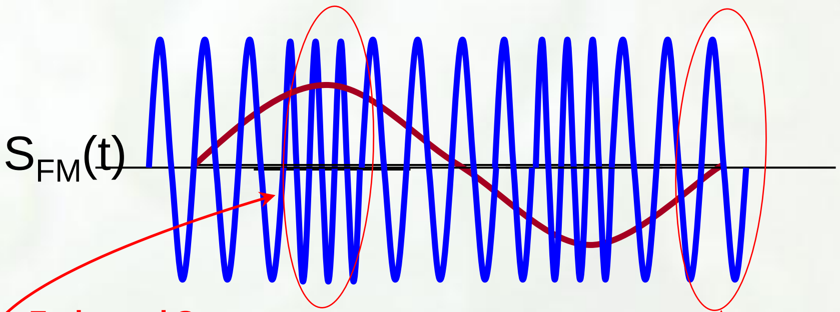
FM→ Pemodulasi Sinusoidal Tunggal

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

$$S_{FM}(t) = V_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(t)dt\right]$$
$$= V_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t V_m \cos(2\pi f_m t)dt\right]$$
$$= V_c \cos\left[2\pi f_c t + 2\pi k_f V_m \int_0^t \cos(2\pi f_m t)dt\right]$$
$$= V_c \cos\left[2\pi f_c t + \frac{2\pi\Delta f}{2\pi f_m}\sin(2\pi f_m t)\right]$$
$$= V_c \cos\left[2\pi f_c t + \frac{\Delta f}{f_m}\sin(2\pi f_m t)\right]$$
$$= V_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)]$$

$\theta_i(t)$

Sudut/Angular



Frekuensi Sesaat

$$f_i(t) = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt}$$

$$f_i(t) = f_c + k_f V_m \cos(2\pi f_m t)$$

$$f_i\big|_{max} = f_c + \Delta f \quad ; \quad f_i\big|_{min} = f_c - \Delta f$$

