https://unsplash.com/photos/cQWXGcHwVrg

2 – Direct Sequence Spread Spectrum (DSSS)

Motivation

The beauty of telecommunications:

- **Beautiful mathematical theory, very abstract**
- **Very concrete software/hardware system you can play with**

Some more theory and math…

- Some more theory
- Main intuition and practical aspects

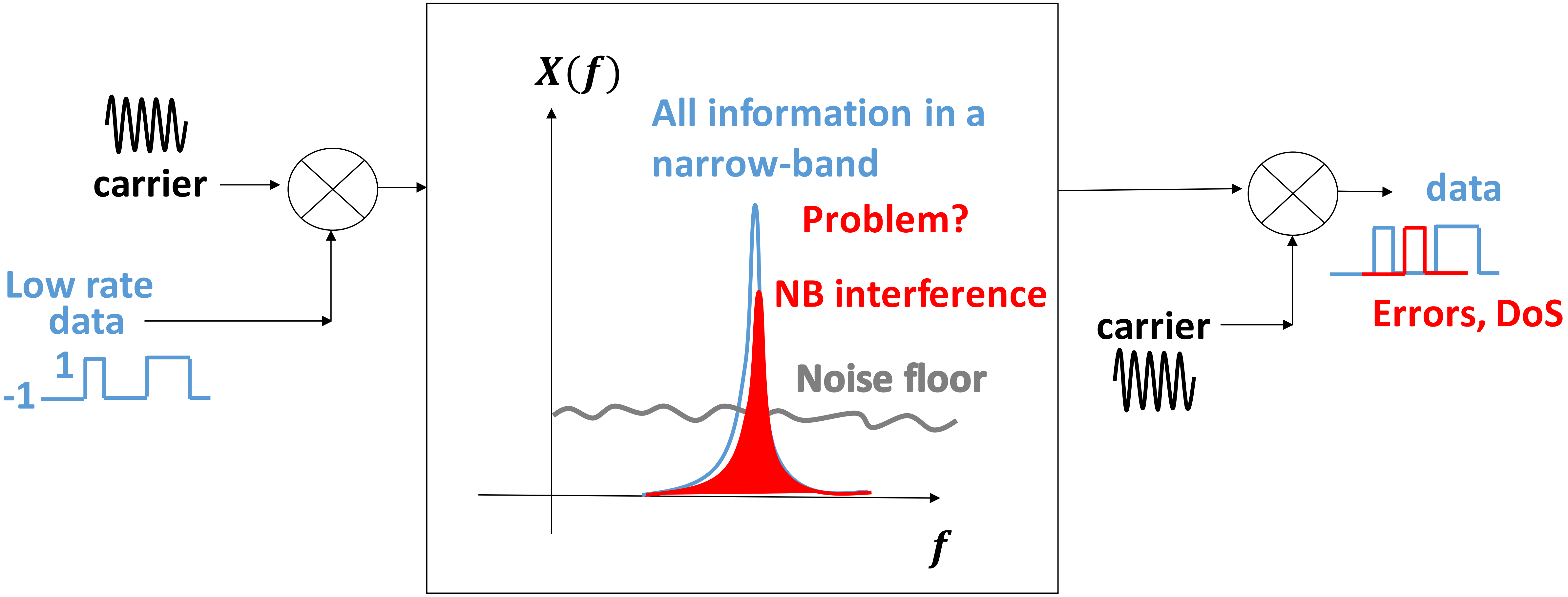
You will soon put this into practice in Lab1!

