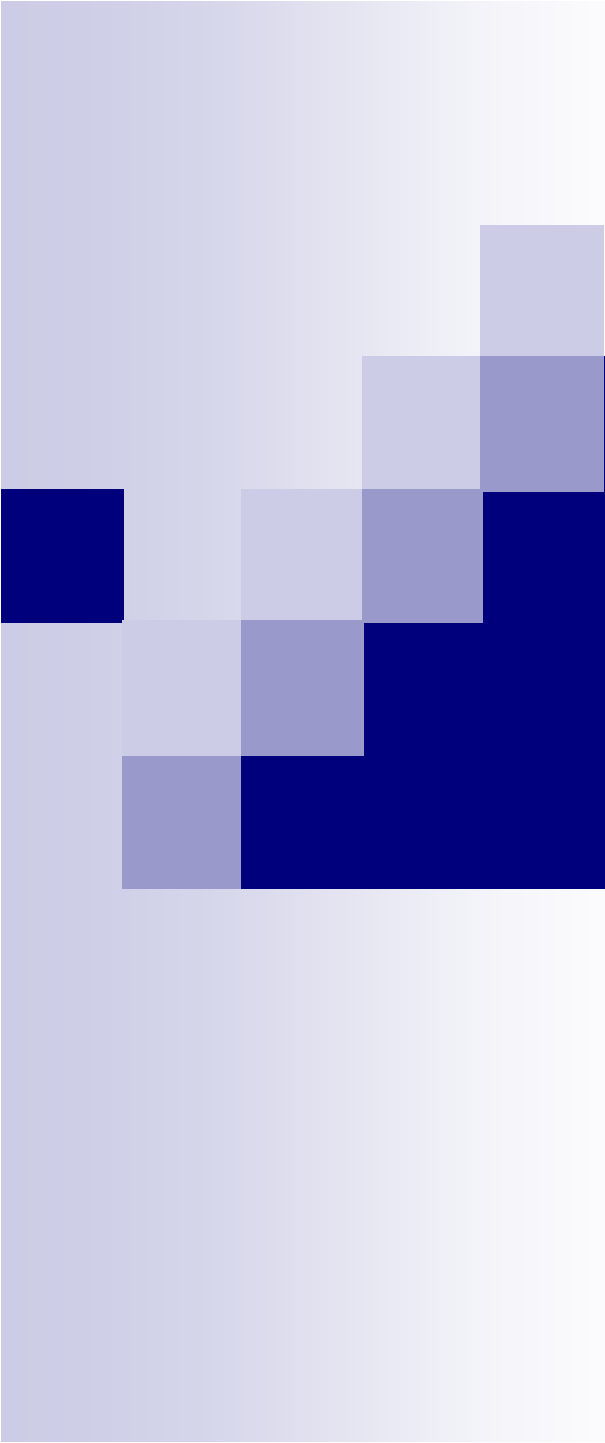


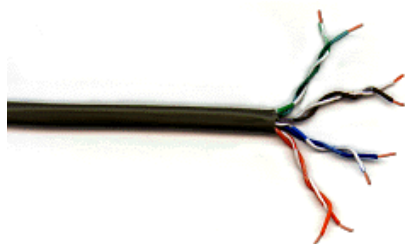


Broadband Mobile Communications

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)



Coaxial cable
(cable TV)



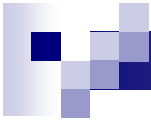
Optical fiber
(submarine cable)



Magnetic disc
(hard-disc drive)

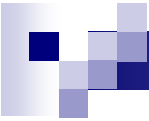


Water
(underwater
acoustics)



