RF Tasarım

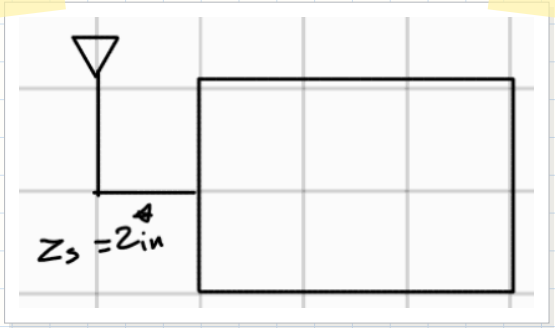
Receiver Noise Floor, Sensitivity, DR ve SFDR

Orijinal not: Ders7.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.*

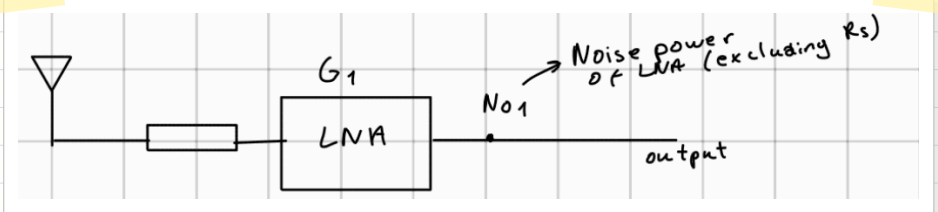
orj. s. 1



orijinal çizim, s. 1

Input noise power $\frac{\overline{v_{in,n}^2}}{R_{in}} = \frac{kTR_s}{R_{in}} = kT$ in 1Hz BW

in B Bandwidth kTB



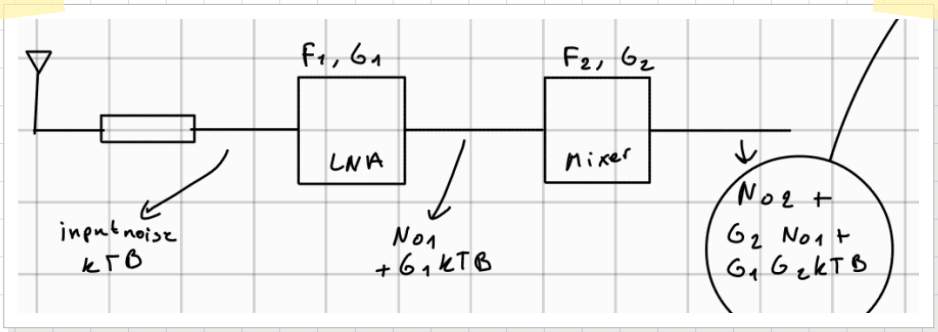
orijinal çizim, s. 1

$$F = \frac{\text{Total noise power including } R_s}{A_v^2 \cdot \text{Noise from only } R_s}$$

$$= \frac{\overline{v_{n,out}^2}}{A_v^2} \cdot \frac{1}{4kTR_s}$$

$$F_1 = \frac{N_{o1} + \overbrace{G_1 kTB}^{\text{girişteki gürültü}}}{G_1 \cdot kTB}$$

$$N_{o1} = (F_1 - 1)\, G_1\, kTB$$



orijinal çizim, s. 1

↕ Added Noise

$$N_i = \frac{\text{Total noise power at output}}{G_1 G_2}$$

N_i : input referred total noise

Receiver noise Floor

$$F = \frac{N_o + G\,kTB}{G} \cdot \frac{1}{kTB}$$

~~$N_o = (F - 1)\, kTB \cdot G$~~

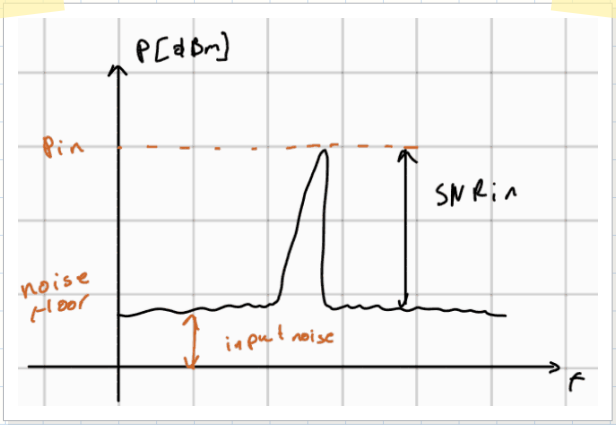
$$F\,kTB = \frac{N_o}{G} + kTB = \text{noise Floor}$$

