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Modulation and Coding

PART II

SPREAD SPECTRUM FUNDAMENTALS

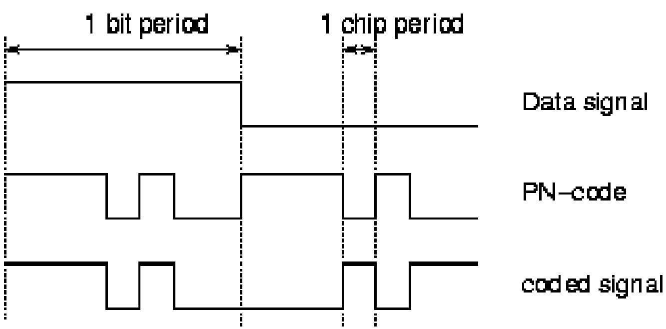
Spread Spectrum uses wide band, **noise-like signals**. Because Spread Spectrum signals are noise-like, they are hard to detect, to intercept and to demodulate. Spread signals are intentionally made to have a much wider bandwidth than the information they carry

Spread Spectrum signals are harder to jam (interfere with) than narrowband signals. We call these features **Low Probability of Intercept (LPI)** and **anti-jam (AJ)**

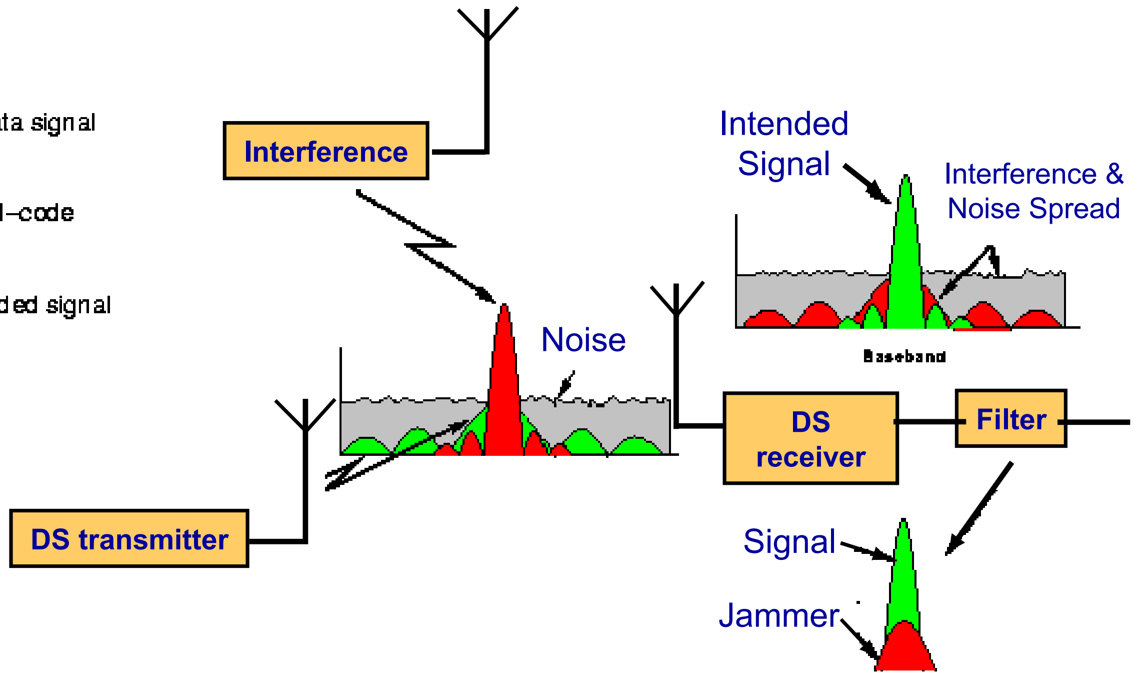
Spread Spectrum signals use fast codes that run many times the information bandwidth or data rate. These special "Spreading" codes are called "Pseudo Random" or **Pseudo Noise codes**. They are called "Pseudo" because they are not completely random.