Communication system model

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

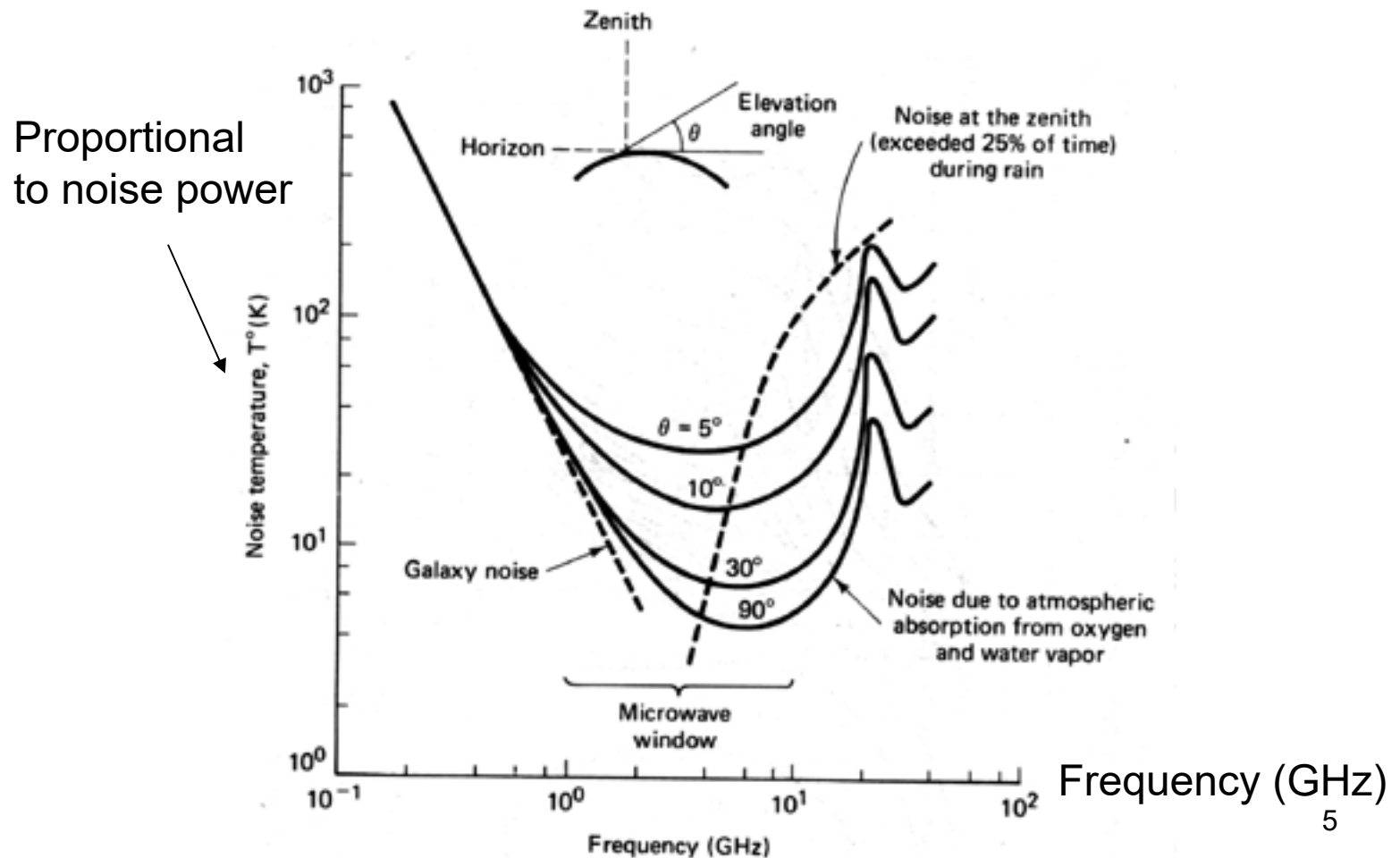


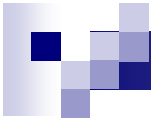
Various channel noise

- 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.



