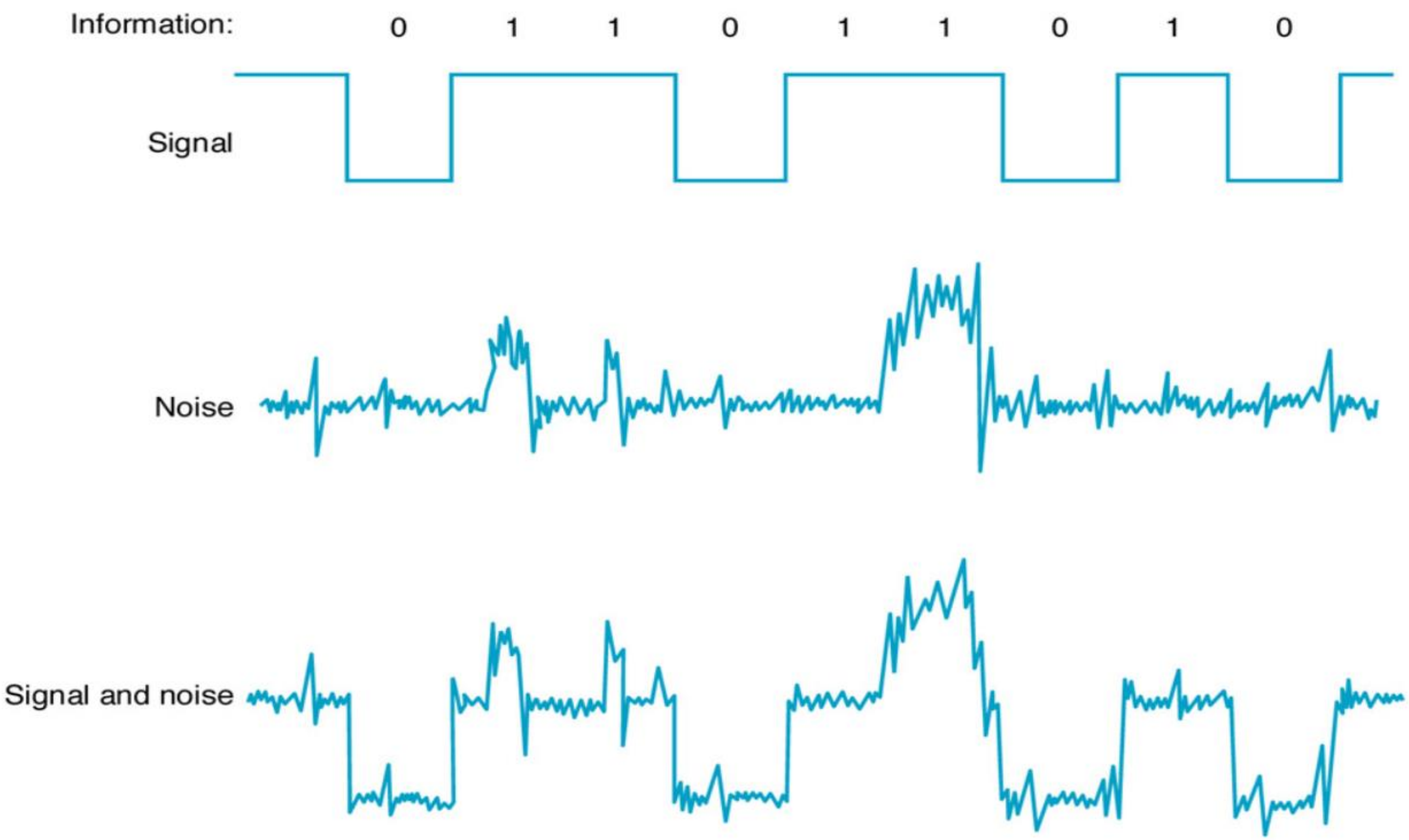
UESTC4004
Digital Communications

Transmission Design at the Physical Layer
-Design for QoS

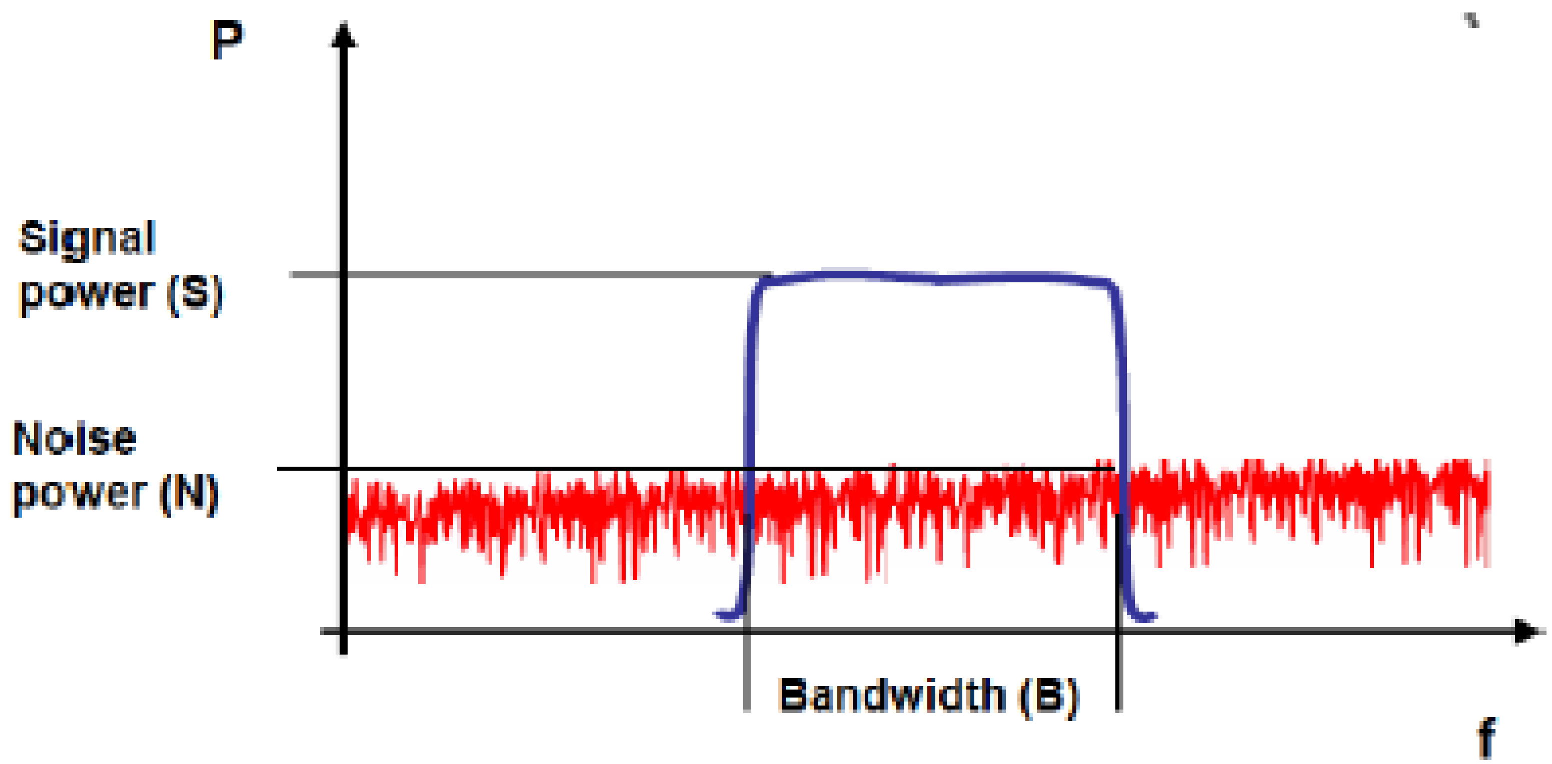
Noise Power, Noise Figure and Noise Temperature

Noise

- “Any unwanted input” – Undesirable portion of an electrical signal
- Limits systems ability to process weak signals