Deviasi frekuensi

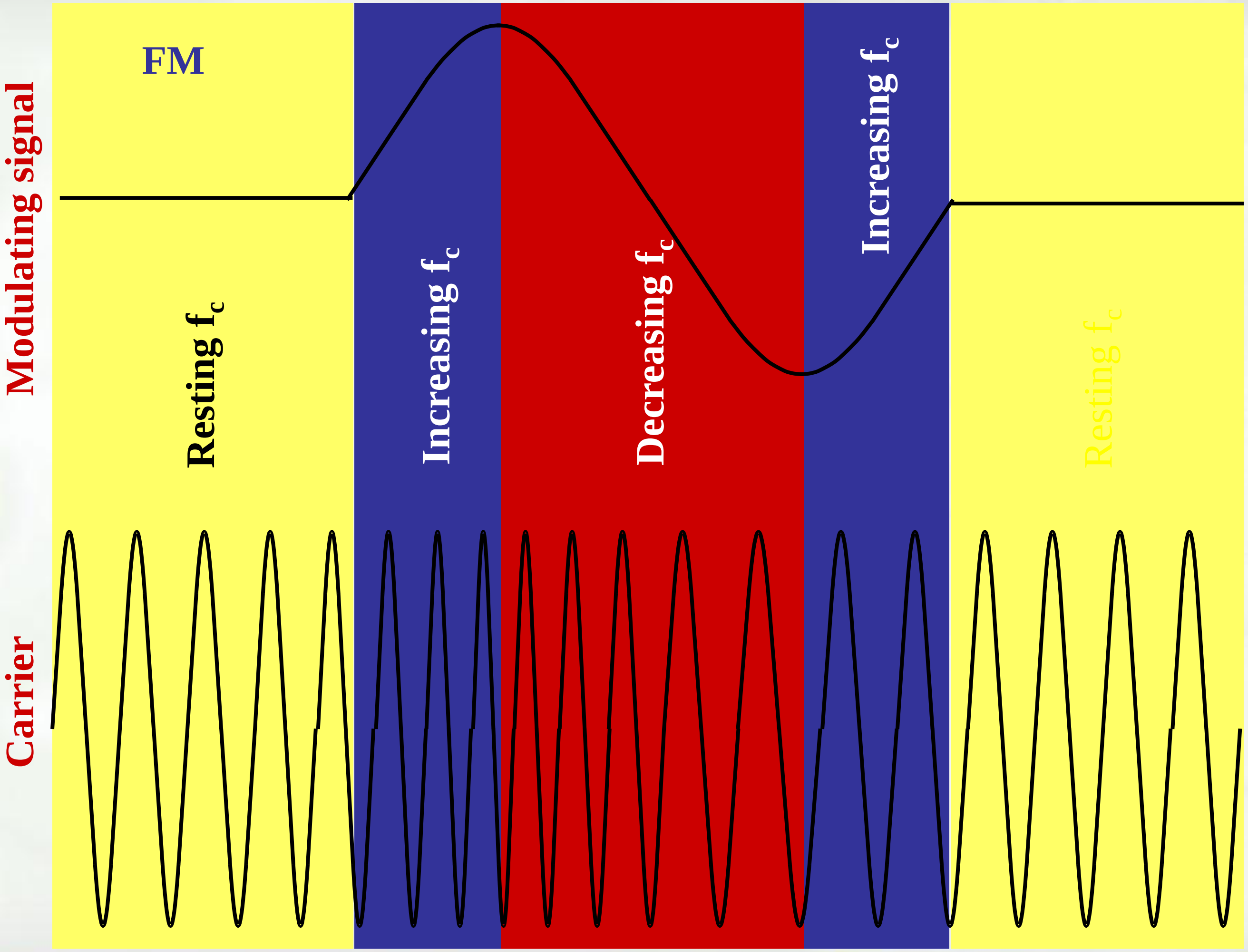
$$\Delta f = k_f V_m$$

Index Modulasi

$$\beta = \frac{\Delta f}{f_m}$$

FREQUENCY MODULATION

Ilustrasi Sinyal FM pada Domain Waktu



FREQUENCY MODULATION

FM→ Pemodulasi Sinyal Sembarang

- When $m(t)$ is a band of signals, *e.g.* speech or music the analysis is very difficult (impossible?).
- Calculations usually assume a single tone frequency equal to the maximum input frequency.

E.g. $m(t) \equiv$ band 20Hz $\rightarrow$ 15kHz, fm = 15kHz is used.

SPECTRUM SINYAL FM

FREQUENCY MODULATION (FM)

Spectrum FM untuk info Single Tone

- Berikut ini adalah persamaan FM untuk info single tone :

$$S_{FM}(t) = V_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right]$$

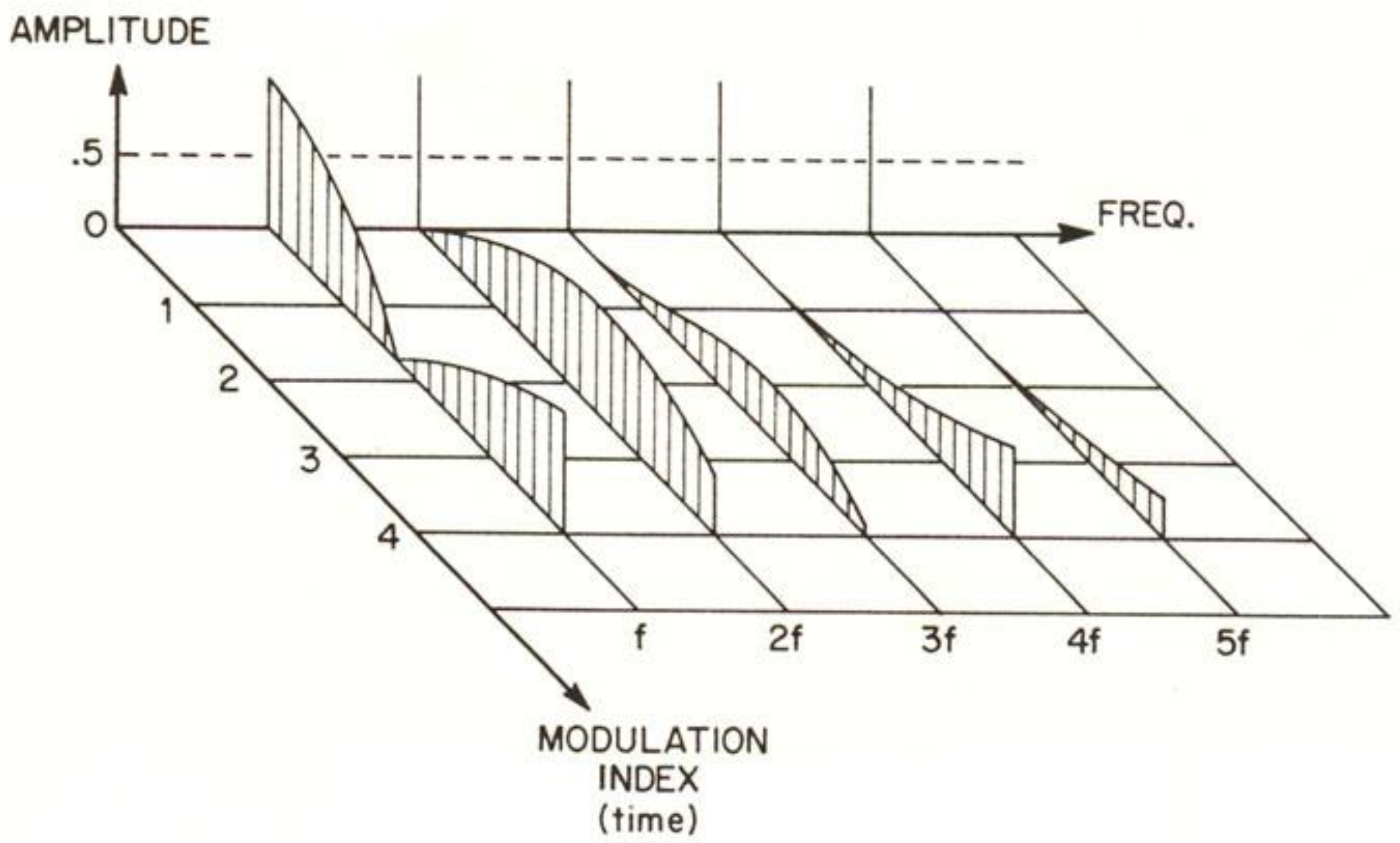
- Persamaan tersebut dapat dijabarkan menjadi persamaan berikut :

$$S_{FM}(t) = V_c \sum_{-\infty}^{+\infty} J_n(\beta) \cos(2\pi f_c + n2\pi f_m)t$$

