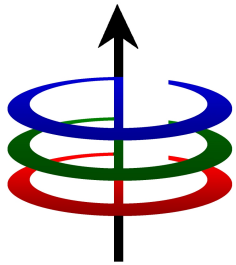
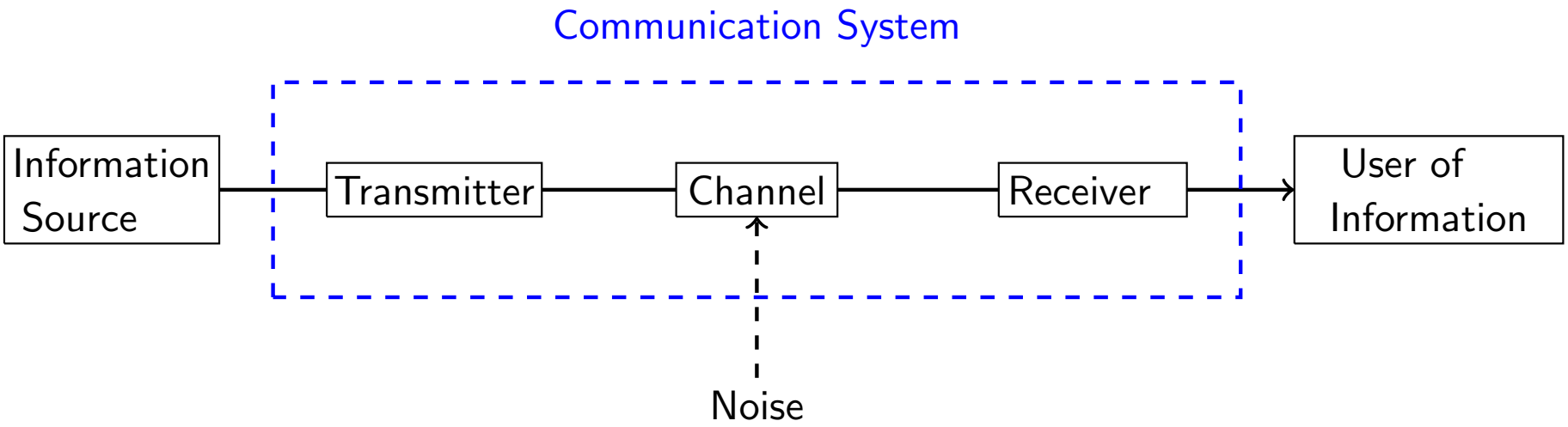
ECE 113: Communication Electronics

