RF Tasarım

Ders 3: LNA, mikser, osilatör, PA, modülasyon, S-parametreleri

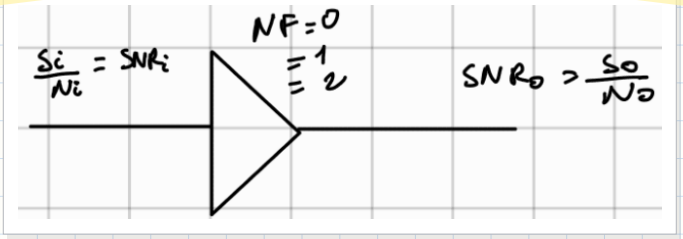
Orijinal not: Ders3.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

orj. s. 1

LNA



orijinal çizim, s. 1

$$N_o = N_i G + N_A$$

$$SNR_i > SNR_o$$

Low Noise Figure NF_{dB}[1] $= \dfrac{SNR_i}{SNR_o} = SNR_i[dB] - SNR_o[dB]$

istenilenler

- Linearity
- Low power consumption
- Low area "
- Gain [S_{21}]
- Matching

$$NF = 10 \log F$$

F: Noise factor
NF: Noise figure

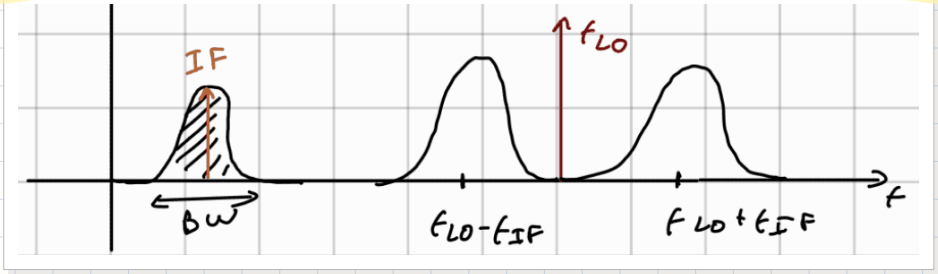
[1] Claude notu: muhtemelen $F = SNR_i/SNR_o$ ve $NF_{dB} = 10 \log F$ olmalı.

Mixers

Upconversion

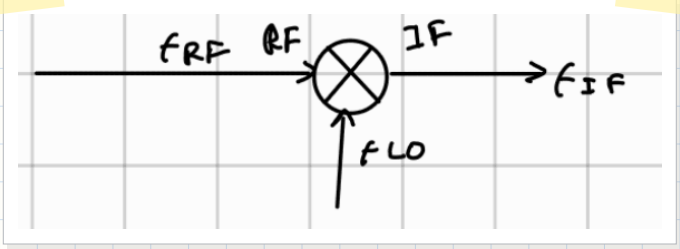


orijinal çizim, s. 1

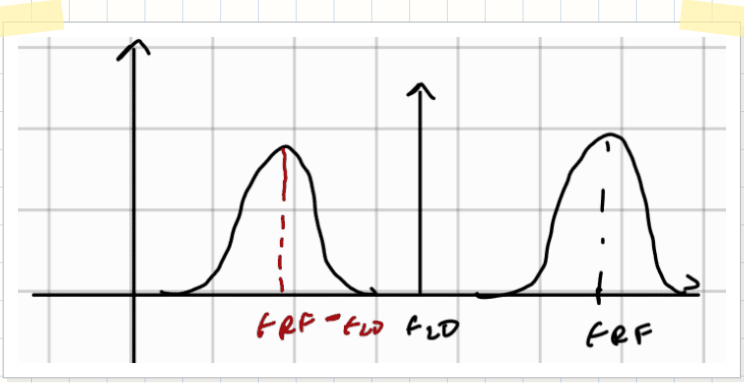


orijinal çizim, s. 1

Down conversion



orijinal çizim, s. 1



orijinal çizim, s. 1

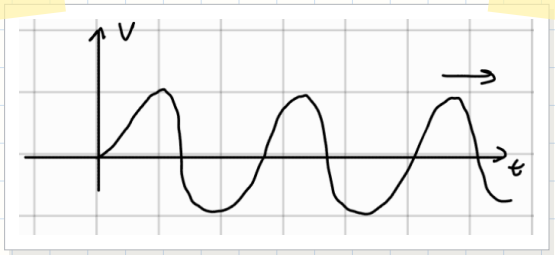
$$g(t) = \cos 2\pi f_0 t \;\rightarrow\; G(f) = \mathcal{F}\{g(t)\} = \int_{-\infty}^{\infty} \cos 2\pi f_0 t \, e^{-j2\pi ft}\, dt$$

orj. s. 2

$$= \int_{-\infty}^{\infty} \frac{e^{j2\pi f_0 t} + e^{-j2\pi f_0 t}}{2} e^{-j2\pi ft}\, dt \;?+$$

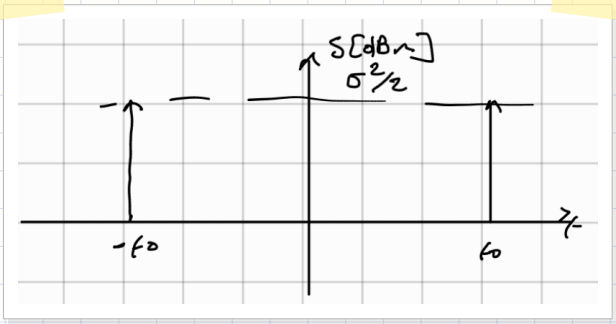
$$= \frac{1}{2}\left\{\int_{-\infty}^{\infty} e^{j2\pi f_0 t}\, e^{-j2\pi ft}\, dt + \int_{-\infty}^{\infty} e^{-j2\pi f_0 t}\, e^{-j2\pi ft}\, dt\right\}$$