Dimana $J_n(\beta)$ adalah fungsi bessel dan sudah disediakan dalam bentuk grafik dan tabel

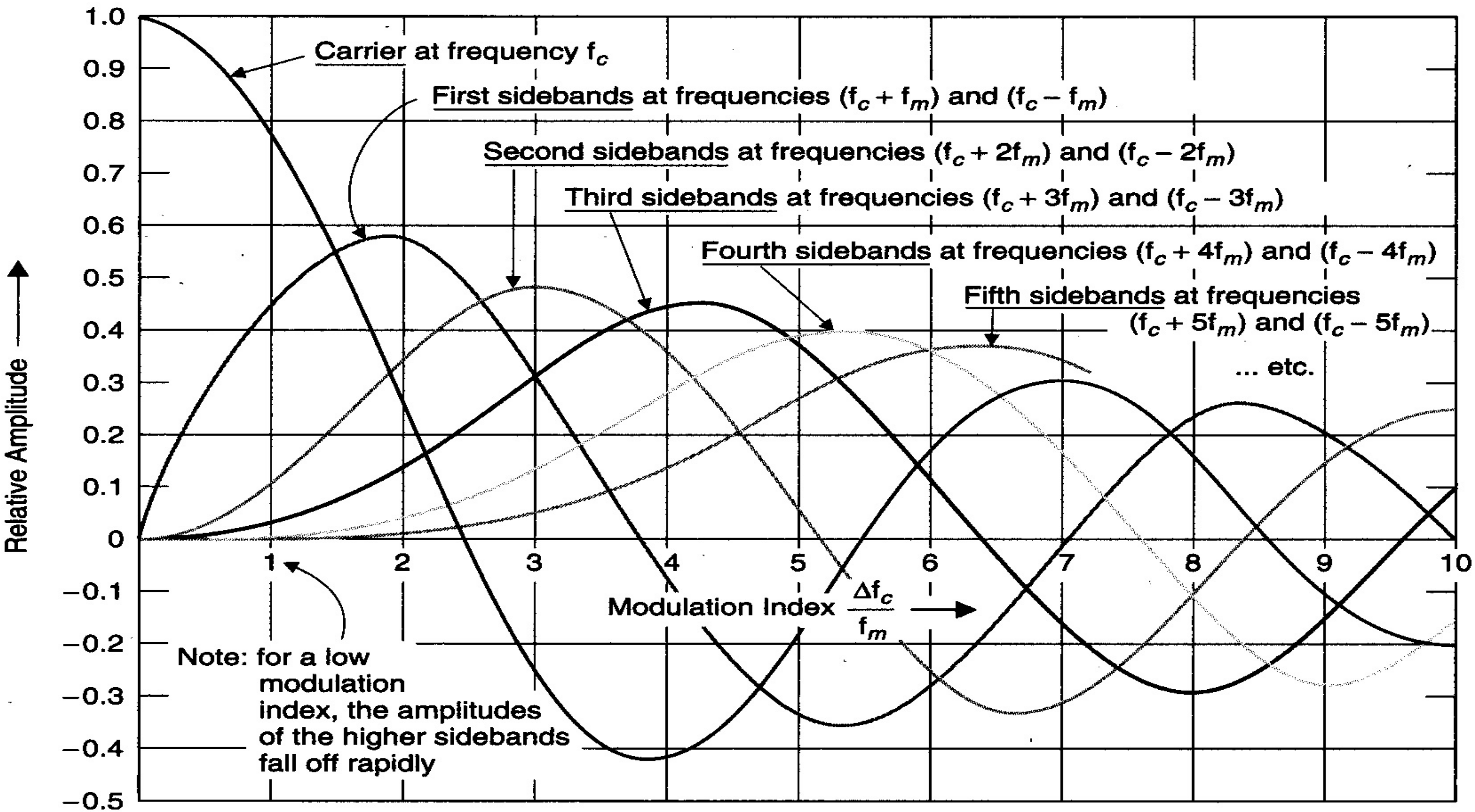
FREQUENCY MODULATION (FM)

Grafik Fungsi Bessel



FREQUENCY MODULATION (FM)

Grafik Fungsi Bessel



FREQUENCY MODULATION (FM)