One of the main advantages of Spread Spectrum schemes is that they allow multiple access techniques based on code-division. By this way, many users can use the same portion of spectrum at the same time. The system main limitation is not bandwidth rather **Multiple User Interference**

SPREAD SPECTRUM FUNDAMENTALS



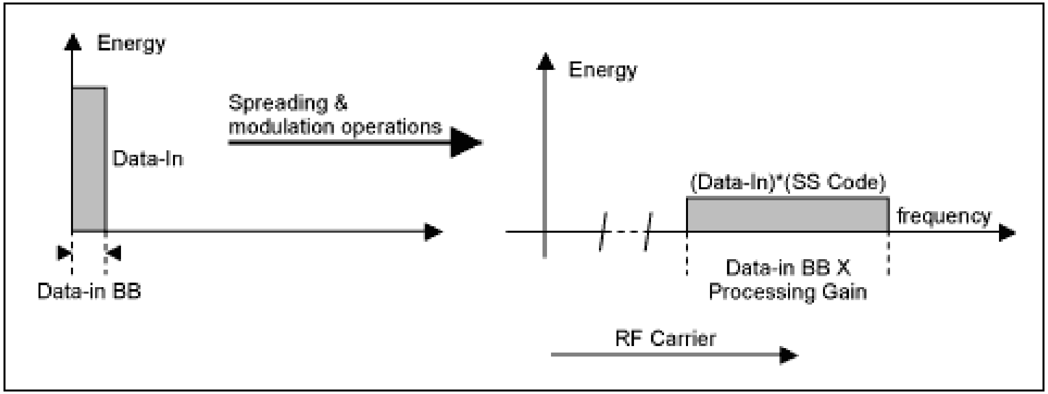
Direct-Sequence spreading



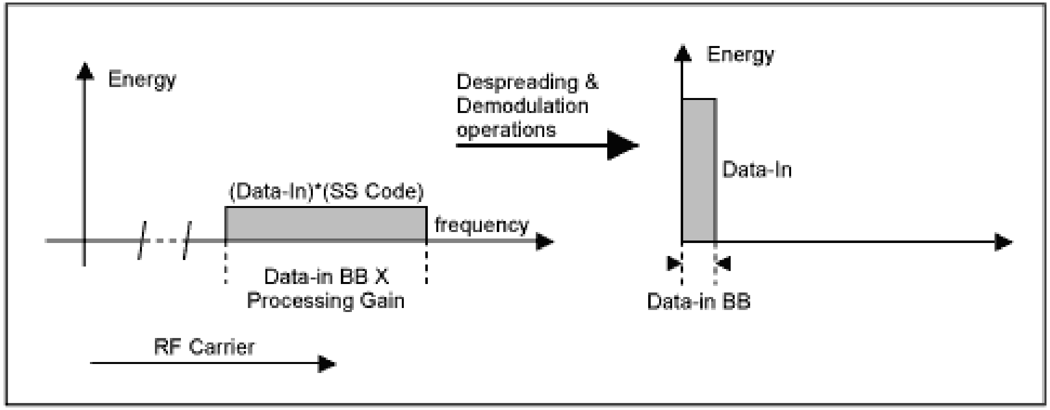
DS-concept, before and after despreading

BANDWIDTH EFFECTS

Spreading

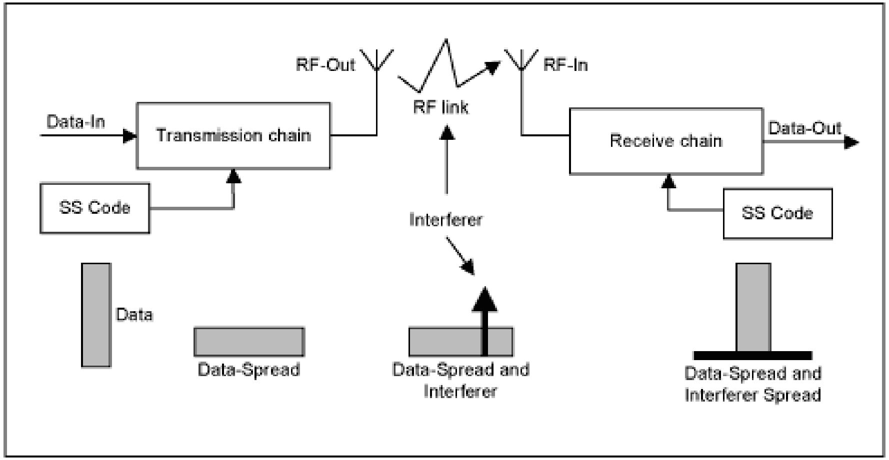


Despreading



Source: An Introduction to Direct-Sequence Spread-Spectrum Communications
http://www.maxim-ic.com/appnotes.cfm/appnote_number/1890