$$= \frac{1}{2}\left[\delta(f - f_0) + \delta(f + f_0)\right]$$



orijinal çizim, s. 2

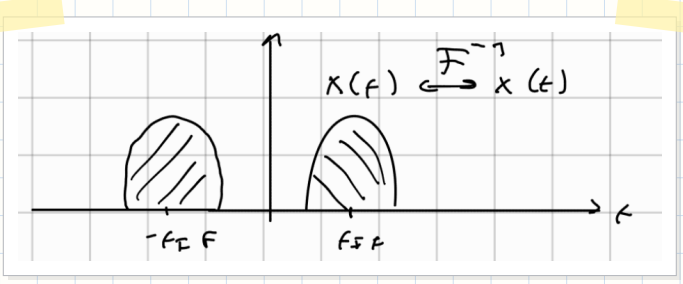
$\Longrightarrow$



orijinal çizim, s. 2

$$g(t) = \cos 2\pi f_0 t$$

$$\sigma^2 = \mathcal{E}\left[g^2(t)\right] - \mathcal{E}^2\left[g(t)\right]$$



orijinal çizim, s. 2

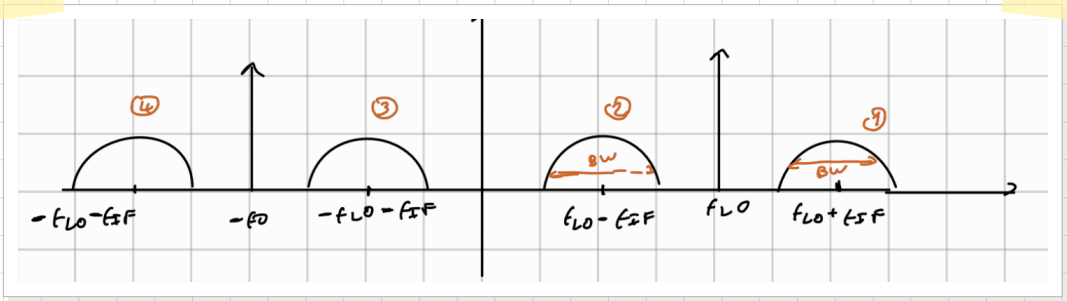
$$y_{RF}(t) = x(t)\left[\cos 2\pi f_{LO} t\right]$$

$$Y(f) = X(f) \circledast \frac{1}{2}\left[\delta(f - f_{LO}) + \delta(f + f_{LO})\right]$$

$$= \left[X(f - f_{IF}) + X(f + f_{IF})\right] \circledast \frac{1}{2}\left[\delta(f - f_{LO}) + \delta(f + f_{LO})\right]$$

$$= \frac{1}{2}\Big[\underbrace{X(f - f_{IF} - f_{LO})}_{f-[f_{IF}+f_{LO}]\ ①} + \underbrace{X(f - f_{IF} + f_{LO})}_{f-[f_{IF}-f_{LO}]\ ③}$$

$$+ \underbrace{X(f + f_{IF} - f_{LO})}_{f-[f_{LO}-f_{IF}]\ ②} + \underbrace{X(f + f_{IF} + f_{LO})}_{f-[-f_{LO}-f_{IF}]\ ④}\Big]$$



orijinal çizim, s. 2

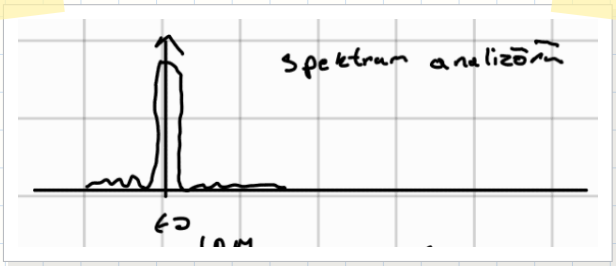
orj. s. 3

$x(t) = \cos 2\pi f_1 t \rightarrow f_1 = 100\,\text{MHz} \rightarrow BW = 10\,\text{MHz}$

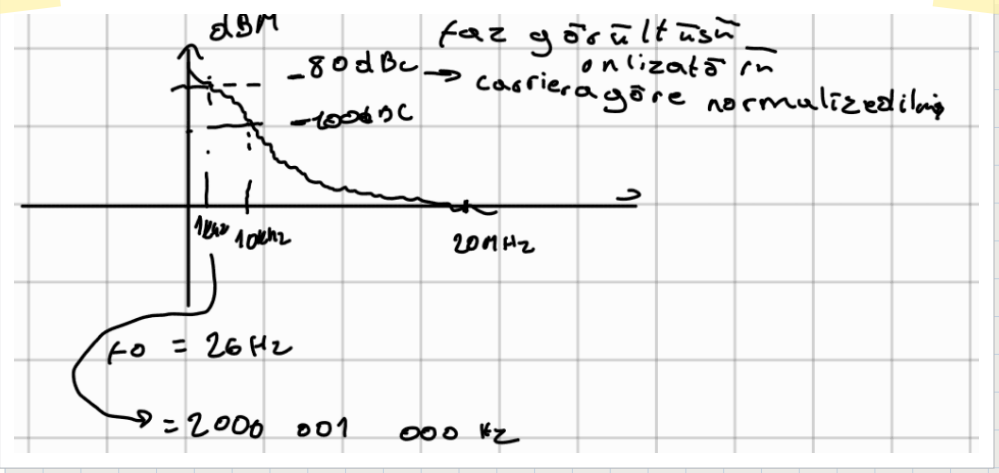
$?(t) = \cos 2\pi f_2 t \rightarrow f_2 = 2\,\text{GHz}$

oluşacak frekanslar: 2,1 GHz ve 1,9 GHz

Osilatörler & VCO (Voltage controlled oscilator)



