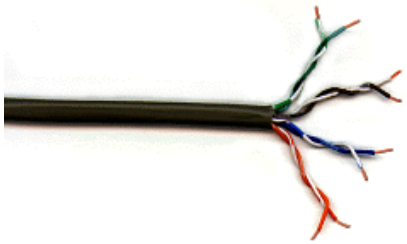
Broadband Mobile Communications

Lecture 1

What is a communication system?

- A (1-to-1) system used to send a message from one end to the other end, through a medium



Twisted pair
(telephone cable)

Optical fiber
(submarine cable)

Coaxial cable
(cable TV)

Magnetic disc
(hard-disc drive)

Water
(underwater
acoustics)

Communication system model

- A simple model consists of transmitter (Tx), receiver (Rx), and imperfect channel (Ch)

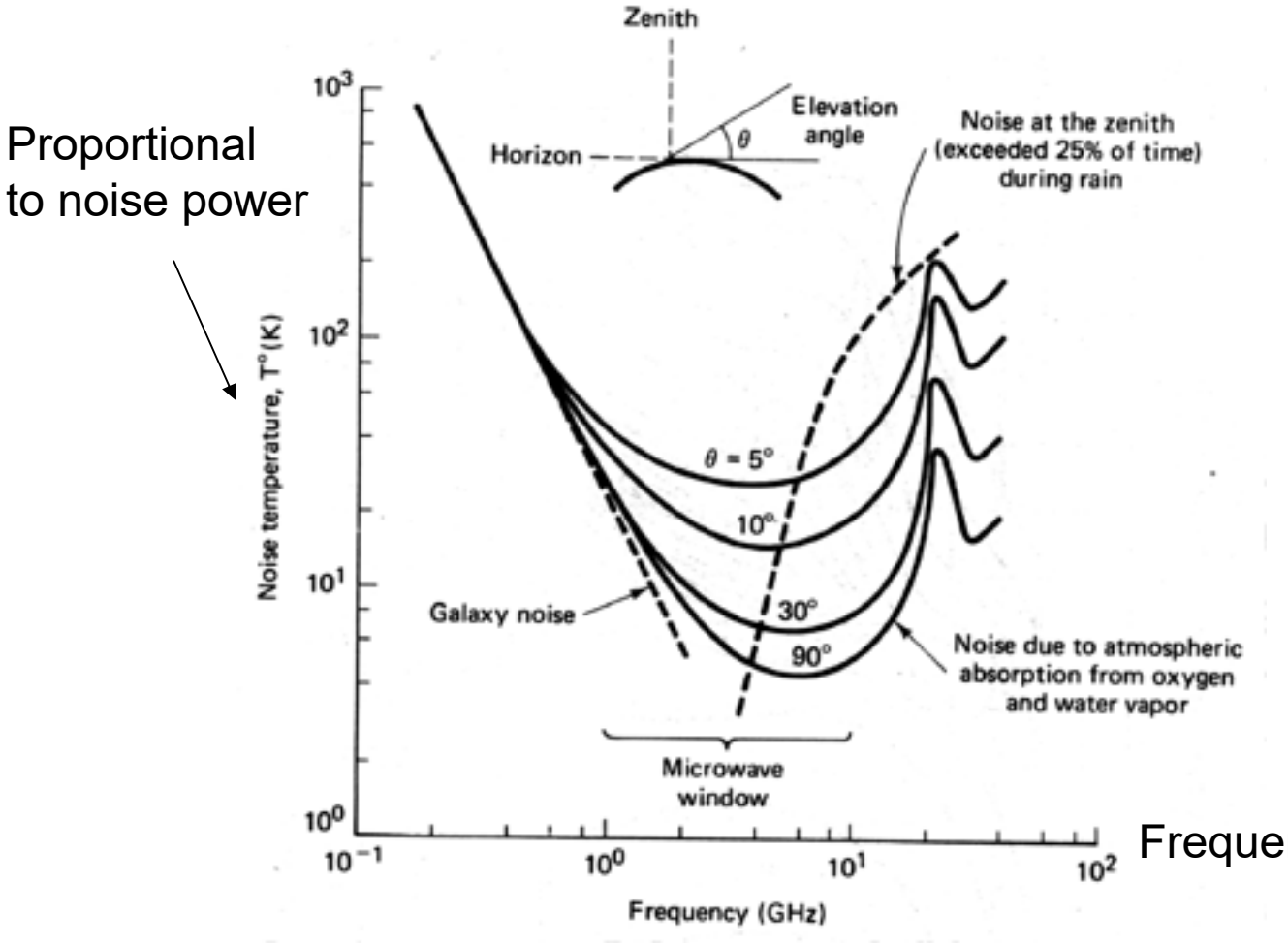
- A simple communication system design

Various channel noise

- Device (system) noise
  - Shot noise ← transistor
  - Thermal noise ← resistor
  - …
- External (ambient) noise
  - Atmospheric noise
  - Galactic noise
  - Oxygen (and water vapor) absorption
  - …
- A lot more (e.g. interference, fading, shadowing, …)
  - Will discuss later

Antenna noise

- Particularly important for wireless commun.