Tabel Fungsi Bessel

TABLE 4.1 TABLE OF BESSEL FUNCTION VALUES

n	$\beta = 0.1$	$\beta = 0.2$	$\beta = 0.5$	$\beta = 1$	$\beta = 2$	$\beta = 5$	$\beta = 8$	$\beta = 10$
0	0.997	0.990	0.938	0.765	0.224	−0.178	0.172	−0.246
1	0.050	0.100	0.242	0.440	0.577	−0.328	0.235	0.043
2	0.001	0.005	0.031	0.115	0.353	0.047	−0.113	0.255
3				0.020	0.129	0.365	−0.291	0.058
4				0.002	0.034	0.391	−0.105	−0.220
5					0.007	0.261	0.186	−0.234
6					0.001	0.131	0.338	−0.014
7						0.053	0.321	0.217
8						0.018	0.223	0.318
9						0.006	0.126	0.292
10						0.001	0.061	0.207
11							0.026	0.123
12							0.010	0.063
13							0.003	0.029
14							0.001	0.012
15								0.004
16								0.001

Single and double underlines indicate the number of harmonics containing 70% and 98% of total power, respectively.

FREQUENCY MODULATION (FM)

Keterangan Fungsi Bessel

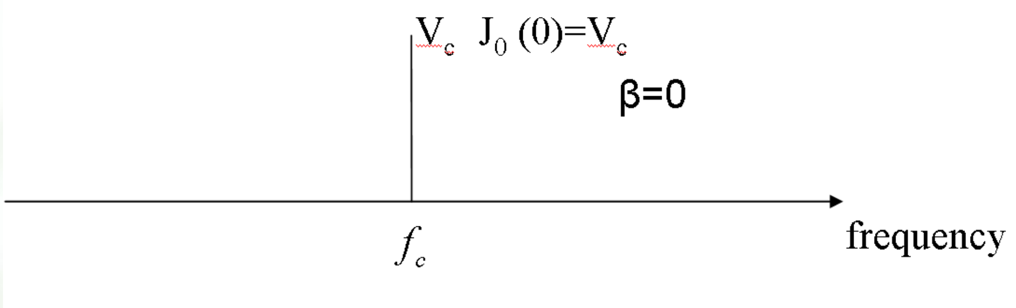
- Fungsi bessel merepresentasikan sideband – sideband yang muncul diantara frekuensi carrier dan terletak pada frekuensi informasi dan kelipatannya.
- Jumlah sideband pada fungsi bessel tak hingga.
- Pada sinyal FM, fungsi bessel menentukan amplituda sinyal carrier dan amplituda sidebandnya.
- Sideband yang amplitudanya kurang dari 1% amplituda sinyal carrier, dapat diabaikan.

FREQUENCY MODULATION (FM)

Contoh Spektrum FM (Fungsi Bessel)

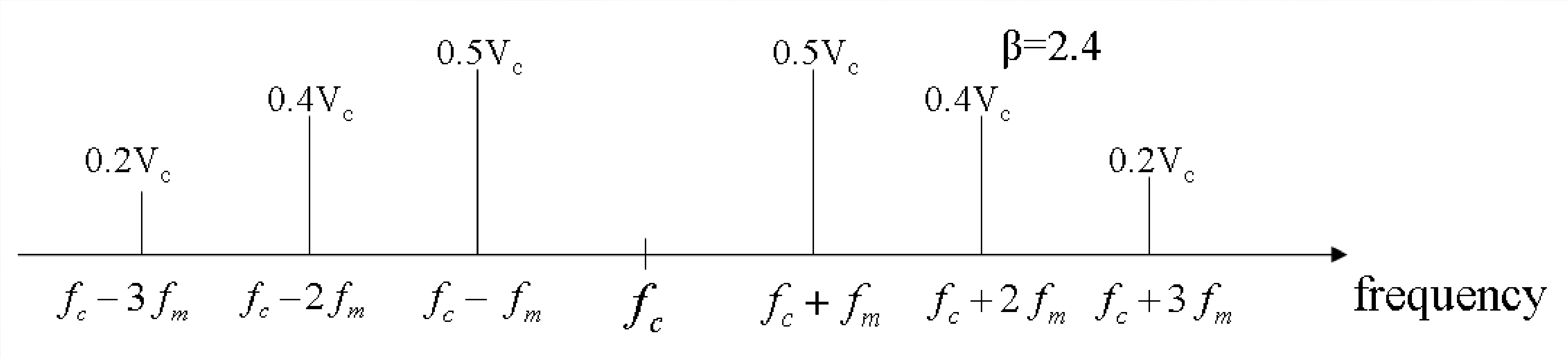
β = 0

→ Saat β **= 0 hanya ada carier dan tidak ada info yang dimodulasi dan $J_0(0)$ = 1, dan nilai $J_n(0)$ = 0,**