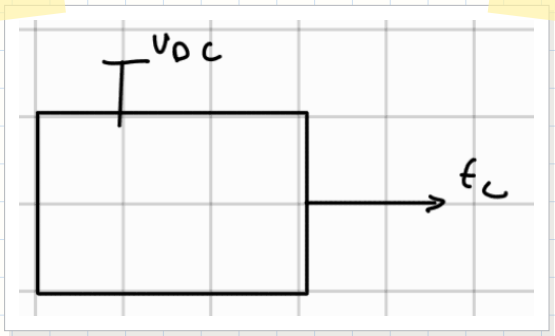
orijinal çizim, s. 3



orijinal çizim, s. 3

⋆ Frequency stability, phase Noise

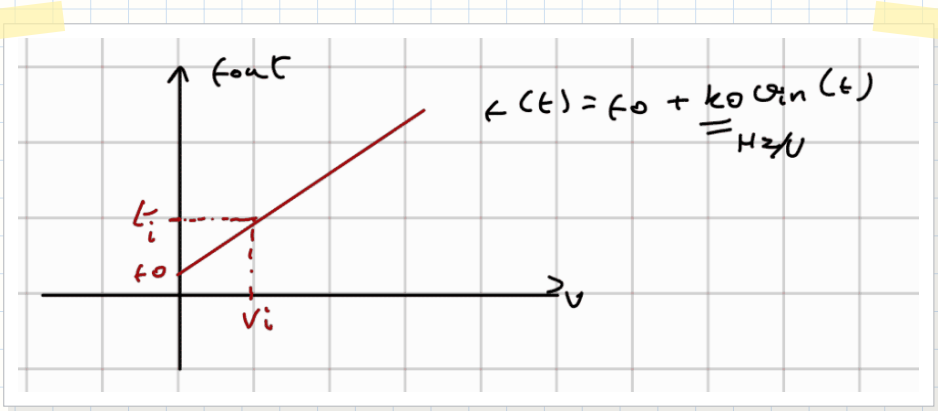
Osilatör



orijinal çizim, s. 3

kristal osilatörlerin beslemeye ihtiyacı ?yoktur

VCO gerilim kontrollü osilatör



orijinal çizim, s. 3

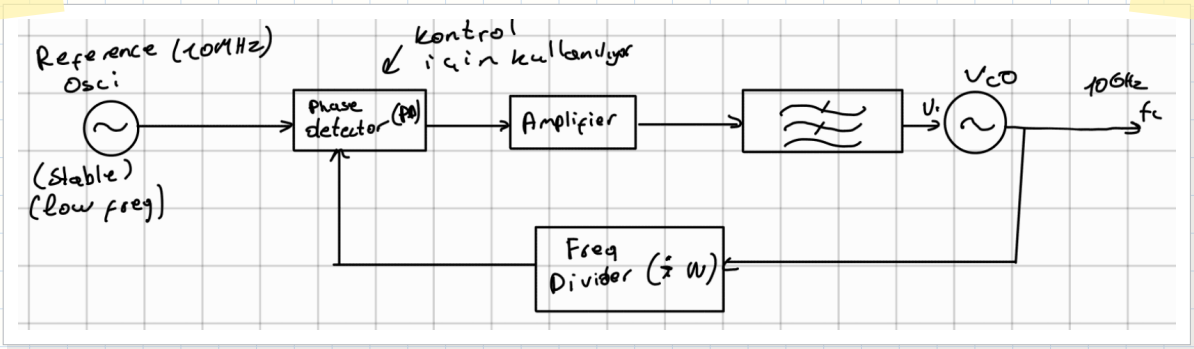
orj. s. 4

Osilatör çeşitleri

→ VCO

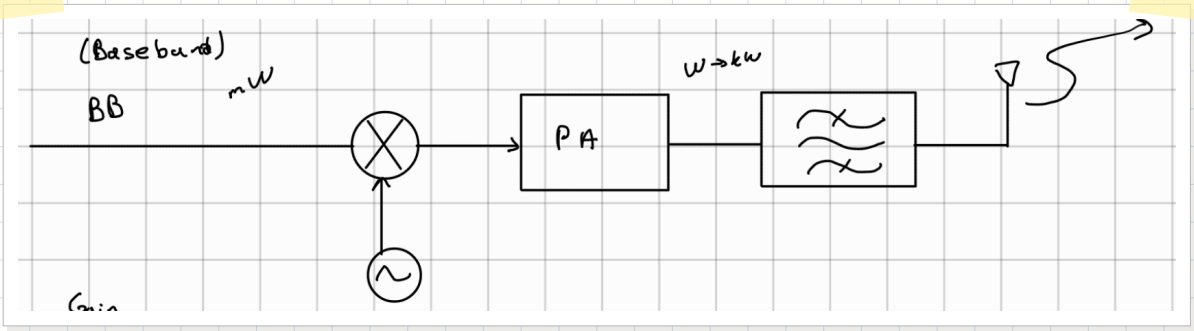
→ TCXO (Temperature controlled Osc.)
↪ sıcak kontrollü, geri besleme ile sıcaklık etkisini minimize eder
→ OCXO (Oven Controlled Osc.)
fırın kontrollü

PLL (Phase Locked loop)



orijinal çizim, s. 4

Power Amplifier

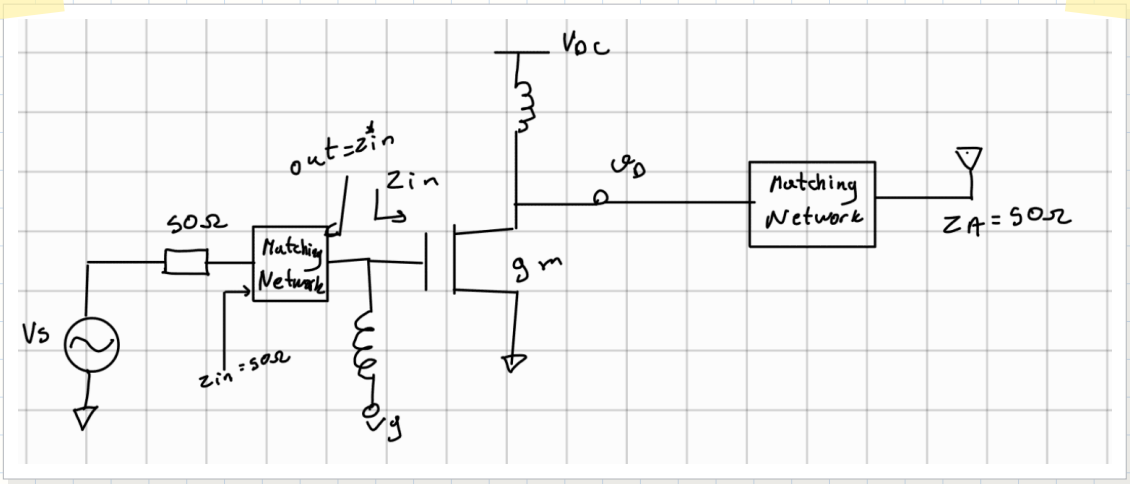


orijinal çizim, s. 4

Gain
(Max) Output power
Bandwidth
Power efficiency (PAE) Power added efficiency
Linearity
I/O Matching