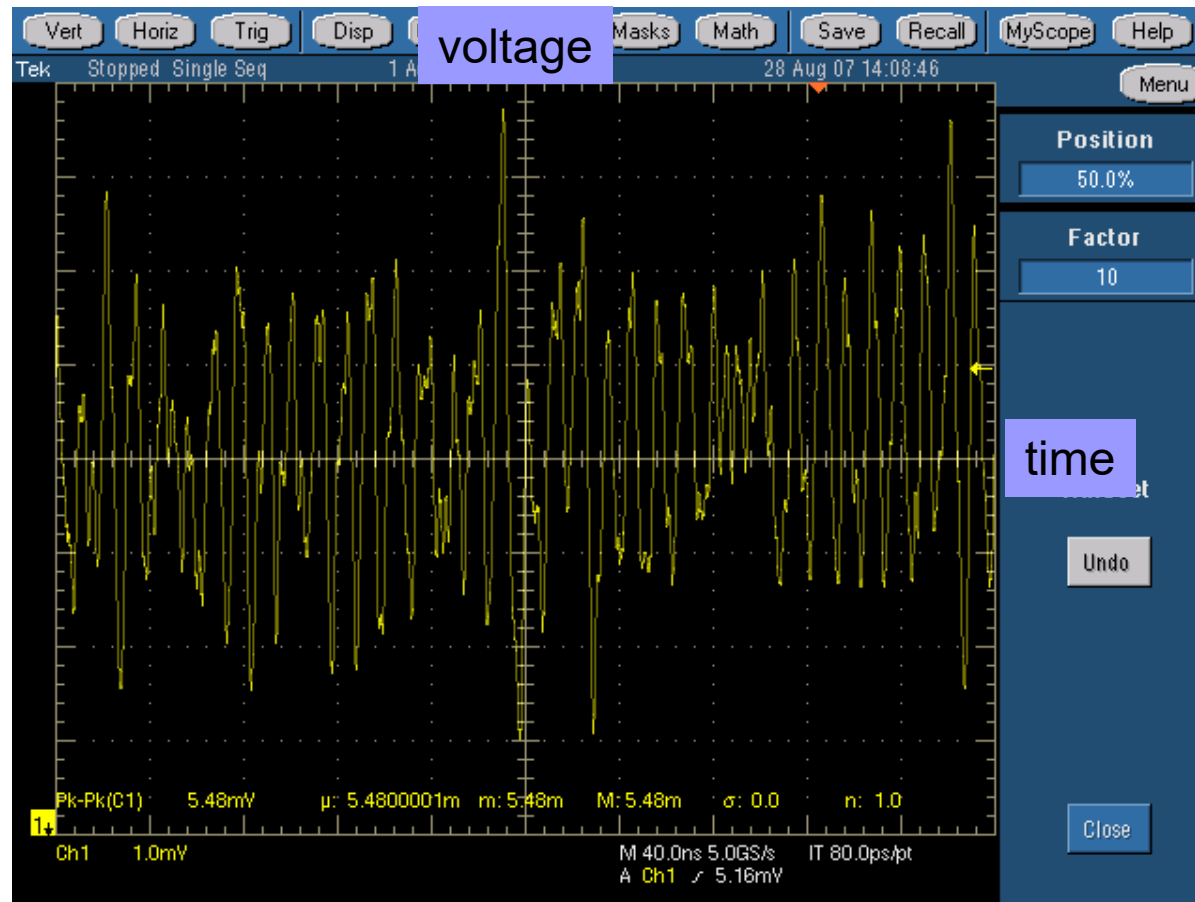


Thermal noise

- 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

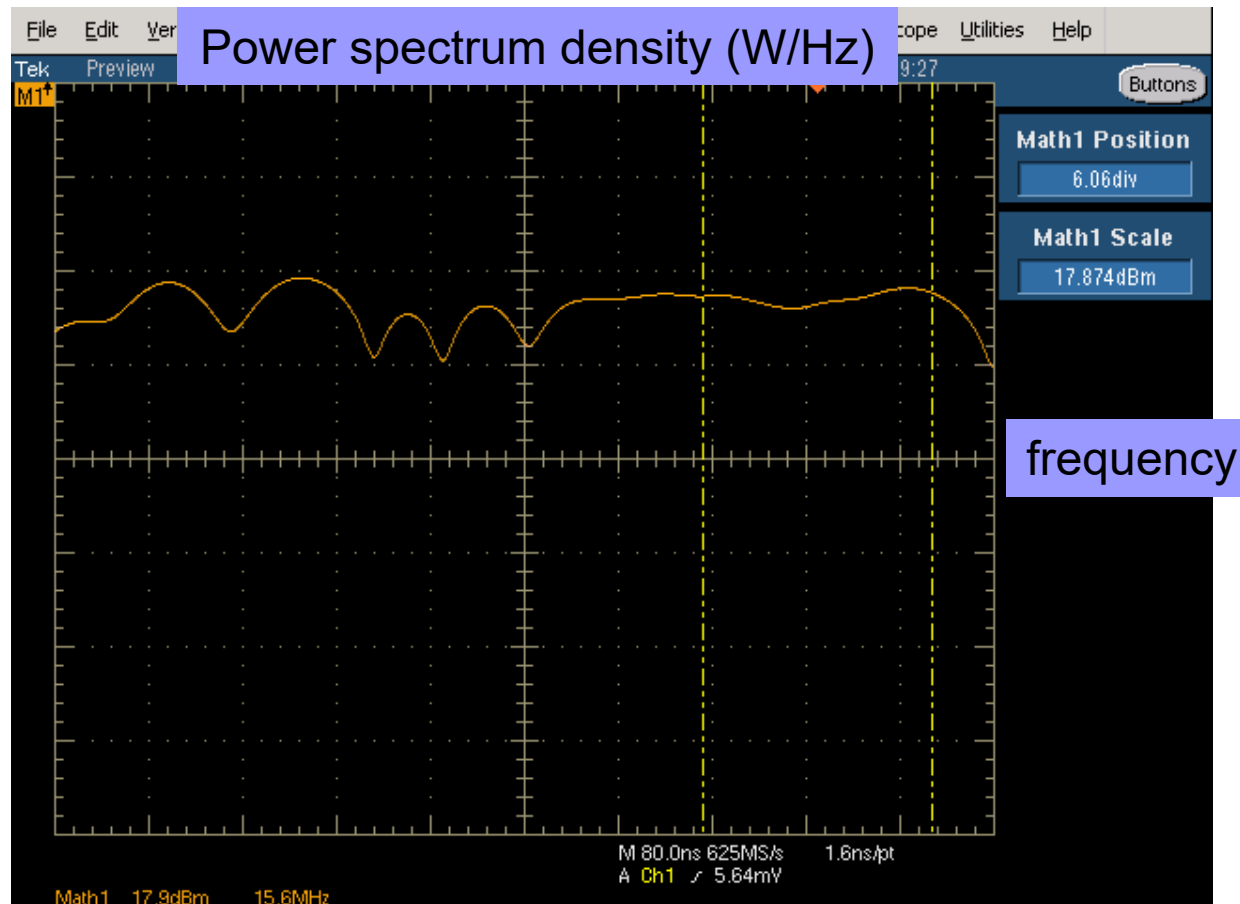
