RF Tasarım

Direct conversion alıcı, dezavantajları, I/Q mismatch

Orijinal not: Ders-12.pdf

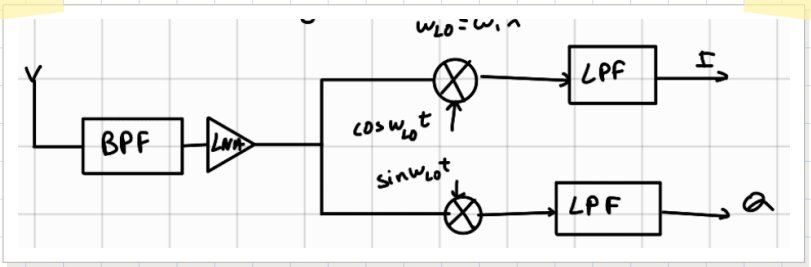
UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

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

Direct Conversion Receiver

"Zero-IF" or "homodyne"



orijinal çizim, s. 1

→ One step Conversion

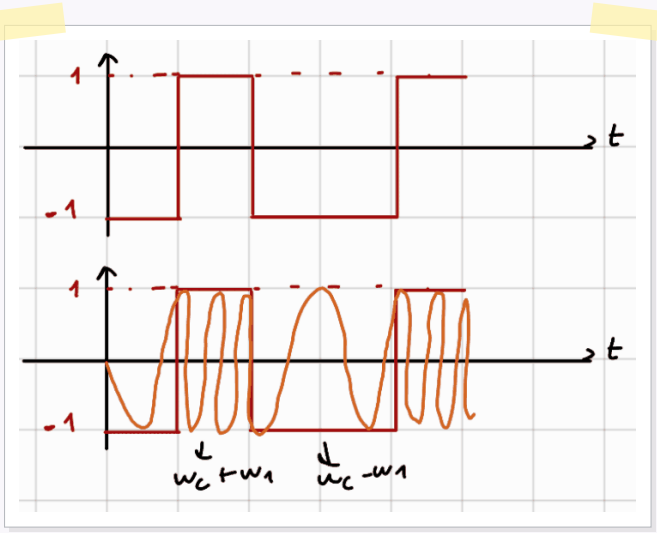
Özellikleri

- ✓ No image
- ✓ Simple design process
- ✓ Mixing spurs are reduced

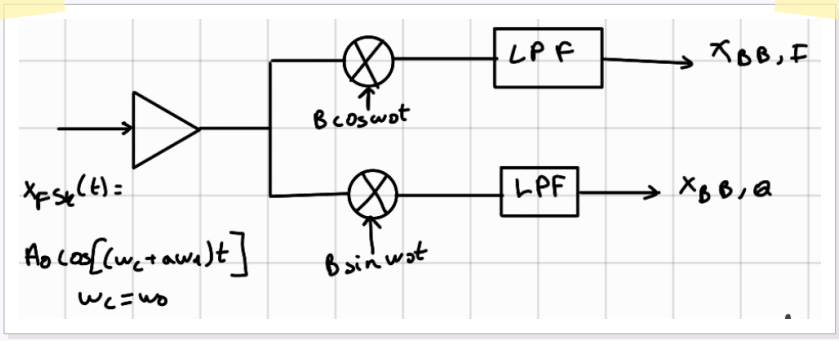
Örnek

FSK Direct Conversion Receiver

$$x_{FSK}(t) = A_0 \cos[(\omega_c + a\omega_1)t], \quad a = \pm 1$$



orijinal çizim, s. 1



orijinal çizim, s. 1

$$x_{BB,I} = A_0 \cos[(\omega_c + a\omega_1)t] \cdot B\cos\omega_0 t$$

$$= \underbrace{\frac{A_0 B}{2}}_{A_1}[\cos(2\omega_c + a\omega_1)t + \cos a\omega_1 t] \xrightarrow{\text{LPF}} x_{BB,I} = A_1 \cos a\omega_1 t$$

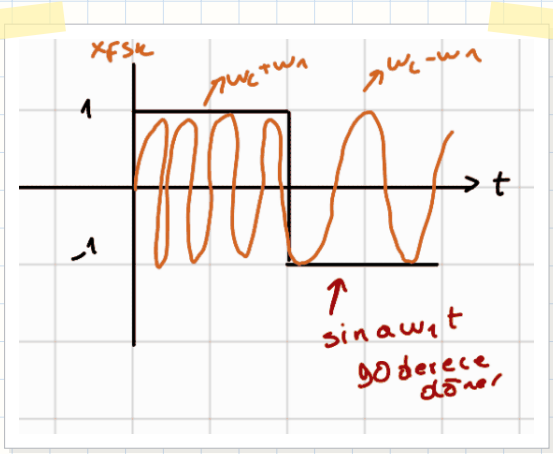
$$x_{BB,Q} = A_0 \cos[(\omega_c + a\omega_1)t] \cdot B\sin\omega_0 t$$