A, AB, B, C → Linear
F, E → High power efficiency
D → Low freq

orj. s. 5

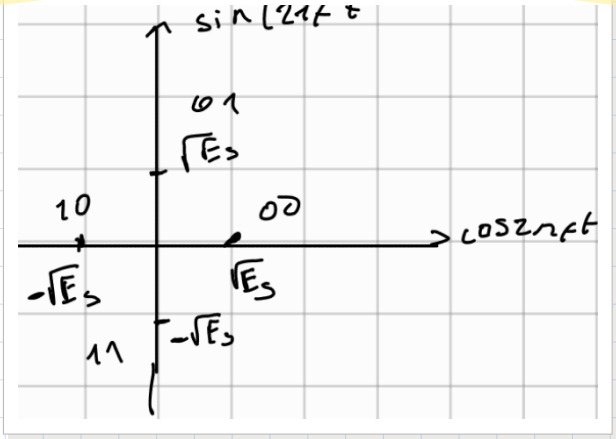


orijinal çizim, s. 5

Modulation

BPSK: '0' → $\sqrt{E_s}\cos 2\pi ft$

'1' → $-\sqrt{E_s}\cos 2\pi ft$



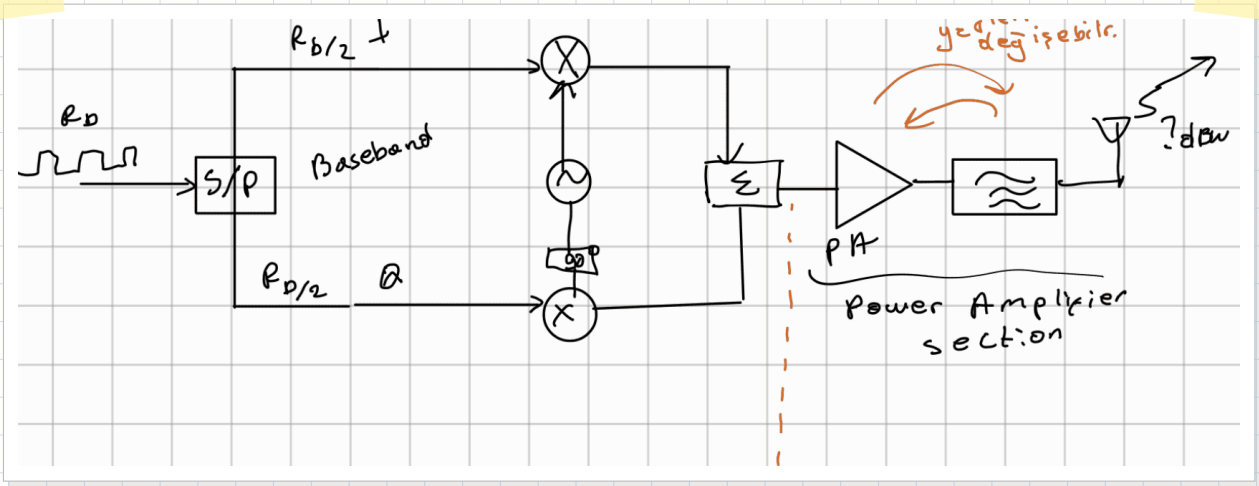
orijinal çizim, s. 5

QPSK: '00' → $\sqrt{E_s}\cos 2\pi ft + \sqrt{E_s}\sin 2\pi ft$

'01'

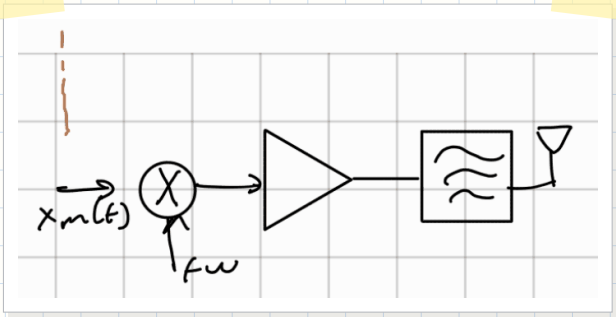
'10' →

'11'

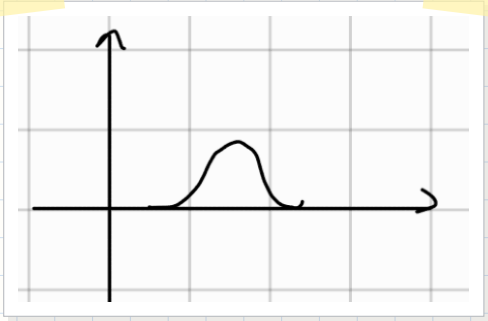


orijinal çizim, s. 5

orj. s. 6

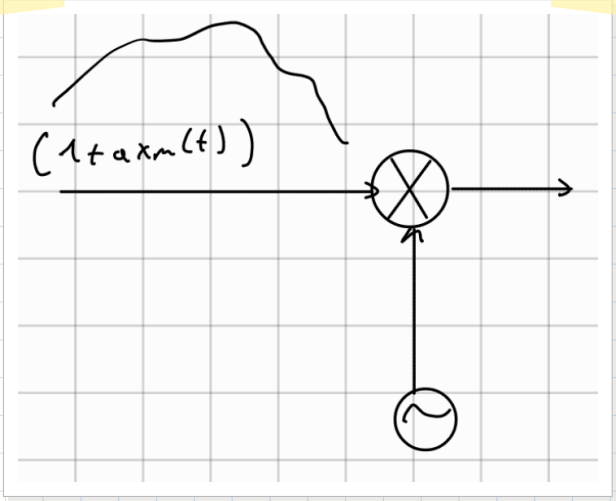


orijinal çizim, s. 6



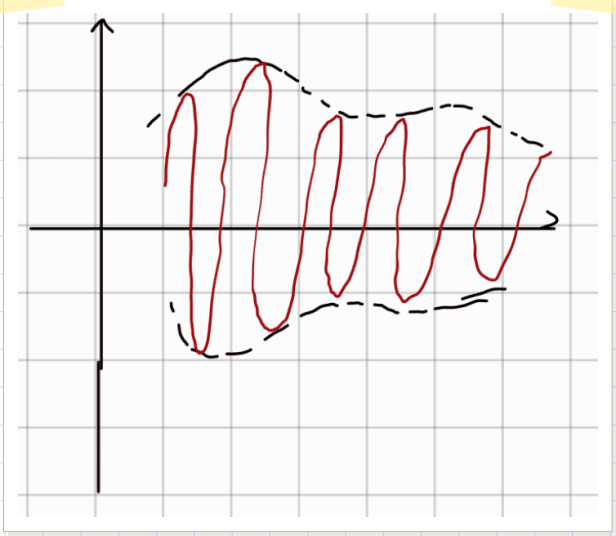
orijinal çizim, s. 6

AM (Amplitude Modulation)

