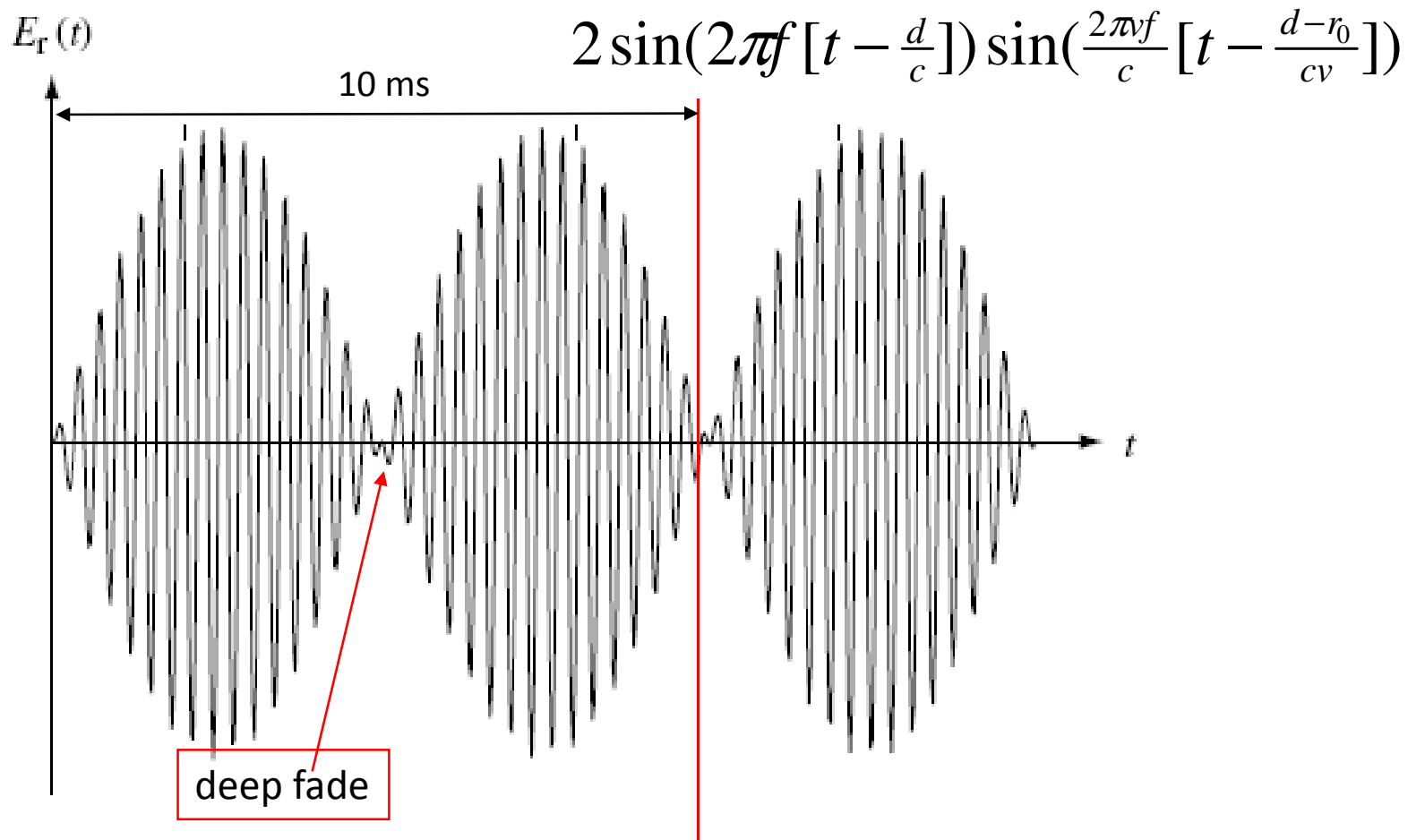


Preview: Challenges and Techniques of Wireless Design

	Performance affected	Mitigation techniques
Shadow fading (large-scale fading)	received signal strength	use fade margin— increase power or reduce distance
today → Fast fading (small-scale fading)	bit/packet error rate at deep fade	diversity
Delay spread (small-scale fading)	ISI	equalization; spread-spectrum; OFDM; directional antenna