- Hands on practice
- Complete TX -> RX chain over the air

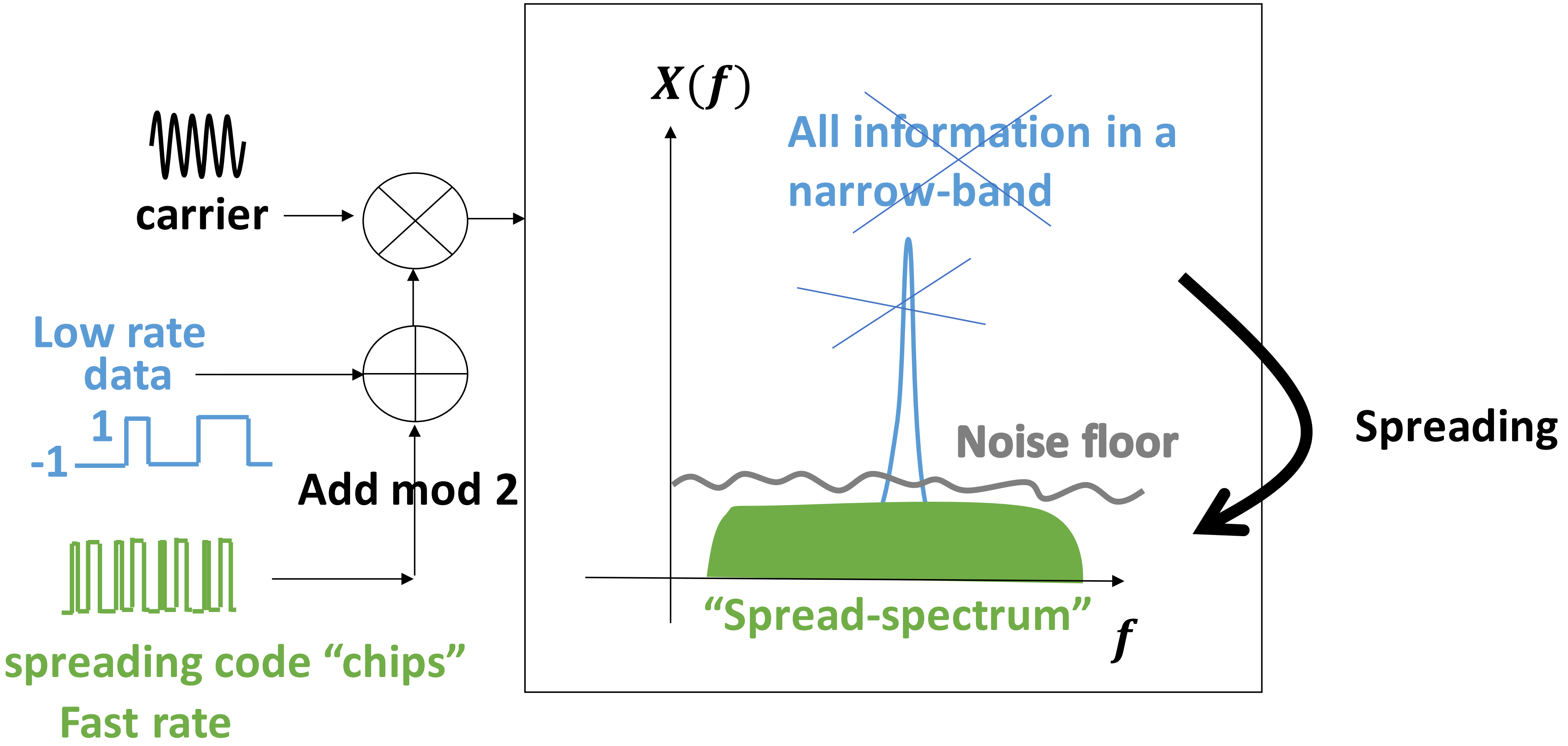
But we will soon see some very concrete applications of DSSS!

