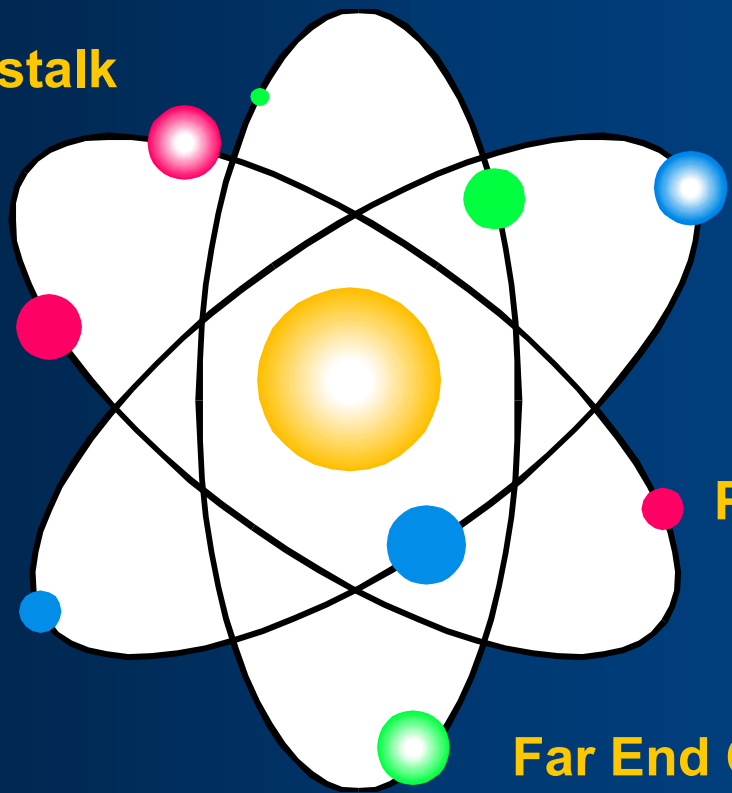
Twisted Pair Transmission from the Electron View



Near End Crosstalk

Delay Skew

Attenuation

Propagation Delay

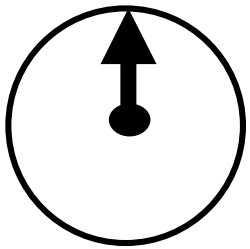
Return Loss

Far End Crosstalk

Traveling Down the Copper Highway

- A simple “model” to study and explain the parameters
- Signals are like electrons following a somewhat bumpy path

Propagation Delay

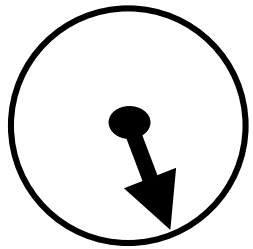


Electrons travel at constant speed

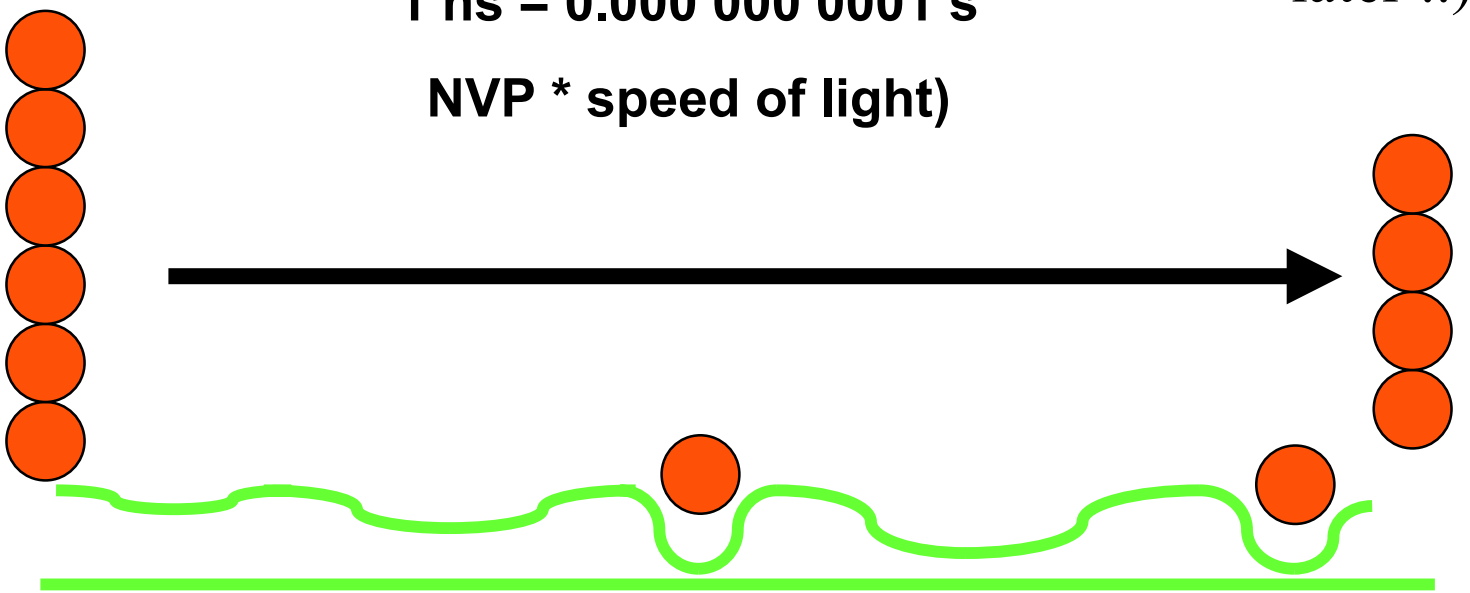
(≈ 20 cm or 8” per ns,

1 ns = 0.000 000 0001 s

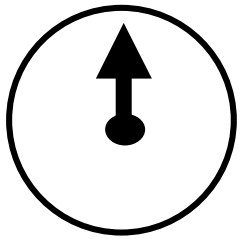
NVP * speed of light)



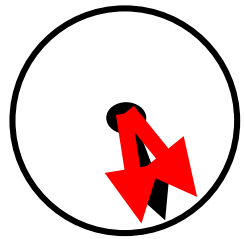
(max 555 ns later ..)