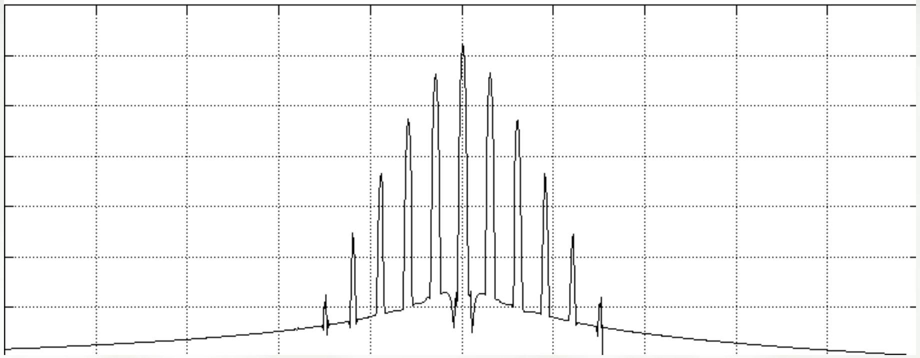
β = 2.4

Dari Grafik (pendekatan) → $J_0(2.4) = 0$, $J_1(2.4) = 0.5$, $J_2(2.4) = 0.45$ and $J_3(2.4) = 0.2$

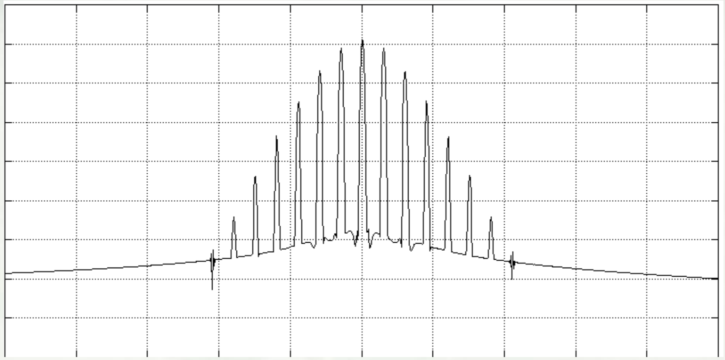


FREQUENCY MODULATION (FM)

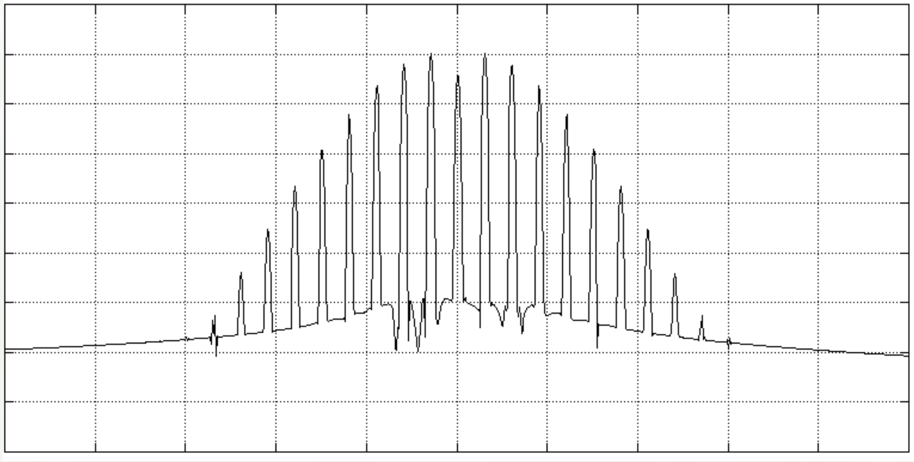
Spectrum sinyal FM untuk beberapa index modulasi



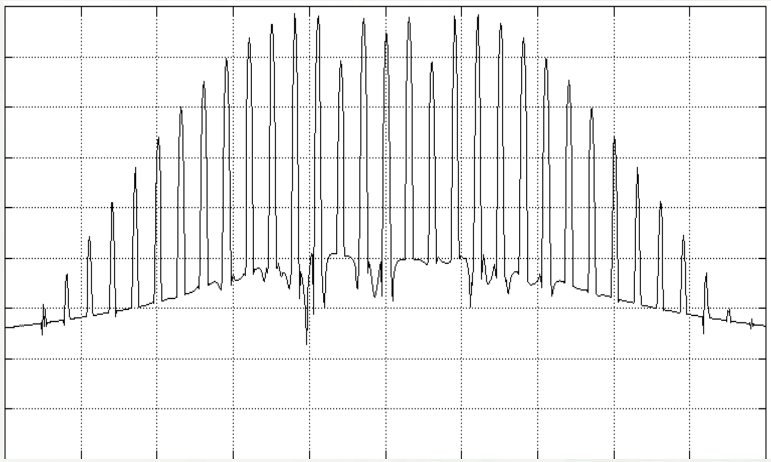
β=0.5



β=1



β=5



β=10

BANDWIDTH FM

FREQUENCY MODULATION (FM)