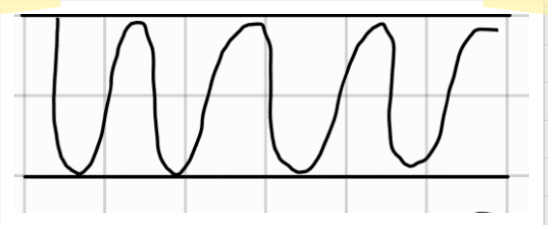


orijinal çizim, s. 6

high Freq RF signal



orijinal çizim, s. 6

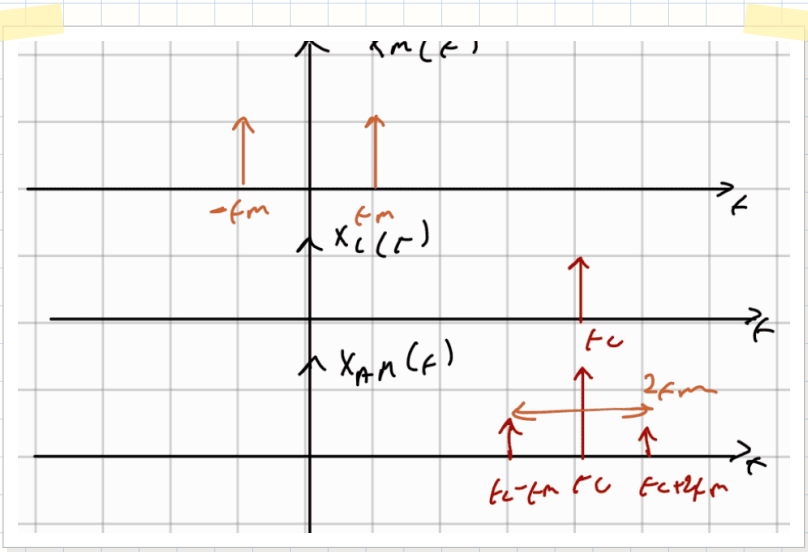


orijinal çizim, s. 6

$$x_{AM}(t) = [1 + a\,x_m(t)]\,A_c \cos(2\pi f_c t + \phi_c)$$

normalizasyon için

→ $= A_m \cos(2\pi f_m t + \phi_m)$ olsun



orijinal çizim, s. 6

orj. s. 7

Frequency Modulation (FM)

$$x_{FM}(t) = A_c \cos\left[\omega_c(t) \cdot t + \phi_c\right]$$

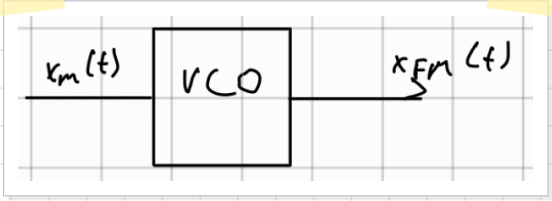
$$\omega_i(t) = \omega_c + k_f \cdot A_m \sin(2\pi f_m t)$$

$$BW_{FM} = 2(1 + k_f) f_m$$

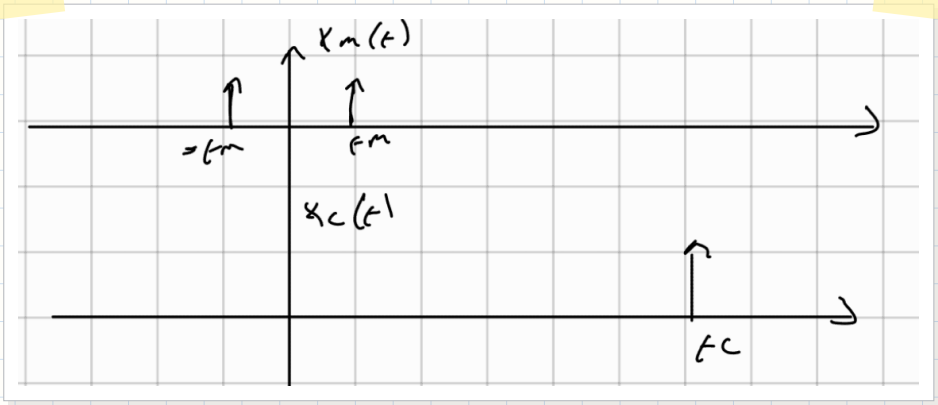
$$\underbrace{k_f \ll 1 \quad BW_{FM} \approx 2f_m}_{\text{NBFM}}$$

$$k_f = \frac{f_m}{f_c} \qquad \begin{matrix} 3\ \text{kHz} \\ 1\ \text{MHz} \end{matrix}$$