$$= \frac{A_0 B}{2}[\sin(2\omega_c + a\omega_1)t - \sin a\omega_1 t]$$

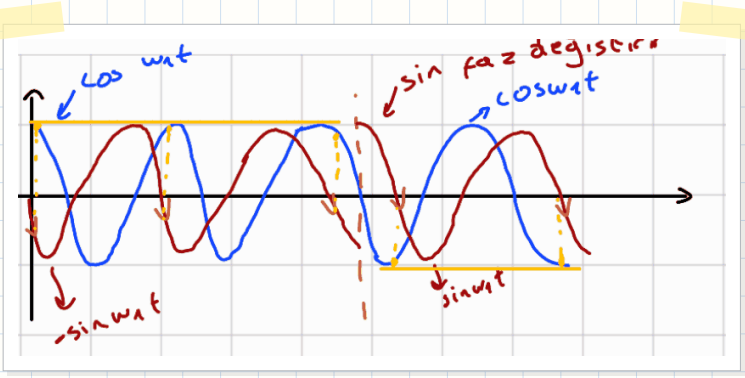
$$\hookrightarrow x_{BB,Q} = -A_1 \sin a\omega_1 t$$

orj. s. 2

Anlamak için 2 bit gönderdiğimizi düşünelim

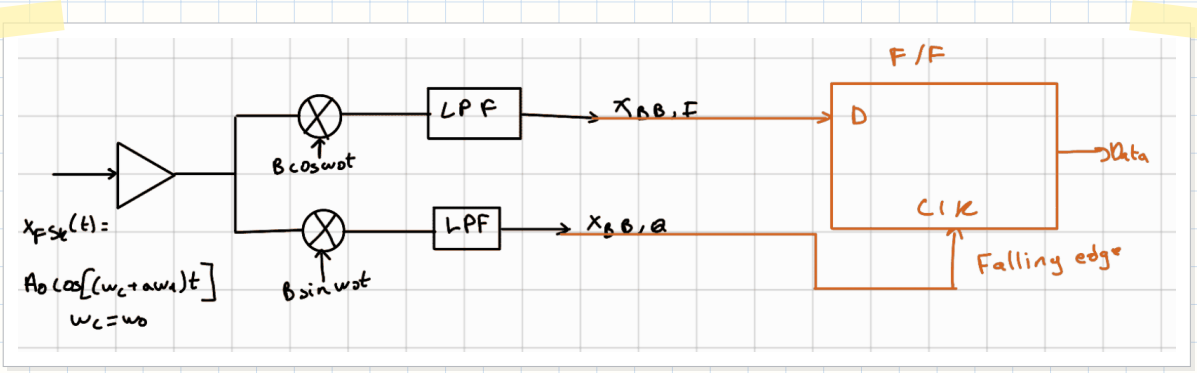


orijinal çizim, s. 2



orijinal çizim, s. 2

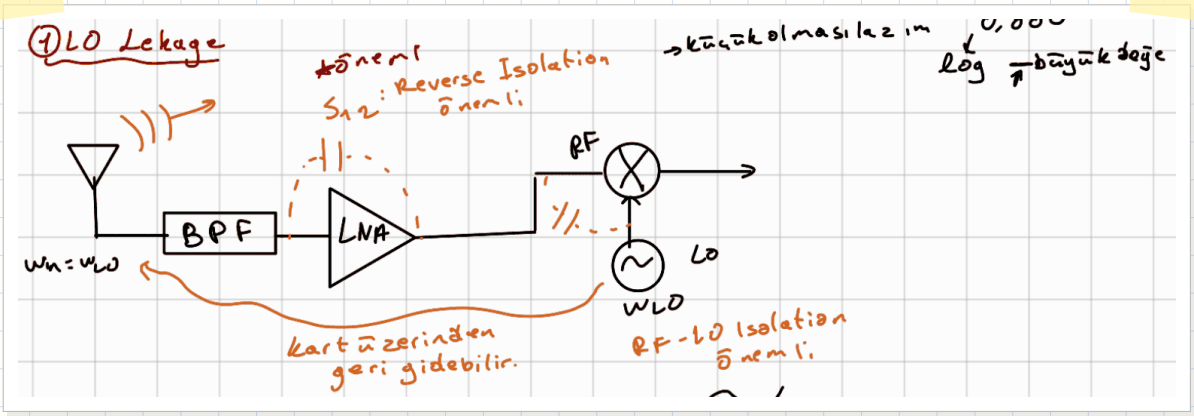
Şimdi bunları bir demodülatöre sokuyoruz