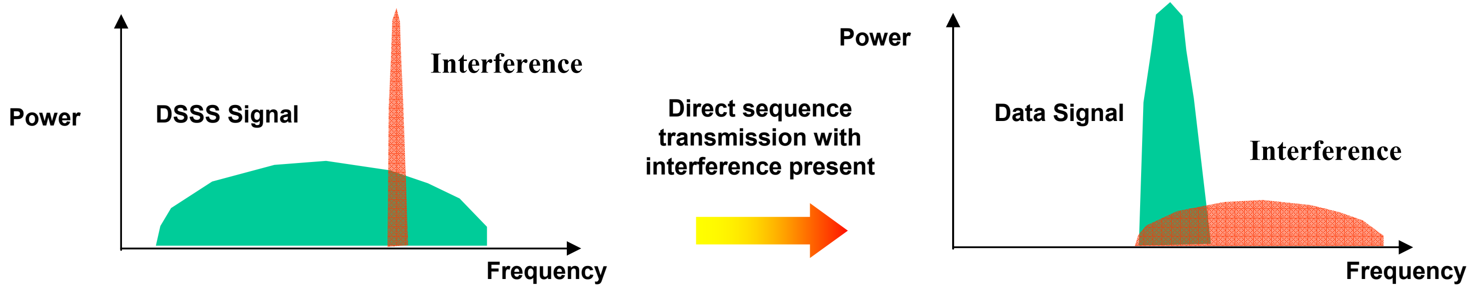
ANTI-JAMMING EFFECTS



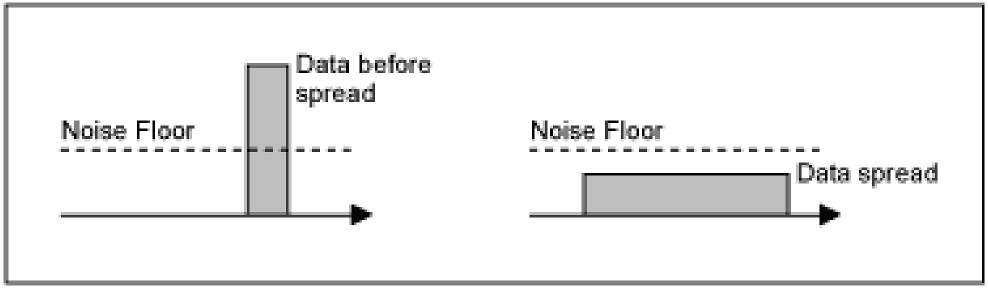
This characteristic is the main advantage of SS. Intentional interference (jamming) or unintentional interference are rejected because they do not use the correct **SS code**.

Only the desired signal, coded with a key known to the receiver, is seen at the receiver when the de-spreading operation is performed.

Rejection also applies to other SS signals not having the right key, allowing for different SS communications to be active simultaneously in the same band. This concept is applied in Code Division Multiple Access (CDMA) systems.



RESISTANCE TO INTERCEPTION

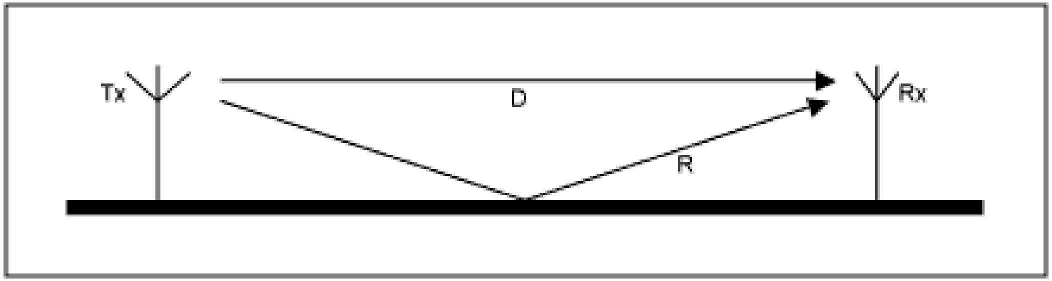


Resistance to interception is the second advantage provided by SS techniques. Because non-authorized listeners do not have the key used to spread the original signal, they cannot decode it.