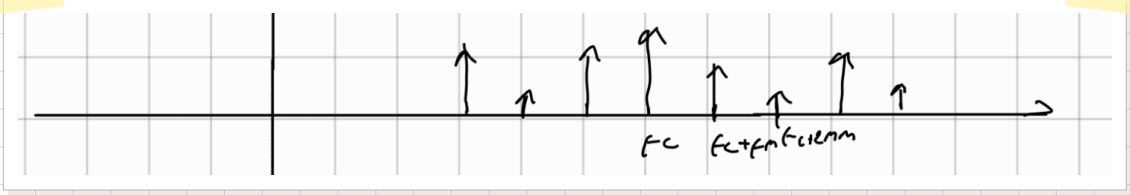
88 – 108 MHz radyo



orijinal çizim, s. 7



orijinal çizim, s. 7

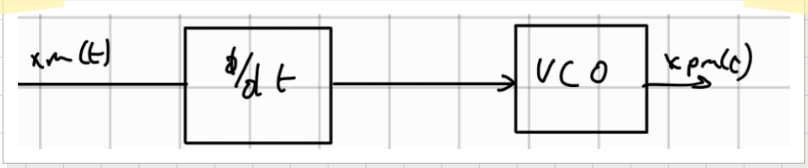


orijinal çizim, s. 7

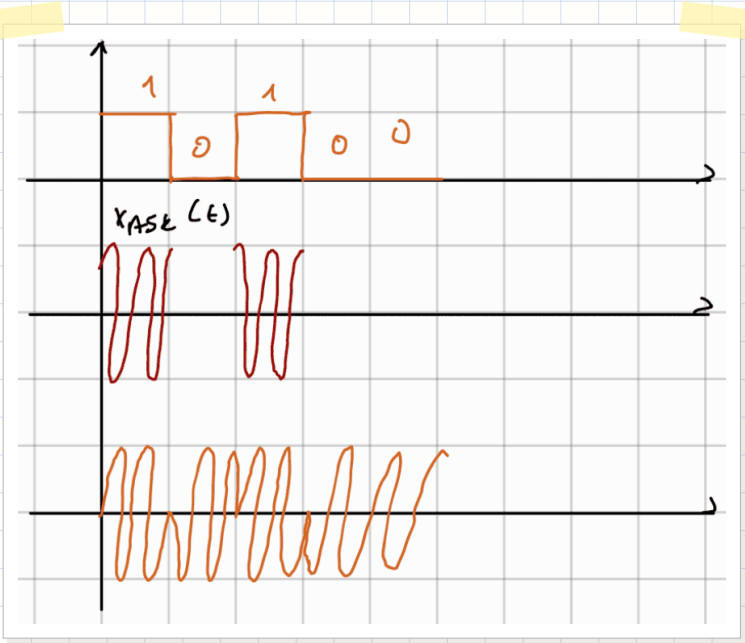
Phase Modulation

$$x_{PM}(t) = A_c \cos\left(\omega_c t + x_m(t)\right)$$

$$x_m(t) = A_m \cos 2\pi f_m t$$



orijinal çizim, s. 7



orijinal çizim, s. 7

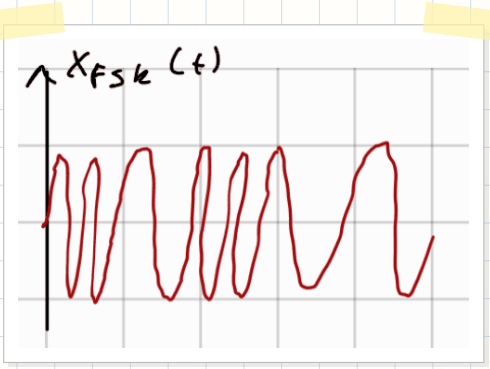
'0' → 0

'1' → $\cos 2\pi ft$

'0' → $\cos 2\pi f_0 t$

'1' → $\cos(2\pi f_0 t + 180°)$

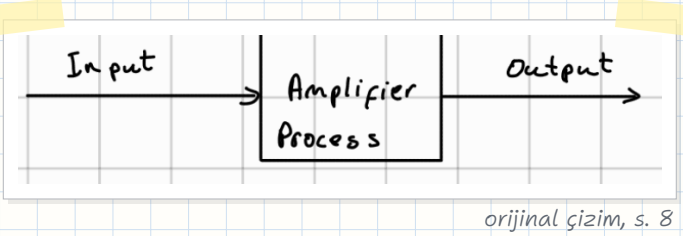
orj. s. 8



orijinal çizim, s. 8

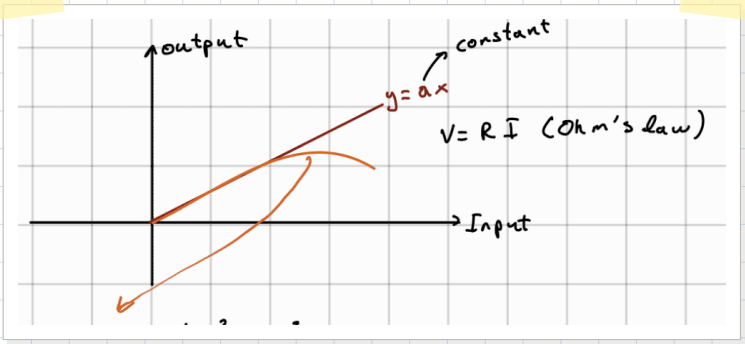
? okunamadı

Linearity



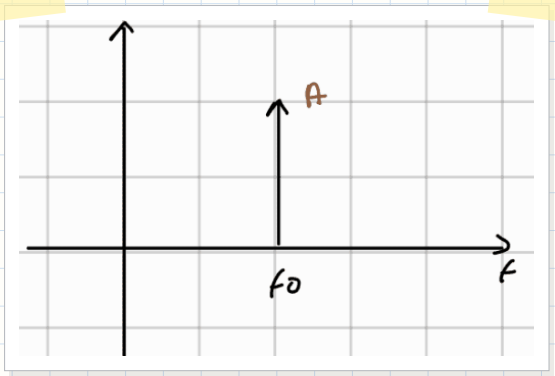
orijinal çizim, s. 8

$$y = ax$$



orijinal çizim, s. 8

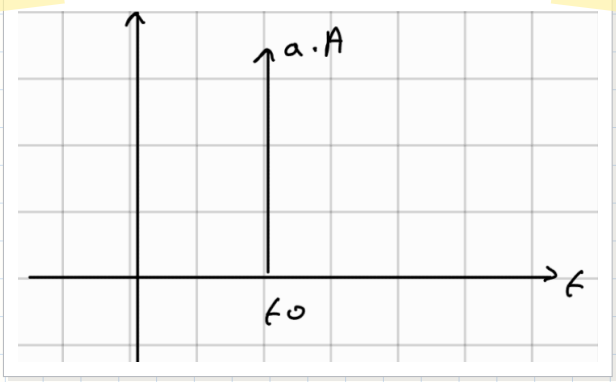
$$y = ax + bx^2 + cx^3 + \cdots$$



orijinal çizim, s. 8

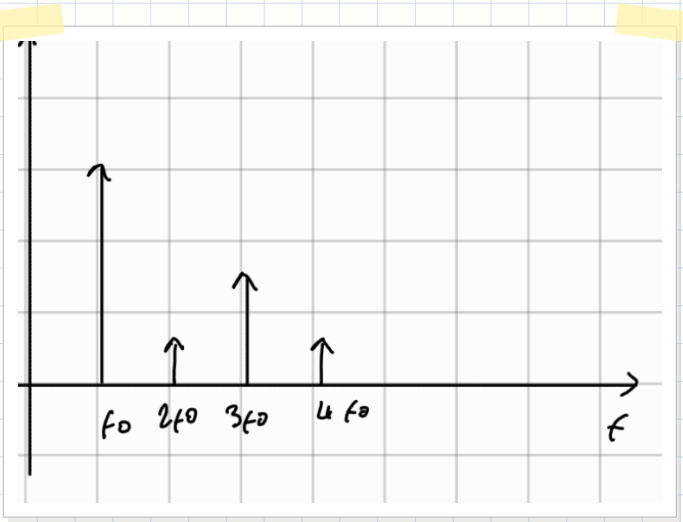
$$x(t) = \cos 2\pi f_0 t$$

$$y = ax \Longrightarrow$$



orijinal çizim, s. 8

$$y = ax + bx^2 + \cdots \Longrightarrow$$



orijinal çizim, s. 8

orj. s. 9

Non-Linearity Problems

- Gain Compression
- Intermodulation
- Desensitization

Phasor

?*S

$$x(t) = A\cos(\omega t + \phi)$$
$$X = Ae^{j\phi}$$

$$= Re\left\{A\cos(\omega t + \phi) + j\sin(\omega t + \phi)\right\}$$
$$= Re\left\{Ae^{j(\omega t+\phi)}\right\}$$
$$= Re\left\{A \cdot e^{j\omega t}e^{j\phi}\right\} = Re\left\{e^{j\omega t} \cdot X\right\}$$