Lecture 1: RF Front-End Design

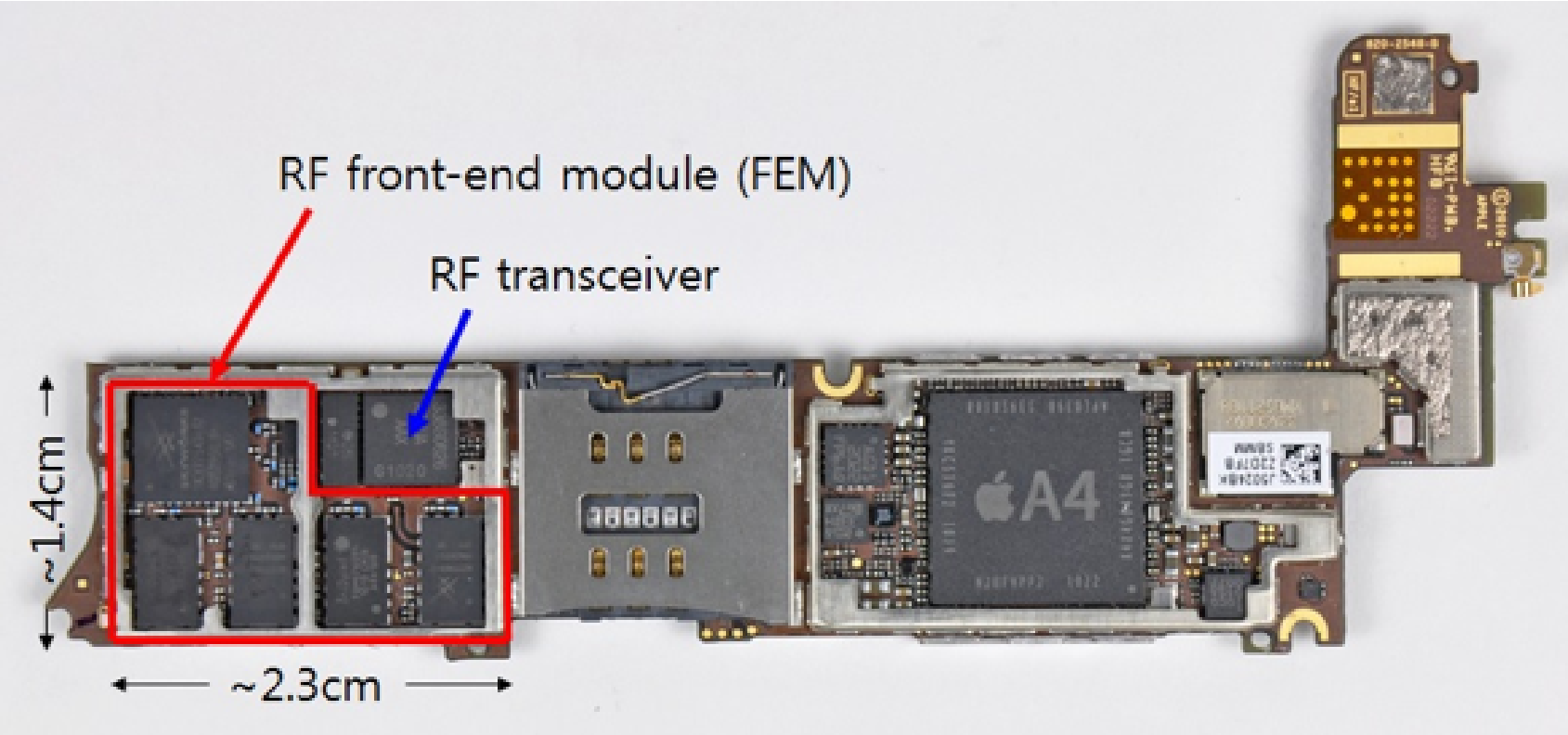
January 17, 2019



Recall


Communication System
Information Source
Transmitter
Channel
Receiver
User of Information
Noise

Mobile Phones



https://www.researchgate.net/profile/Chirn_Boon/publication/266660407/figure/fig1/AS:392163268546594@1470510417849/Figure-1-RF-front-end-modules-FEMs-on-the-Apple-iPhone-4.jpg