Recall: deep fade



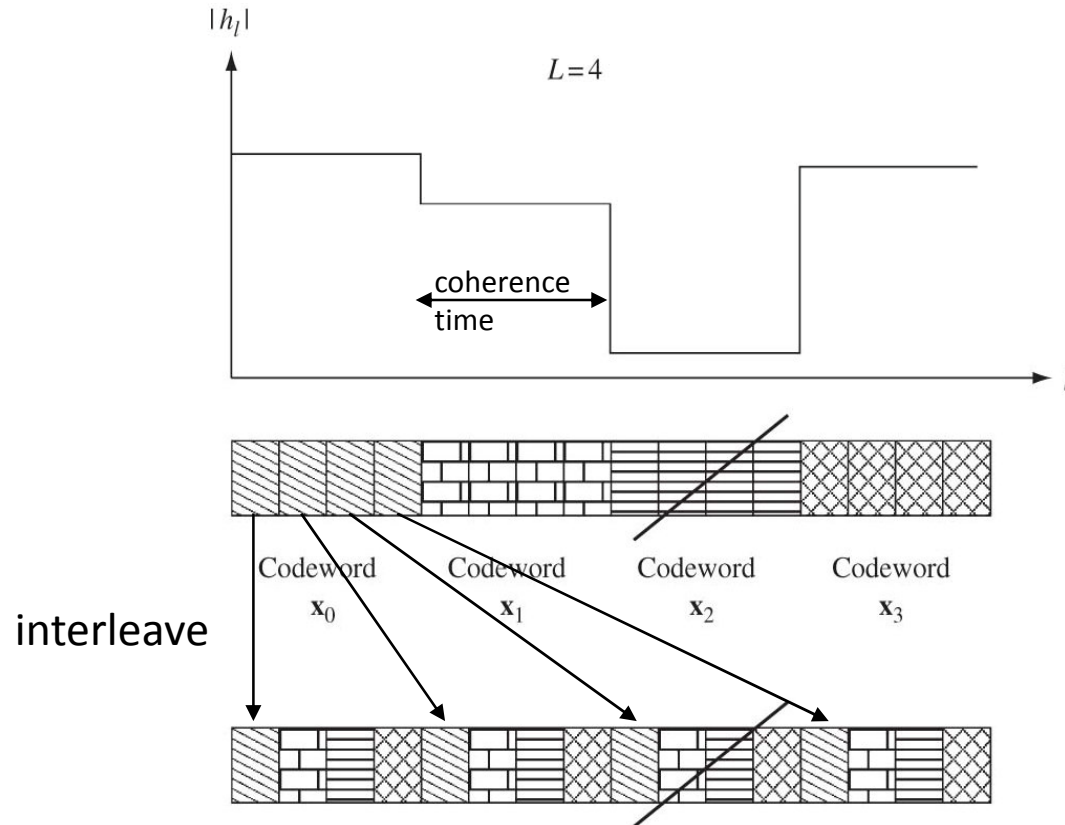
Diversity

- Time: when signal is bad at time t , it may not be bad at $t+\Delta t$
- Space: when one position (with d_1 and d_2) is in deep fade, another position (with d'_1 and d'_2) may be not
- Frequency: when one frequency is in deep fade (or has large interference), another frequency may be in good shape