Delay Skew

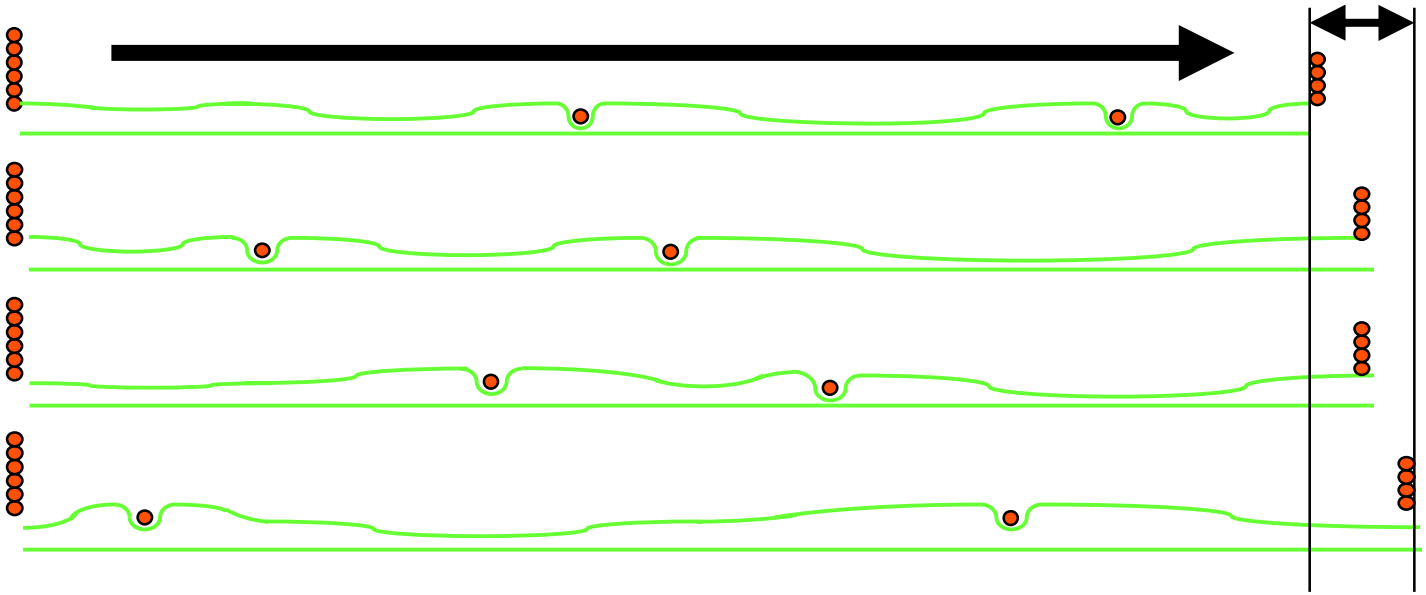


The length of every electronic road in a cable is slightly different because of twist rates

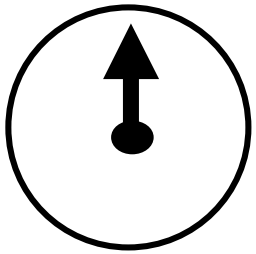


(max 50 ns difference ..)

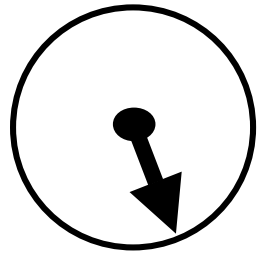
A typical data cable: an electronic highway with four lanes



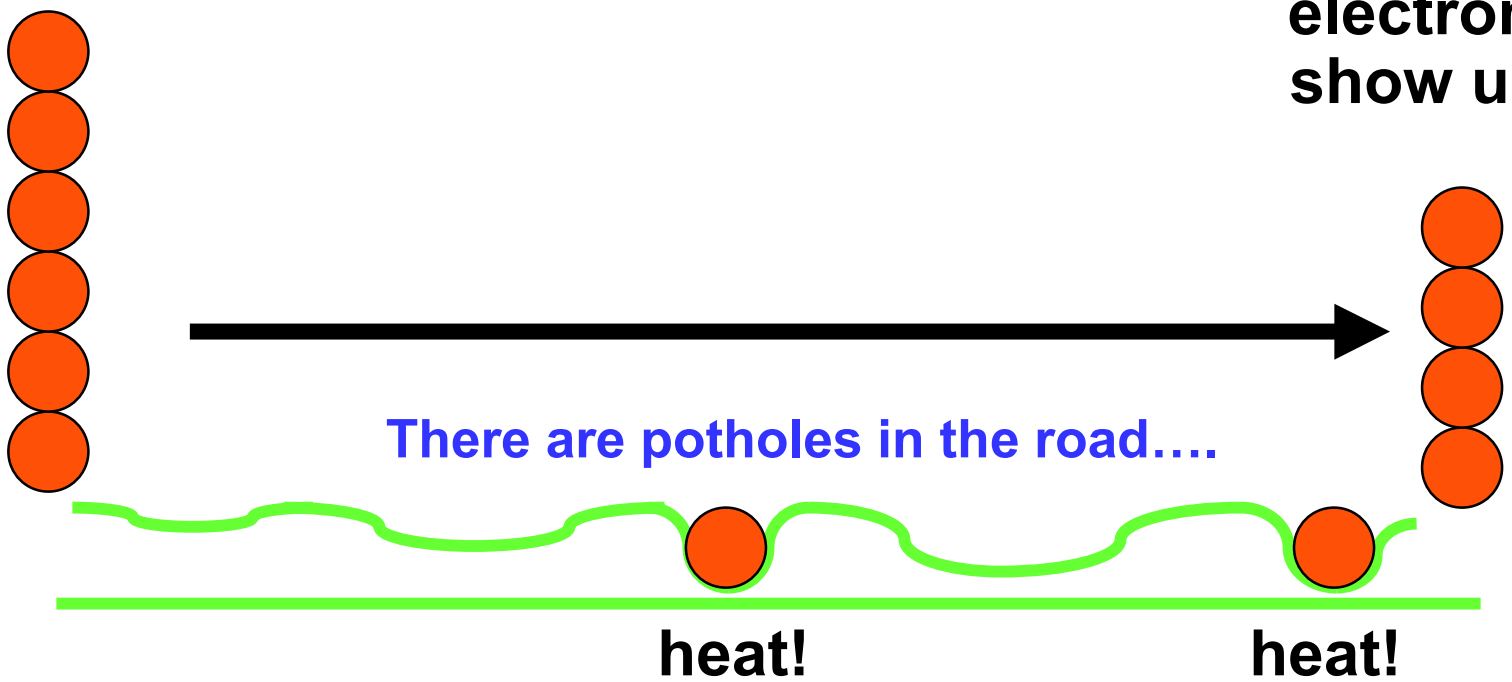
Attenuation



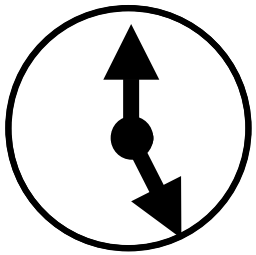
is represented by the electrons that get stuck

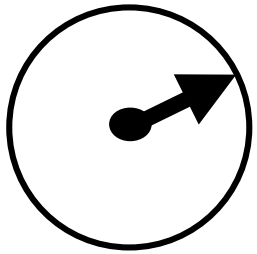


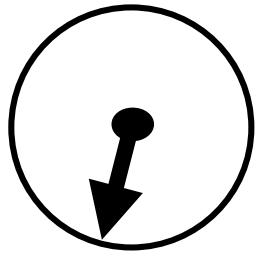
Fewer electrons show up!