- GPS
- Robust communications
- Hands on practice

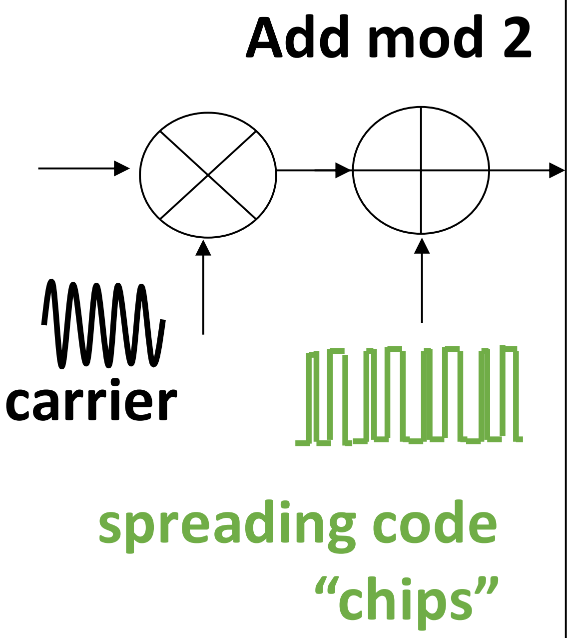
We have seen narrow-band modulations

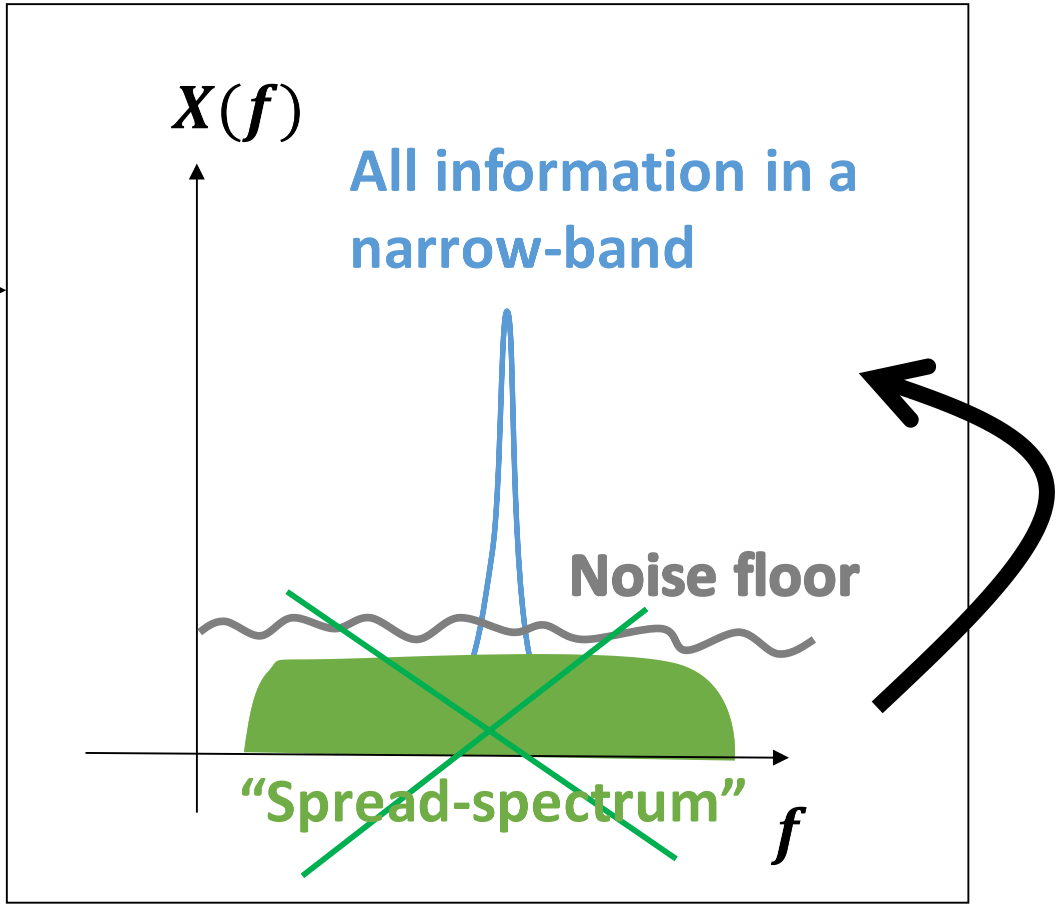


Let's spread it at the transmitter



Let’s de-spread it at the receiver



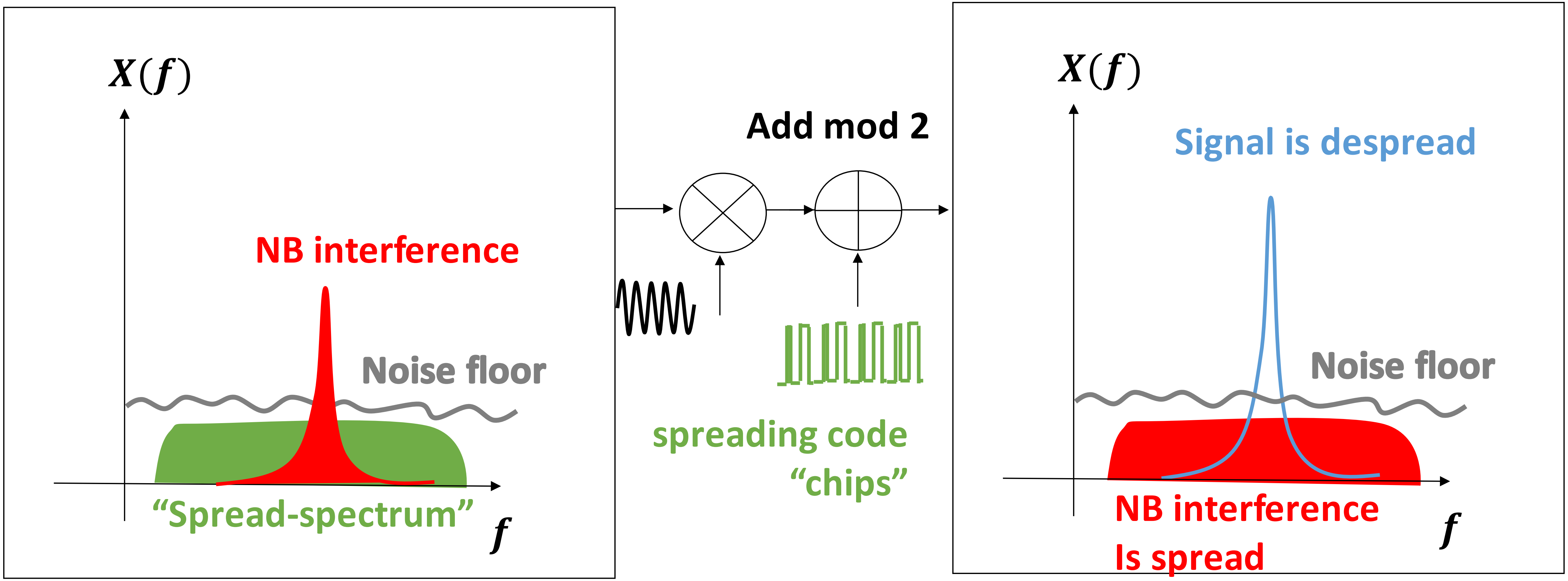


Processing gain:
chip rate / symbol rate

De-spreading
“Digging the signal out of noise”