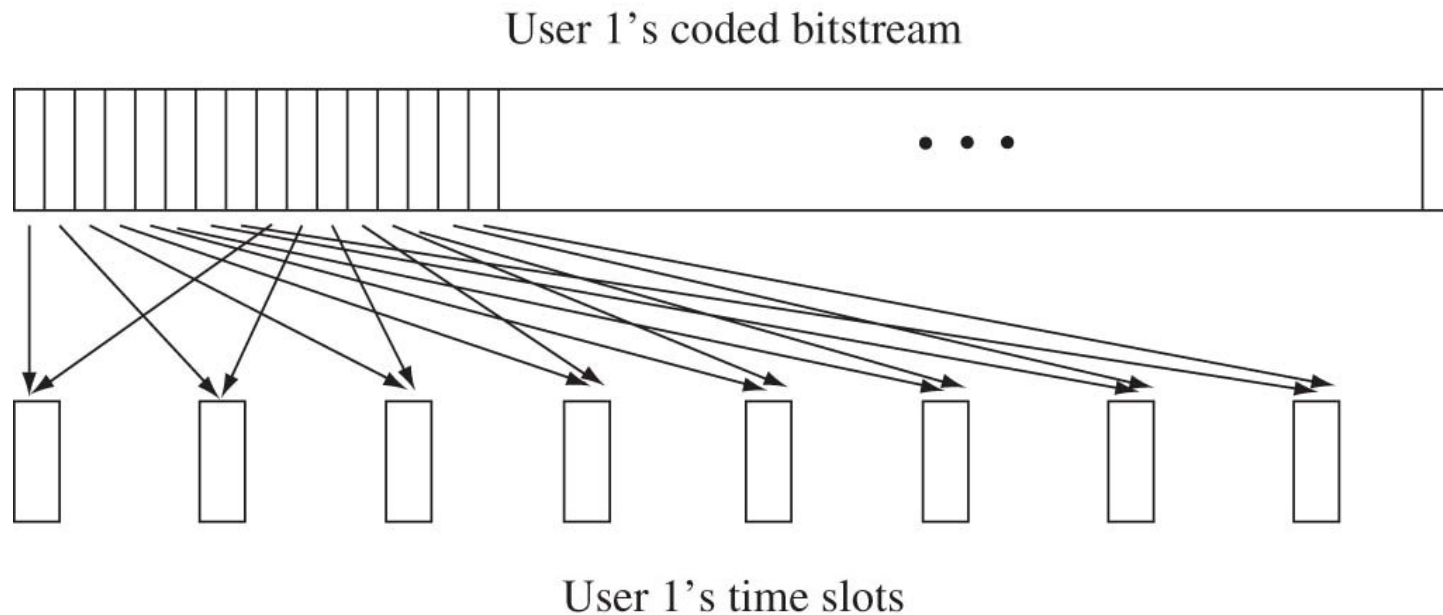
$$2\pi f \frac{d_1 - d_2}{c} + \pi = 2\pi \frac{d_1 - d_2}{\lambda} + \pi$$

Time Diversity

- Time diversity can be obtained by **interleaving** and **coding** over symbols across different coherent time periods



Example: GSM

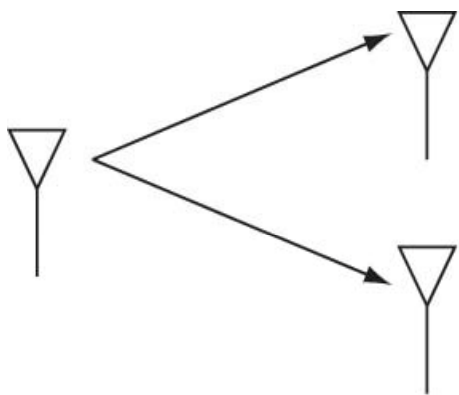


- Amount of time diversity limited by delay constraint and how fast channel varies
- In GSM, delay constraint is 40 ms (voice)

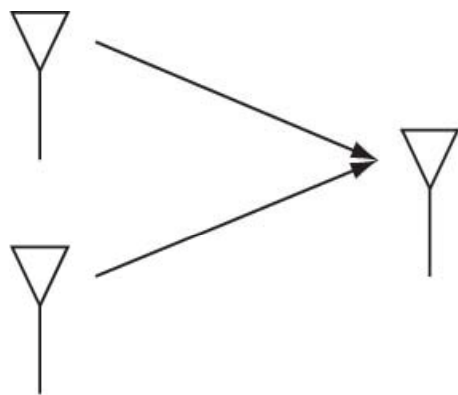
Beyond Repetition Coding

- Repetition coding gets full diversity, but sends only one symbol every L symbol times
- We can use other codes, e.g. Reed-Solomon code
- A detour to coding theory and Reed-Solomon code.

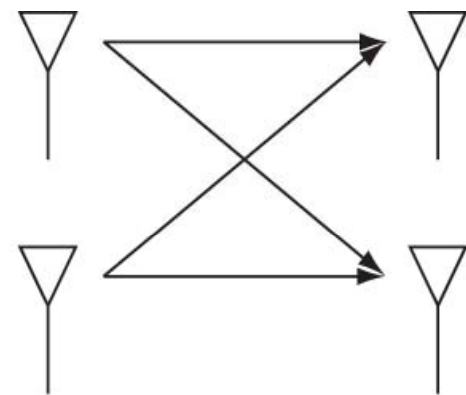
Space Diversity: Antenna



(a)
Receive



(b)
Transmit



(c)
Both

User Diversity: Cooperative Diversity

- Different users can form a distributed antenna array to help each other in increasing diversity
- Interesting characteristics:
 - users have to exchange information and this consumes bandwidth
 - broadcast nature of the wireless medium can be exploited
- MIMO: Multiple input multiple output

