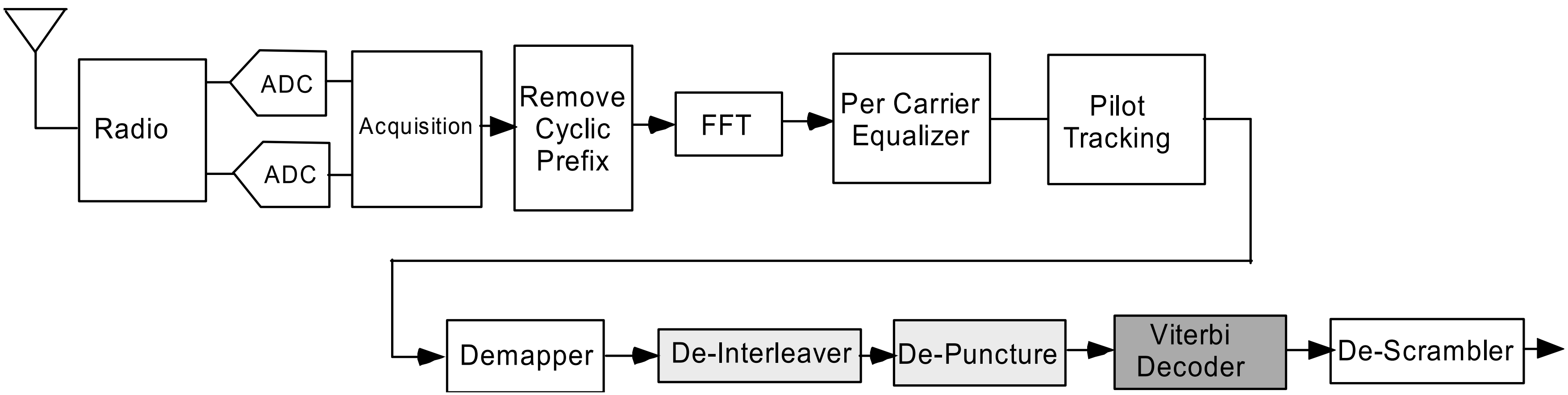
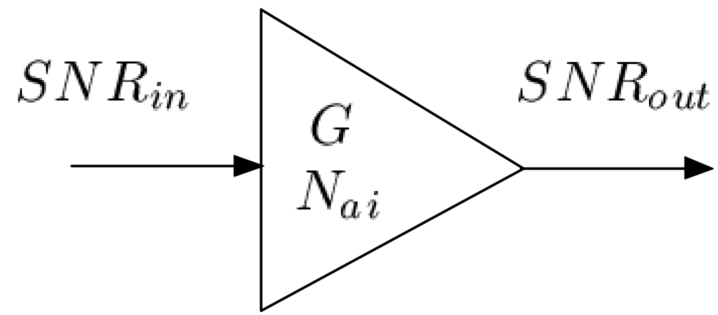
SNR and Noise Figure

Silicon DSP Corporation


Radio
ADC
ADC
Acquisition
Remove Cyclic Prefix
FFT
Per Carrier Equalizer
Pilot Tracking
Demapper
De-Interleaver
De-Puncture
Viterbi Decoder
De-Scrambler

Definition of Noise Figure F

$$F = \frac{SNR_{in}}{SNR_{out}} = \frac{\frac{S_i}{N_i}}{\frac{GS_i}{G(N_i + N_{ai})}}$$



S_i = signal power at the amplifier input port

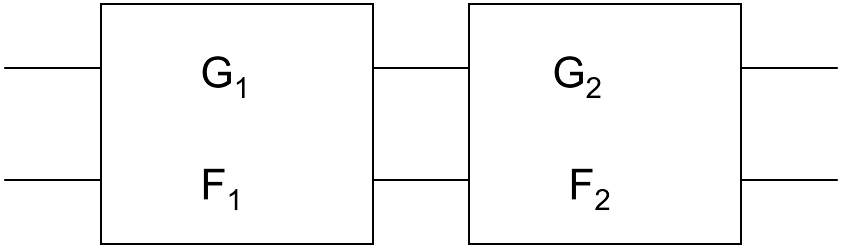
N_i = noise power at the amplifier input port