AM Radio Architecture

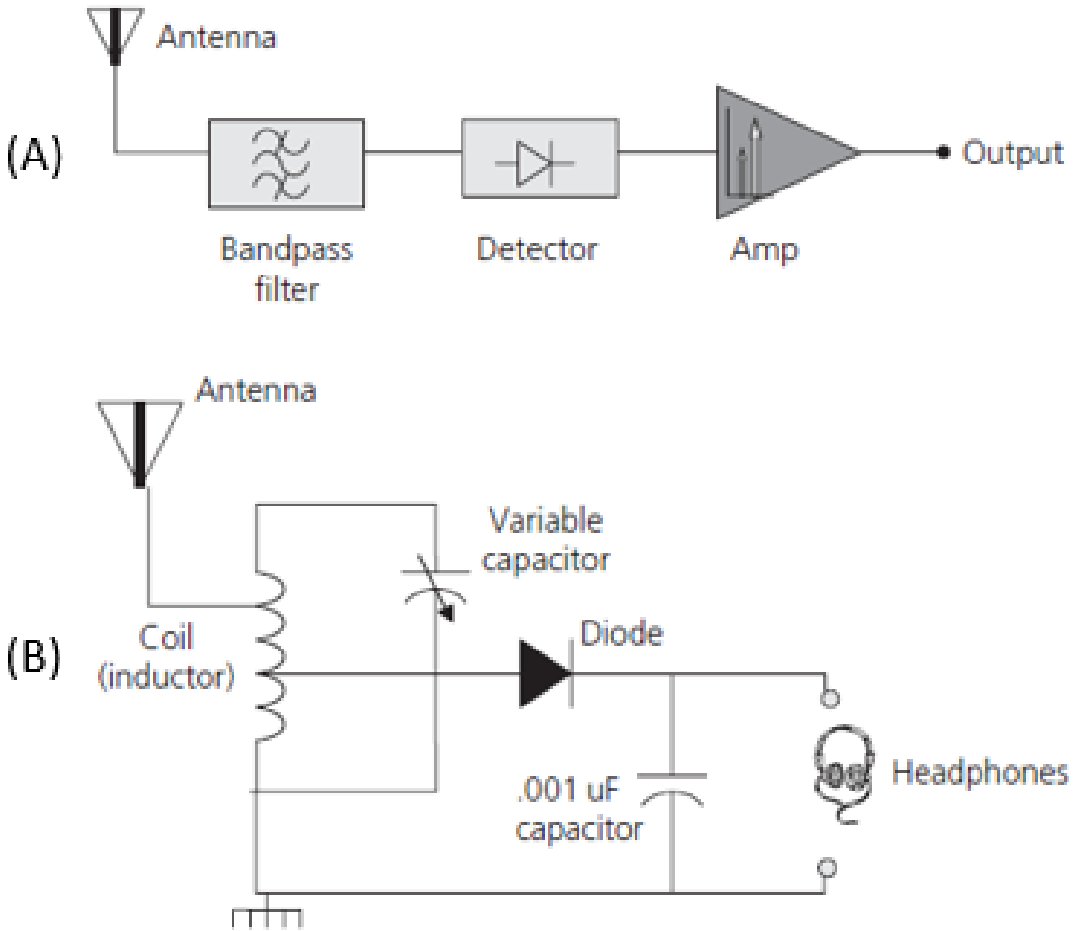


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Figure 1: (A) Block Diagram (B) Circuit Schematic