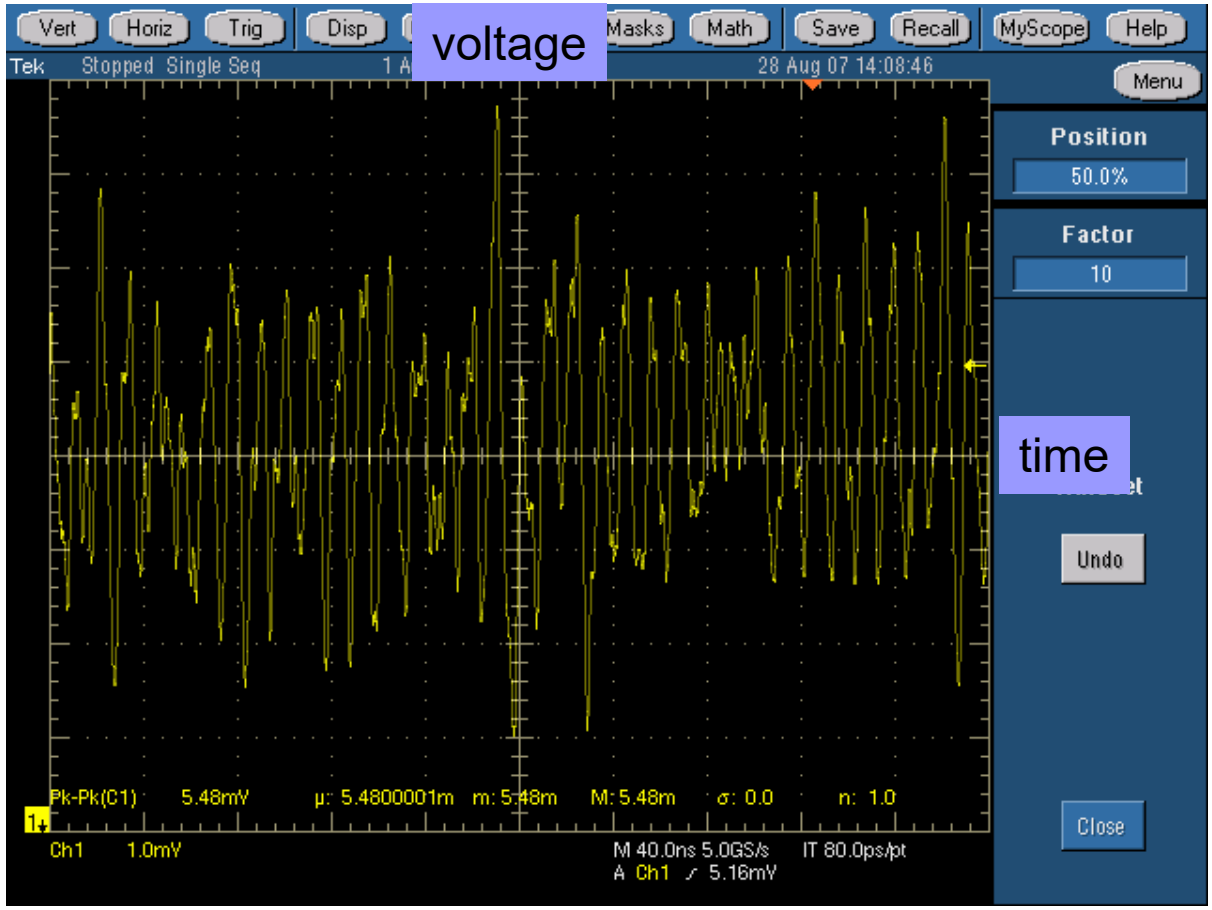


Thermal noise

- Caused by random motion of electrons in resistors
  - Each electron has its own thermal energy
  - Not all electrons move at equal speed, in the same direction, specified by the current