For now just assume local synchronized copies

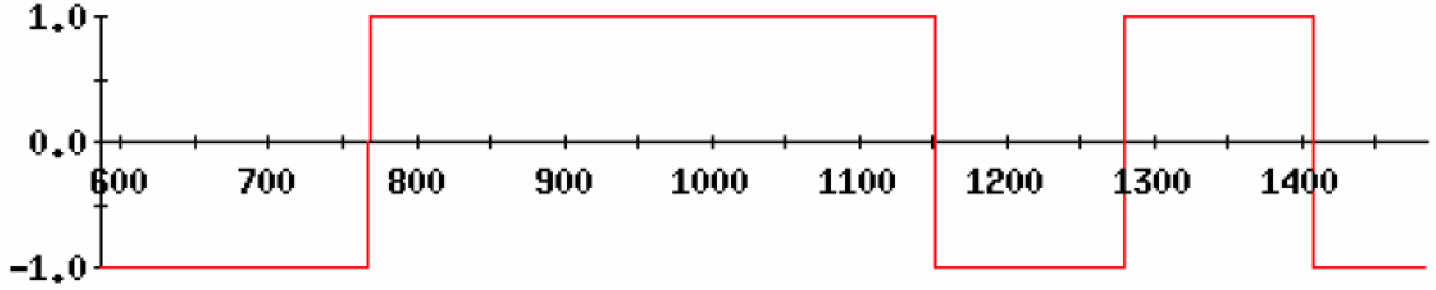
What happens to narrow-band interference?



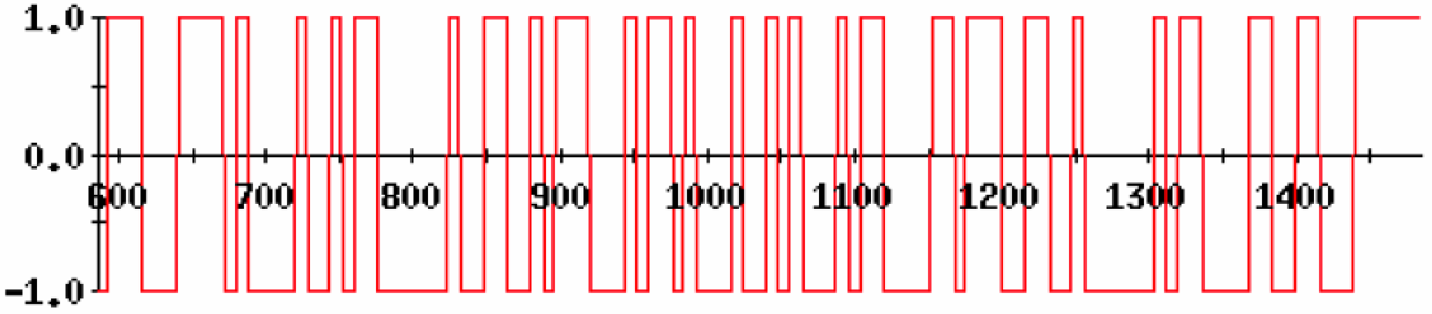
Despreading a NB signal = spreading it

Example

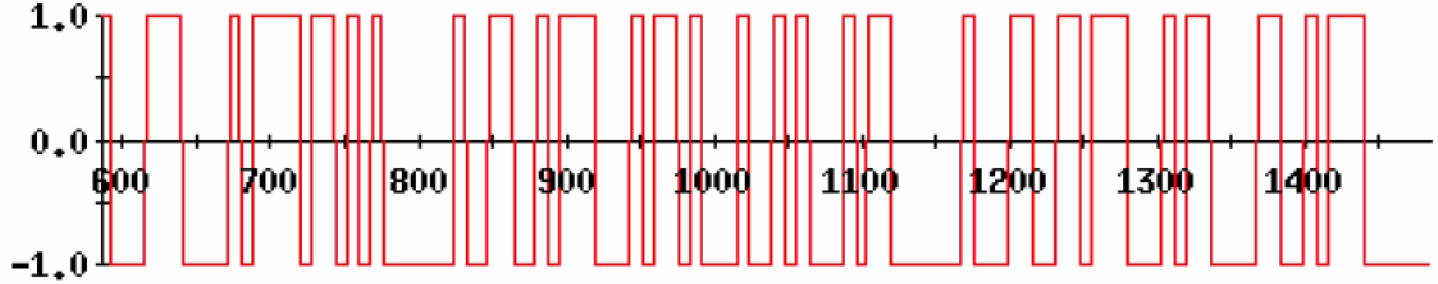
information (bits)



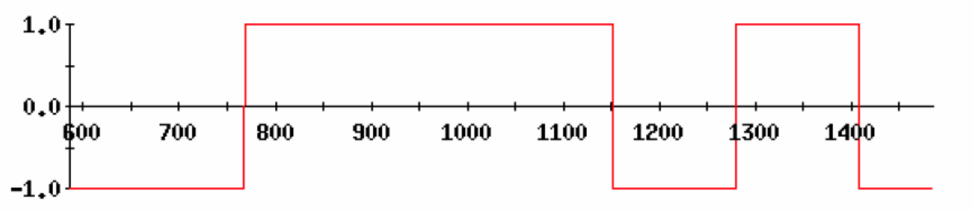
spreading code (chips)