Other Receiver Architectures

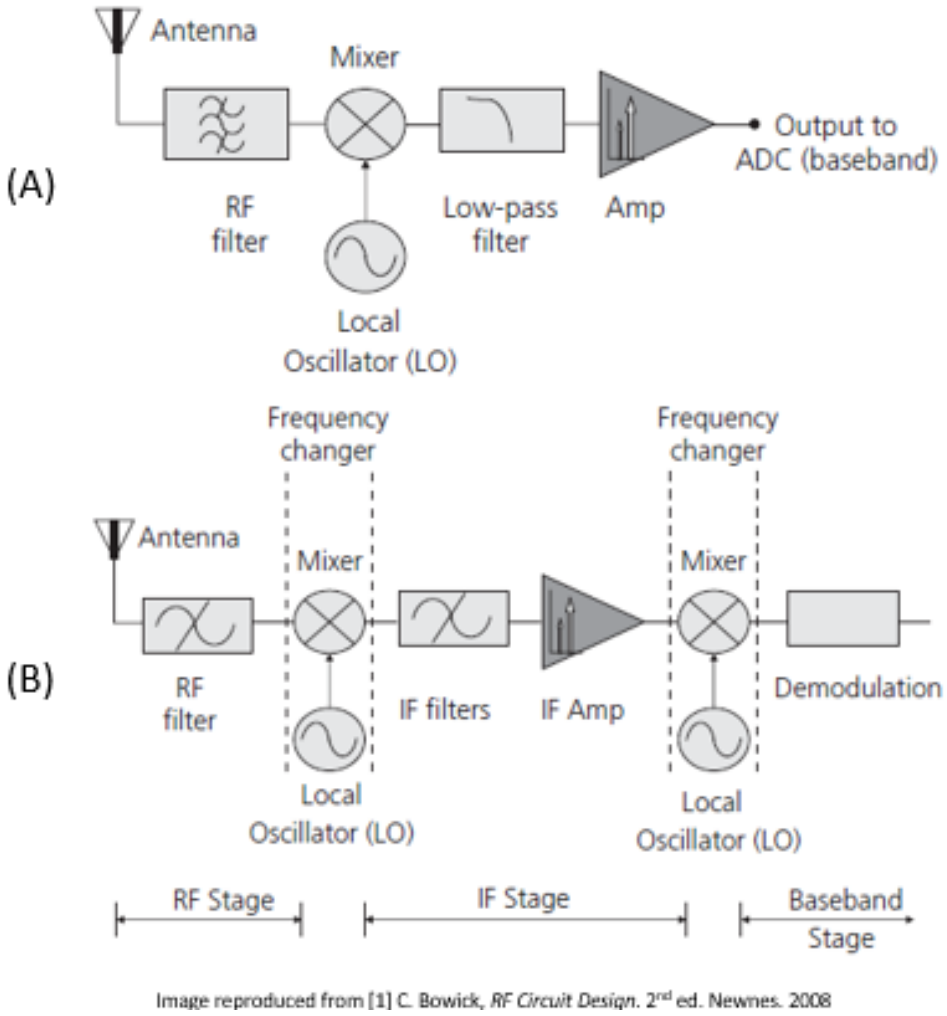

Figure 2: (A) Direct Conversion Receiver (B) Superheterodyne Receiver

"Key" Performance Parameters

- Signal to Noise Ratio (SNR)
- Selectivity
- Sensitivity

SNR

- Ratio of desired signal power to noise power
- Measured at the input (SNR_{in}) and output (SNR_{out})
- Dependent on several system parameters: modulation scheme, IF filters' group delay distortion, detector linearity and distortion, ...
- Unit: decibels (dB)
- other variations
  - Signal plus noise to noise ratio $(\frac{S+N}{N})$
  - Signal plus noise plus distortion to noise ratio (SINAD)

Selectivity

- capability to screen out unwanted signal and to pass (select) the desired signal
- Can be achieved at a different stages in a superheterodyne receiver by using selective components at the RF, IF, and baseband stages
- Should be as high as possible close to the antenna to remove large interfering signals before they enter the active devices

Sensitivity

- need to detect very weak signals in the presence of noise
- translates directly into communication distance and reliability
- can be improved by:
  - increasing transmitter power
  - increasing antenna aperture
  - improving noise performance of receiver system

Sensitivity

Noise Floor

- determines its sensitivity to low level signals and its capability of detecting and demodulating those signals
- amount of noise produced by the receiver's internal circuitry which directly affects the sensitivity of the receiver

Minimum Detectable Signal (MDS)

- signal power at the antenna input terminal of the receiver required to produce some standard SNR value