$$v(t) = 2\cos(\omega t + 30°) \rightarrow V = 2e^{j30°}$$

Impedance

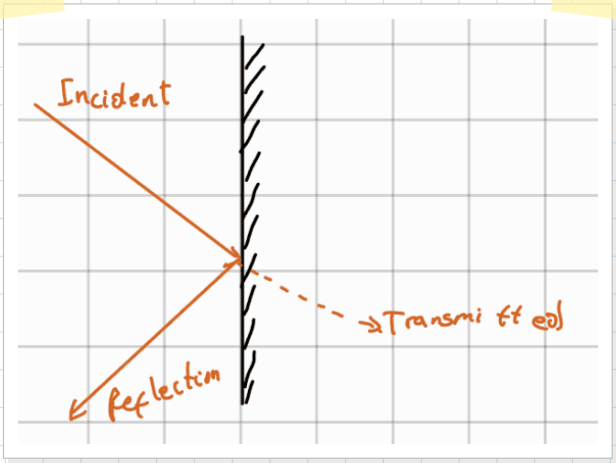
$$R = \frac{V}{I} \Rightarrow Z(f) = \frac{V(f)}{I(f)} = R + jX$$

$$R \rightarrow \quad Z = R$$
$$L \rightarrow \quad Z_L = j\omega L$$
$$C \rightarrow \quad Z_C = \frac{1}{j\omega C}$$