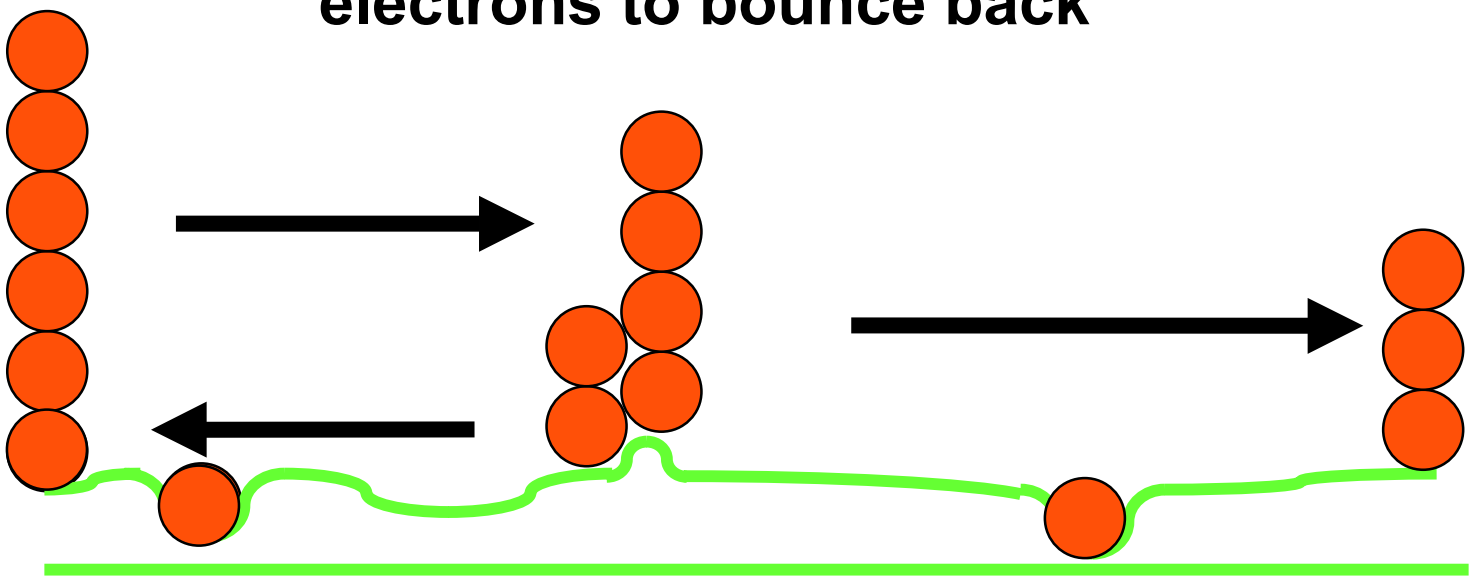
Return Loss Test



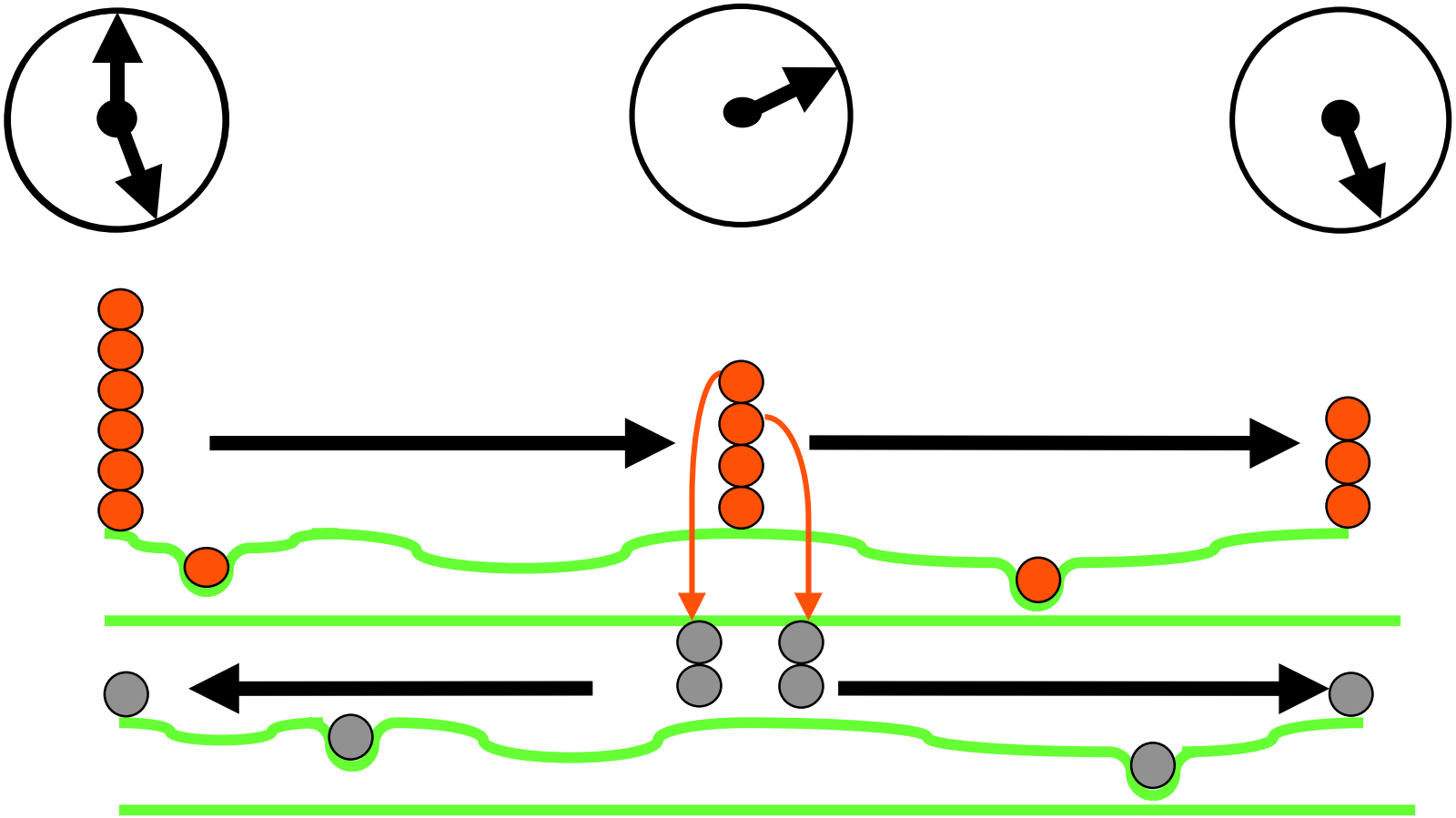




There are bumps in the road that cause some electrons to bounce back

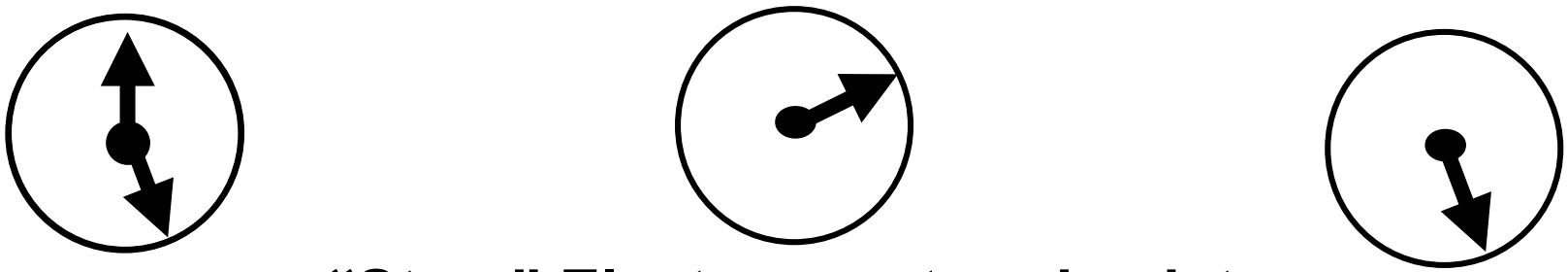


Crosstalk

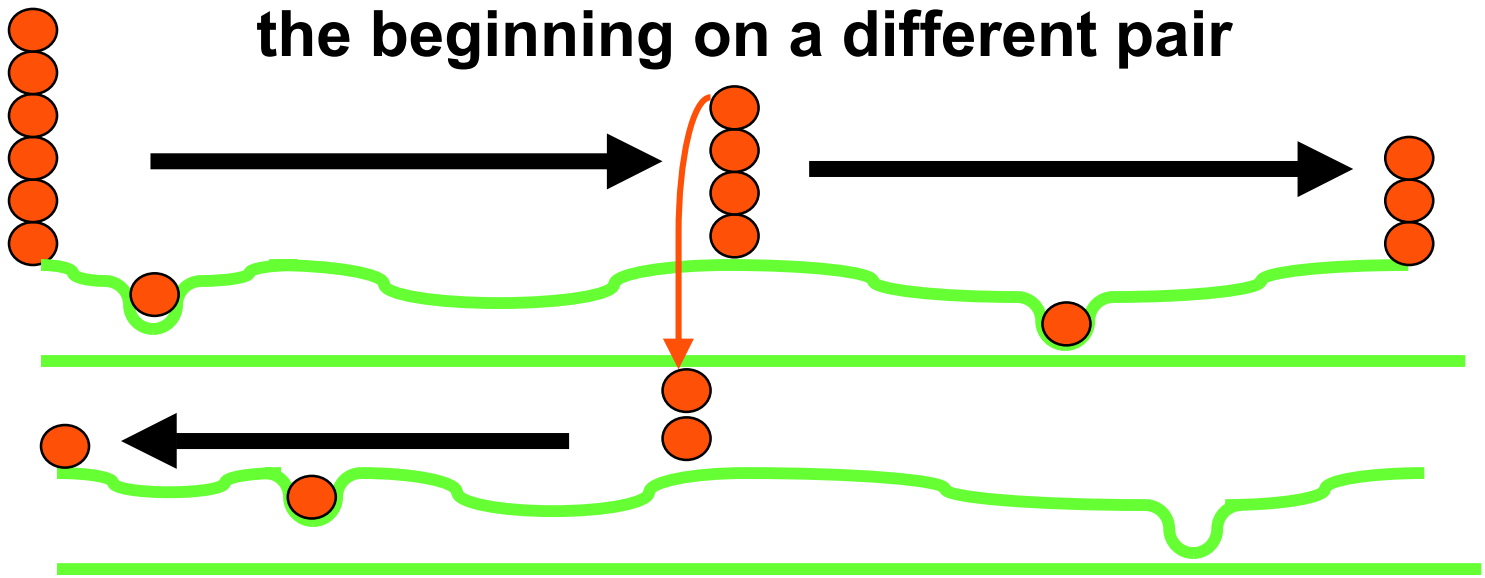


