CDMA (Part 2)

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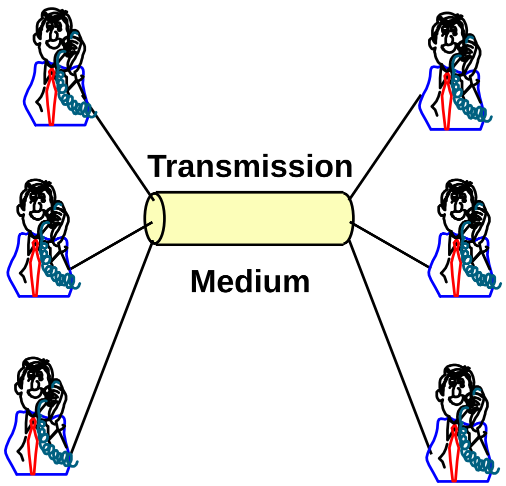
Multiple Access

Multiple Access: **Simultaneous private use of a transmission medium by multiple, independent users.**

Since the beginning of telephony and radio, system operators have tried to squeeze the maximum amount of traffic over each circuit.

- Types of Media -- Examples:
  - Twisted pair - copper
  - Coaxial cable
  - Fiber optic cable
  - **Air interface (radio signals)**
- Advantages of Multiple Access
  - Increased capacity: serve more users
  - Reduced capital requirements since fewer media can carry the traffic
  - Decreased per-user expense
  - Easier to manage and administer



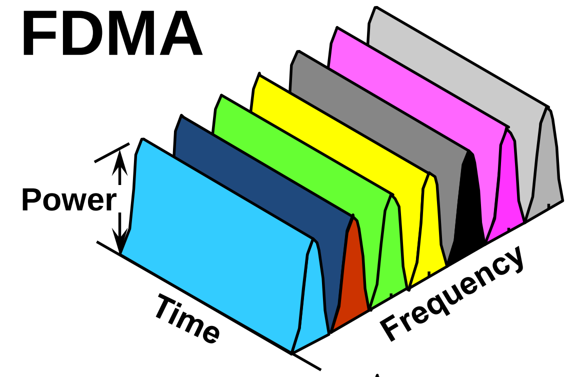
Each pair of users enjoys a dedicated, private circuit through the transmission medium, unaware that the other users exist.

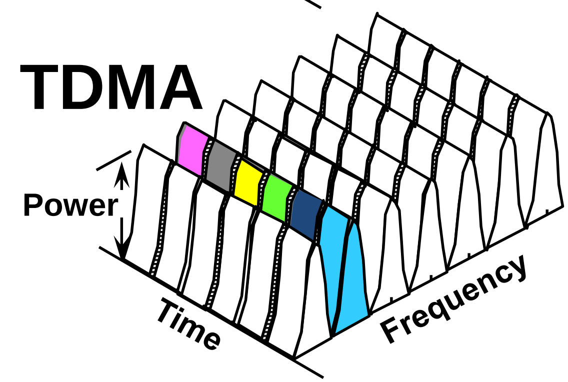
Channels

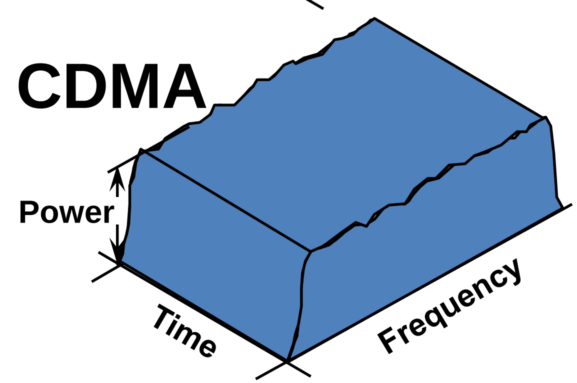
Channel: An individually-assigned, dedicated pathway through a transmission medium for one user's information.