Noise Power



Most of input noise = Thermal Noise

Noise power N = kTB

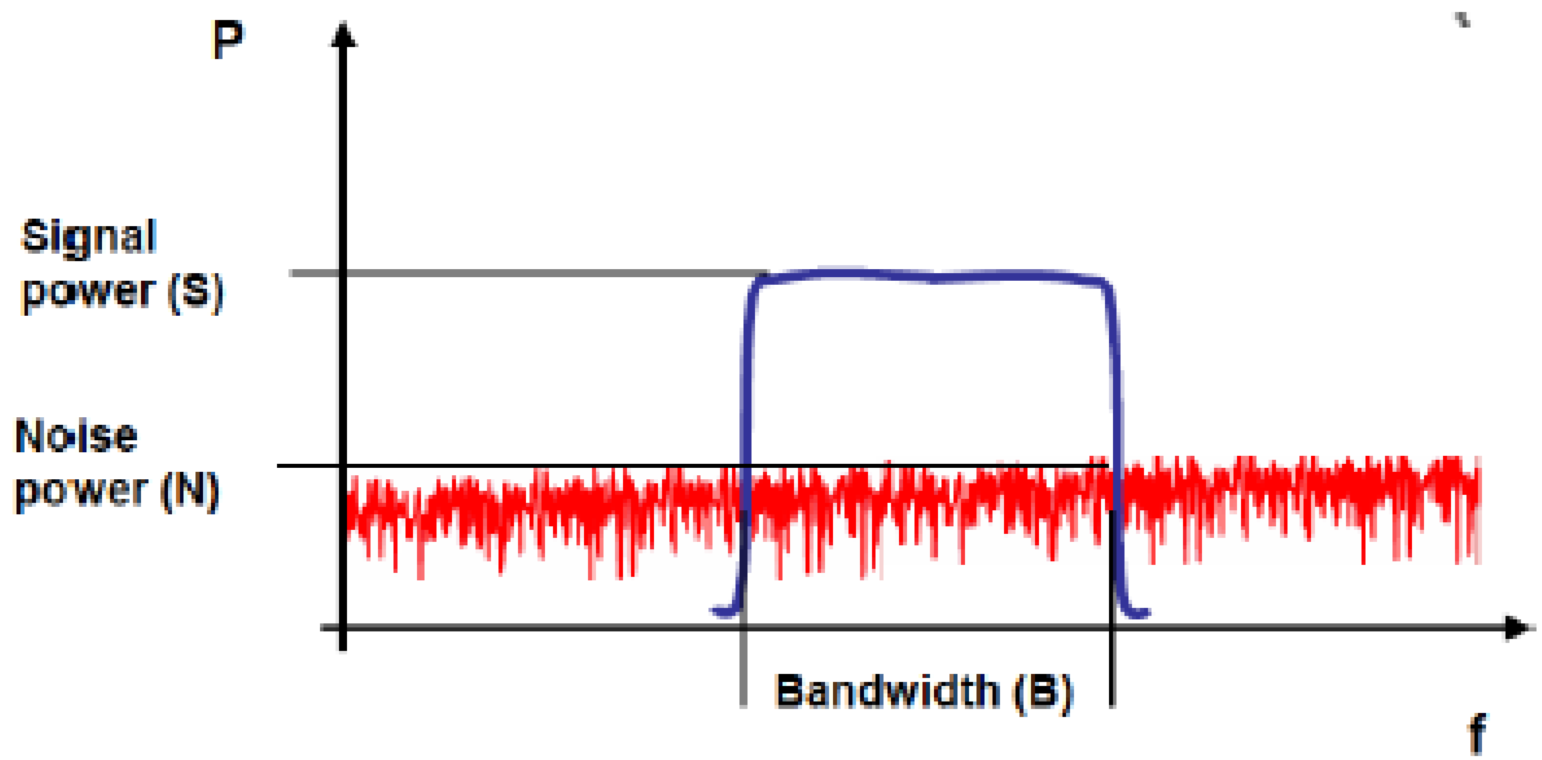
$N = kTB$

k = Boltzmann’s constant 1.38×10^{-23} J/k

T = Absolute temperature of device 开尔文

B = Bandwidth

Noise Power



$\frac{E_b}{N_0}$

用能量定义

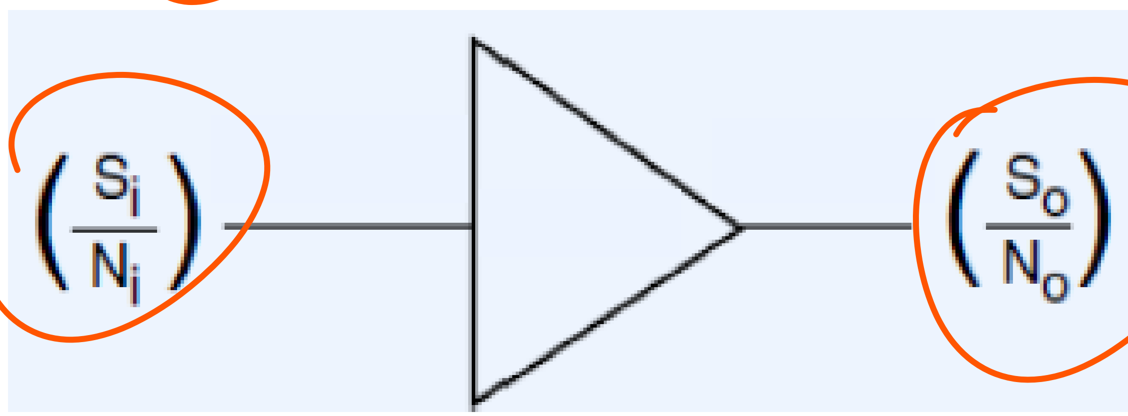
Signal to Noise Ratio (SNR)

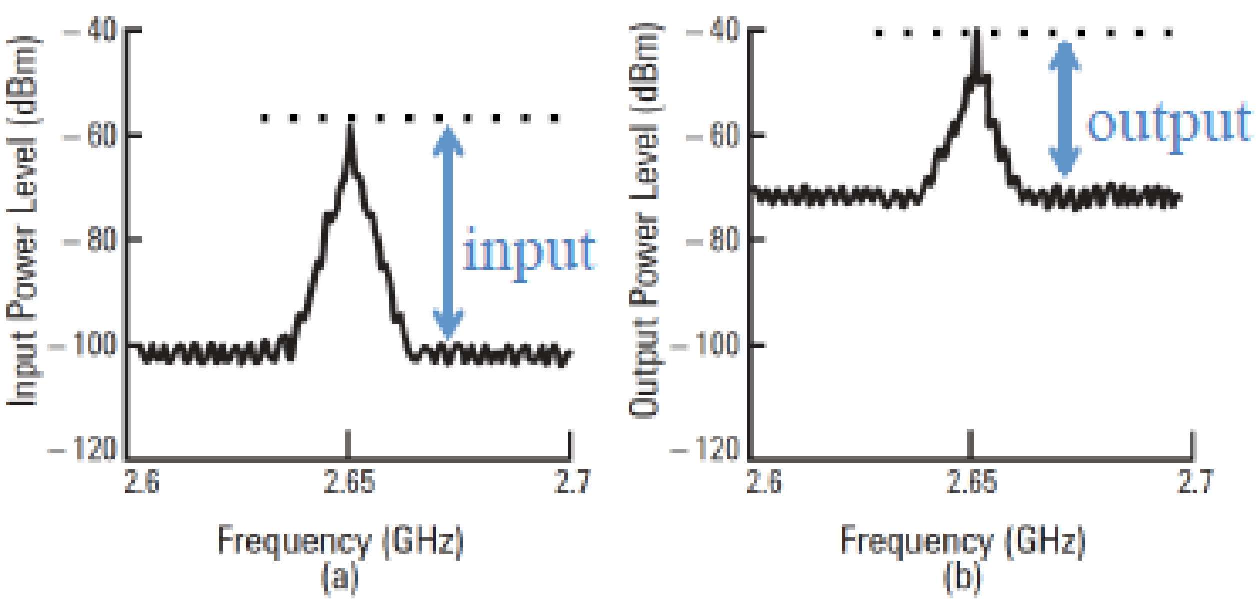
$N_0 = \frac{N}{BW}$

$$\boxed{SNR = \frac{S(f)}{N(f)} = \frac{Average\ signal\ power}{Average\ noise\ power}}$$

信噪比 的比值

Noise Figure





- Noise figure represents the degradation in the signal-to-noise ratio as the signal passes through a device

$$F = \frac{S_i/N_i}{S_0/N_0} = \frac{S_i/N_i}{GS_i/G(N_i+N_{ai})}$$

where

S_i = signal power at the input port

N_i =noise power at the input port

N_{ai} =amplifier noise referred to the input port

G =amplifier gain

F is always greater than 1

$S_0 = GS_i$

$N_0 = G(N_i + N_{ai})$

$F = \frac{N_i + N_{ai}}{N_i}$

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Noise Figure

$(S/N)dB = 10\log_{10}\left(\frac{S}{N}\right)$
$= 10(\log_{10} S - \log_{10} N)$