The road is not level and electrons fly off!

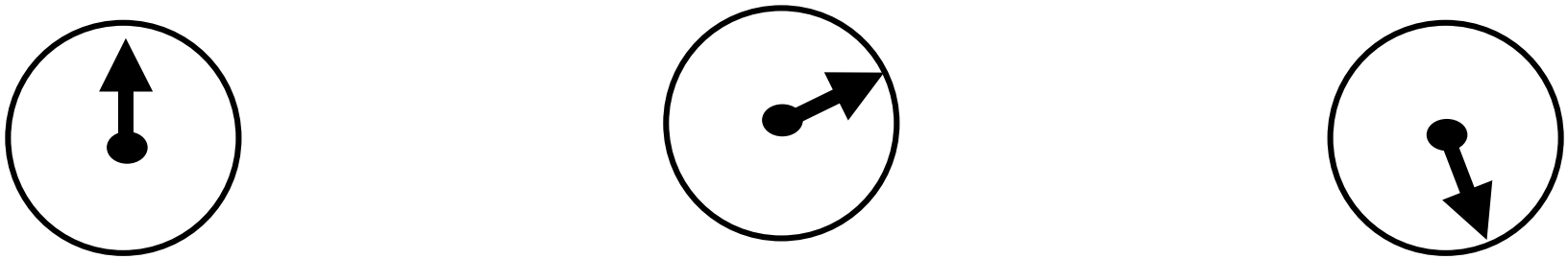
Near End Crosstalk Test (NEXT)



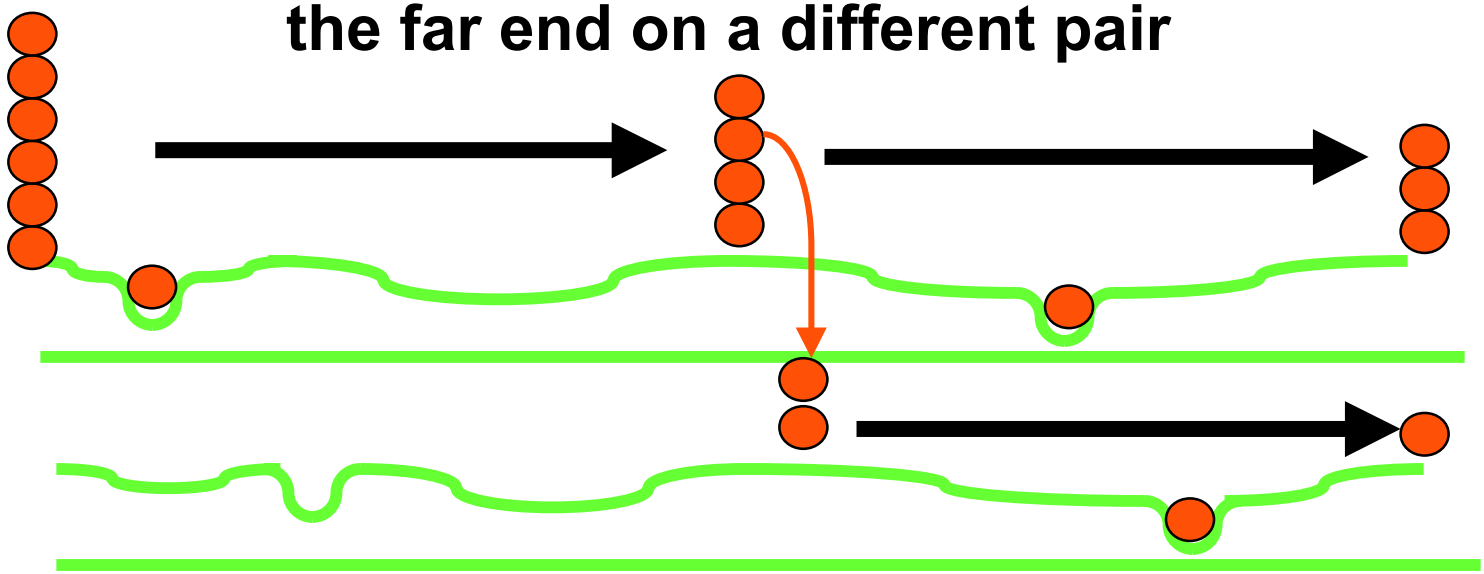
“Stray” Electrons return back to the beginning on a different pair



Far End Crosstalk Test (FEXT)