Without the right key, the SS signal appears as noise or as an interferer (scanning methods can break the code, however, if the key is short.)

Signal levels can be **even below the noise floor**, because the spreading operation reduces the spectral density (total energy is the same, but it is widely spread in frequency). The message is thus made invisible, an effect that is particularly strong with the DSSS technique. Other receivers cannot "see" the transmission; they only register a slight increase in the overall noise level.

RESISTANCE TO MULTI-PATH EFFECTS

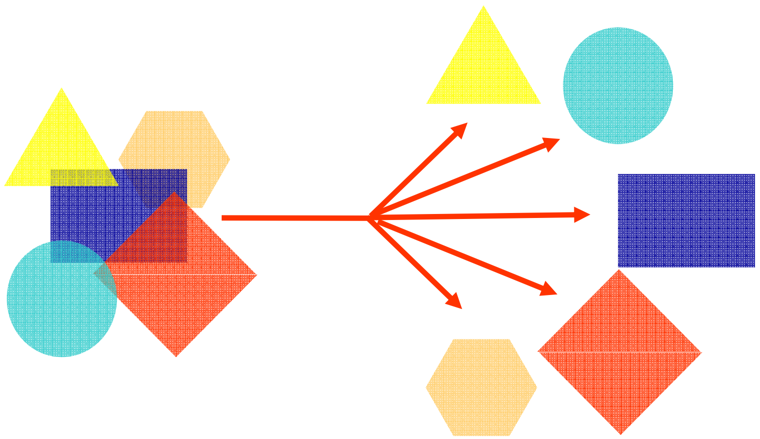


Wireless channels often include **multiple path propagation**, in which the signal has more than one path from transmitter to receiver. Such multi-paths can be caused by atmospheric reflection or refraction, and by reflection from the ground or from objects (e.g. on an indoor channel, furniture, walls…)

The reflected path (R) can interfere with the direct path (D) in a phenomenon called **multipath fading**. Because the de-spreading process synchronizes to signal D, signal R is rejected even though it contains the same key. Methods are available to use the reflected-path signals by de-spreading them and adding the extracted results to the main one.

SS ALLOWS CDMA

SS is not a modulation scheme, and should not be confused with other types of modulation. One can, for example, use SS techniques to transmit a signal modulated via FSK or BPSK. Thanks to the coding basis, SS can also be used for **CDMA (Code Division Multiple Access).**



CDMA access to the air is determined by a key or code. In that sense, spread spectrum is a CDMA access. The key must be defined and known in advance at the transmitter and receiver ends.

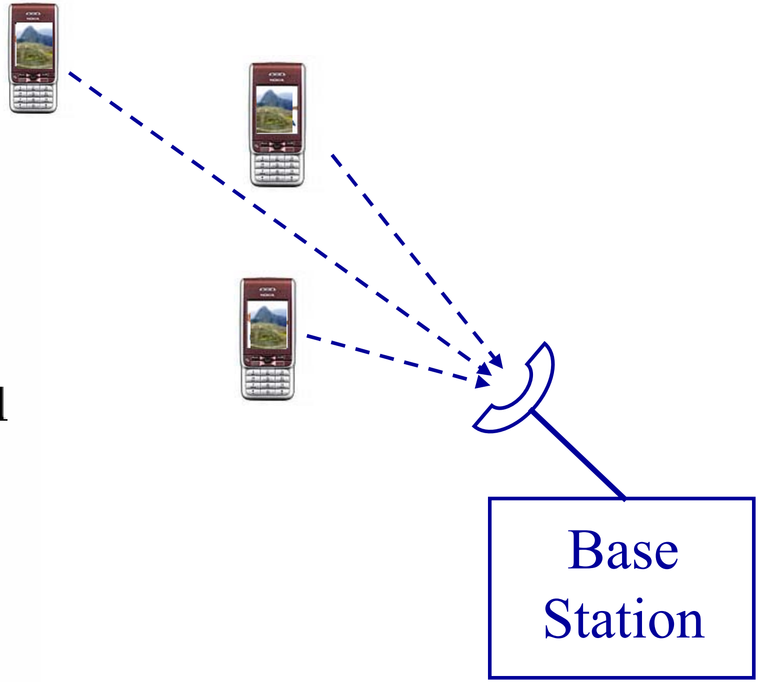
Examples are UMTS and Bluetooth (Frequency Hopping).