$$\text{noise floor} = F \cdot kTB$$

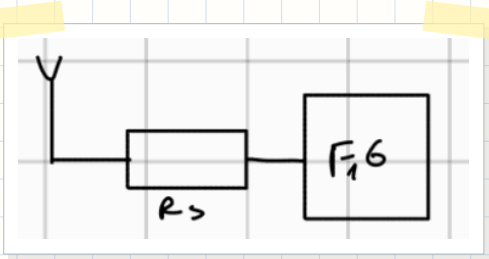
$F \leftarrow$ Noise factor, $k \leftarrow$ Boltzman constant, $T \leftarrow$ temperature

orj. s. 2

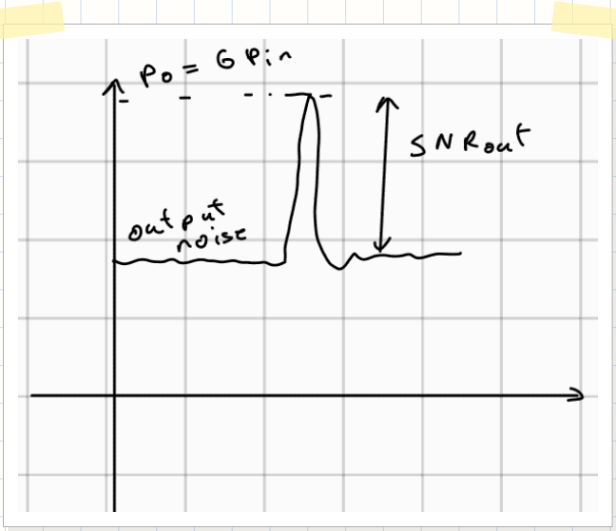
Receiver SNR & Noise



orijinal çizim, s. 2



orijinal çizim, s. 2



orijinal çizim, s. 2

$$SNR_{out} < SNR_{in}$$

output noise = input Noise + N_A

$$\text{noise floor} = FkTB = \underbrace{10\log F}_{NF} + \underbrace{10\log k\overset{25^\circ}{T}}_{-174\ \text{dBm/Hz}} + 10\log B$$

$$\text{noise floor} = -174\,\frac{\text{dBm}}{\text{Hz}} + 10\log\frac{B}{10^6} + NF$$

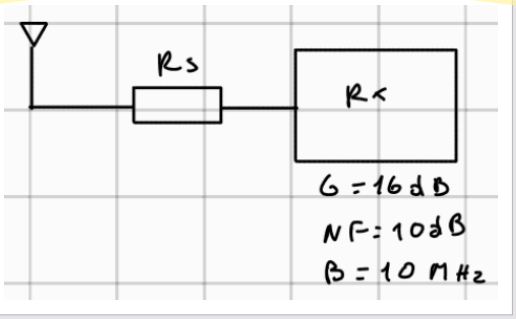


orijinal çizim, s. 2

$$\text{Output referred total noise} = FkTB \cdot G$$

$$= NF - 174\,\frac{\text{dBm}}{\text{Hz}} + 10\log B + 10\log G$$

Örnek



orijinal çizim, s. 2

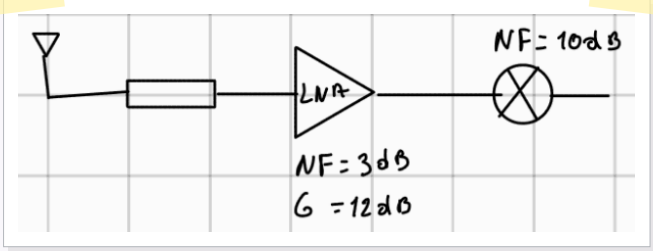
$$\text{noise floor} = FkTB = -174\,\frac{\text{dBm}}{\text{Hz}} + 10\log(10 \cdot 10^6) + \overbrace{10}^{NF}$$

$$= -174 + 70 + 10 = -94 \text{ dBm}$$

$$N_{out,t} = -94 + 16 = -78 \text{ dBm}$$

orj. s. 3

Örnek



orijinal çizim, s. 3

Calculate NF total

$$F = F_1 + \frac{F_2 - 1}{G_1} \quad \leftarrow \text{Skaler olmalı}$$

$$= 10^{3/10} + \frac{10^{12/10}[1] - 1}{10^{12/10}} = 2{,}57$$

$$NF = 10 \log F = 10 \log(2{,}57) = 4{,}1 \text{ dB}$$

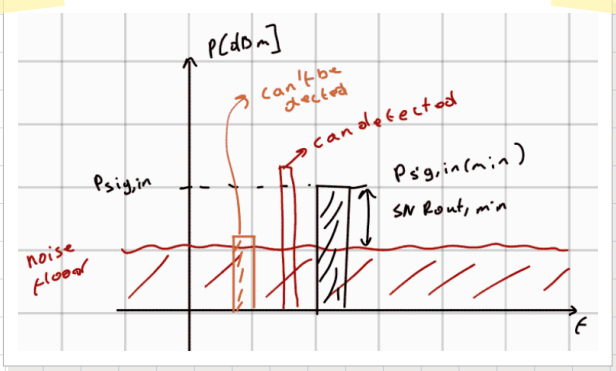
Calculate Noise floor ($B = 5$ MHz)