“Stray” Electrons continue to the far end on a different pair



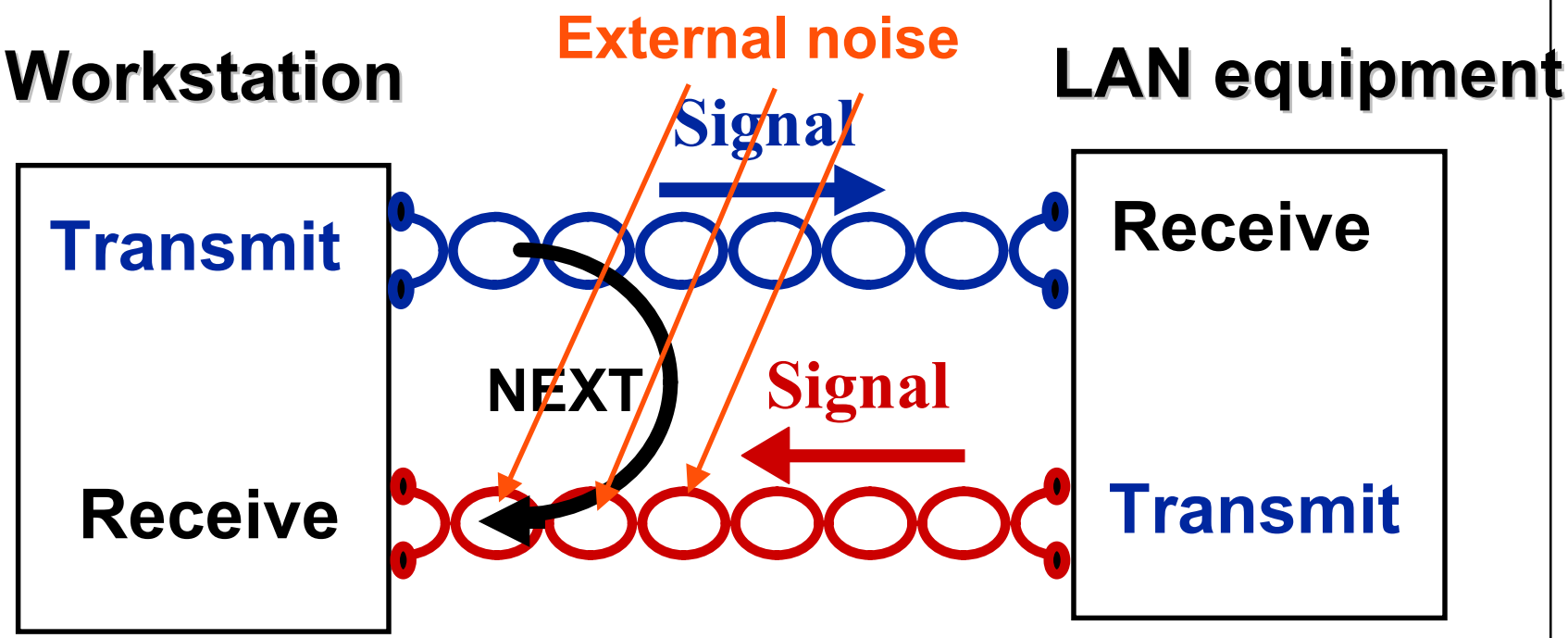
Recap of the “basic” parameters

- Propagation delay (travel time)
- Delay skew (differences in travel time)
- Attenuation (loss of power -- potholes)
- Return loss (reflections -- bumps)
- NEXT (disturbance -- electrons jump road and travel back).
- FEXT (disturbance -- electrons jump the road and travel to the end).

How do these parameters relate to network applications?

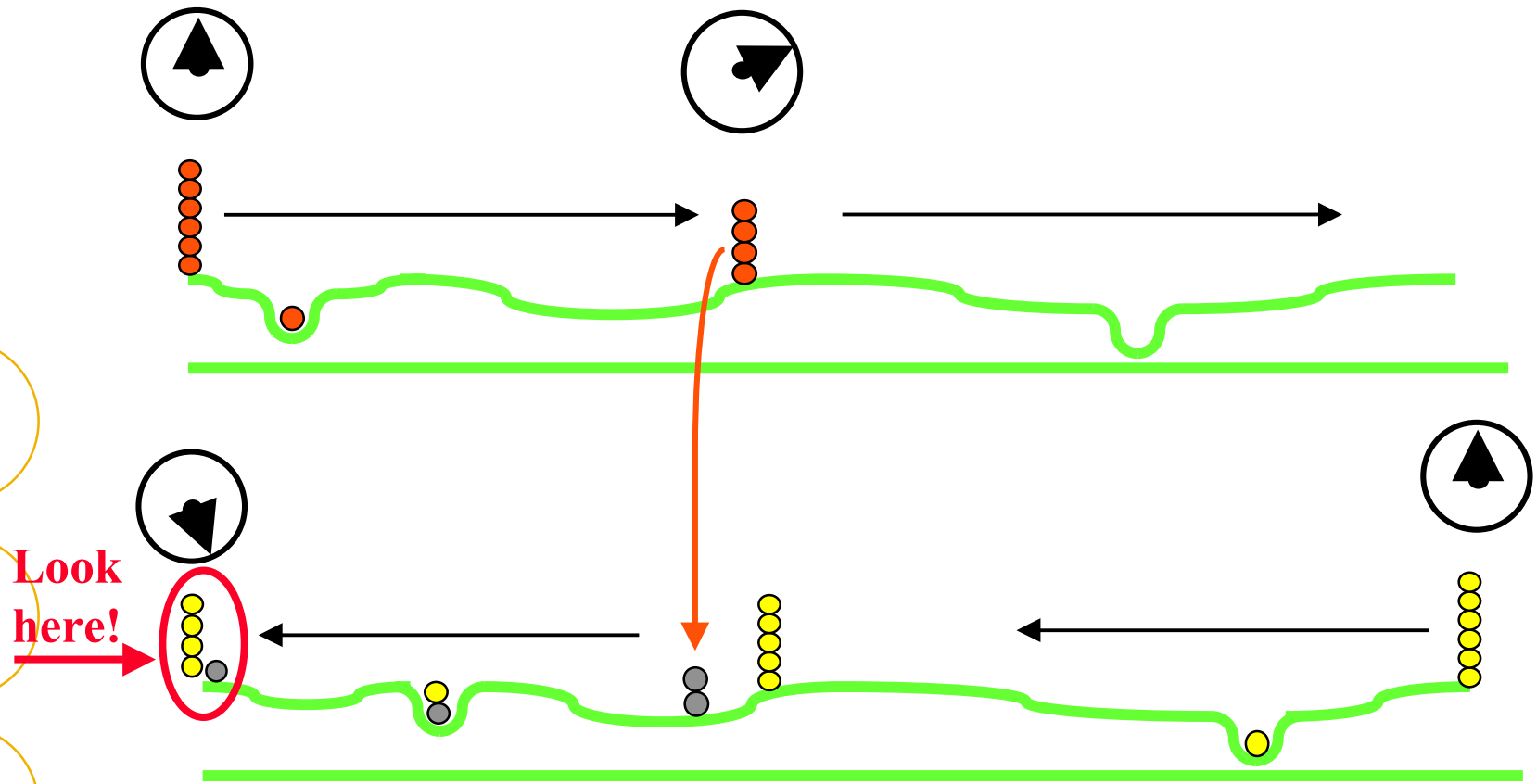
The two-wire pair system

Near-End Crosstalk (NEXT) adds disturbance



SNR = Attenuation-to-Crosstalk Ratio (ACR)