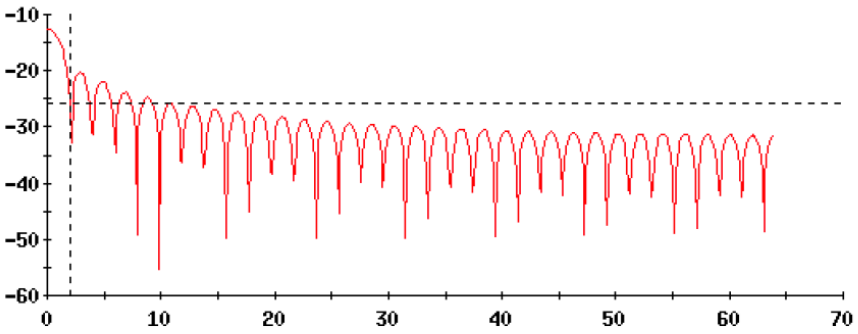
spread signal



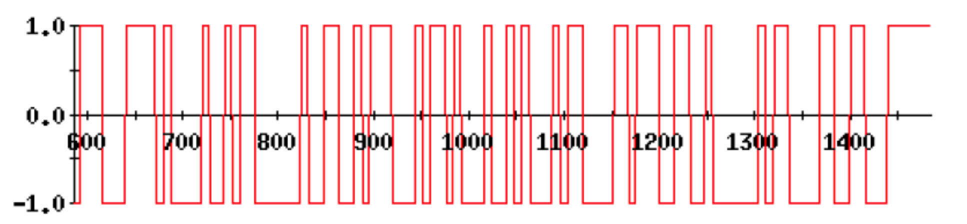
Example



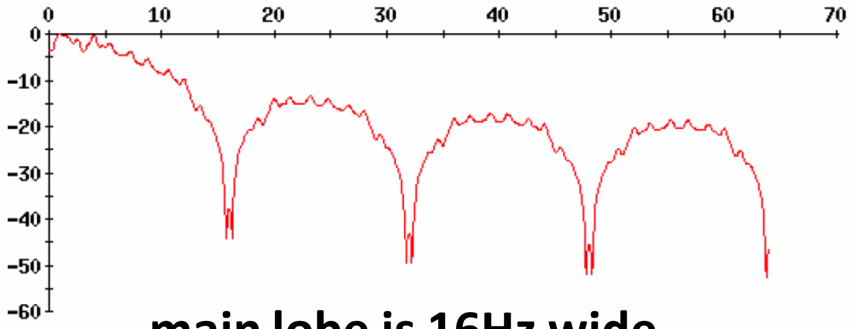
symbol rate is 2



main lobe is 2Hz wide



symbol rate is 16



main lobe is 16Hz wide

How do we generate spreading codes?

Wish list

Spread the signal — **Fast chipping rate**

Recognize the signal below the noise floor — **High autocorrelation**

Transmit multiple signals at the same time on the same band — **Orthogonal codes (low cross-correlation)**

Make it harder to:

- **Detect the signal**
- **Interfere with the signal**
- **Send the signal in advance**

Secret code

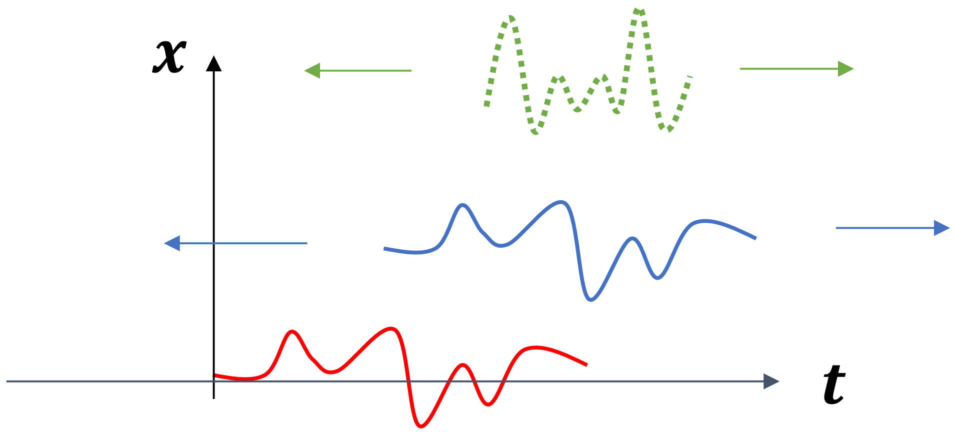
Unpredictable (cryptographically secure sequence) code