Noise factor

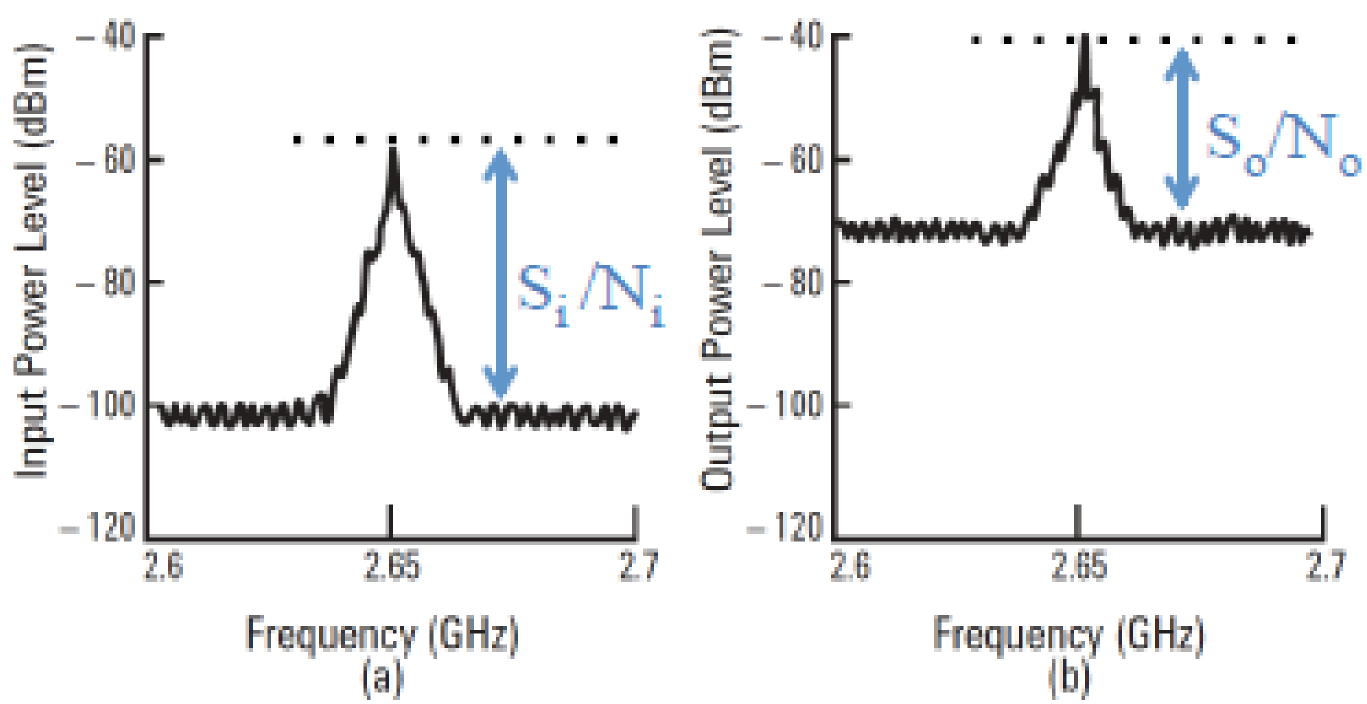
$$\boxed{F = \frac{S_i/N_i}{S_0/N_0}}$$

Modern usage of "noise figure" is usually reserved for the quantity NF, expressed in dB units:

$$\boxed{NF = 10\log_{10} F\ [dB]}$$

比率与加减

$$\boldsymbol{NF = (S_i/N_i)_{dB} - (S_0/N_0)_{dB}}$$



$(S_i/N_i)_{dB} = 40$ dB
$(S_0/N_0)_{dB} = 30dB$
Noise Figure = 10dB

Noise Temperature

- Comes from the random motion of electrons
  - Thermal noise

- **Convenient** common basis for measuring random electrical noise from any source

- Relation with Noise Figure
  - $T_R = T_0(F-1)$

有效噪声温度

T_R: The effective noise temperature of device
T_0: a reference temperature 290K (room temperature)