Frequency Diversity: FHSS (Frequency Hopping Spread Spectrum)

- ❑ Discrete changes of carrier frequency
 - sequence of frequency changes determined via pseudo random number sequence
 - used in 802.11, GSM, etc
- ❑ Co-inventor: Hedy Lamarr
 - patent# 2,292,387
issued on August 11, 1942
 - make it hard for enemies to detect or jam
 - used a piano roll to change between 88 frequencies

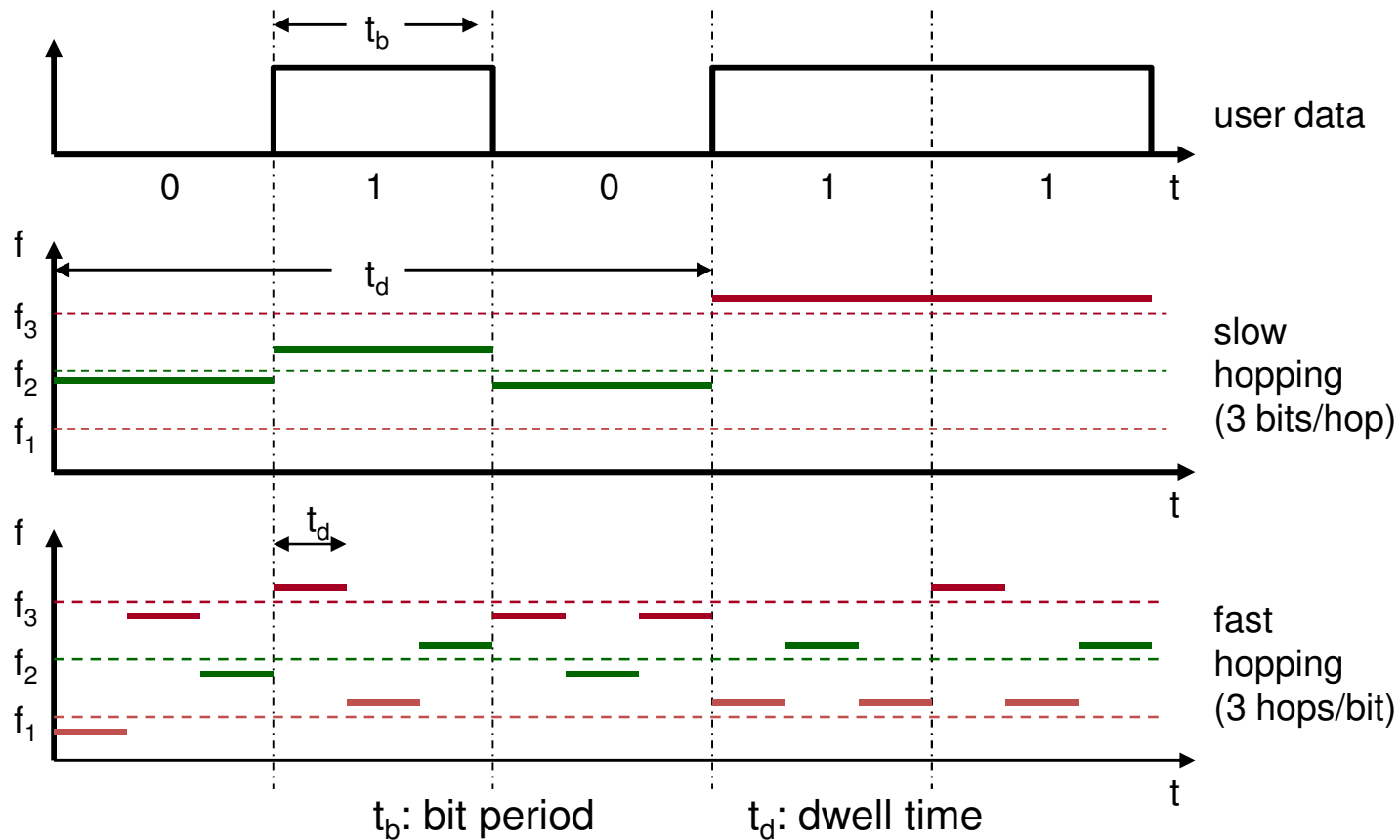


http://en.wikipedia.org/wiki/Hedy_Lamarr

Frequency Diversity: FHSS (Frequency Hopping Spread Spectrum)