Thermal noise is Additive White Gaussian noise (AWGN)

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



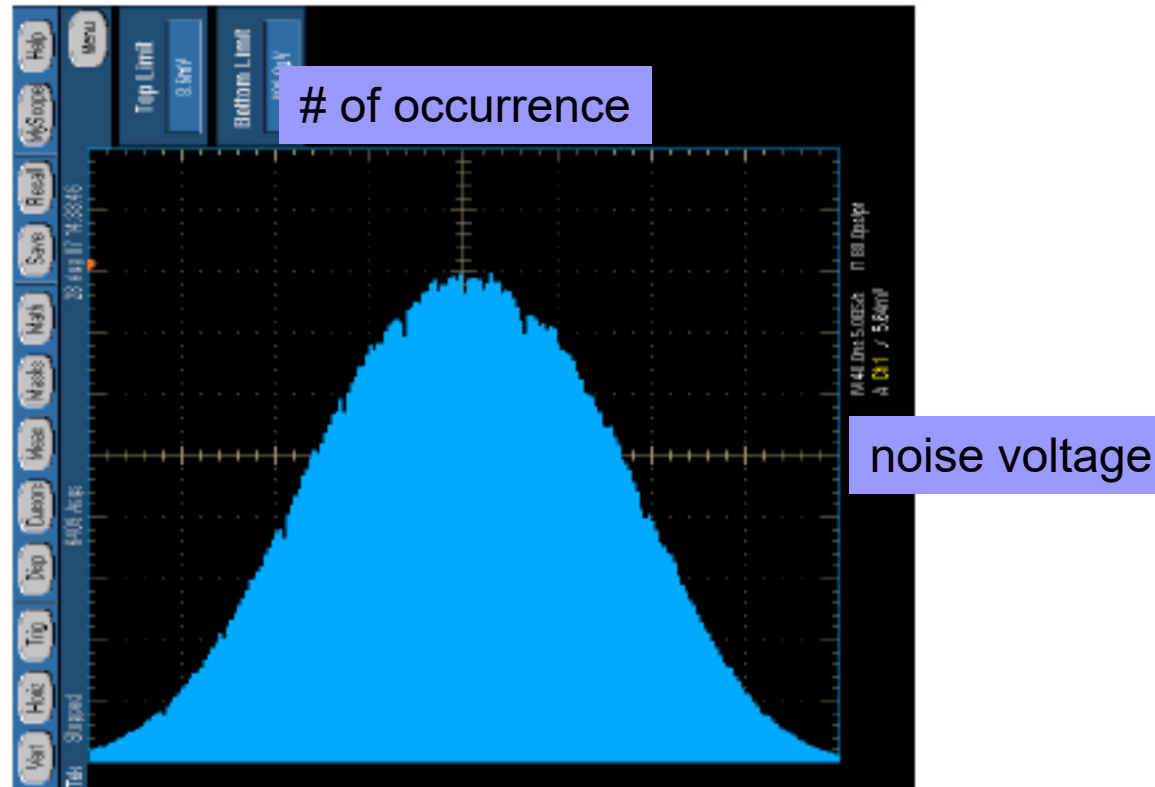
Thermal noise is Additive White Gaussian noise (AWGN)