NEAR-FAR PROBLEMS IN CDMA

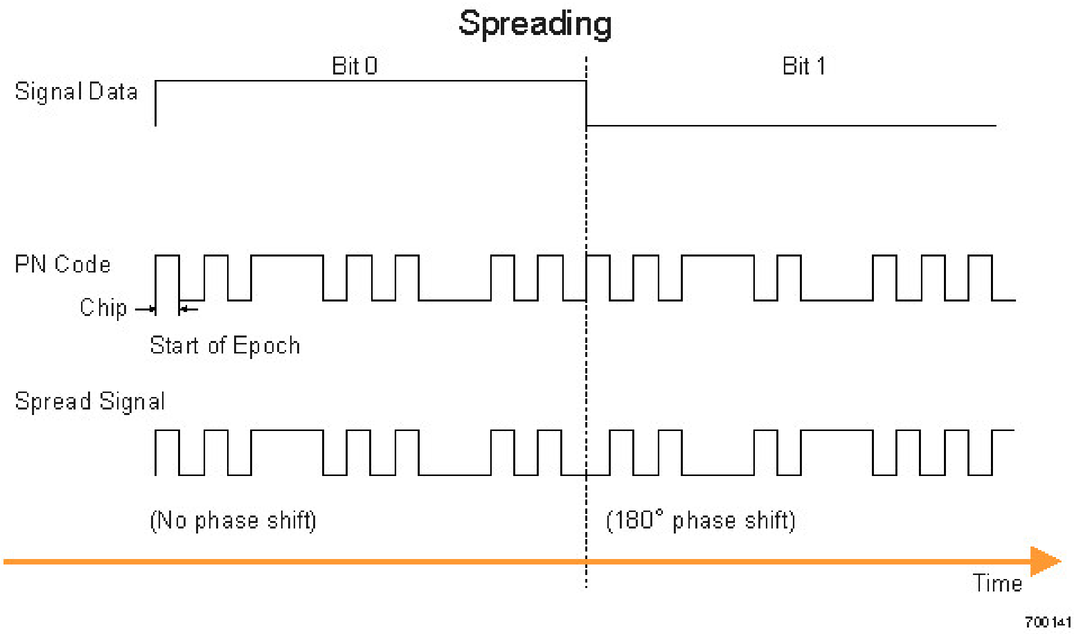
- Users may be received with very different powers:
  - Users near the base station are received with high power
  - Users far from the base station are received with low power
  - For a path loss exponent of 4 and a cell size of 1 km, example:

$$\frac{P_2}{P_1} = \left(\frac{1000}{50}\right)^4 = 160{,}000 = 52dB!$$

  - Nearby users will completely swamp far away users
- Solution: **Power Control**



DIRECT SEQUENCE SS



PROCESSING GAIN

An important concept relating to bandwidth is the **processing gain (G_p).** This is a theoretical system gain that reflects the relative advantage that frequency spreading provides. The processing gain is equal to the ratio of the **bandwidth of the transmitted signal B** to the **data bit rate R_b**

$$G_P = \frac{W}{R_b}$$

There are two major benefits from high processing gain:

- **Interference rejection:** the ability of the system to reject interference is directly proportional to G_p.

- **System capacity:** the capacity of the system is directly proportional to G_p.

Therefore the higher the PN code bit rate (the wider the CDMA bandwidth), the better system performance.

SPREADING CODES

- The spreading code must be unique for each user
- Elements of the code are binary
- Ideally all codes are orthogonal

OPTICAL ORTHOGONAL CODES

Codes created by *L* chips (with *w* ‘*1*’s and the other ‘*0*’s), *w* is named weight. Their parameters are:

L: length (in chips)
w: weight
λ_a: represents the maximum value of self-correlation for any given code of the set, for a shift different from 0 (where self-correlation is 1)
λ_c: maximum cross-correlation between any given couple of codes of the set.