Two versions

- slow hopping: several user bits per frequency
- fast hopping: several frequencies per user bit



FHSS: Advantages

- ❑ Frequency selective fading and interference limited to short period
- ❑ Simple implementation
- ❑ Uses only small portion of spectrum at any time
 - explores frequency **sequentially**

Direct Sequence Spread Spectrum (DSSS)

- One symbol is spread to multiple chips
 - the number of chips is called the expansion factor
- The increased rate provides frequency diversity (explores frequency in **parallel**)

DSSS Encoding

chip:

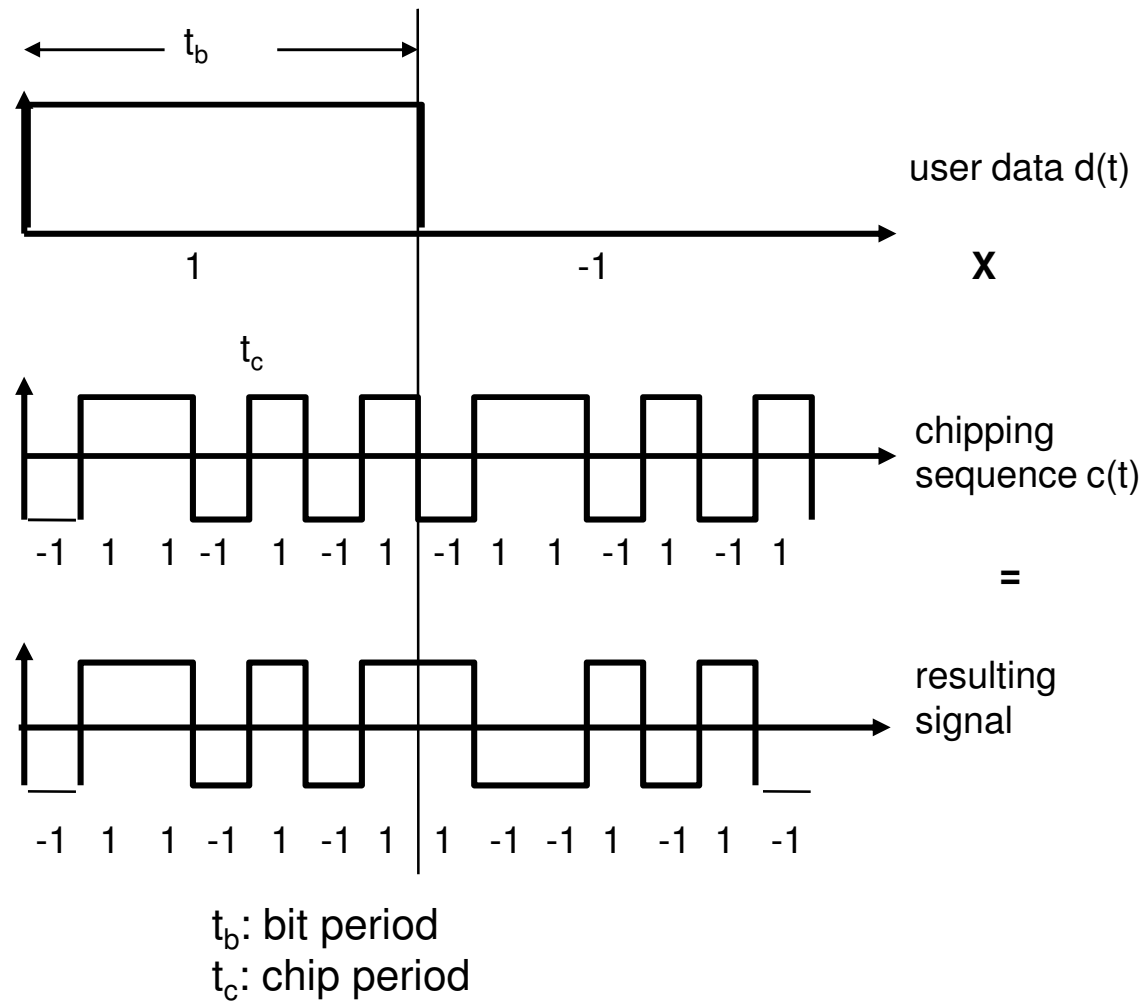
-1 1 1 -1 1 -1

Data: [1 -1]