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



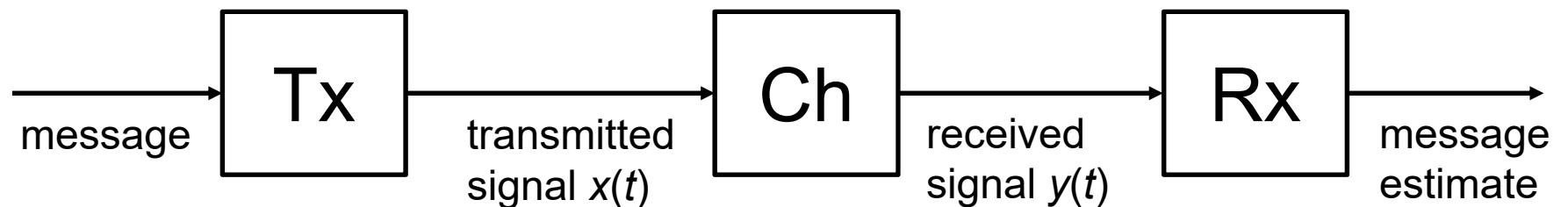
Thermal noise is Additive White Gaussian noise (AWGN)

- Histogram of thermal noise samples

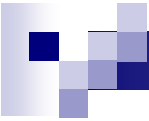


Communication system models

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



- An example of communication system



Question

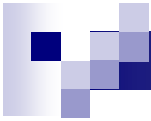
- What is the most scarce resource in wireless communication systems?
 - - Regulated by governments
 - Ex. 國家通訊傳播委員會NCC
 - Ex. Federal Communications Commission (FCC)
- Why is transmit power limited?
 - Si-based circuits can only handle a few volts of signal
 - Heat dissipation
 - Health or safety reasons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

Question

- What are important factors that can increase data rate?
- Why can't the channel capacity be infinite?



● 中山高速公路后里段

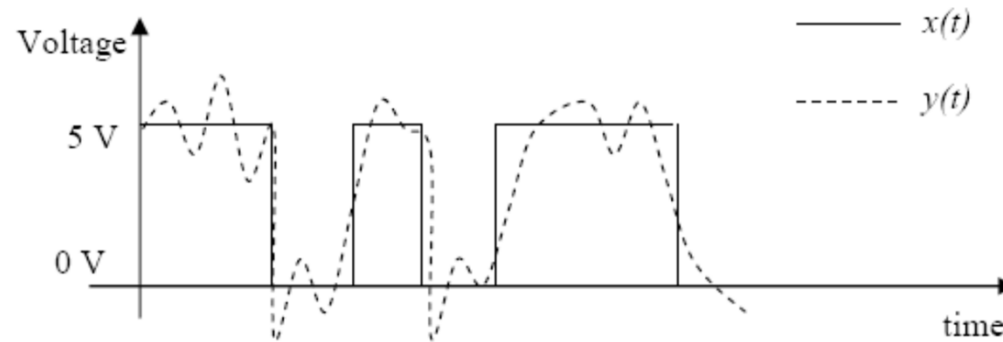


What if the data rate is increased?