- The (average) thermal noise power P is given by
  - $P = k\,T\,B$
    - k: Boltzmann constant
    - T: temperature in Kelvin degree
    - B: bandwidth → think of power spectrum density

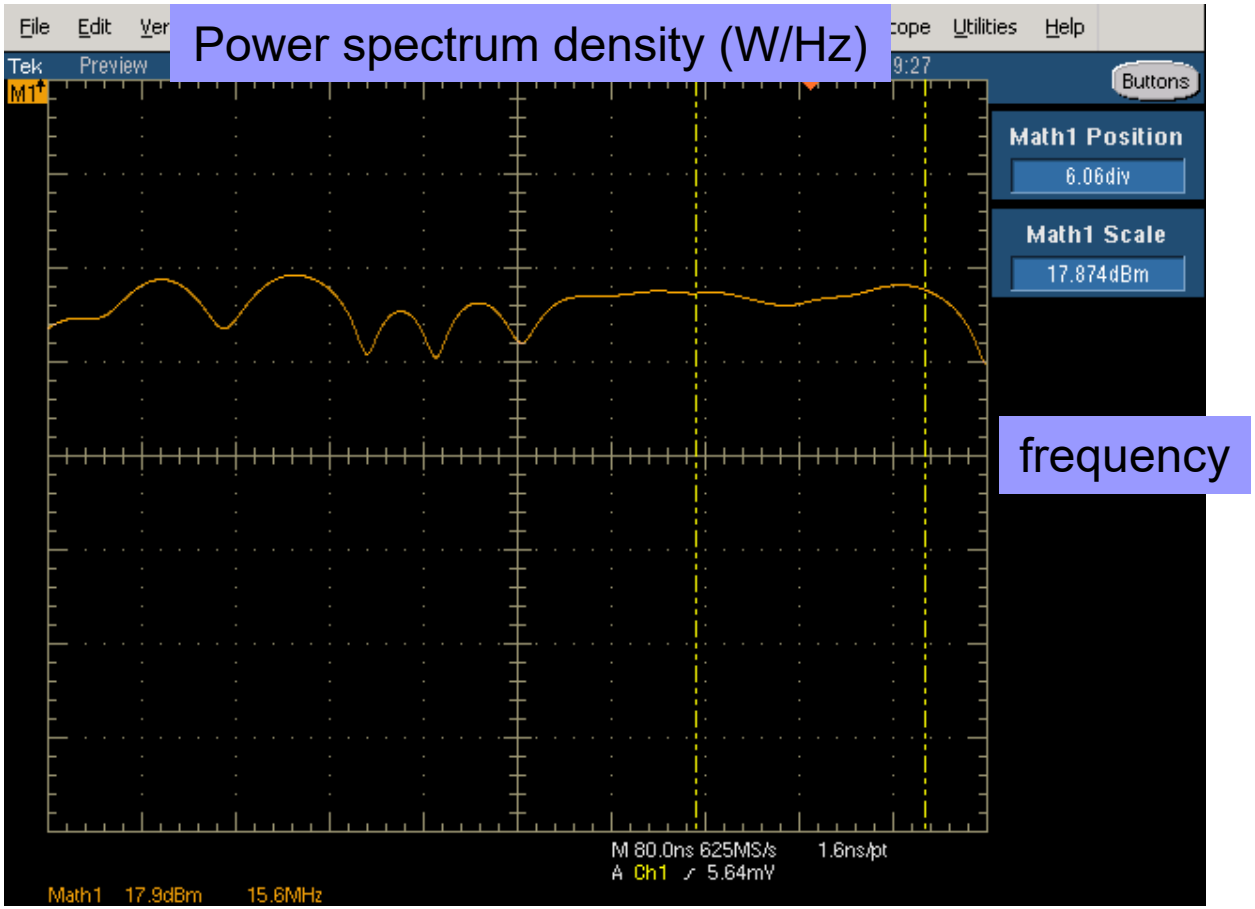
Thermal noise is Additive White Gaussian noise (AWGN)