orijinal çizim, s. 2

Drawbacks of Direct Conversion Receivers

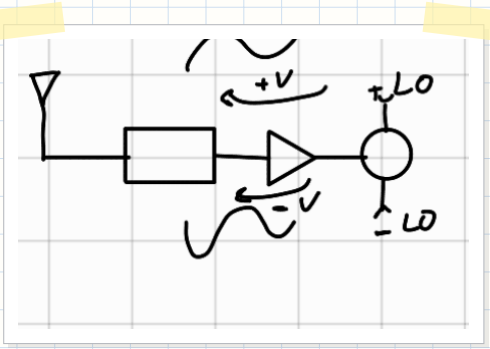
(1) LO Leakage



orijinal çizim, s. 2

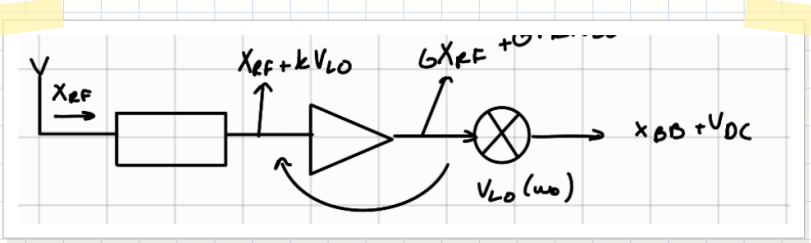
To minimize LO leakage

1) Differential Oscillator
2) Symmetric layout for Oscillator



orijinal çizim, s. 2

(2) DC offset

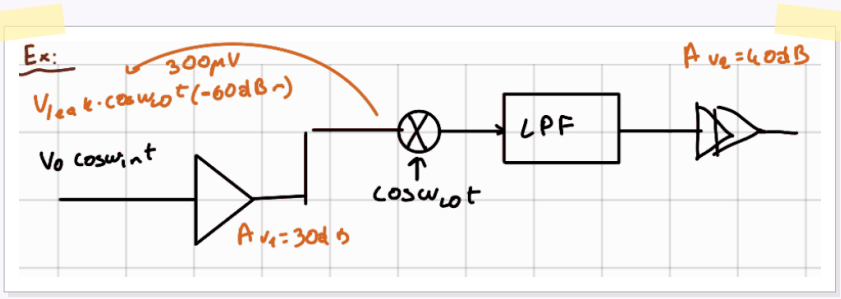


orijinal çizim, s. 2

DC offsetten kurtulmalıyız

orj. s. 3

Örnek

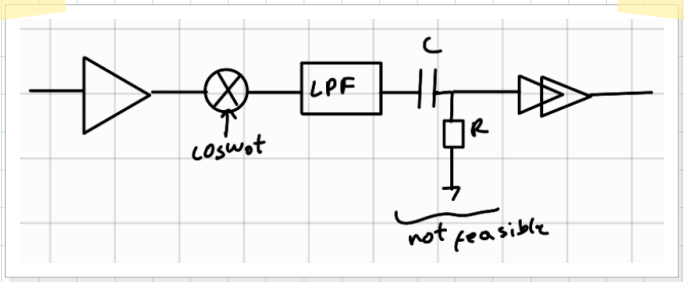


orijinal çizim, s. 3

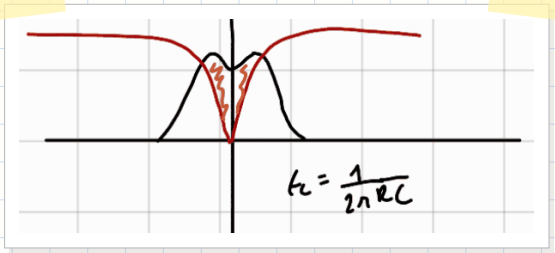
LO leakage at the input of LNA is −60 dBm