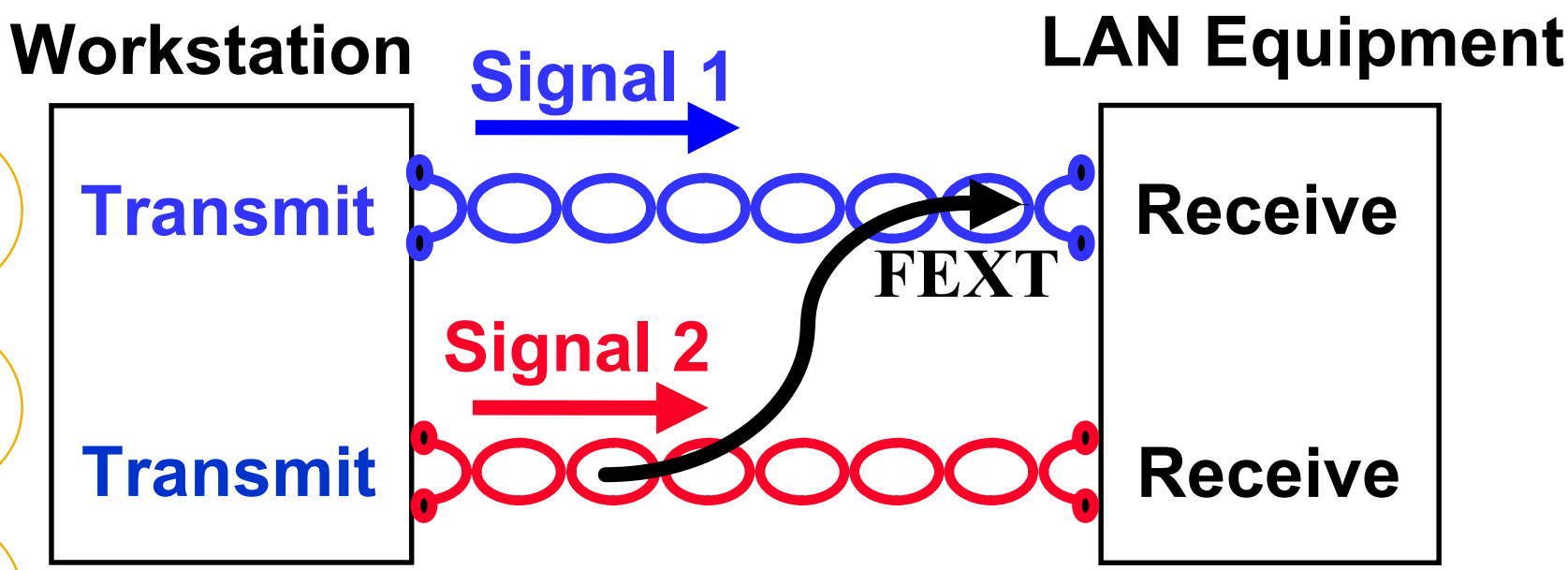
The two-wire pair system



At a receiver input you need more signal electrons than stray electrons

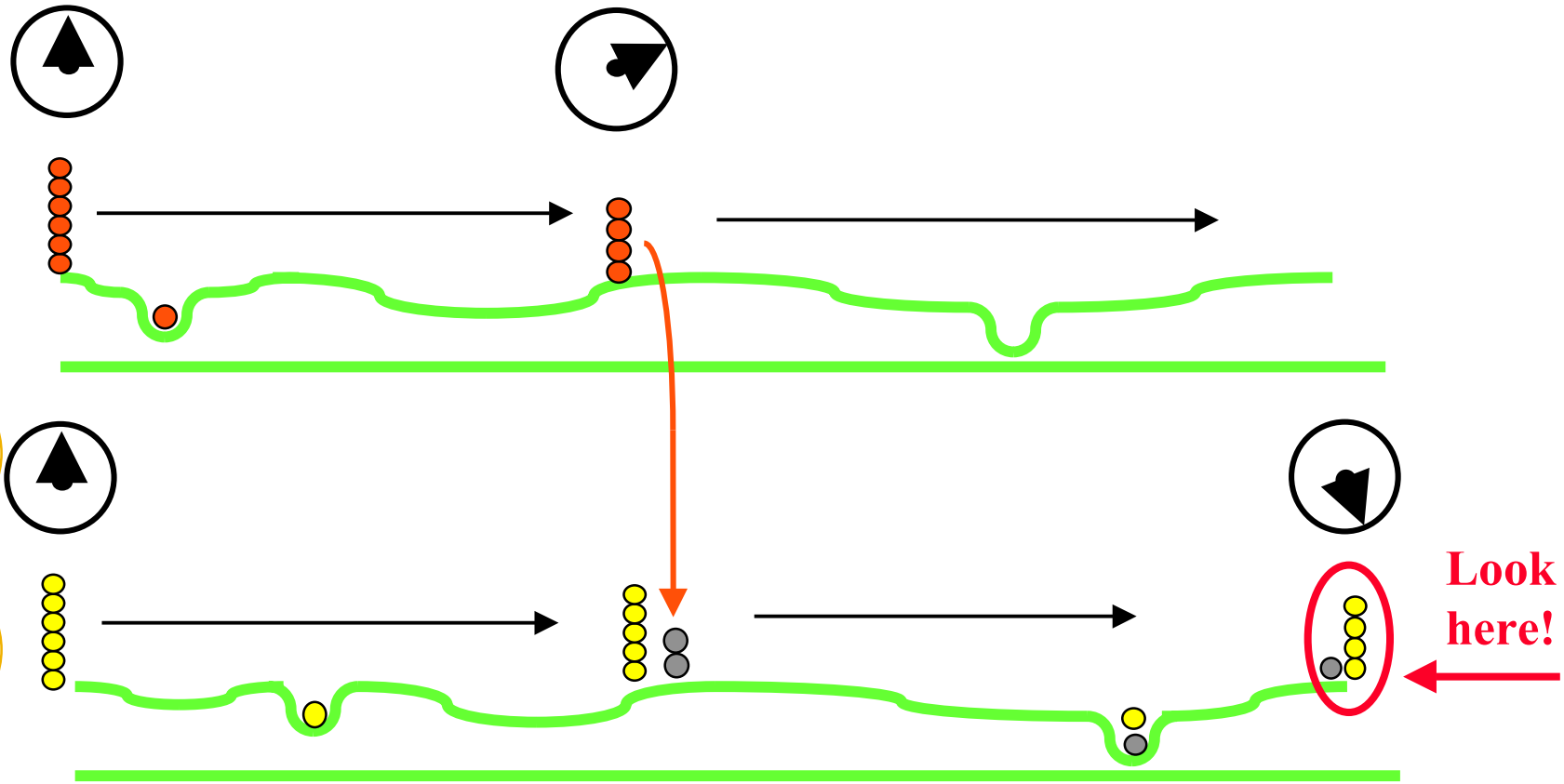
Multiple pair - parallel transmission

Far-End Crosstalk (FEXT) adds disturbance



SNR = Equal Level Far-End Crosstalk (ELFEXT)