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

G = amplifier gain

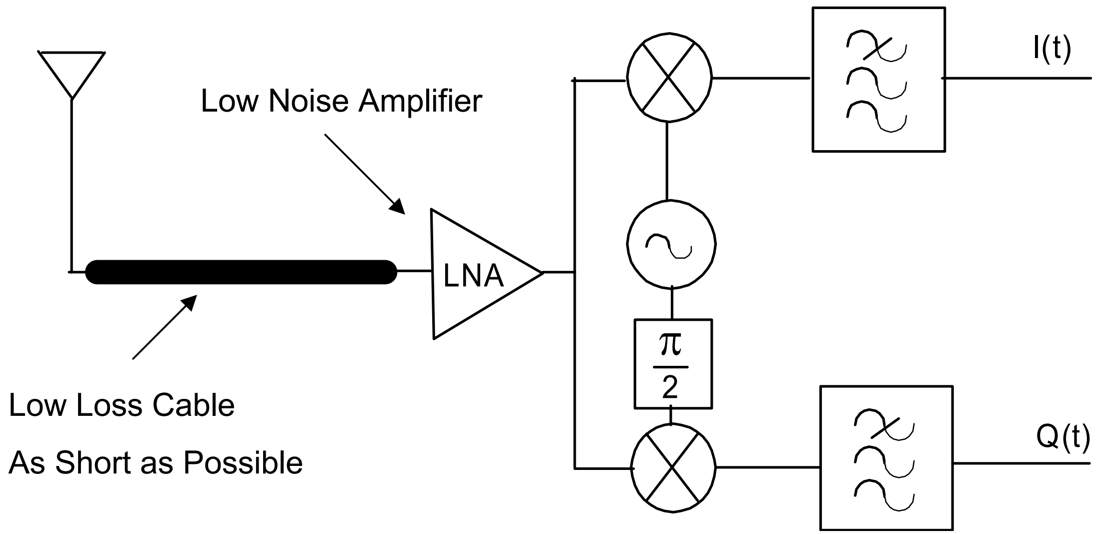
$$F = \frac{N_i + N_{ai}}{N_i} = 1 + \frac{N_{ai}}{N_i}$$

Composite Noise Figure



$$F_{composite} = F_1 + \frac{F_2 - 1}{G_1}$$

$$F_{composite} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + ... + \frac{F_n - 1}{G_1 G_2 ... G_{n-1}}$$



$$F_{composite} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + ... + \frac{F_n - 1}{G_1 G_2 ... G_{n-1}}$$

Effective Noise Temperature

$$N_{ai} = \kappa T_R W$$

$$N_i = \kappa T_i W$$

κ Boltzmann's constant = 1.38 X 10^{-23} J/K

= -228.6 dBJ/K

$$F = 1 + \frac{N_{ai}}{N_i}$$

$$F = 1 + \frac{\kappa T_R W}{\kappa T_i W}$$

$$F = 1 + \frac{T_R}{T_i}$$

$$T_{composite} = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + ... + \frac{T_n}{G_1 G_2 ... G_{n-1}}$$