$$\text{Noise floor} = -174 \frac{\text{dBm}}{\text{Hz}} + 10 \log(5 \cdot 10^6) + 4{,}1$$

$$\text{Noise floor} = -102{,}9 \text{ dBm}$$

Sensitivity and Dynamic Range

Sensitivity is the minimum[input] signal which can be detected with the acceptable output SNR.



orijinal çizim, s. 3

$$NF = \frac{(SNR)_{in}}{(SNR)_{out}} = \frac{P_{sig,in}/P_{n,in}}{SNR_{out}}$$

[1] Claude notu: pay kısmındaki üs muhtemelen 10/10 olmalı (mikserin NF'i 10 dB); 2,57 sonucu bu okumayla uyumlu.

$$P_{sig,in} = \underbrace{P_{n,in}}_{\substack{kTB \\ \text{if } R_s = R_{in}}} \cdot F \cdot SNR_{out}$$

$$P_{sig,in} = \underbrace{kTB \cdot F}_{\substack{\text{noise} \\ \text{floor}}} \cdot SNR_{out}$$

$$P_{sig,in(min)}\Big|_{dB} = \text{noise floor}_{dB} + SNR_{out,dB}$$

orj. s. 4

$$\underbrace{P_{sig,in(min)}\Big|_{dB}}_{\text{sensitivity}} = -174\,\frac{dBm}{Hz} + 10\log B + NF + SNR_{out}\Big|_{dB}$$

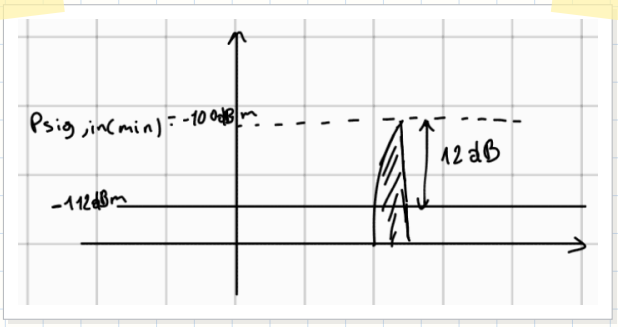
Örnek

A GSM receiver has $SNR_{out(min)} = 12$ dB
channel BW = 20 khz
NF = 9 dB

what is the minimum acceptable signal power ?

$$P_{sig,in(min)} = -174\,\frac{dBm}{Hz} + \underbrace{10\log(20 \cdot 10^3)}_{53^2} + 9 + 12$$

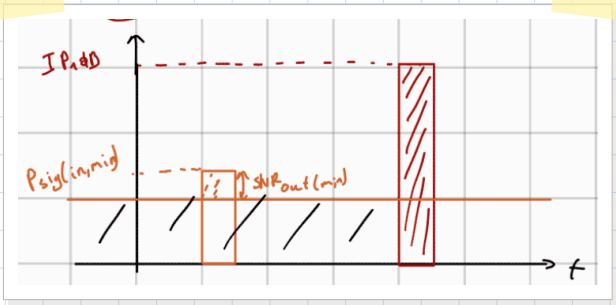
$$= -112 + 12 = -100 \text{ dBm}$$



orijinal çizim, s. 4

[2] Claude notu: $10\log(20 \cdot 10^3) \approx 43$ dB'dir; 53 dB, 200 kHz'lik bant genişliğine karşılık gelir (GSM kanalı 200 kHz).