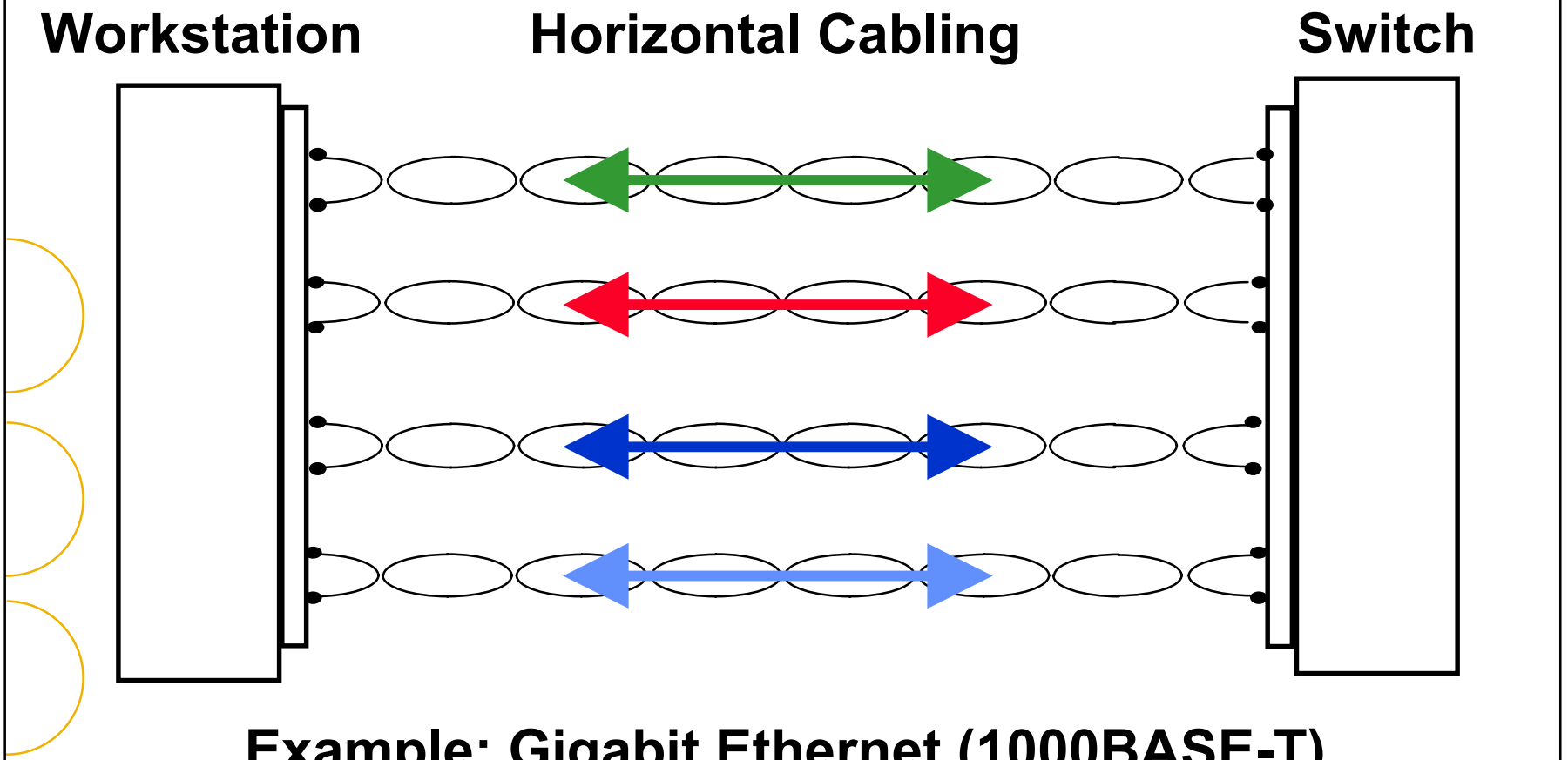
Parallel Transmission



At a receiver input you need more signal electrons than stray electrons

The “New” Transmission Model

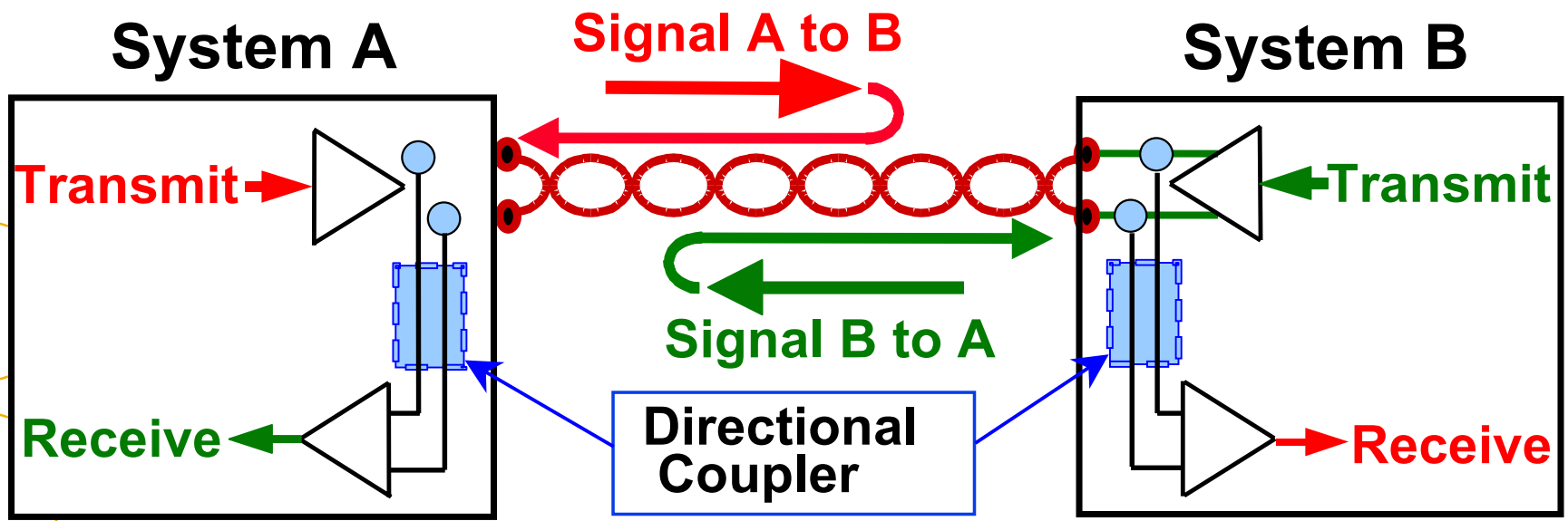
Four wire pairs – Full duplex on each pair



Example: Gigabit Ethernet (1000BASE-T)