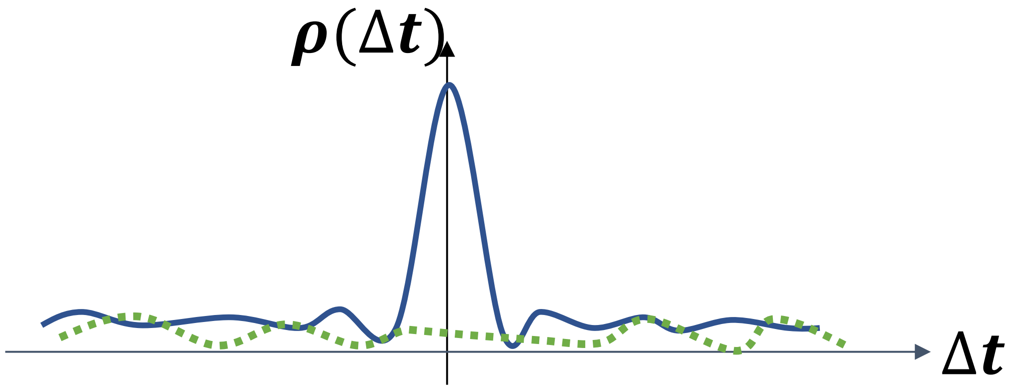
Refresher on correlation

Cross-correlation

Measures the "similarity" among two signals for many possible time shifts

- High if the signals are similar
- High if the signals are aligned in time



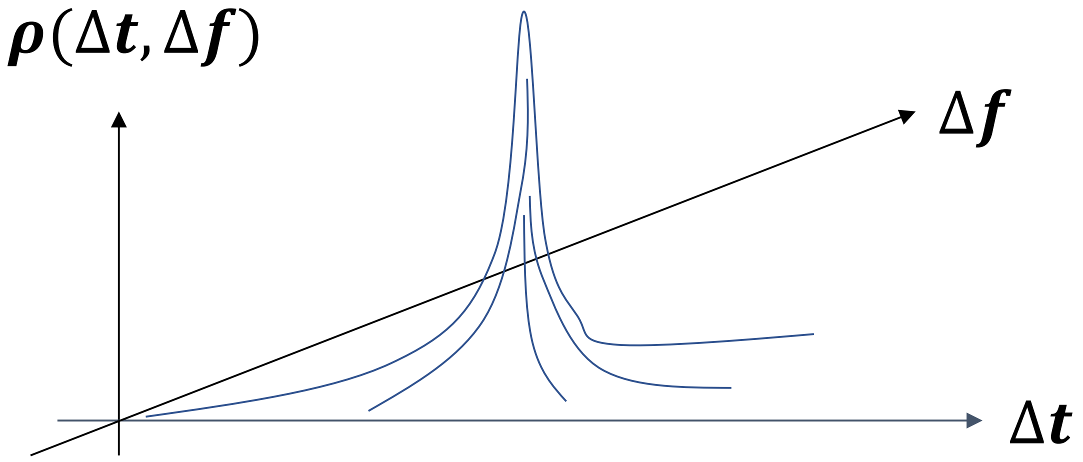


Refresher on correlation

Cross-correlation 2D

Measures the "similarity" among two signals for many possible time shifts and Doppler shifts

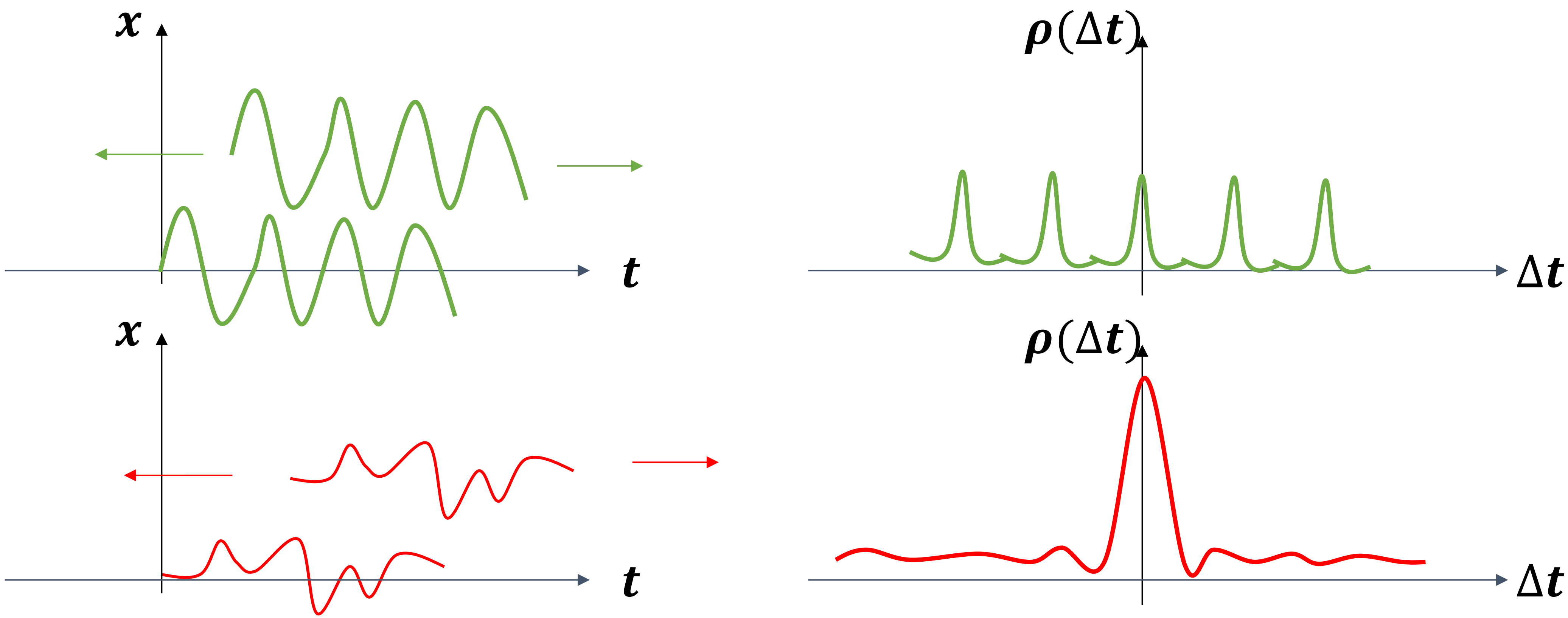
- High if the signals are similar
- High if the signals are aligned in time and frequency