The transmission medium is a resource that can be subdivided into individual channels according to the technology used.

- **FDMA Frequency Division Multiple Access**
  - Each user on a different frequency
  - A channel is a frequency
- **TDMA Time Division Multiple Access**
  - Each user on a different window period in time ("time slot")
  - A channel is a specific time slot on a specific frequency
- **CDMA Code Division Multiple Access**
  - A channel is a unique code pattern
  - Each user uses the same frequency all the time, but mixed with different distinguishing code patterns

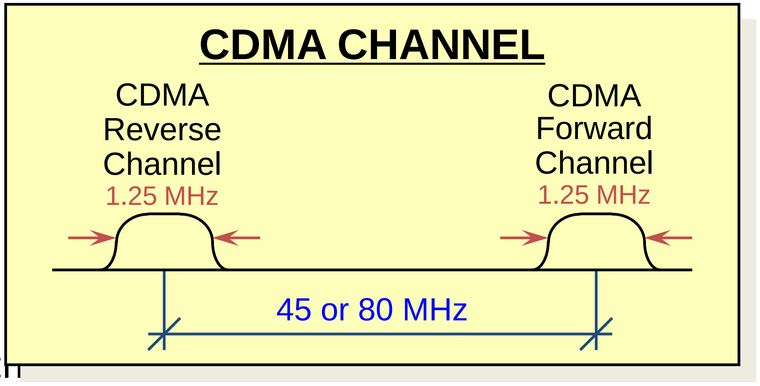






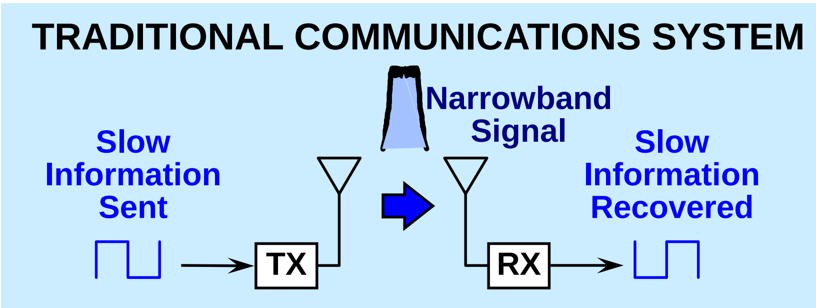
Defining Our Terms

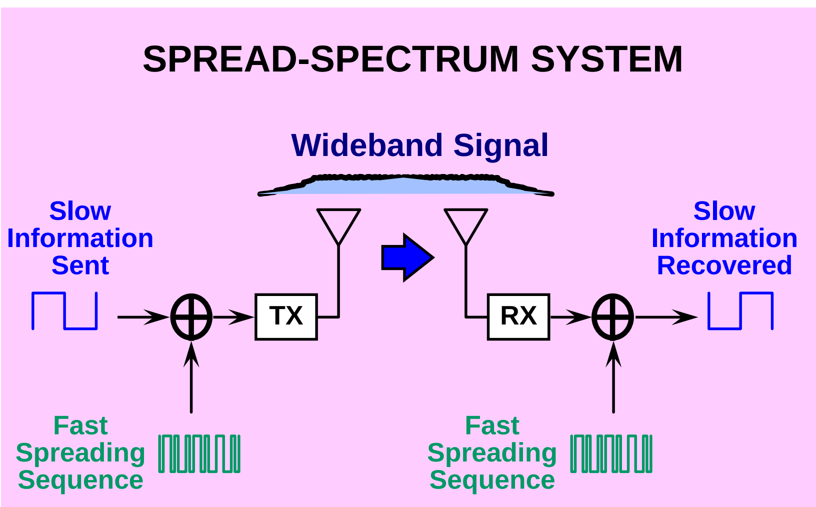
- **<u>CDMA Channel</u> or <u>CDMA Carrier</u> or <u>CDMA Frequency</u>**
  - Duplex channel made of two 1.25 MHz-wide bands of electromagnetic spectrum, one for Base Station to Mobile Station communication (called the <u>FORWARD LINK</u> or the <u>DOWNLINK</u>) and another for Mobile Station to Base Station communication (called the <u>REVERSE LINK</u> or the <u>UPLINK</u>)
  - In 800 Cellular these two simplex 1.25 MHz bands are 45 MHz apart
  - In 1900 MHz PCS they are 80 MHz apart
- **<u>CDMA Forward Channel</u>**
  - 1.25 MHz Forward Link
- **<u>CDMA Reverse Channel</u>**
  - 1.25 MHz Reverse Link