- Waveform of thermal noise $n(t) = y(t) - x(t)$



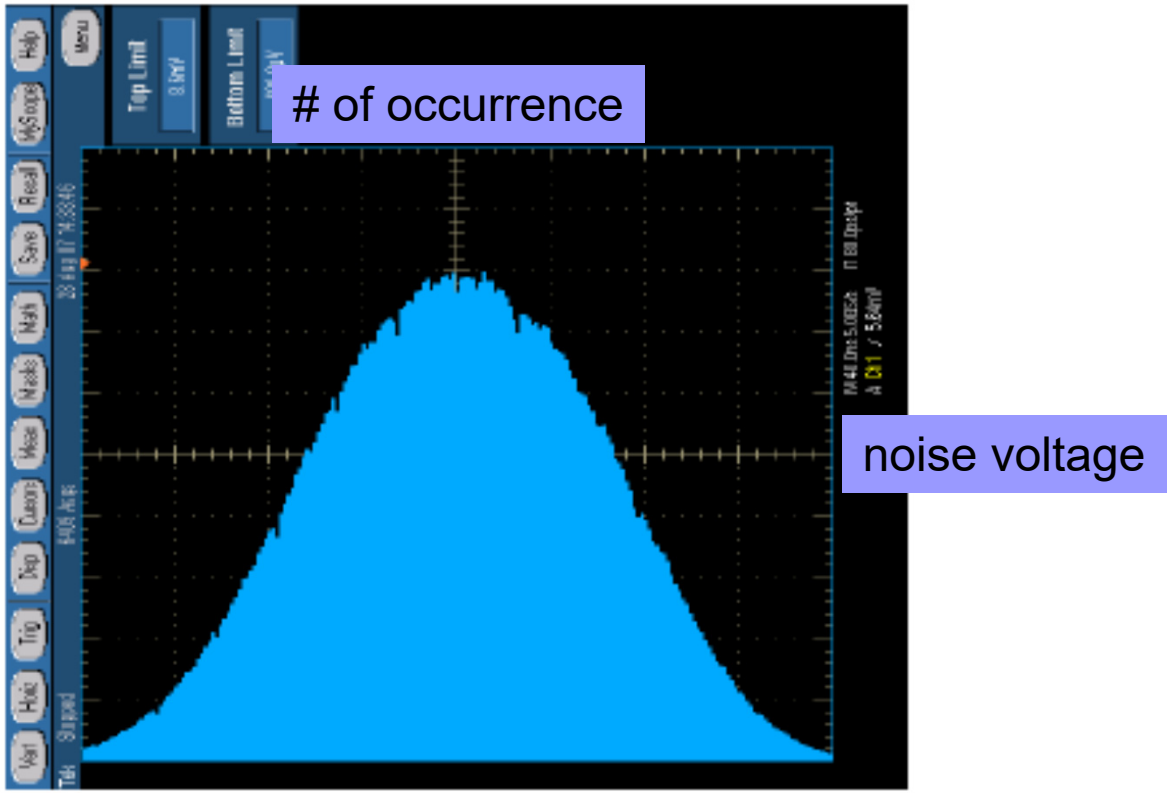
Thermal noise is Additive White Gaussian noise (AWGN)