Full Duplex Transmission

Return Loss adds disturbance



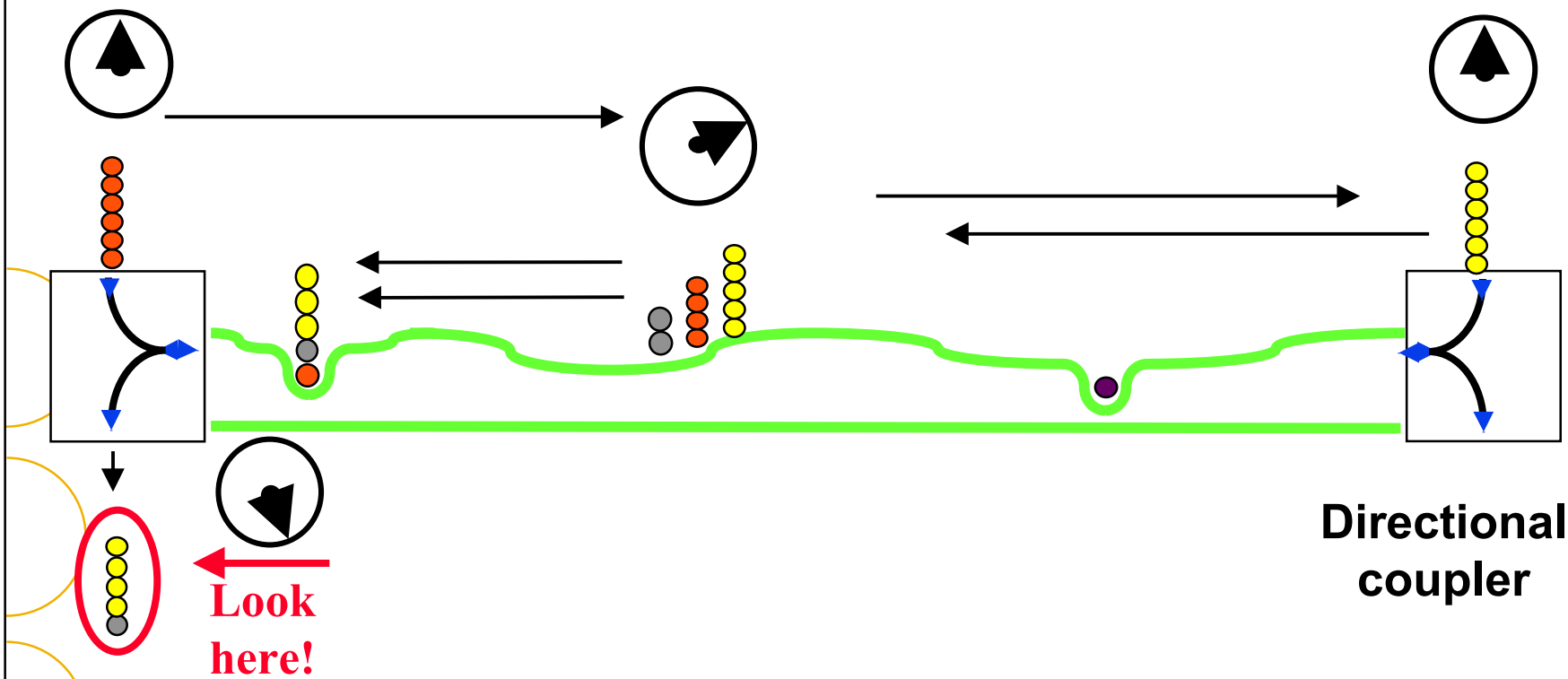
Desired signal = attenuated signal from other end

Noise = reflected signal on same wire pair.

SNR = Return Loss - Attenuation

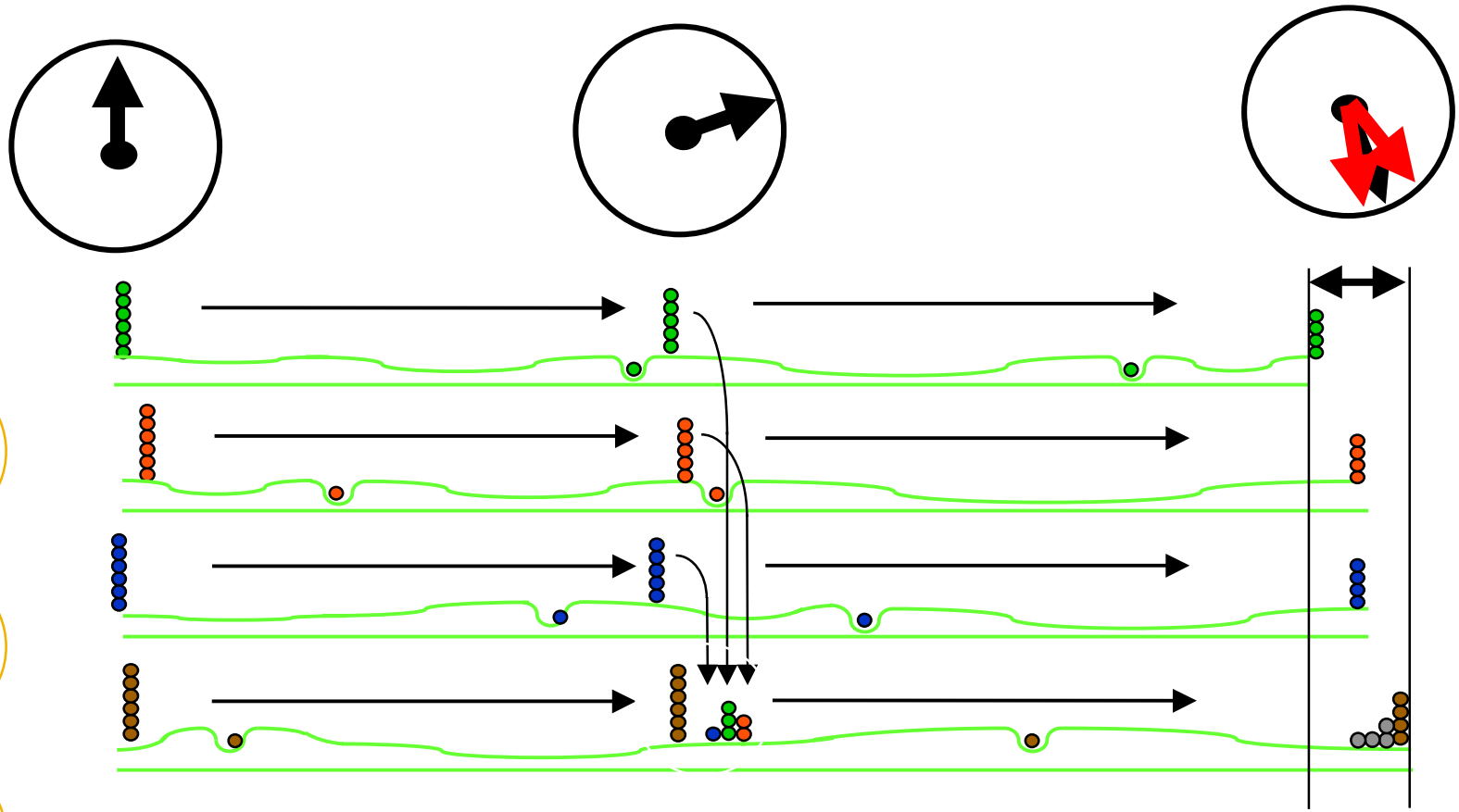
Full Duplex Transmission

Signals travel in both directions on a wire pair



At a receiver input you need more signal electrons than stray electrons

The concept of “power sum”



Power sum takes crosstalk from all 4 pairs into consideration. Remember it can happen at both ends.

What do applications need? (1)

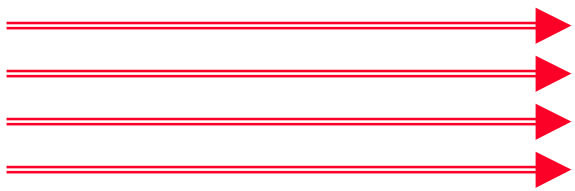
- Two wire pair systems with signals in opposite directions
  - 10BASE-T, 100BASE-TX, Token Ring
  - Attenuation, NEXT, ACR

- Two or more wire pair systems, each wire pair transmission in the same direction
  - 100VG-Any LAN, 100BASE-T4, 1000BASE-T
  - Attenuation, FEXT, ELFEXT

What do applications need? (2)

- Signals in both directions on a wire pair ("full duplex" using "directional couplers")
  - 1000BASE-T
  - Attenuation, *NEXT*, Return Loss

- Signal transmission on more than two wire pairs in either direction:
  - 1000BASE-T
  - PS NEXT, PS ELFEXT



Application Requirements

Type	Data Rate	Pairs Used	Max. Frequency
10BASE-T	10 Mbps	2	10 MHz
100BASE-T4	100 Mbps	4	15 MHz
100BASE-TX	100 Mbps	2	80 MHz
100VG- AnyLAN	100 Mbps	4	15 MHz
ATM-155	155 Mbps	2	100 MHz
1000BASE-T	1000 Mbps	4	100 MHz