Significant Sideband

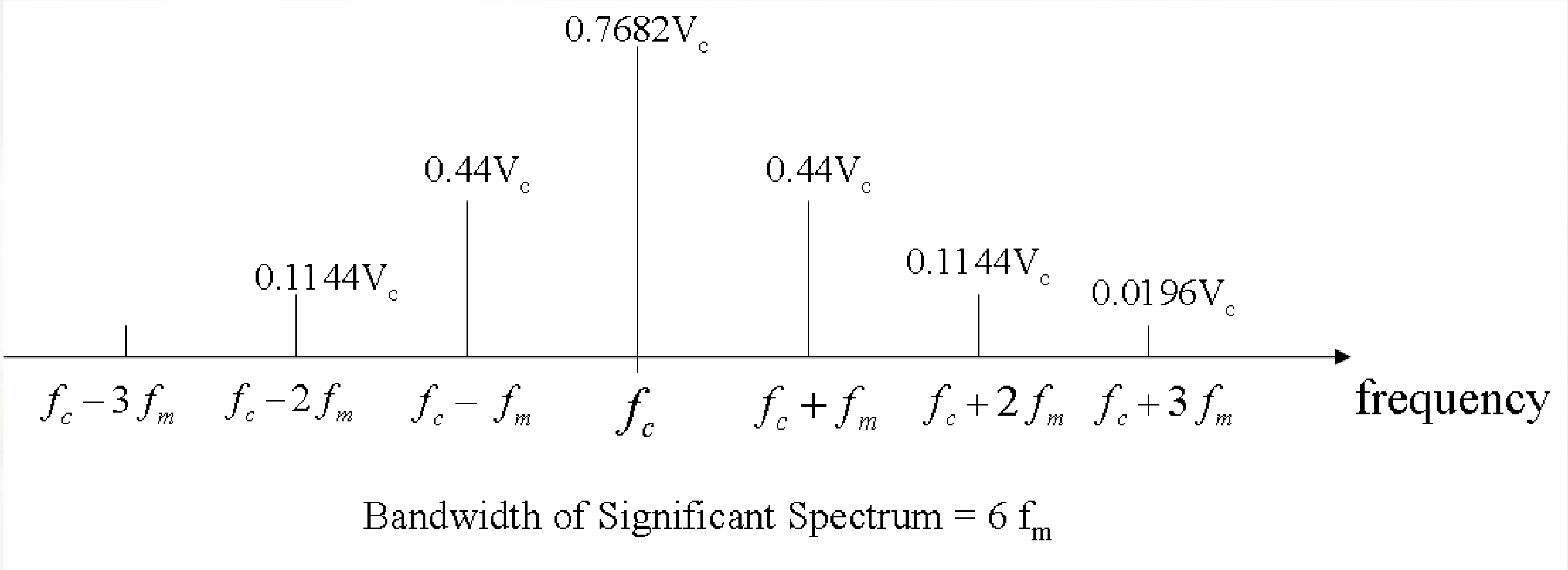
- Seperti terlihat pada tabel fungsi bessel, untuk nilai n diatas nilai tertentu, nilai $J_n(\beta)$ menjadi sangat kecil. Pada FM spectrum sideband dianggap signifikan jika **$J_n(\beta) \geq 0.01$ (1%).**
- Meskipun sebenarnya BW signal FM tidak terbatas, tetapi komponen sideband dengan amplituda $\boldsymbol{V_c J_n(\beta)}$ dimana $\boldsymbol{J_n(\beta) < 0.01}$ menjadi tidak signifikan dan bisa diabaikan

Example: A message signal with a frequency f_m Hz modulates a carrier f_c to produce FM with a modulation index β = 1. Sketch the spectrum.

n	$J_n(1)$	Amplitude	Frequency
0	0.7652	$0.7652V_c$	f_c
1	0.4400	$0.44V_c$	f_c+f_m $f_c - f_m$
2	0.1149	$0.1149V_c$	f_c+2f_m $f_c - 2f_m$
3	0.0196	$0.0196V_c$	f_c+3f_m $f_c -3 f_m$
4	0.0025	*Insignificant*	
5	0.0002	*Insignificant*	

FREQUENCY MODULATION (FM)

Significant Sideband



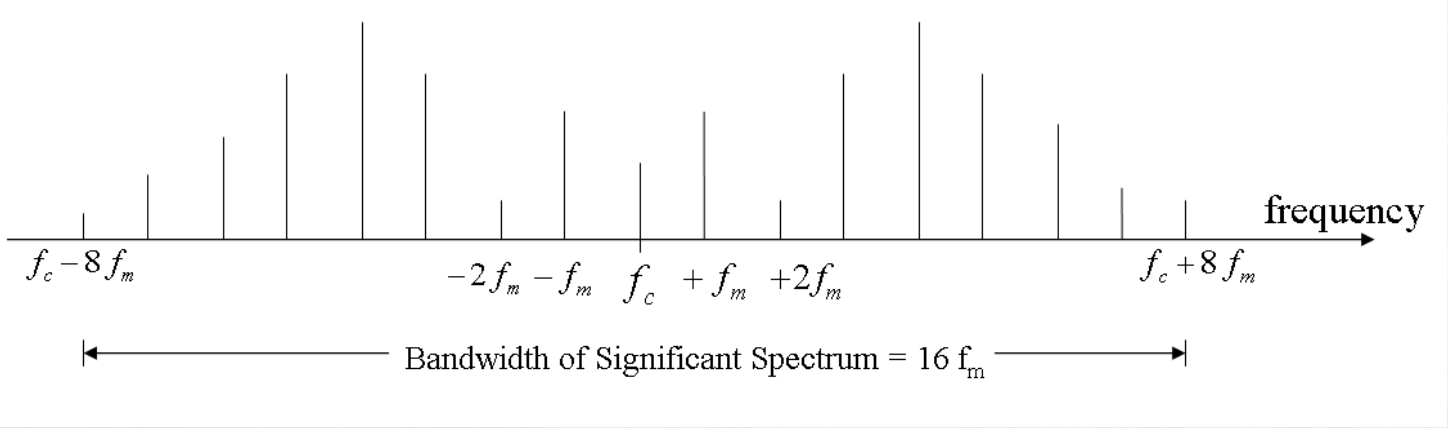
As shown, the bandwidth of the spectrum containing significant components is $6f_m$, for $\beta = 1$.