- Power spectrum density of thermal noise $N(f)$



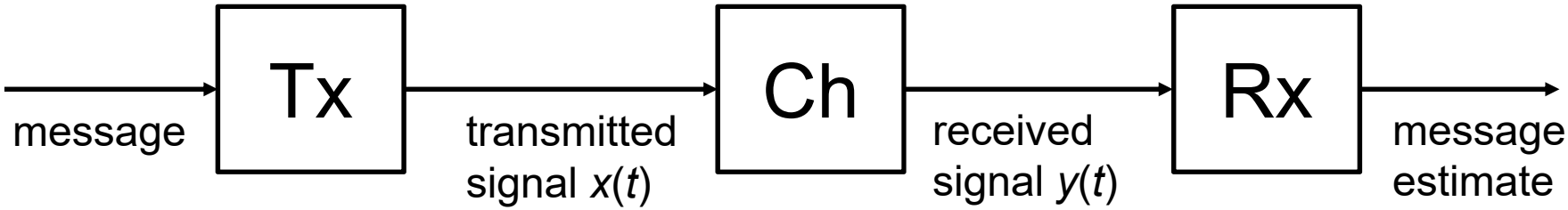
Thermal noise is Additive White Gaussian noise (AWGN)

- Histogram of thermal noise samples



Communication system models

- A simple model consists of transmitter (Tx), receiver (Rx), and imperfect channel (Ch)



- An example of communication system

Question

- What is the most scarce resource in wireless communication systems?
  -
    - Regulated by governments
      - Ex. 國家通訊傳播委員會NCC
      - Ex. Federal Communications Commission (FCC)
- Why is transmit power limited?
  - Si-based circuits can only handle a few volts of signal
  - Heat dissipation
  - Health or safety reasons
  - Finite-capacity power source (ex. battery)

Question

- What are important factors that can increase data rate?

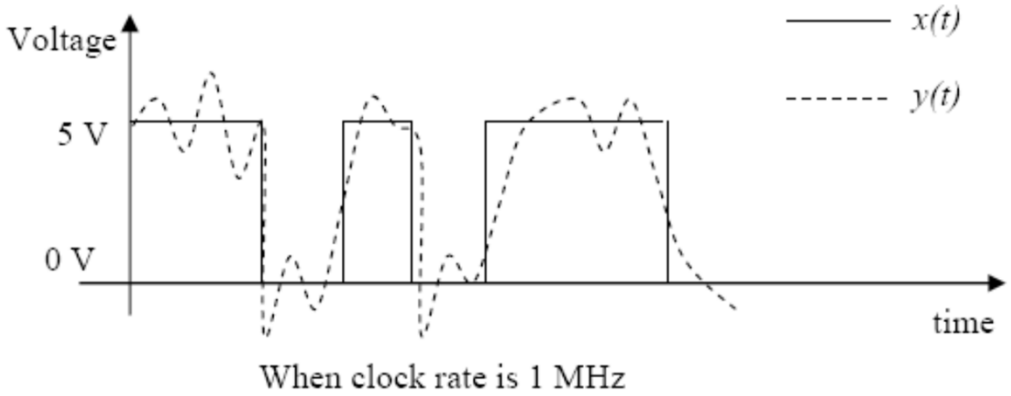
● 中山高速公路后里段

- Why can’t the channel capacity be infinite?

What if the data rate is increased?