参考温度 290K

Exercise

If a wireless link provides an SNR of 20dB to the receiver antenna input terminals, and the receiver is specified to have a noise figure of 6dB, what is the SNR at the detector stage of the receiver?

$$NF = 6\,dB = \left(\frac{S}{N}\right)_i - \left(\frac{S}{N}\right)_o$$

$$\Rightarrow \left(\frac{S}{N}\right)_o = 14\,dB$$

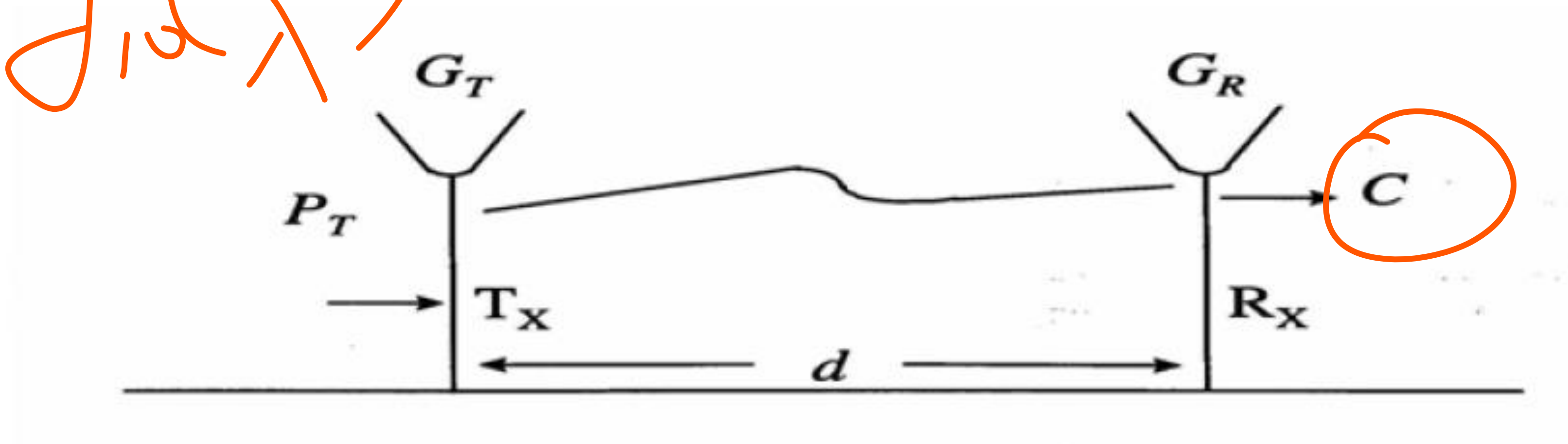
QoS

- ANALOGUE SYSTEMS - $^{S}/_{N}$
- DIGITAL SYSTEMS - BER

Bit Error Rate ⇒ P_B

Radio Systems

$$FSL\begin{cases}92.4+20\log_{10}D+20\log_{10}f\\ 20\log_{10}\left(\frac{4\pi d}{\lambda}\right)\end{cases}$$