FREQUENCY MODULATION (FM)

Significant Sideband

The table below shows the number of significant sidebands for various modulation indices (β) and the associated spectral bandwidth.

β	No of sidebands ≥ 1% of unmodulated carrier	Bandwidth
0.1	2	$2f_m$
0.3	4	$4f_m$
0.5	4	$4f_m$
1.0	6	$6f_m$
2.0	8	$8f_m$
5.0	16	$16f_m$
10.0	28	$28f_m$



FREQUENCY MODULATION (FM)

Bandwidth FM

- Secara teoritis, bandwidth sinyal FM adalah tak hingga. Hal ini bisa dilihat pada grafik fungsi bessel
- Untuk pendekatan, maka bandwidth FM didekati dengan **BANDWIDTH CARSON:**

$$BW = 2\,(\Delta f + fm) = 2fm(\beta + 1)$$

  - Pada BANDWIDTH CARSON kandungan energi sinyal FM adalah 99 % dari kandungan energi total sinyal FM
  - Δf = deviasi frekuensi maksimum (untuk informasi sinyal sembarang)
  - Δf = deviasi frekuensi(untuk informasi sinyal single tone)
  - fm = frekuensi pemodulasi/informasi maksimum (untuk informasi sinyal sembarang)
  - fm = frekuensi pemodulasi/informasi (untuk informasi sinyal single tone)

FREQUENCY MODULATION (FM)

Bandwidth FM

Index Modulasi	Jumlah Sideband yang Significant	Bandwidth dalam f_m
0.1	2	2
0.3	4	4
0.5	4	4
1.0	4	4
2.0	6	6
5.0	12	12
10.0	22	22
20.0	42	42
30.0	62	62

POWER FM

FREQUENCY MODULATION (FM)

FM Power Distribution

- Seperti terlihat pada tabel fungsi bessel, terlihat bahwa ketika amplituda pada sideband meningkat, amplituda pada carier, J_0 turun.
- Hal ini dikarenakan pada FM, total daya transmit selalu konstan dan rata-rata daya total sama dengan daya carier (unmodulated), sehingga daya FM selalu konstan baik dengan maupun tanpa ada sinyal pemodulasi
- Sehingga efeknya, total daya yang awalnya berada di carier menjadi terdistribusi pada seluruh spectrum komponen sidebandnya, pada batas nilai signifikan dalam fungsi besel untuk nilai index modulasi tertentu.
- Pada nilai index modulasi tertentu, amplitudo carier bisa sama dengan nol, dimana dayanya dibawa hanya oleh sidebandnya saja → **Null Carrier**

FREQUENCY MODULATION (FM)

FM Power Distribution

Dari Persamaan sinyal FM : $S_{FM}(t) = V_c \sum_{-\infty}^{+\infty} J_n(\beta)\cos(2\pi f_c + n2\pi f_m)t$

Kita bisa lihat bahwa nilai maksimum dari komponennya adalah $V_c J_n(\beta)$ untuk komponen ke n

Nilai daya rata-rata untuk satu komponen = $\frac{(V_{RMS})^2}{R} = \frac{\left(\frac{V_{pk}}{\sqrt{2}}\right)^2}{R}$

sehingga daya rata-rata untuk komponen ke-n adalah = $\frac{\left(\frac{V_c J_n(\beta)}{\sqrt{2}}\right)^2}{R} = \frac{(V_c J_n(\beta))^2}{2R}$

sehingga, total daya pada spectrum yang tak terbatas adalah :