$$F = 1 + \frac{T_R}{T_i}$$

$$T_R = (F - 1)T_i$$

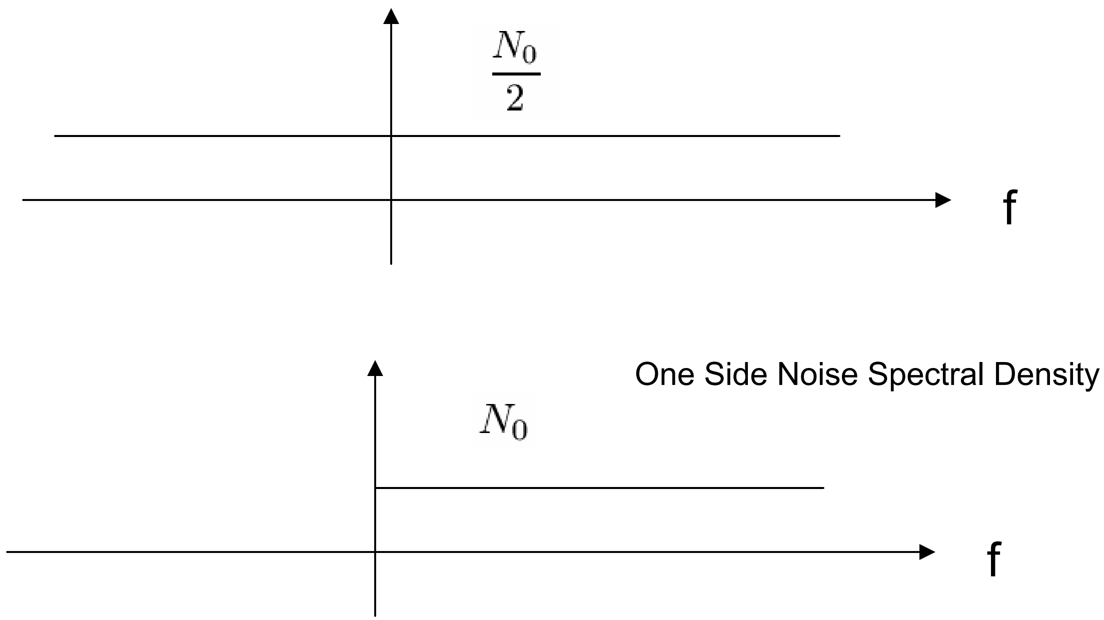
$$T_i = T_0^0 = 290K$$

Reference Temperature

$$\boxed{T_R = (F - 1)290K}$$

$$N_0(\mathrm{at}T_0^0) = \kappa T_0^0 = 1.38 \times 10^{-23} \times 290 = 4.00 \times 10^{-21} \ \mathrm{W/Hz}$$

One Sided Noise Spectral Density



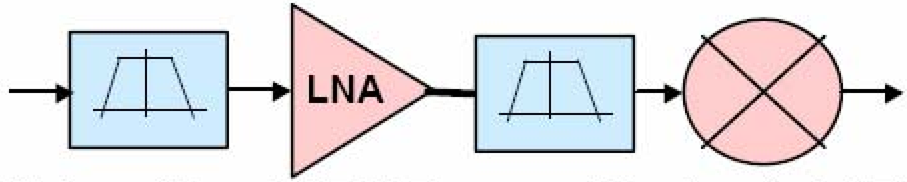
$$T_s = T_A + T_R$$

T_A Antenna Noise Temperature (Sky Temp to Antenna (e.g. 400K)

T_R Total Receiver Noise Temperature. Includes loss from antenna to LNA, LNA , Mixer Loss …

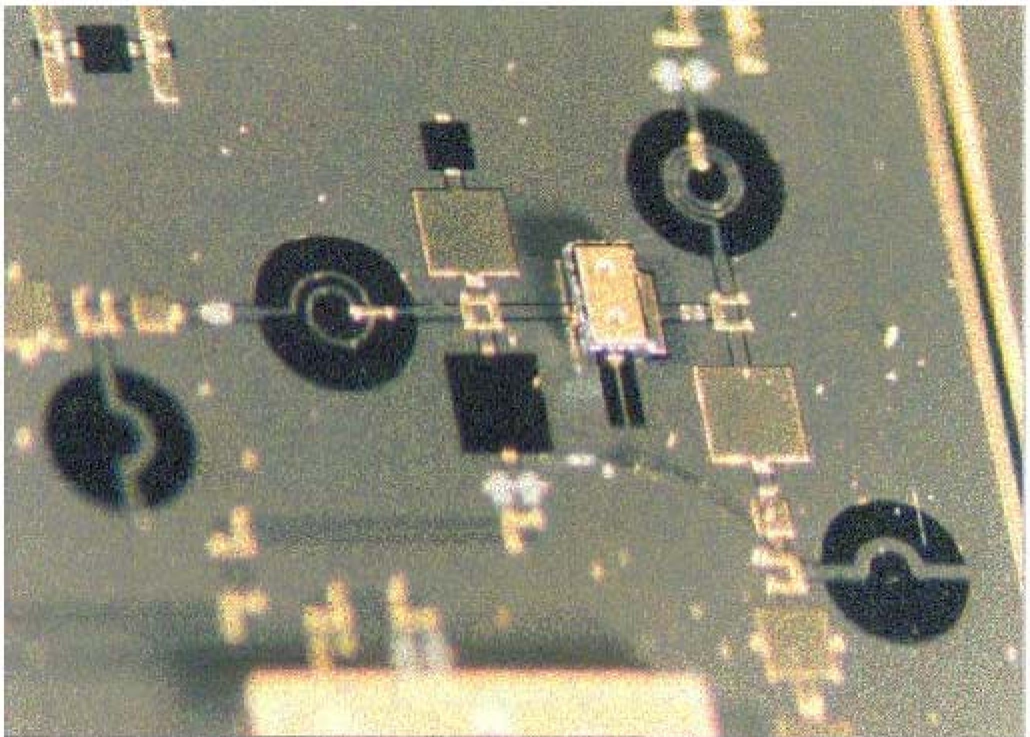
T_s Total System Noise Temperature.