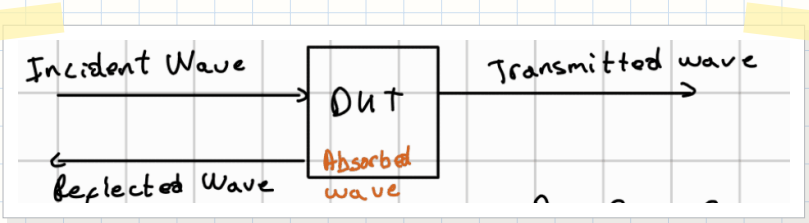
Admittance

$$Y = \frac{1}{Z}$$

Reflection, Transmission & matching



orijinal çizim, s. 9

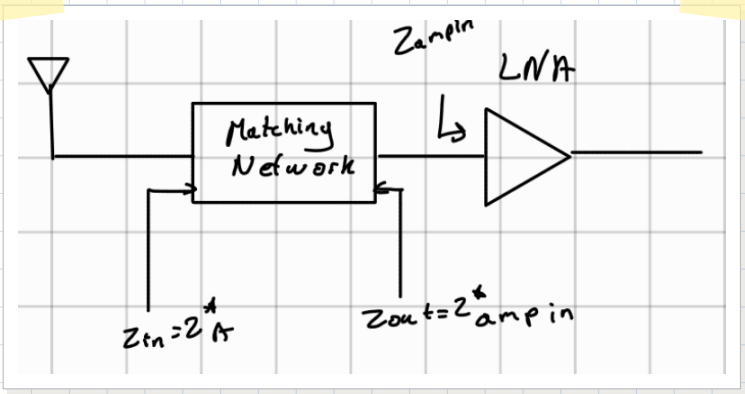


orijinal çizim, s. 9

$$P_{in} = P_{ref} + P_{abs}$$

orj. s. 10

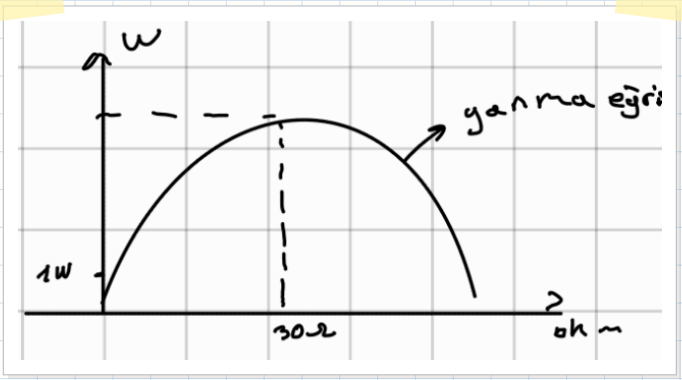
Matching



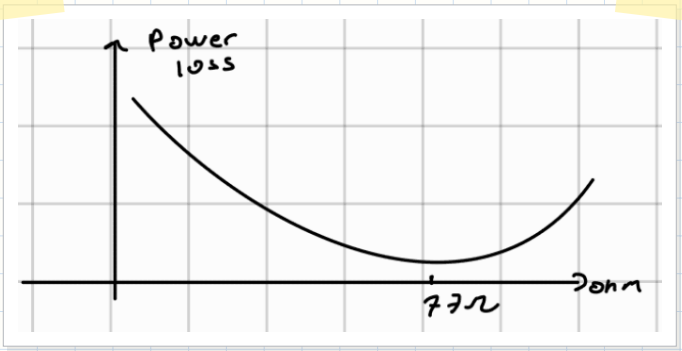
orijinal çizim, s. 10

50 Ω

Power handling 30 Ω



orijinal çizim, s. 10

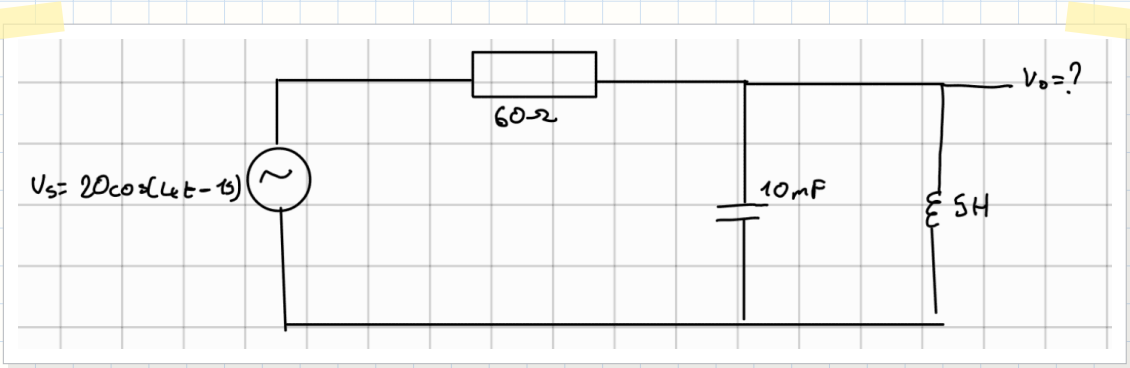


orijinal çizim, s. 10

53,5 Ω → ?seçer

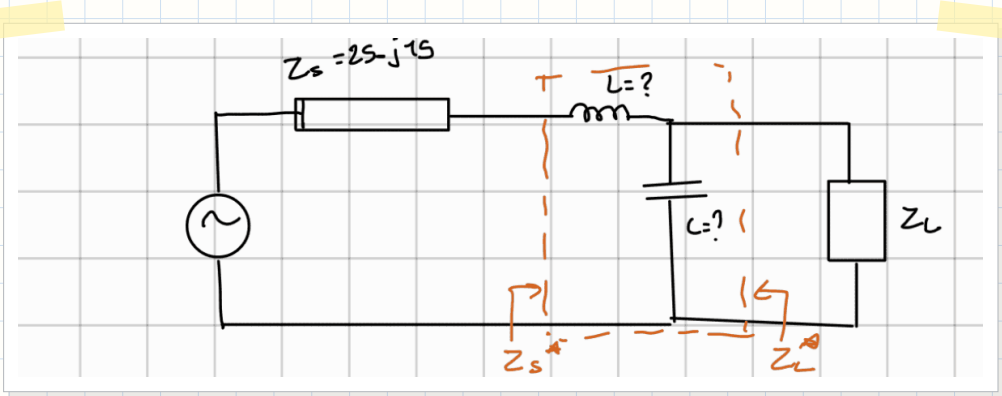
Ödev

①



orijinal çizim, s. 10

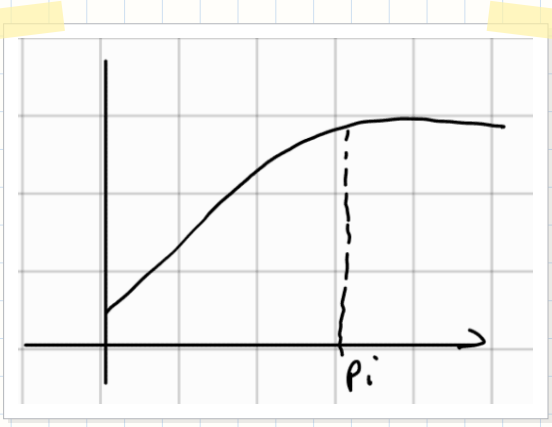
②



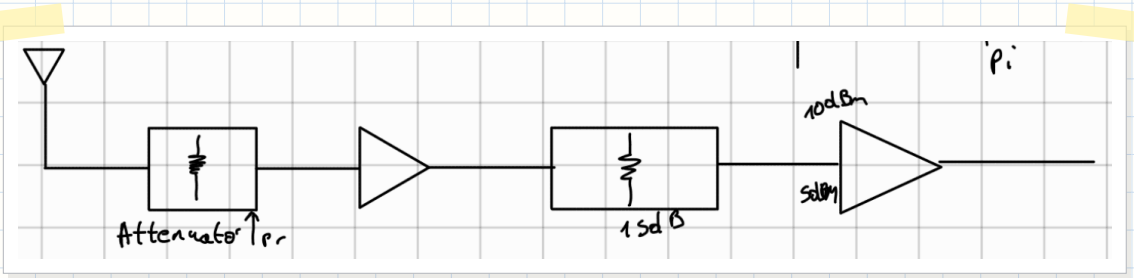
orijinal çizim, s. 10

orj. s. 11

Attenuator (zayıflatıcı)



orijinal çizim, s. 11



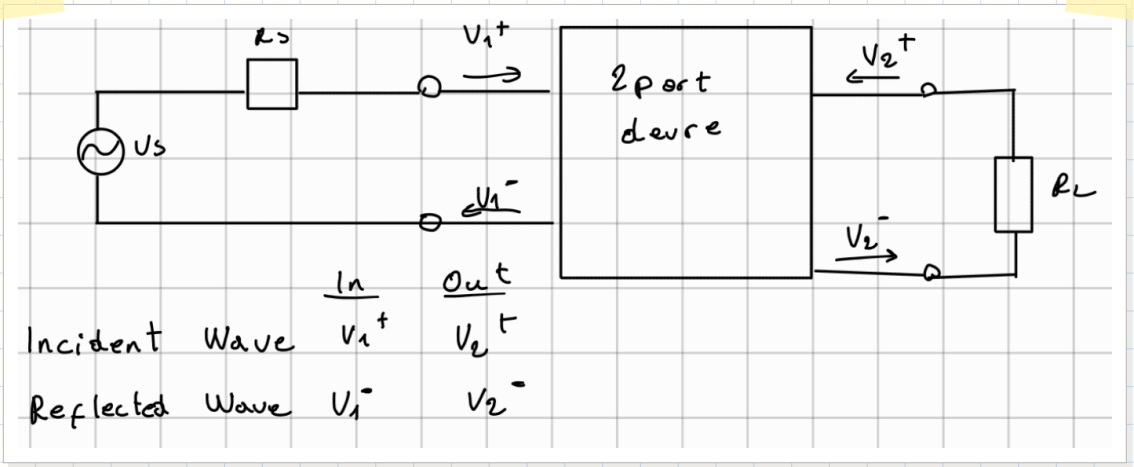
orijinal çizim, s. 11

Step Attenuator 1 dB → 0 ~ 30 dB
2 dB → 0 ~ 40 dB

Amfiyi doyurmadan linear bölgede çalışması için

Fixed Attention

S-parameters



orijinal çizim, s. 11

$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$V_1^- = S_{11}V_1^+ + S_{12}V_2^+$$
$$V_2^- = S_{21}V_1^+ + S_{22}V_2^+$$

$$S_{11} = \left.\frac{V_1^-}{V_1^+}\right|_{V_2^+=0}$$ shows the accuracy of input matching

V_1^- ne kadar küçükse yansıma o kadar azdır

$S_{11} \leq -15$ dB den küçükse

orj. s. 12

$$S_{22} = \left.\frac{V_2^-}{V_2^+}\right|_{V_1^+=0}$$ Shows the accuracy of output matching

$S_{22} \leq -15$ dB

$$S_{12} = \left.\frac{V_1^-}{V_2^+}\right|_{V_1^+=0}$$

Reverse Isolation

çıkıştan girişe gelen sinyal

$$S_{21} = \left.\frac{V_2^-}{V_1^+}\right|_{V_2^+=0}$$

Gain