Total Daya rata-rata pada Referensi Resistansi 1 ohm ⇒

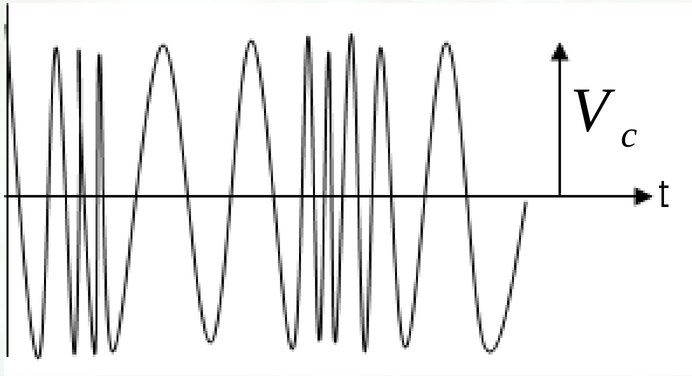
$$P_T = \sum_{n=-\infty}^{\infty} \frac{(V_c J_n(\beta))^2}{2}$$

⇒ **Dengan cara ini kita harus menghitung seluruh komponen spectrum FM yang tidak terbatas untuk menghitung daya total FM**

FREQUENCY MODULATION (FM)

FM Power Distribution

Tapi, karena terlihat dari bentuk gelombang FM, dimana nilai maksimumnya konstan sebesar Vc, maka :



Sehingga nilai RMS nya adalah :

$$V_{RMS} = \left(\frac{V_{pk}}{\sqrt{2}}\right)^2 = \frac{V_c}{\sqrt{2}}$$

Sehingga rata-rata daya total pada referensi 1 ohm bisa kita tuliskan :

$$P_T = \sum_{n=-\infty}^{\infty} \frac{(V_c J_n(\beta))^2}{2} = \left(\frac{V_c}{\sqrt{2}}\right)^2 = \frac{V_c^2}{2}$$

Sehingga jika kita tahu amplituda carier V_c dari sinyal FM, maka daya rata-rata total FM untuk seluruh spectrum bisa dihitung dengan mudah

FREQUENCY MODULATION (FM)

FM Power Distribution-Contoh

Misalkan suatu FM broadcasting mengirimkan suara 4 Khz dengan deviasi frequensi 2 Khz, jika diketahui tegangan carier sebelum modulasi adalah 10 V rms pada impedance 50 ohm, maka berapa daya FM ?

JAWAB :

$$\beta = \frac{\Delta f}{f_m} = \frac{2khz}{4khz} = 0,5$$

β	Carrier	Sideband	
		1^{st}	2^{nd}
0,5	0,94	0,24	0,03

carier voltage =10x0,94 = 9,4 volt
Daya = $9,4^2$/50=1,7672 watt

the first sideband voltage =10x0,24=2,4volt
Daya =$2,4^2$/50 x 2pair = 0,2304 watt

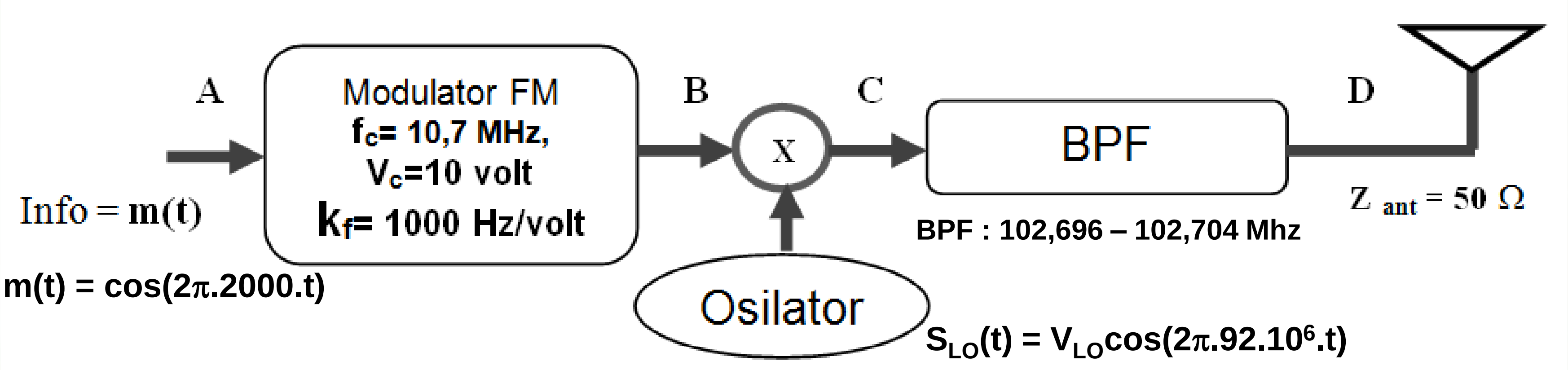
second sideband voltage = 10x0,03=0,3 volt
Daya =$0,3^2$/50=0,0018 x2pair = 0,0036 watt

Daya Total=
1,7672+0,2304+0,0036 =
10^2/50=2 Watt

FREQUENCY MODULATION (FM)

Contoh Soal

Perhatikan **pemancar FM** dengan diagram blok sbb :



a. **Gambarkan gelombang** sinyal FM (di B) pada gambar diatas (domain waktu)
b. Hitung bandwidth carson dan daya rata-rata FM (di B)
c. Gambarkan **spektrum** sinyal FM di **B, C** dan di **D** !


THANK
YOU