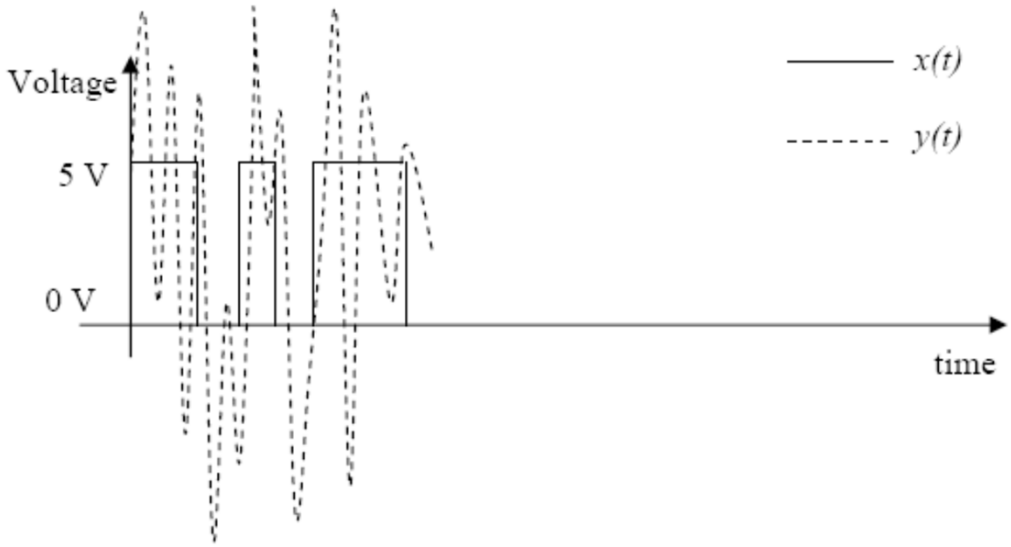
- Consider the simple commu. system. Increasing the bit time from 1 μs to 0.01 μs means
  - Data rate: →
  - A 100X increase in required bandwidth
    - Recall the Fourier transform
  - A 100X increase in noise power, since thermal noise has a constant power spectrum density
    - More difficult to recover the transmitted signal

What if the data rate is increased?



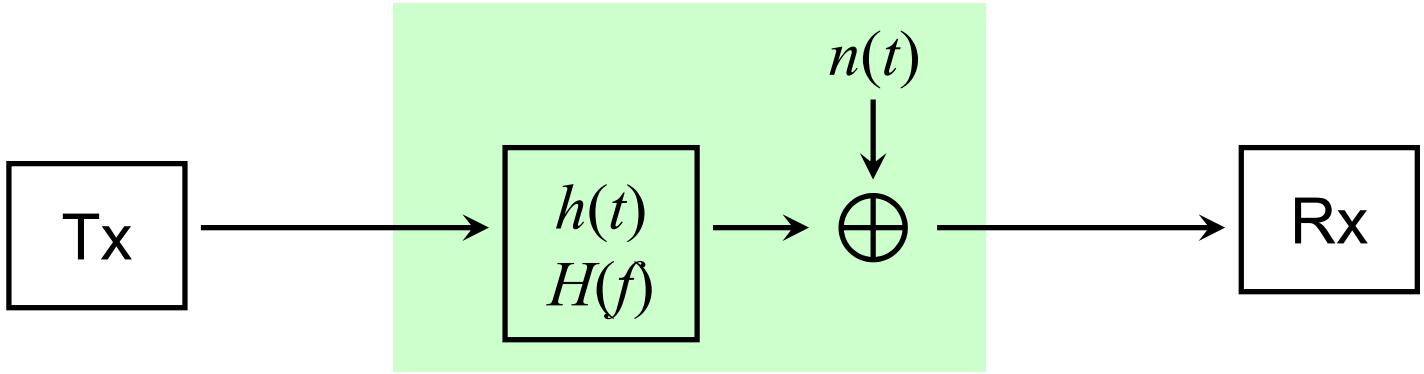
When clock rate is 1 MHz

- 1101011



When clock rate is 100 MHz

Question



- Why can't we simply subtract the noise?
  - (If so, channel capacity becomes infinite, what a wonderful life!)

Question

- If we have a technique that achieves the (1-to-1) Shannon capacity bound, can all users transmit packets at such a rate?

dB notation

- Power P in dB
  =
  - $P_{(\text{dBW})}$ =
  - $P_{(\text{dBm})}$ =

- Amplitude A in dB
  =
  =

Power	Power in dB
2	3 dB
3	4.7 dB
10	dB
100	dB
A * B	$A_{dB} + B_{dB}$
5	dB
0.5	dB
0.1	dB
0.01	dB
200	dB