$$-60 + 30 + 40 = 10 \text{ dBm} \rightarrow V_{DC} \approx 1V$$

Solving DC Offset

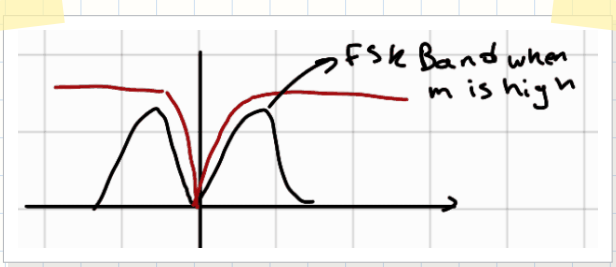


orijinal çizim, s. 3



orijinal çizim, s. 3

$$f_c = \frac{1}{2\pi RC}$$

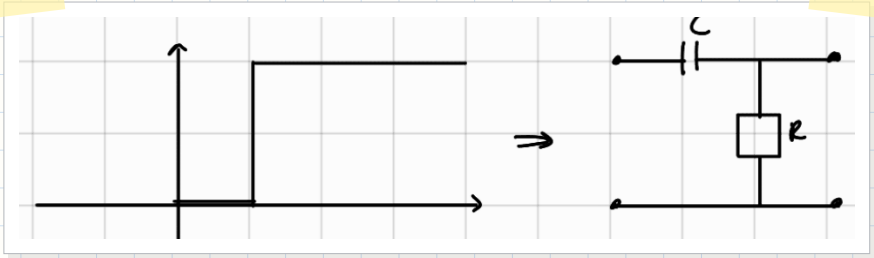


orijinal çizim, s. 3

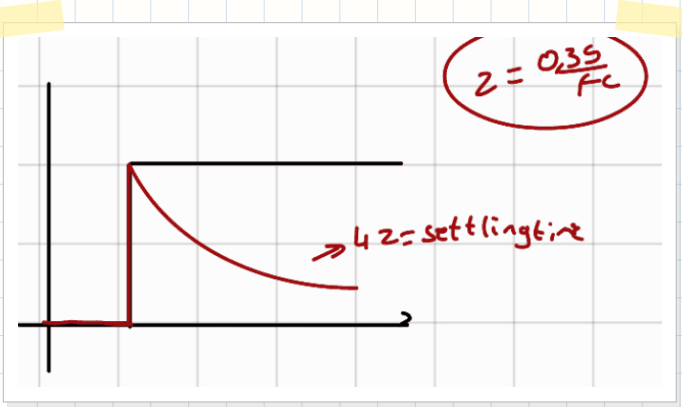
$$m = \frac{f_2 - f_1}{f_c}$$

modulation index (FSK)

Bunun başka dezavantajı var



orijinal çizim, s. 3

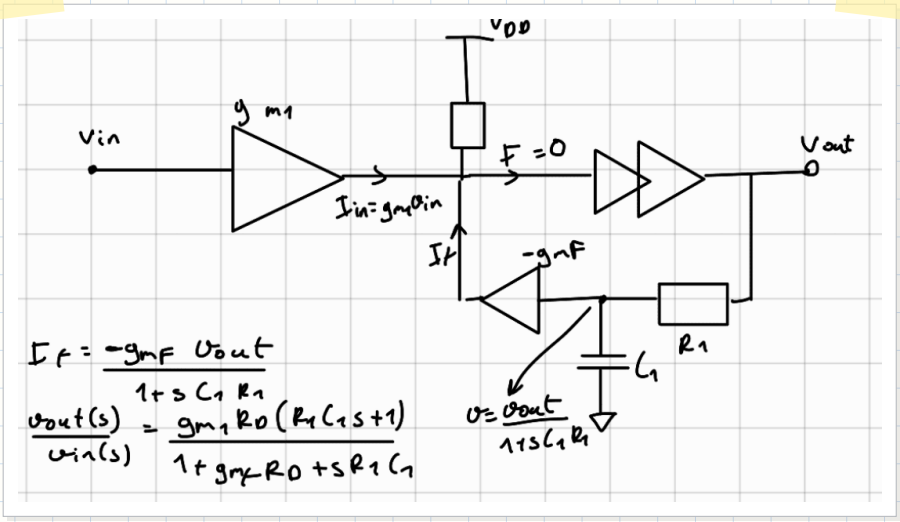


orijinal çizim, s. 3



orijinal çizim, s. 3

Çözüm 1:

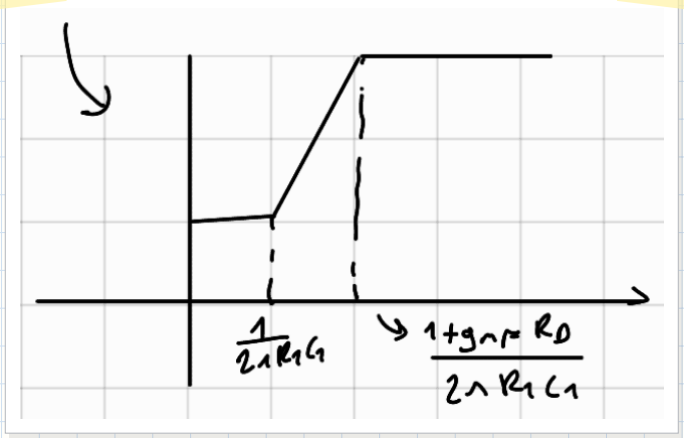


orijinal çizim, s. 3

$$I_F = \frac{-g_{mF} V_{out}}{1 + sC_1R_1}$$

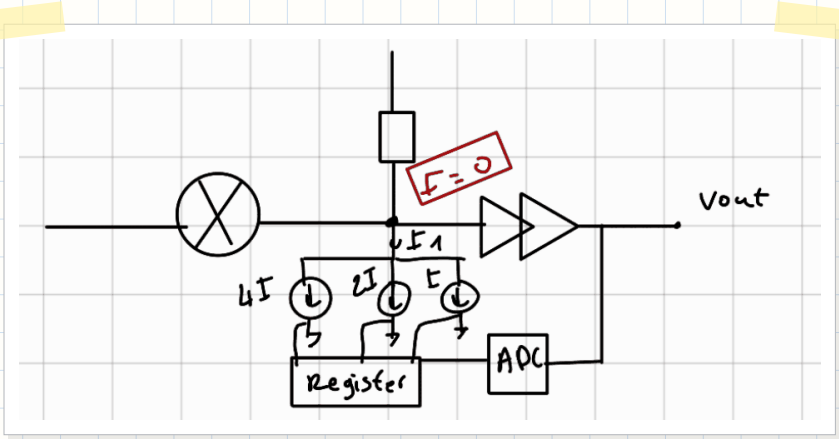
$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{g_{m1}R_0(R_1C_1s + 1)}{1 + g_{mF}R_0 + sR_1C_1}$$

orj. s. 4



orijinal çizim, s. 4

Çözüm 2:



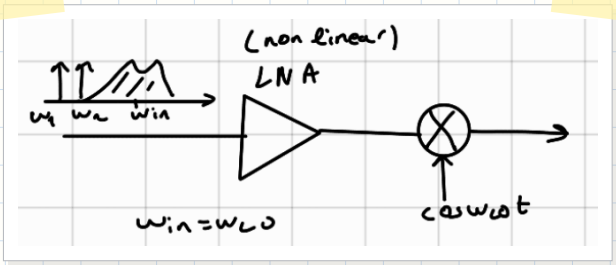
orijinal çizim, s. 4

Drawback of Direct conversion Receivers

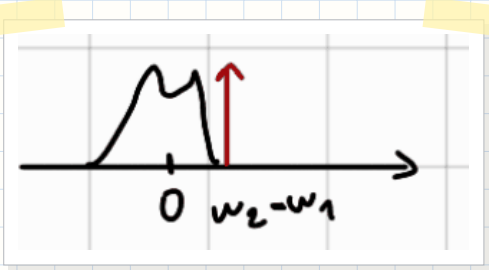
(3) Even Order Distorsion

$2\omega_2 - \omega_1 \rightarrow 3^{rd}$ order distortion

$\omega_2 - \omega_1 \rightarrow 2^{nd}$ (Even)



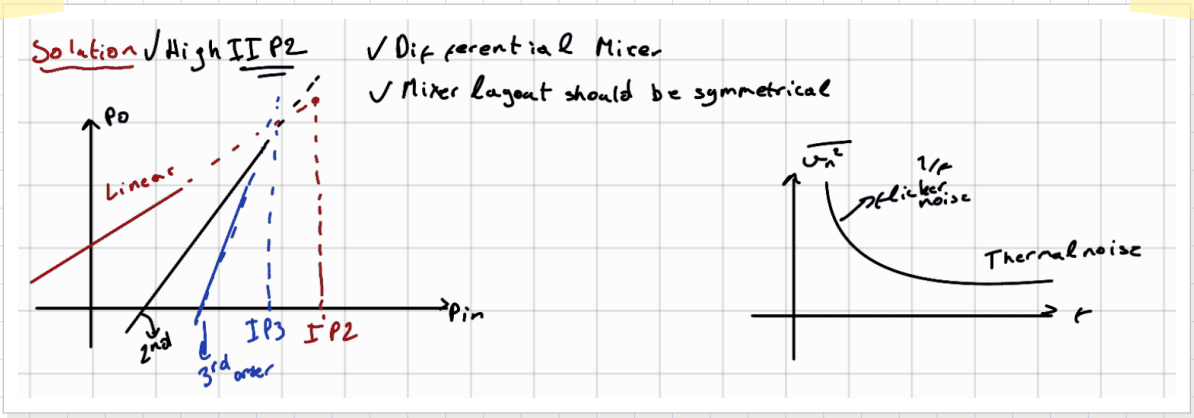
orijinal çizim, s. 4



orijinal çizim, s. 4

Çözüm:

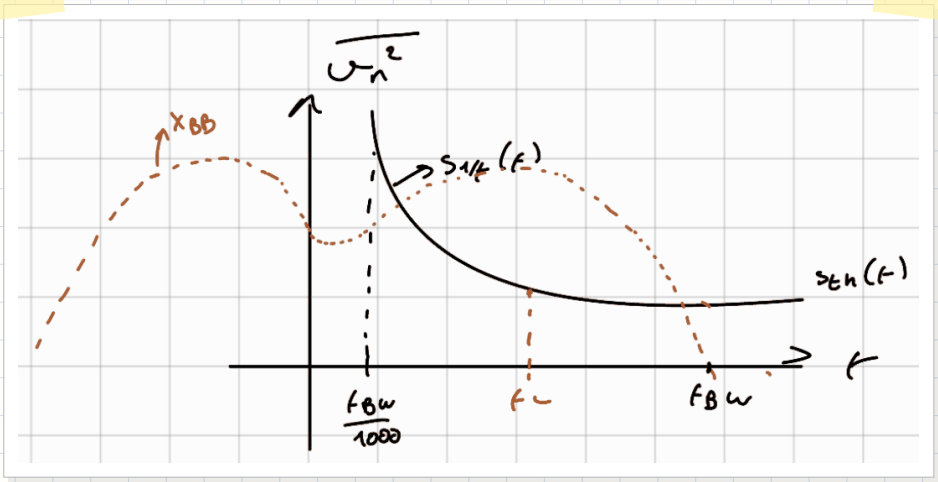
- ✓ High IIP2
- ✓ Differential Mixer
- ✓ Mixer layout should be symmetrical



orijinal çizim, s. 4

orj. s. 5

(4) Flicker noise



orijinal çizim, s. 5

f_{BW} : Half of RF channel Band width
$S_{1/f}(f) = \frac{a}{f}$: PSD of flicker noise
$S_{th}(f) = S_{th}$: PSD of thermal noise
f_c : corner frequency

We ignore noise effect below $\frac{f_{BW}}{1000}$ since they vary slowly

$$S_{1/f}(f) = \frac{a}{f} \rightarrow S_{1/f}(f_c) = \frac{a}{f_c} = S_{th} \rightarrow a = f_c S_{th}$$

$$P_{n1} = \int_{\frac{f_{BW}}{1000}}^{f_c} \frac{a}{f}\,df + \int_{f_c}^{f_{BW}} S_{th}\,df$$

$$= \underset{f_c S_{th}}{a} \ln\frac{1000 f_c}{f_{BW}} + (f_{BW} - f_c) S_{th}$$

$$P_{n1} = \left(5{,}9 + \ln\frac{f_c}{f_{BW}}\right) f_c S_{th} + f_{BW} \cdot S_{th}$$ ← önemli

In the absence of flicker noise = $P_{n2} \approx S_{th} \cdot f_{BW}$

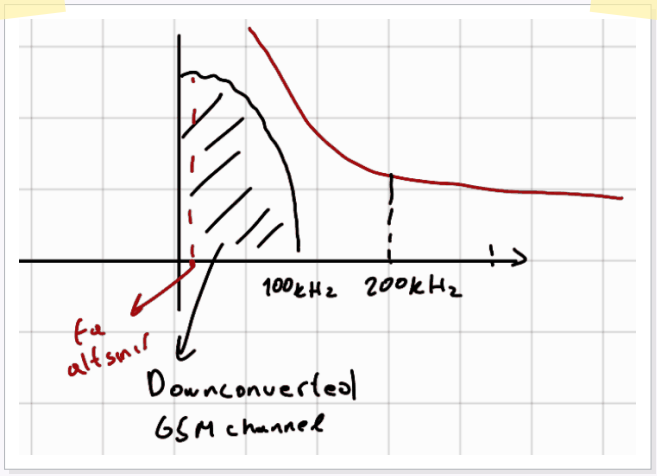
→ **Flicker noise Penalty**

↓↓ azaltmak istiyoruz

$$\frac{P_{n1}}{P_{n2}} = 1 + \left(5{,}9 + \ln\frac{f_c}{f_{BW}}\right) \cdot \frac{f_c}{f_{BW}}$$ ← önemli

orj. s. 6

Örnek



orijinal çizim, s. 6

Flicker noise penalty

$$\rightarrow P_{n1} = \int_{\frac{f_{BW}}{1000}}^{100\,kHz} \frac{a}{f}\,df + \text{sonrasında işaret yok}$$

→ normalde f_c ana bant bitiyor ? fc gözükmüyor ? Bu formülü uygularken dikkat edin