$$MDS_{in}(dBm) = -174dBm + 10log(B) + NF_{sys}$$

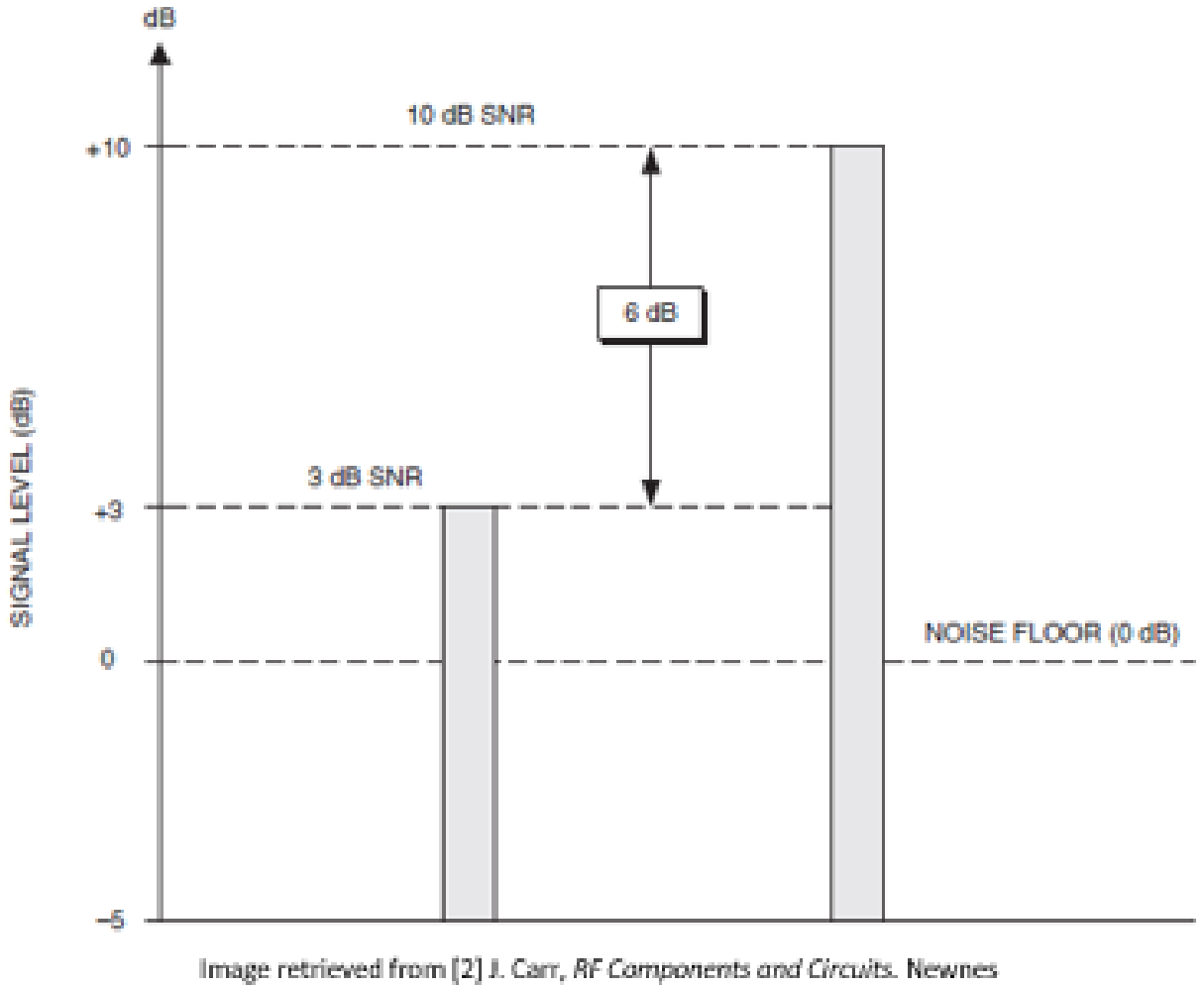

Figure 3: SNR situation for minimum and good reception

RF Front-End

- "Everything" between the antenna and baseband signal
  - filters
  - low noise amplifiers
  - direct conversion mixers
- Can be designed to maximize resources, weigh trade-offs and achieve the best communication performance
  - sets the stage for possible bit-error-rate (BER) at final bit detection