- **<u>CDMA Code Channel</u>**
  - Each individual stream of 0's and 1's contained in eith
    CDMA Reverse Channel
  - Code Channels are characterized (made unique) by mathematical codes
  - Code channels in the forward link: Pilot, Sync, Paging and Forward Traffic channels
  - Code channels in the reverse link: Access and Reverse Traffic channels

CDMA Is a Spread-Spectrum System

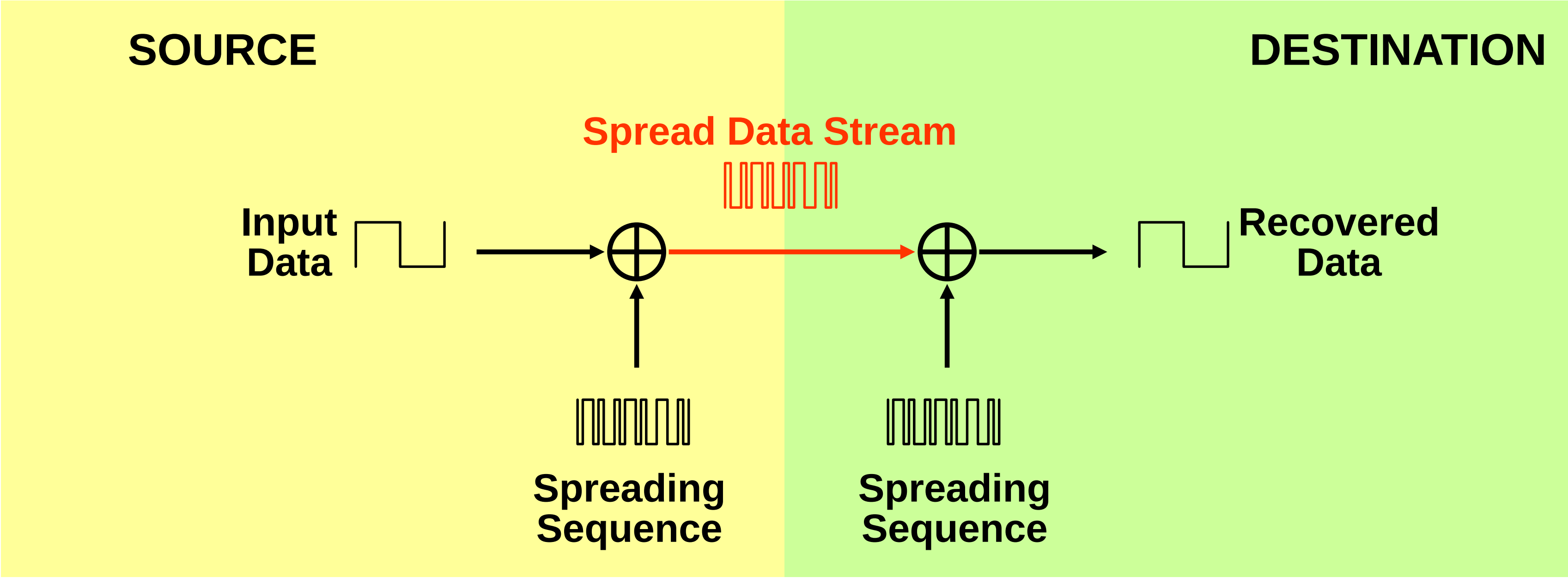




Spread Spectrum Payoff:
Processing Gain

- Traditional technologies try to squeeze the signal into the minimum required bandwidth
- Direct-Sequence Spread spectrum systems mix their input data with a fast spreading sequence and transmit a wideband signal
- The spreading sequence is independently regenerated at the receiver and mixed with the incoming wideband signal to recover the original data