The notation for representing the code is:

C={0,7,9} mod 15 → (1 0 0 0 0 0 0 1 0 1 0 0 0 0 0)

OPTICAL ORTHOGONAL CODES

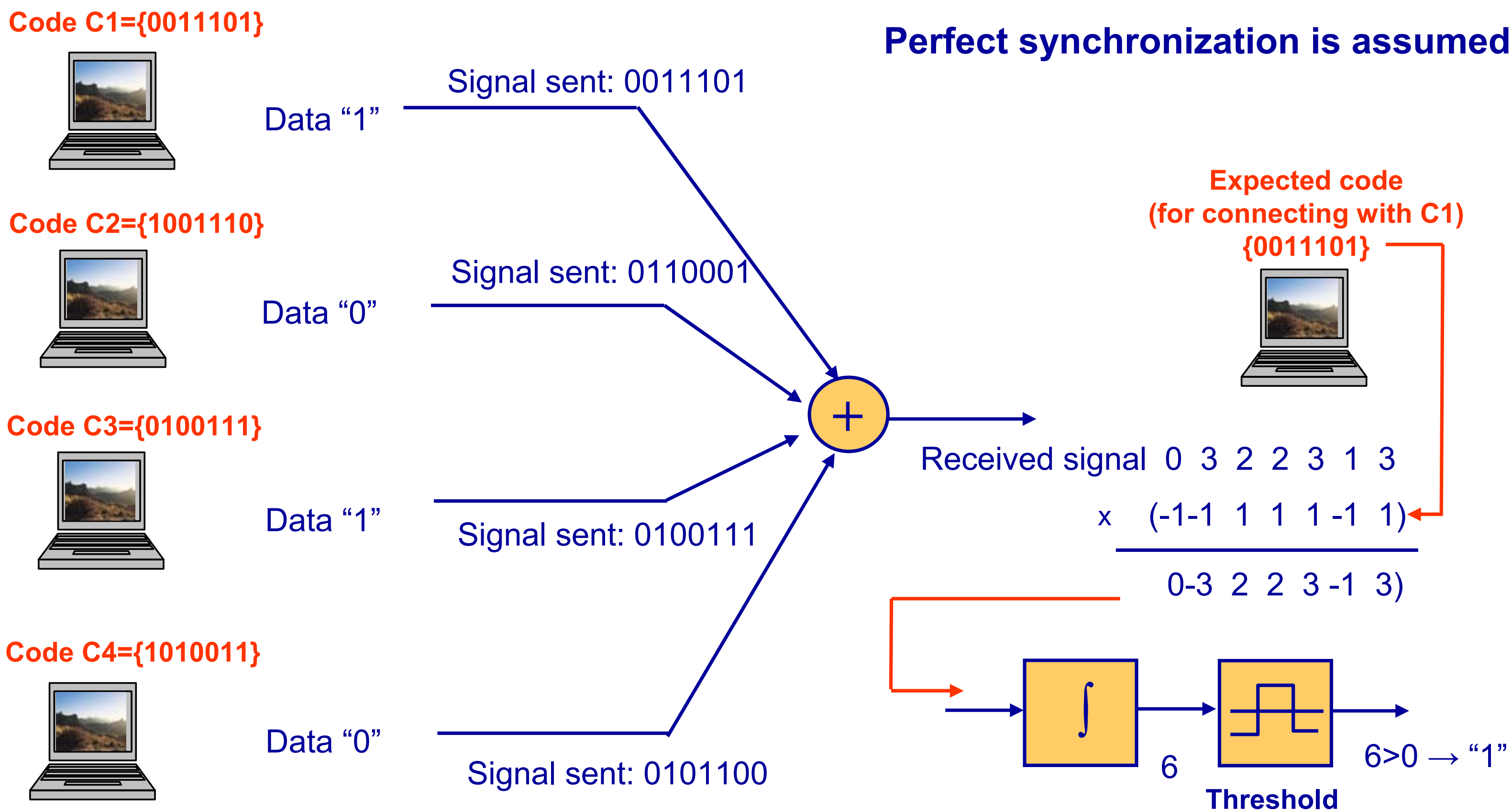
The complete notation should be: (L, w, λ_a, λ_c) or simply (L, w, λ) when λ_a=λ_c=λ.