Dynamic Range



orijinal çizim, s. 4

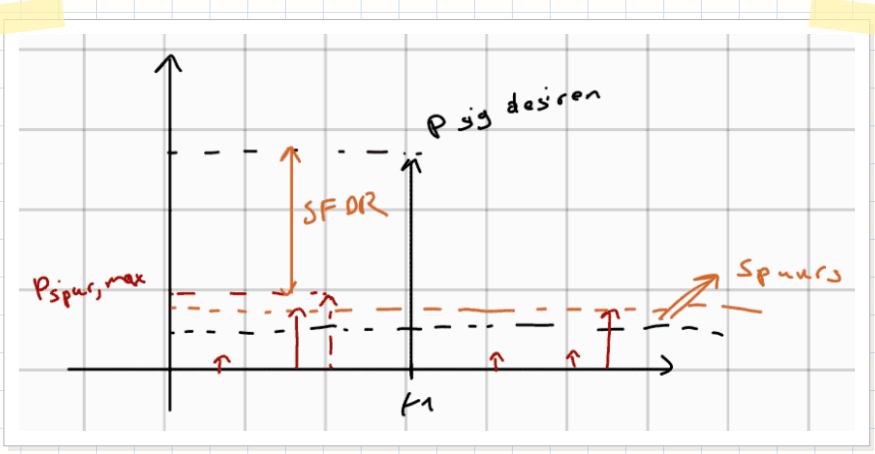
$$DR = IP_{1dB} - \underbrace{P_{sig,in(min)}\big|_{dB}}_{\substack{MDS \\ \text{Minimum detectable signal}}} = IP_{1dB} - MDS$$

SFDR

Spur-free Dynamic Range



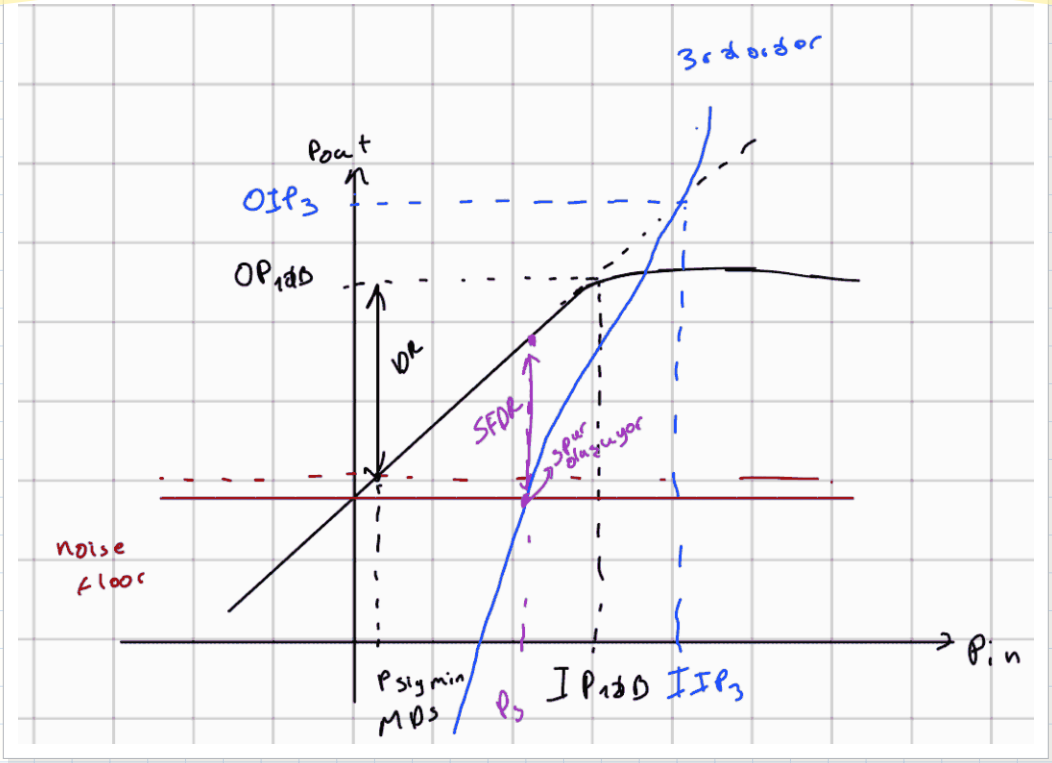
orijinal çizim, s. 4



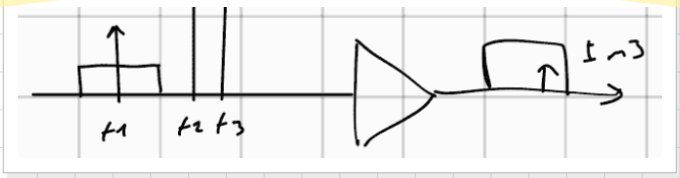
orijinal çizim, s. 4

$$SFDR = P_{sig,desired} - P_{spur(max)}$$

orj. s. 5



orijinal çizim, s. 5



orijinal çizim, s. 5

$$SFDR = \frac{2\,(P_{IIP3} + 174 - NF - 10\log B)}{3} - SNR_{out(min)}$$