PR ↘ Budget

Carrier C = $P_T + G_T - FSL - Fixed\ Loss\ - Media\ Loss + G_R$

G_T, G_R = ANTENNA GAINS

FSL =$20\log_{10}\left(\frac{4\pi d}{\lambda}\right)$ dB 原始公式

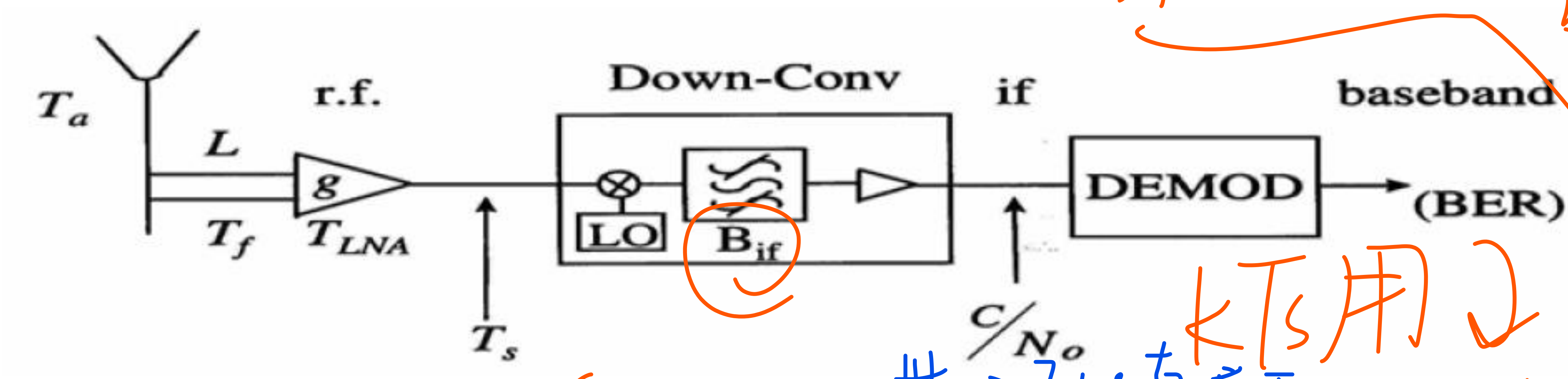
Fixed Loss –waveguide/coax loss, pointing loss

Media Loss – Fading due to rain or multipath/shadowing

$EIRP = P_t + G_t$ (dB)

Radio systems

减就是比率



kTs用J

带dB不能直接乘

1.38×10^{-23}（焦耳）算

T_s= Receiver Noise Temperature

$N_0 = kT_s$ 平均能量

$N = kT_sB_{if}$

B_{if} = Bandwidth

$k = -228.6$ dBW/K/Hz (Boltzmann constant)

N_0 = -174 dBm/Hz at 290 K T_s

再化成dBm

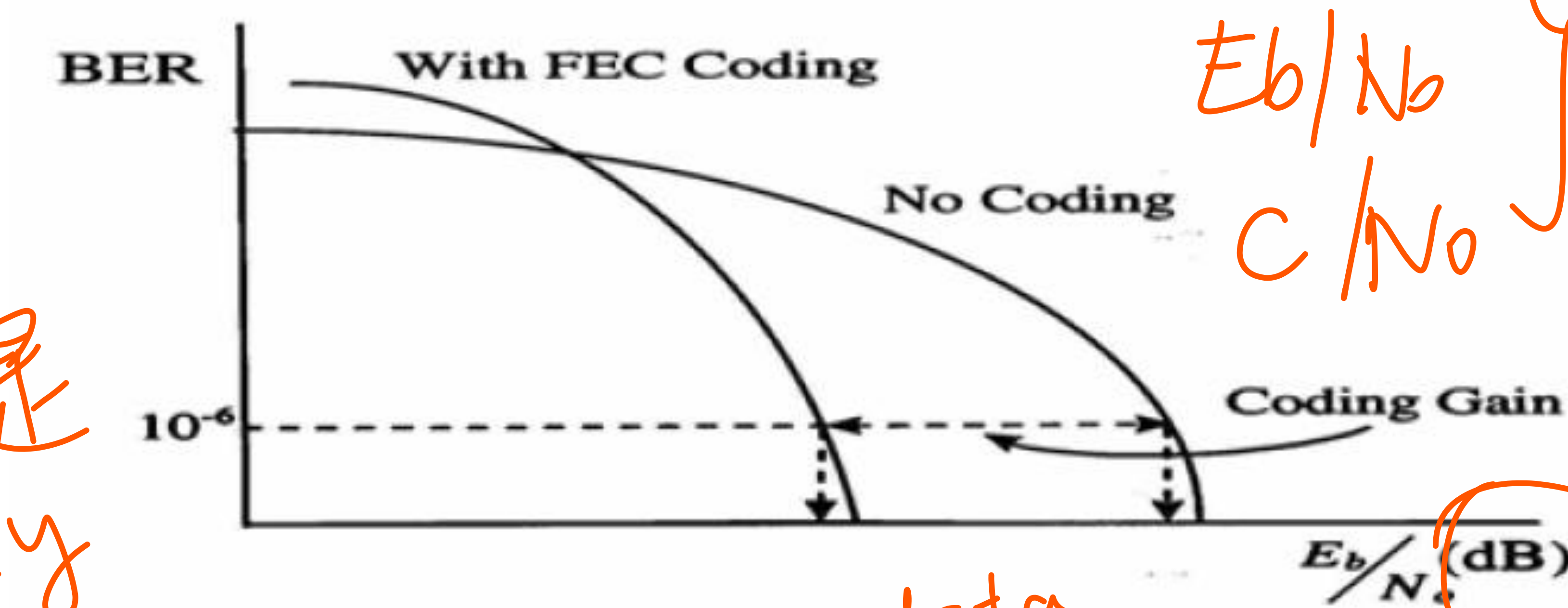
$^{C}/_{N_0}$ $(dB - Hz) = Carrier\ (dBW) - Noise\ Density$ (dBW/Hz)