It is usually combined with OOK modulation

At the receiver, chips expected to be “1” are multiplied by +1, while chips “0” are multiplied by –1. After that, signal is integrated all over the bit time and is compared to a 0-voltage threshold

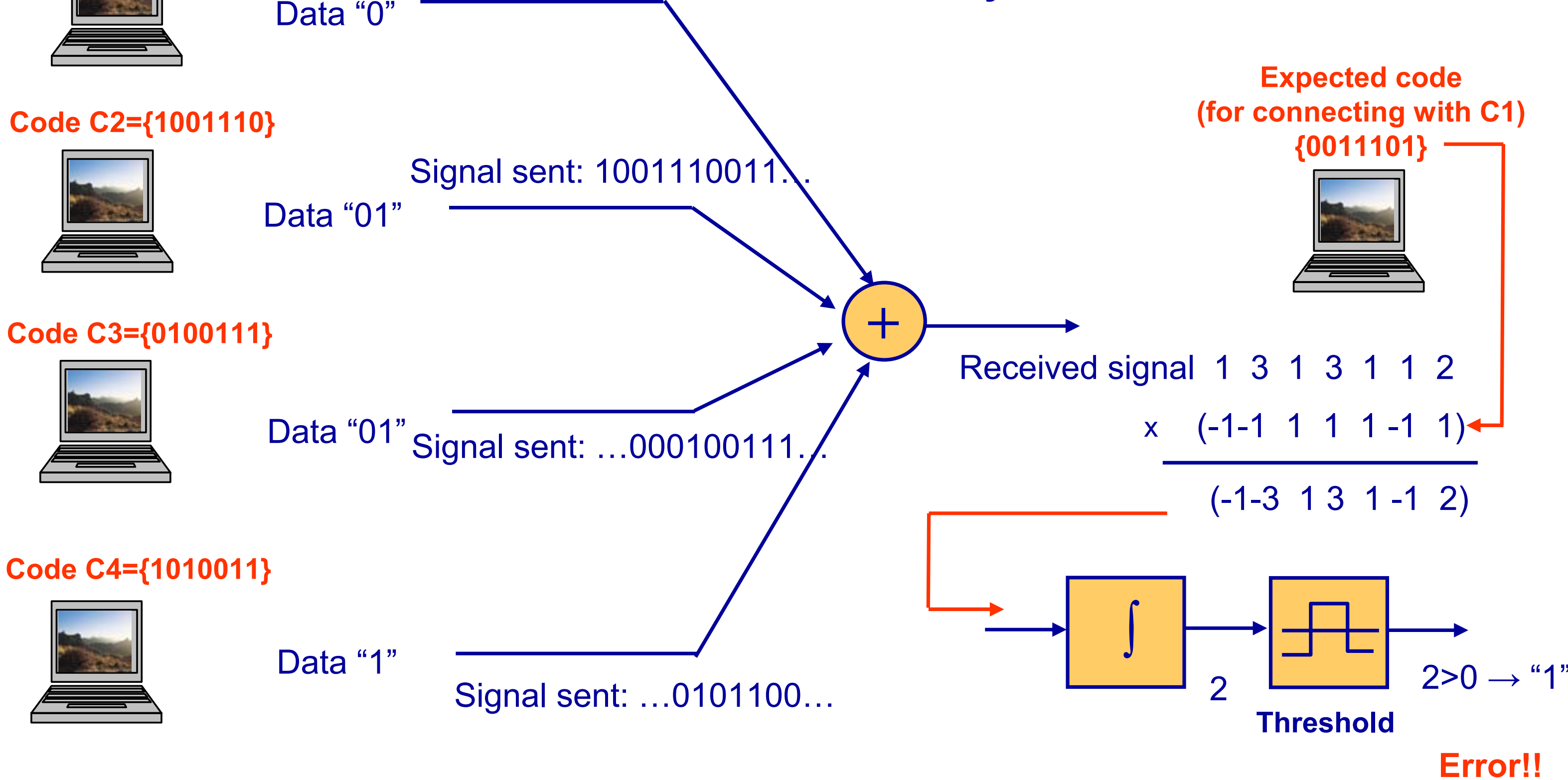
Note that decision is taken after the above operation.

OPTICAL ORTHOGONAL CODES



OPTICAL ORTHOGONAL CODES

Drawbacks: OOC are sensible to Synchronization and MUI.
Non-synchronized transmission



Further Reading

Source: "CDMA tutorial" http://www.bee.net/mhendry/vrml/library/cdma/cdma.htm