Refresher on correlation

Autocorrelation

Measures how good is the cross-correlation of a signals with a delayed copy of itself



Summing up

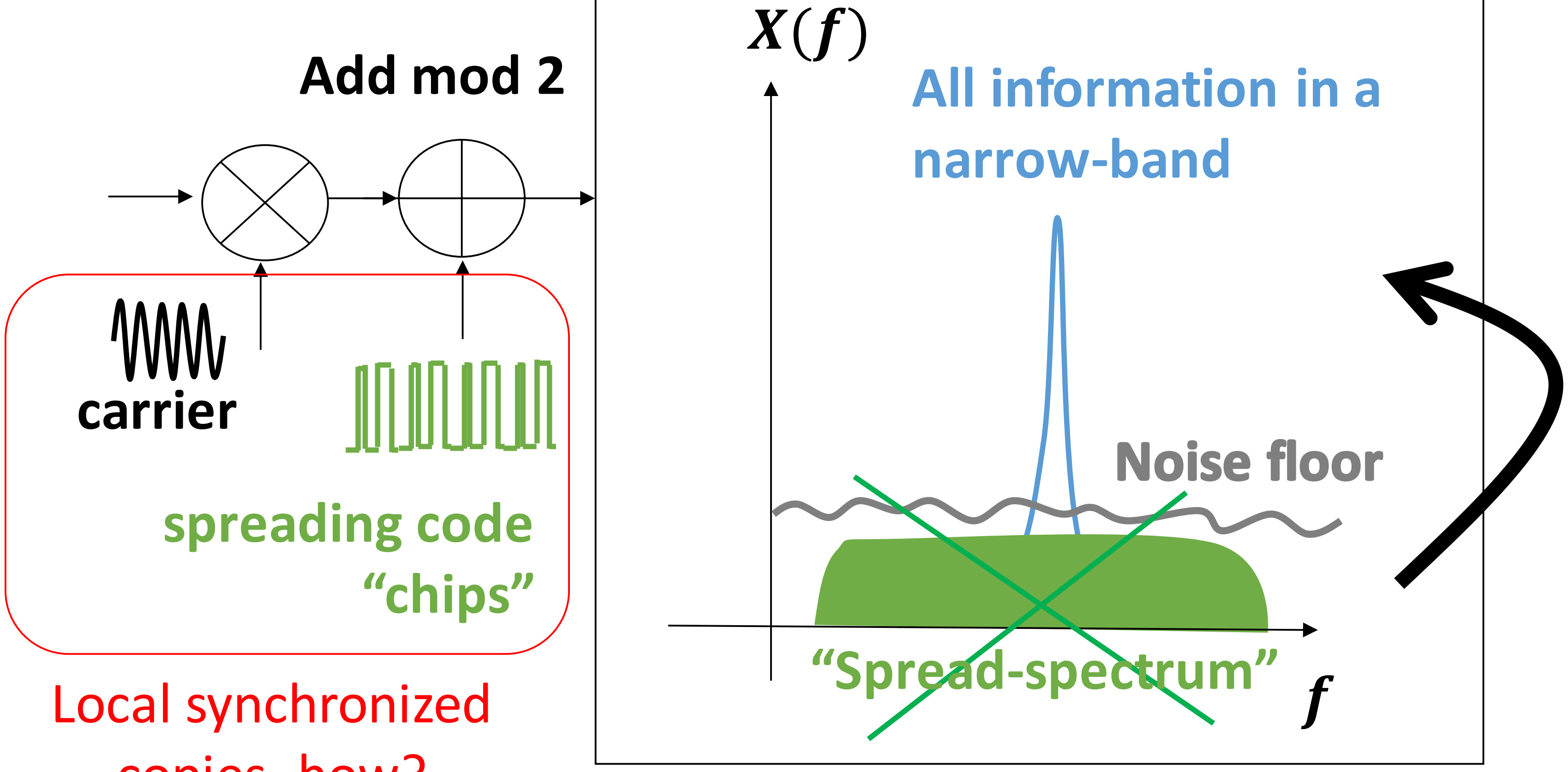
Spreading code
- Fast chipping rate
- High auto-correlation peak only when perfectly aligned
- No cross-correlation with other codes (orthogonality)