- Consider the simple commu. system. Increasing the bit time from $1\ \mu\text{s}$ to $0.01\ \mu\text{s}$ means
 - Data rate: $\rightarrow$
 - A 100X increase in required bandwidth
 - Recall the Fourier transform

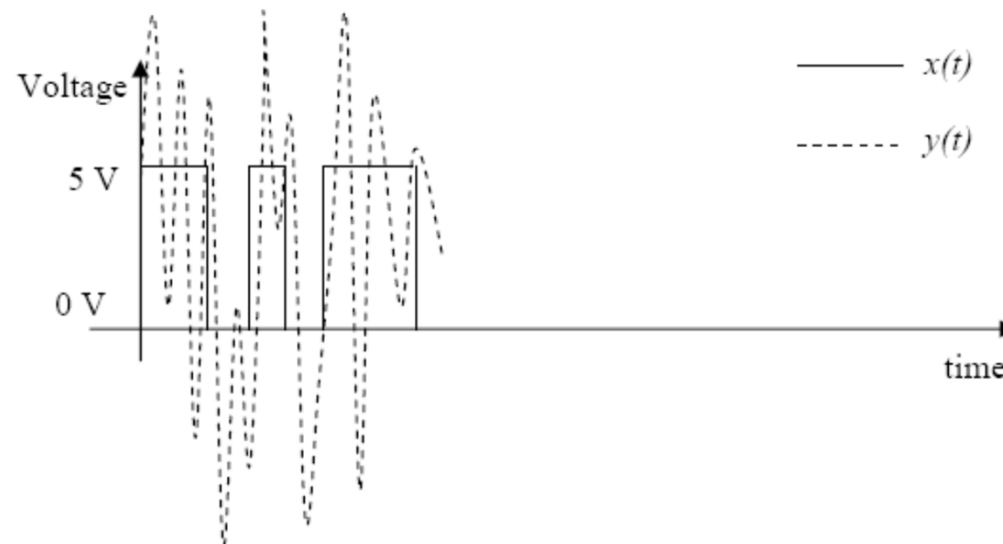
- A 100X increase in noise power, since thermal noise has a constant power spectrum density
 - More difficult to recover the transmitted signal

What if the data rate is increased?



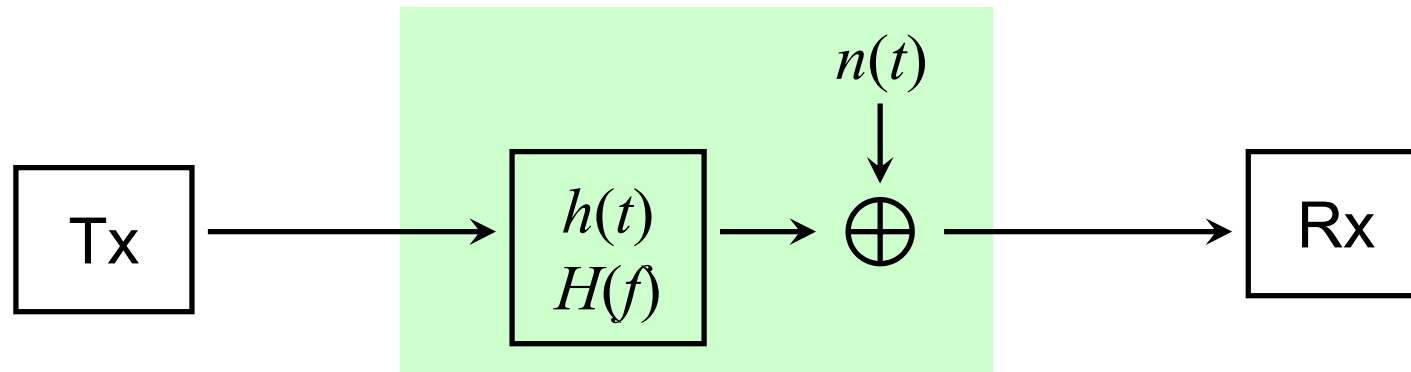
When clock rate is 1 MHz

■ 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

=

$$\square P_{(\text{dBW})} =$$

$$\square P_{(\text{dBm})} =$$

■ Amplitude A in dB

=

=

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