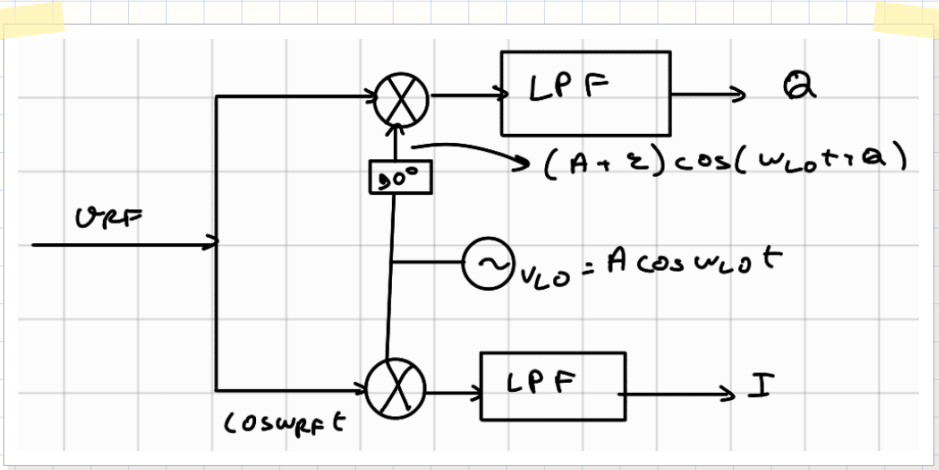
$$= \int_{27\,Hz}^{100\,kHz} \frac{f_c S_{th}}{f}\,df = 8{,}2\,{}^{100k}f_c\,S_{th}$$

$$P_{n2} = {}^{100\,kHz}f_c\,S_{th} = 100k\,S_{th}$$

$$\frac{P_{n1}}{P_{n2}} = \frac{8{,}2 \cdot f_c \cdot S_{th}}{S_{th} \cdot f_c} = 8{,}2$$

I/Q Mismatch (Drawbacks of Quadrature Downconversion)

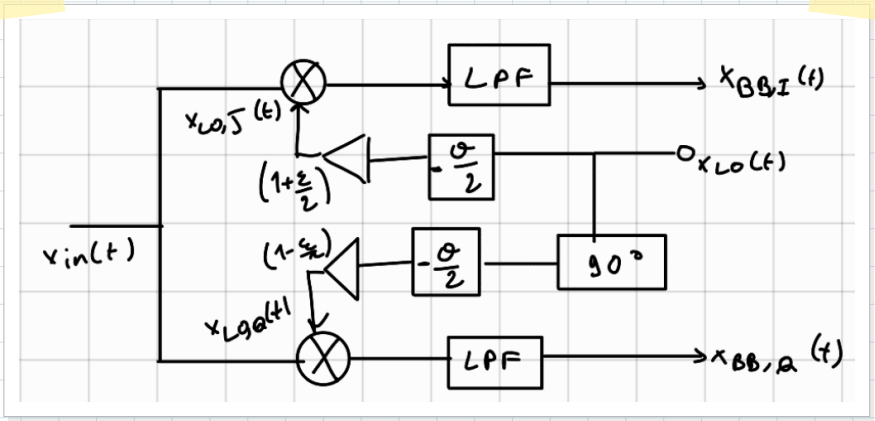
? (up)



orijinal çizim, s. 6

Phase & gain Error

orj. s. 7



orijinal çizim, s. 7

$\varepsilon \rightarrow$ gain error $\quad \theta \rightarrow$ phase error

$$x_{in}(t) = a\cos\omega_c t + b\sin\omega_c t \rightarrow \text{QPSK signal}$$

$$x_{LO,I}(t) = 2\left(1+\frac{\varepsilon}{2}\right)\cos\left(\omega_c t + \frac{\theta}{2}\right)$$
$$x_{LO,Q}(t) = 2\left(1-\frac{\varepsilon}{2}\right)\sin\left(\omega_c t - \frac{\theta}{2}\right)$$

When $\varepsilon = 0,\ \theta = 0$

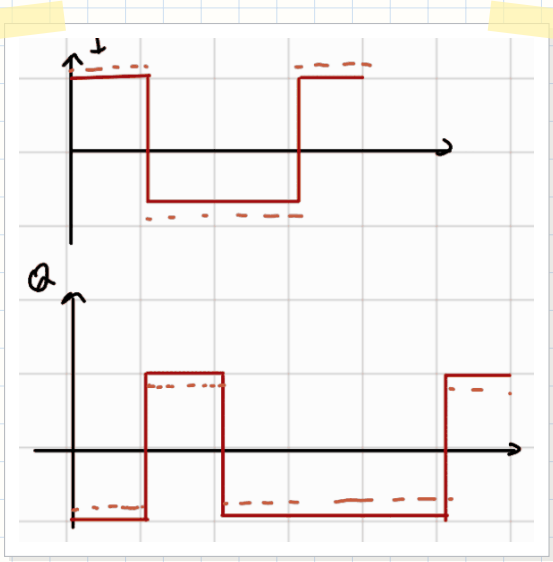
$$\rightarrow x_{BB,I}(t) = a, \qquad x_{BB,Q}(t) = b$$