Spread signal power over a large spectrum
- Robust to narrow-band noise
- Works even below the noise floor

Easy to find with cross-correlation
- Find if there is a signal
- Find Doppler shift and arrival time

Multiple access
- Different transmitters use different codes
- Multiple transmitters can use the same frequency

How to synchronize the copies?

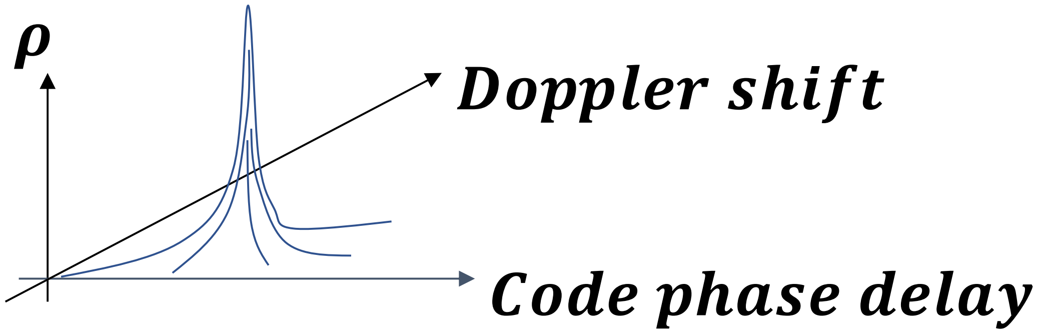


Local synchronized copies, how?

Processing gain:
chip rate / symbol rate

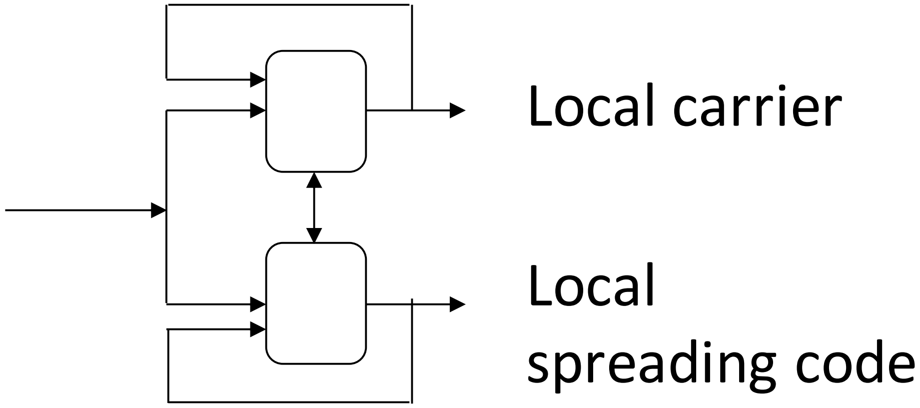
De-spreading
“Digging the signal out of noise”

Acquisition and tracking



Use cross-correlation!

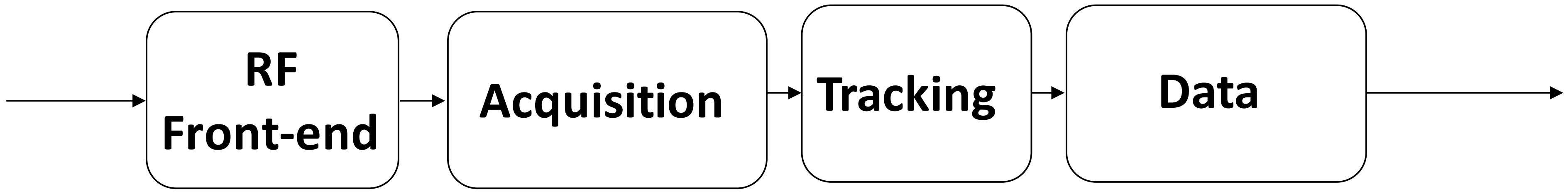
- Compare local copy of the spreading code for each possible frequency shift and time delay
- Find the peak
- Bonus: you known **when** the signal arrived compared to your local time reference



Use control loops!

- Use a feedback loop to keep tracking shifts in time and frequency
- Bonus: use the local copy to de-spread and **get the data bits**

Putting all together: the receiver



This is the basic building block for a GPS DSSS BPSK receiver that we will see next

In the lab you will experiment with a QPSK DSSS tx/rx chain and explore a different receiver