P11 P12

当Eb/No

Radio Systems

Performance



C/N
Eb/No
C/No

这(不是 capacity

$$^{C}/_{N} = {}^{E_b}/_{N_0} \times {}^{R_b}/_{B_{if}}$$

signal power

data rate (bit rate)

$$B_{if} = \frac{R_b}{\rho.m}(1 + r)$$

ρ = code rate (e.g. $\frac{1}{2}, \frac{3}{4}$ etc) 码率

m = no. bits/symbol (e.g. BPSK =1, QPSK =2, etc) 码元比特数

$$^{C}/_{N} = P_t + G_t - FSL - Otherloses + G_R - Noise$$

$$^{C}/_{N} = EIRP - FSL - Otherloses + G_R - Noise$$

(dB)

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Example 1

$R_b = 5Mb/s$

8.24dB

A new radio access operator is to operate a 5Mb/s service in the local loop. The service requires an Eb/No of 10dB at the domestic receiver and has the following characteristics:

$\Rightarrow E_b/N_o = 10dB$

- Frequency = 3.5GHz
- Base station EIRP=20dBm per carrier
- Radio path losses due to terrain=16dB
- Domestic receiver antenna gain =16dBi
- Modulation = QPSK
- Coding rate = 1/2
- RC filter factor r = 0.5
- Noise spectral density No = -174 dBm/Hz

$m=2$

$\rho=1/2$

$C/N = \frac{E_b}{N_o} \cdot \frac{R_b}{B_{if}} = 10dB + 10\log 5\times10^6 - 10\log_{10} B_{if}$

带dB的不能乘算

用加减

$EIRP + Gain - Loss - FSL - N = C/N$

$\Downarrow$

$D = 4.8067\ km$

i. Calculate the bandwidth required

ii. Calculate the range of the coverage area that could be achieved.

i) $C/N = (E_b/N_o) \times (R_b/B_{if})$

$B_{if} = \frac{R_b}{\rho \cdot m}(1+r) = \frac{5\times10^6}{1/2 \cdot 2}(1+0.5) = 7.5\times10^6\ Hz = 7.5\ MHz$

ii) $N = N_o B_{if} = -174\ dBm/Hz + 10\log_{10}(7.5\times10^6) = -105.2\ dBm$

Review Question

$C/N = \frac{E_b}{N_0} \cdot \frac{R_B}{B_{if}}$

$= \left(\frac{E_b}{N_0}\right)dB + 10\log R_B - 10\log B_{if}$

A cellular mobile radio system has the following characteristics:

Frequency = 5 GHz

Cell range = 10000m 10km

Base station antenna gain = 15 dBi

Multipath loss factor = 17 dB

Handset antenna gain = 2 dBi

Noise spectral density No = -174dBm/Hz

Service required Eb/No = 7dB

Modulation = 16 QAM $\Rightarrow m = 4$

Coding rate = ½ ρ

RC filter factor = 0.5 r

$7 + 10\log 5\times10^6 - 10\log 3.75\times10^6 = 8.25\,dB$

i. Calculate the bandwidth required on the radio channel for the 5 Mb/s service.

ii. For a 5 Mb/s data channel, calculate the power required from the base station.

i. $B_{if} = \frac{R_b}{\rho \cdot m}(1+r) = \frac{5\times10^6}{\frac{1}{2}\cdot 4}(1+0.5) = 3.75\,MHz$

ii. $N = N_0 \cdot B_{if} = -174 + 10\log_{10}(3.75\times10^6) = -108.26\,dBm$

$LSF = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) = 126.42\,dB$

$EIRP - FSL - Loss + Gain - N = \frac{C}{N}$

26.41dBm