Two 5 GHz MCM Bandpass Filters



LNA with pHEMT transistor (EC2612)

GaAs (pHEMT) mixer (TGC1411)



LNA:
NF: 2.4 dB
gain: 12.9 dB

BPF + LNA + BPF:
NF: 5.4 dB
gain: 6.8 dB

with Mixer:
NF: 7.5 dB
gain: 22.4 dB

Application to 802.11a

The packet error rate (PER) shall be less than 10% at a PSDU length of 1000 bytes for rate-dependent input levels shall be the numbers listed in Table 91 or less. The minimum input levels are measured at the antenna connector (NF of 10 dB and 5 dB implementation margins are assumed).

Table 91—Receiver performance requirements

Data rate (Mbits/s)	Minimum sensitivity (dBm)	Adjacent channel rejection (dB)	Alternate adjacent channel rejection (dB)
6	–82	16	32
9	–81	15	31
12	–79	13	29
18	–77	11	27
24	–74	8	24
36	–70	4	20
48	–66	0	16
54	–65	–1	15

NF= 10 dB

Input Power at 54 Mps for 10% packet error rate (1000 bytes) -65 dBm (50 Ohm)

W= 20 MHz

$$T_R = (F - 1)290K$$

$$T_R = (10^{NF/10} - 1)290K$$

$$T_R = 2610K$$

$$T_A = 400K$$

$$T_S = 3010K$$

Boltzmann's constant

$$N_0 = 10\log_{10} 3010 - 228.6$$

dBW/Hz

$$NoisePower = 10\log_{10} 3010 - 228.6 + 10\log_{10} 20^6$$

-120.8 dBW

-90.8 dBm

Required Sensitivity -65 dBm at 54 Mbps

$$SNR = S_{dBm} - N_{dBm} = 25.8\ dB$$

Account for Bandwidth of 16.5 MHz
takes 0.835 dB off

$$SNR = 24.96 \text{ dB}$$

E_b/N_0

$$E_b = ST_b = \frac{S}{R_b}$$

$$N = N_0 W$$

$$\frac{E_b}{N_0} = \frac{ST_b}{\frac{N}{W}} = \frac{\frac{S}{R_b}}{\frac{N}{W}}$$