→ **Outputs**

$$x_{BB,I}(t) = a\left(1+\frac{\varepsilon}{2}\right)\cos\left(\frac{\theta}{2}\right) - b\left(1+\frac{\varepsilon}{2}\right)\sin\left(\frac{\theta}{2}\right) \longrightarrow$$
$$x_{BB,Q}(t) = -a\left(1-\frac{\varepsilon}{2}\right)\sin\left(\frac{\theta}{2}\right) + b\left(1-\frac{\varepsilon}{2}\right)\cos\left(\frac{\theta}{2}\right) \longrightarrow$$

→ **Only gain mismatch ($\theta = 0$)**

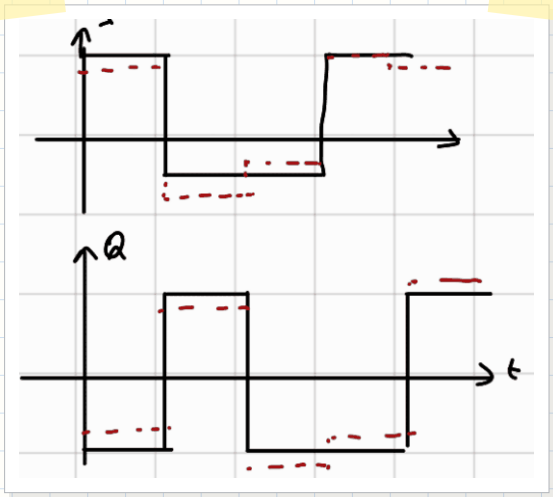
$$x_{BB,I}(t) = a\left(1 + \frac{\varepsilon}{2}\right)$$
$$x_{BB,Q}(t) = b\left(1 - \frac{\varepsilon}{2}\right)$$



orijinal çizim, s. 7

→ **Only phase mismatch ($\varepsilon = 0$)**

$$x_{BB,I}(t) = a\cos\left(\frac{\theta}{2}\right) - b\sin\left(\frac{\theta}{2}\right)$$
$$x_{BB,Q}(t) = -a\sin\left(\frac{\theta}{2}\right) + b\cos\left(\frac{\theta}{2}\right)$$



orijinal çizim, s. 7

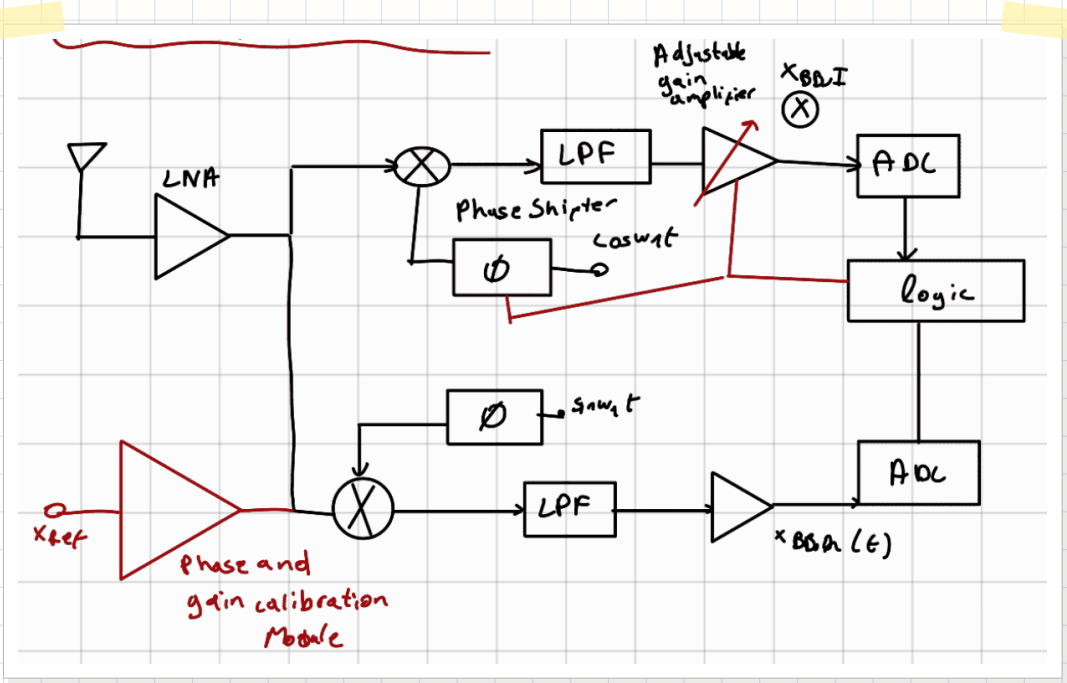


orijinal çizim, s. 7

orj. s. 8

Bunu çözmek için ne yapmak gerekiyor

Solutions of I/Q Mismatch



orijinal çizim, s. 8

I/Q
Mismatch penalty