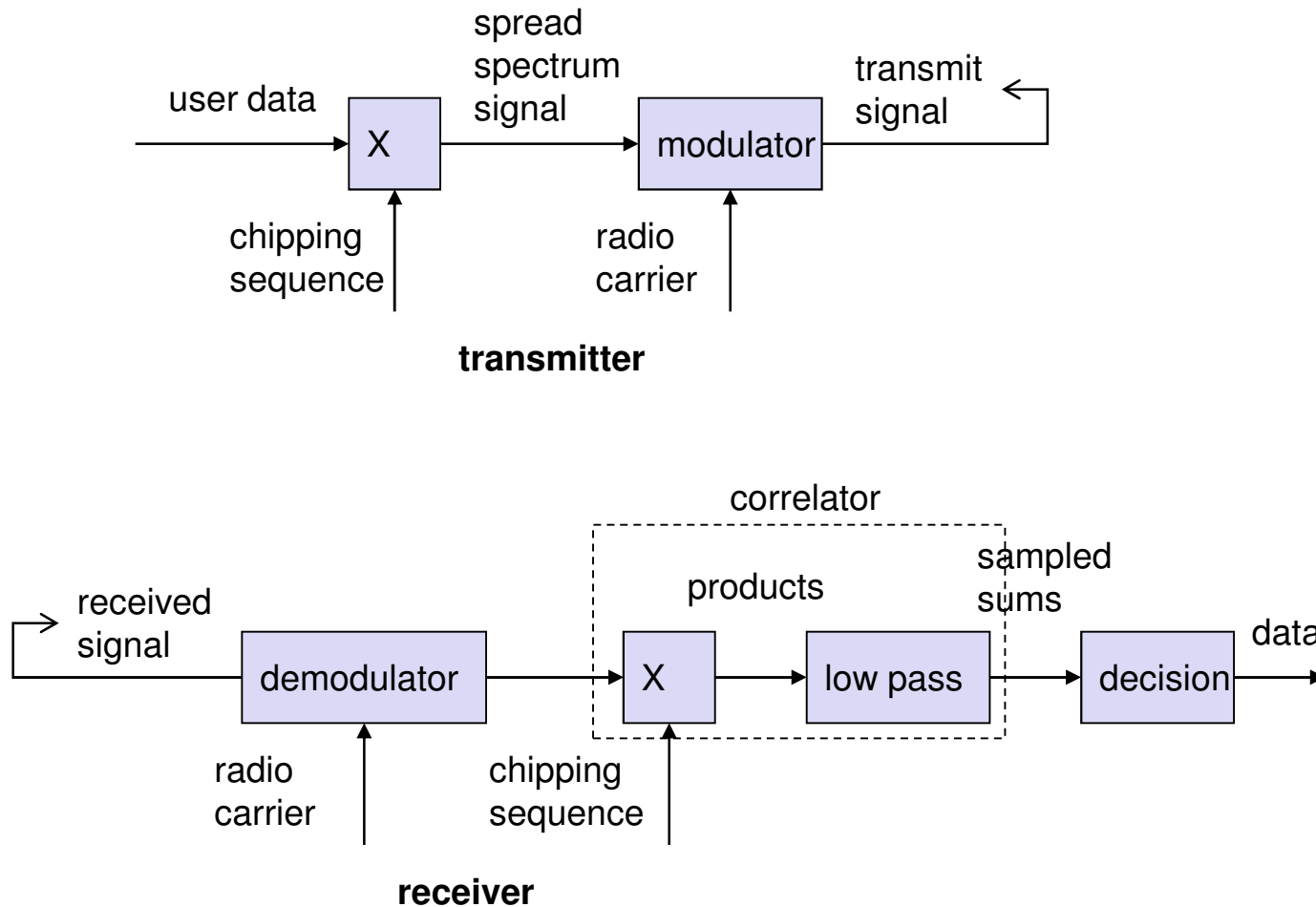
-1 1 1 -1 1 -1

1 -1 -1 1 -1 1

DSSS Encoding



DSSS System Blocks



DSSS as a CDMA scheme

- Allows multiple users to share the spectrum if they use different codes/chipping sequence.