$$\frac{E_b}{N_0} = \frac{S}{N}\left(\frac{W}{R}\right)$$

$$\frac{W}{R} = \frac{16.5}{54} \doteq -5.15 \text{ dB}$$

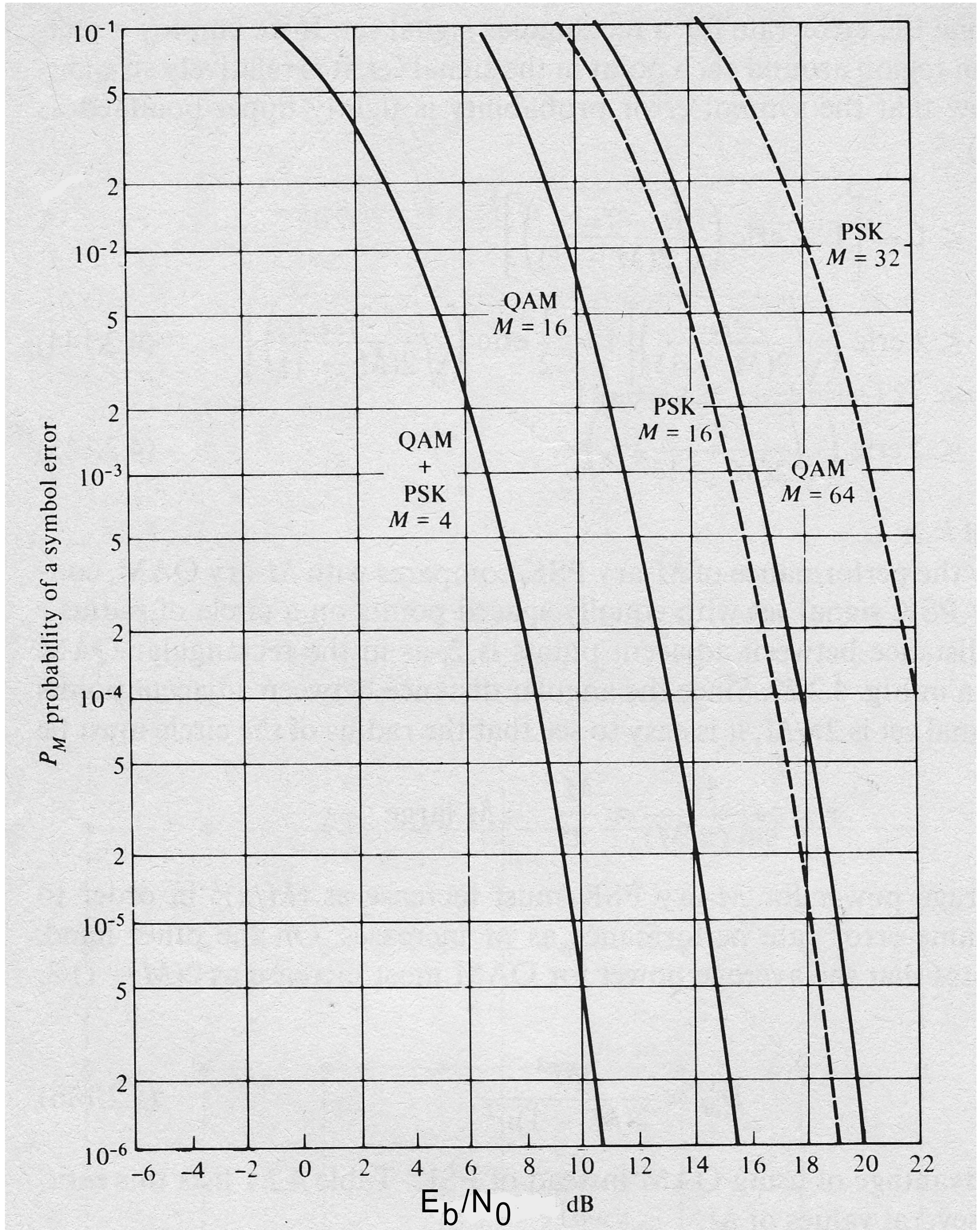
$$\frac{E_b}{N_0} = 24.96 - 5.15 = 19.81 \text{ dB}$$

Table 116bk—Receiver SNR and E_b/N_0 assumptions

Modulation	E_b/N_0 (dB)	Coding rate	Receiver SNR (dB)
QPSK	10.5	1/2	9.4
		3/4	11.2
16-QAM	14.5	1/2	16.4
		3/4	18.2
64-QAM	19.0	2/3	22.7
		3/4	24.4

IEEE 802.16a OFDM

BER < 10^{-6}



Proakis, "Digital Communications," McGraw-Hill, 1983