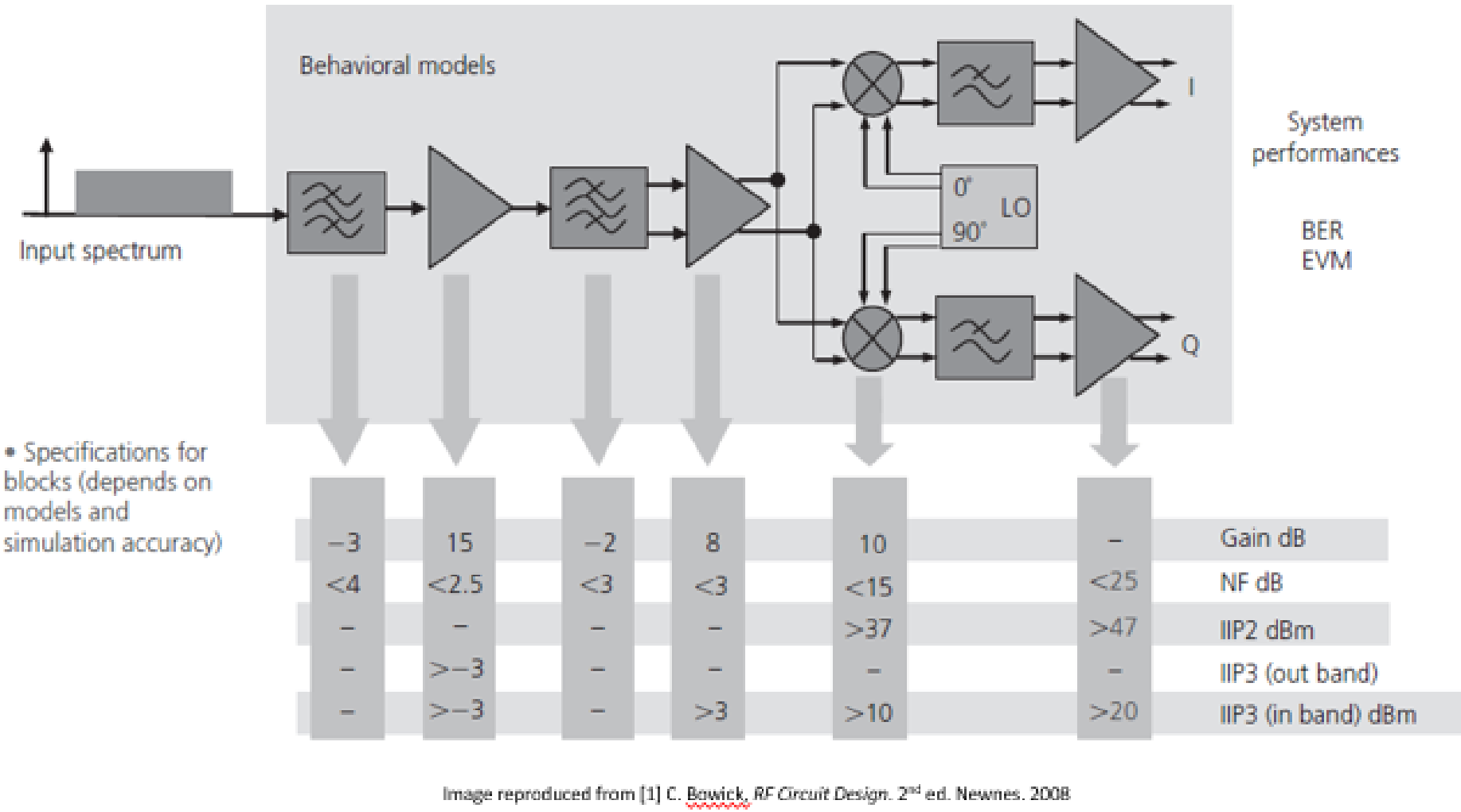

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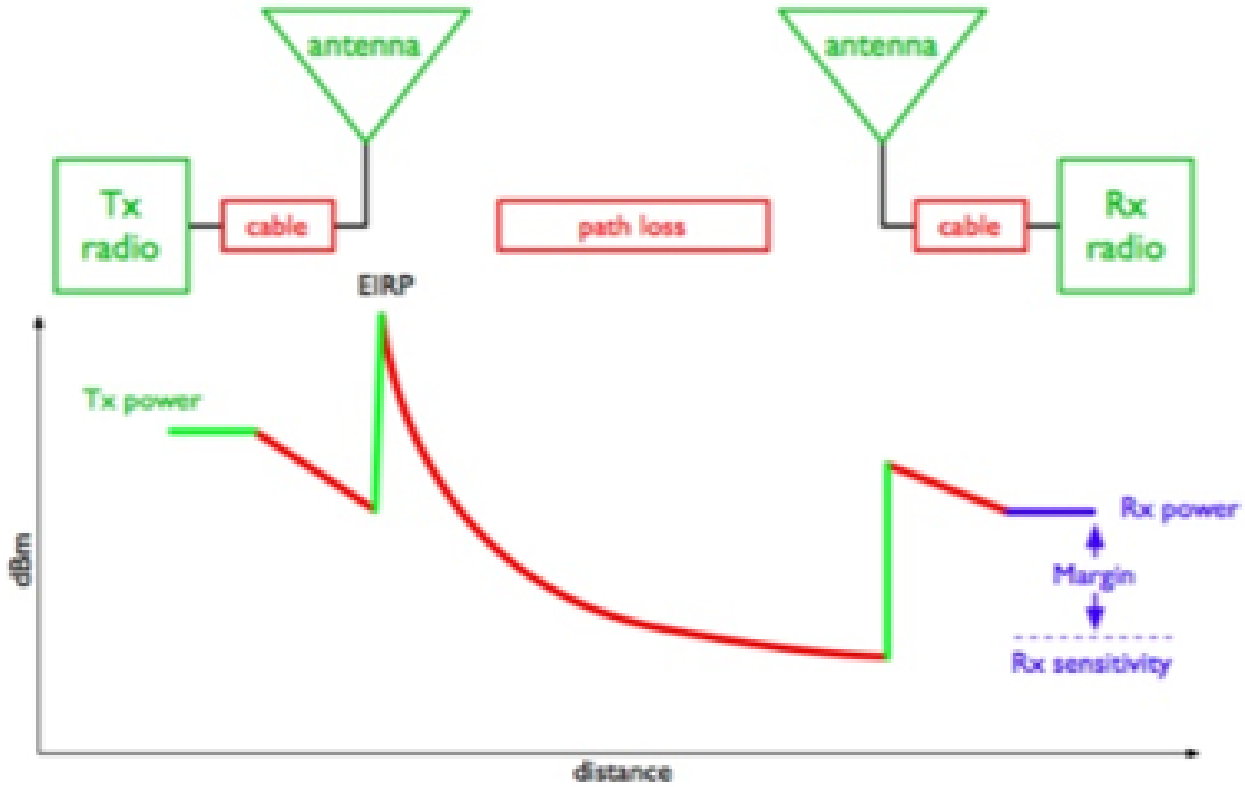
Figure 4: Typical CDMA System Specification

Power in a wireless system



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Link Budget

Path Loss

- Accounts for the free-space reduction in signal strength with distance between the transmitter (Tx) and receiver (Rx)

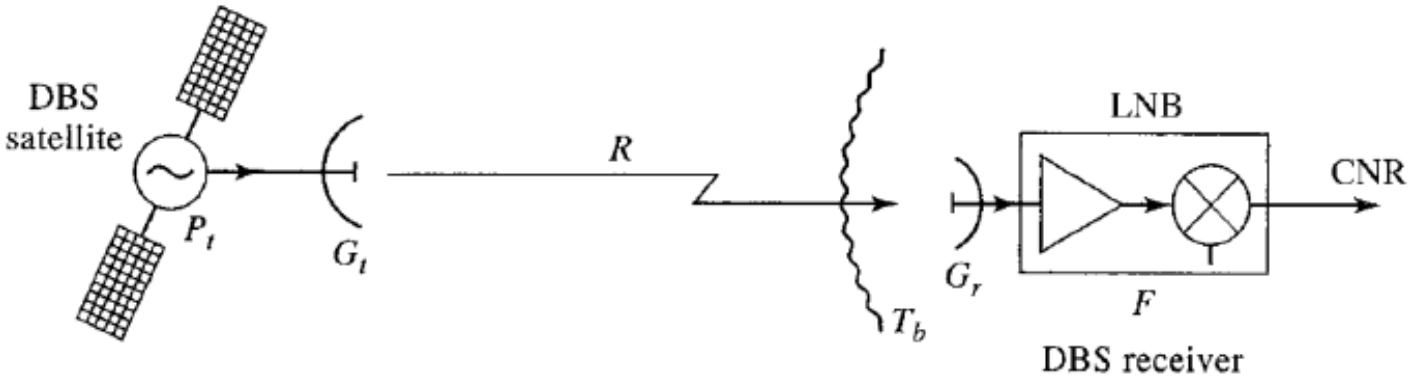
$$L_o(dB) = 20log(\frac{4\pi R}{\lambda})$$

NOTE: frequency-dependence

Link Margin

- In practical communication systems, it is usually desired to have the received power level greater than the threshold level required for the minimum acceptable quality of service usually expressed as the minimum carrier to noise ratio (CNR) or minimum SNR)
- design allowance
- level of robustness to the system to account for other variables that may affect its performance
- sometimes called fade margin
- typically range from 3 dB to 10 dB

Example: DBS Television System



- A DBS satellite is transmitting at an output power of 100 W, IF-bandwidth of 20 MHz and frequency of 17.5 GHz. The distance of the satellite from the Earth receiving station is 39,000 km. The antenna gain of the satellite is 35 dB and the 18-inch receiving dish antenna has a gain of 35 dB. The noise power at the output of the Low-Noise Block (LNB) with gain $= 1$ is 19.36×10^{-15} W. The minimum required CNR is 15 dB.

END