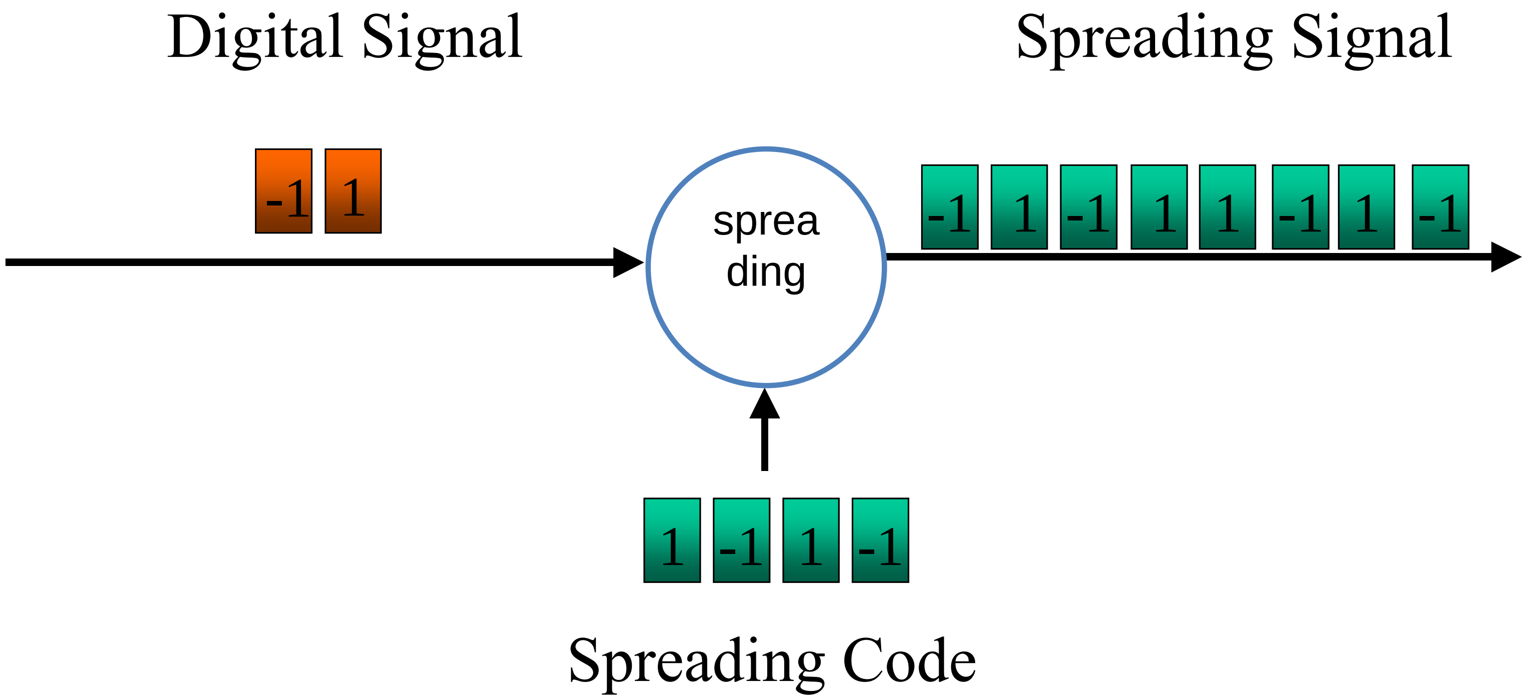
What is Spread Spectrum



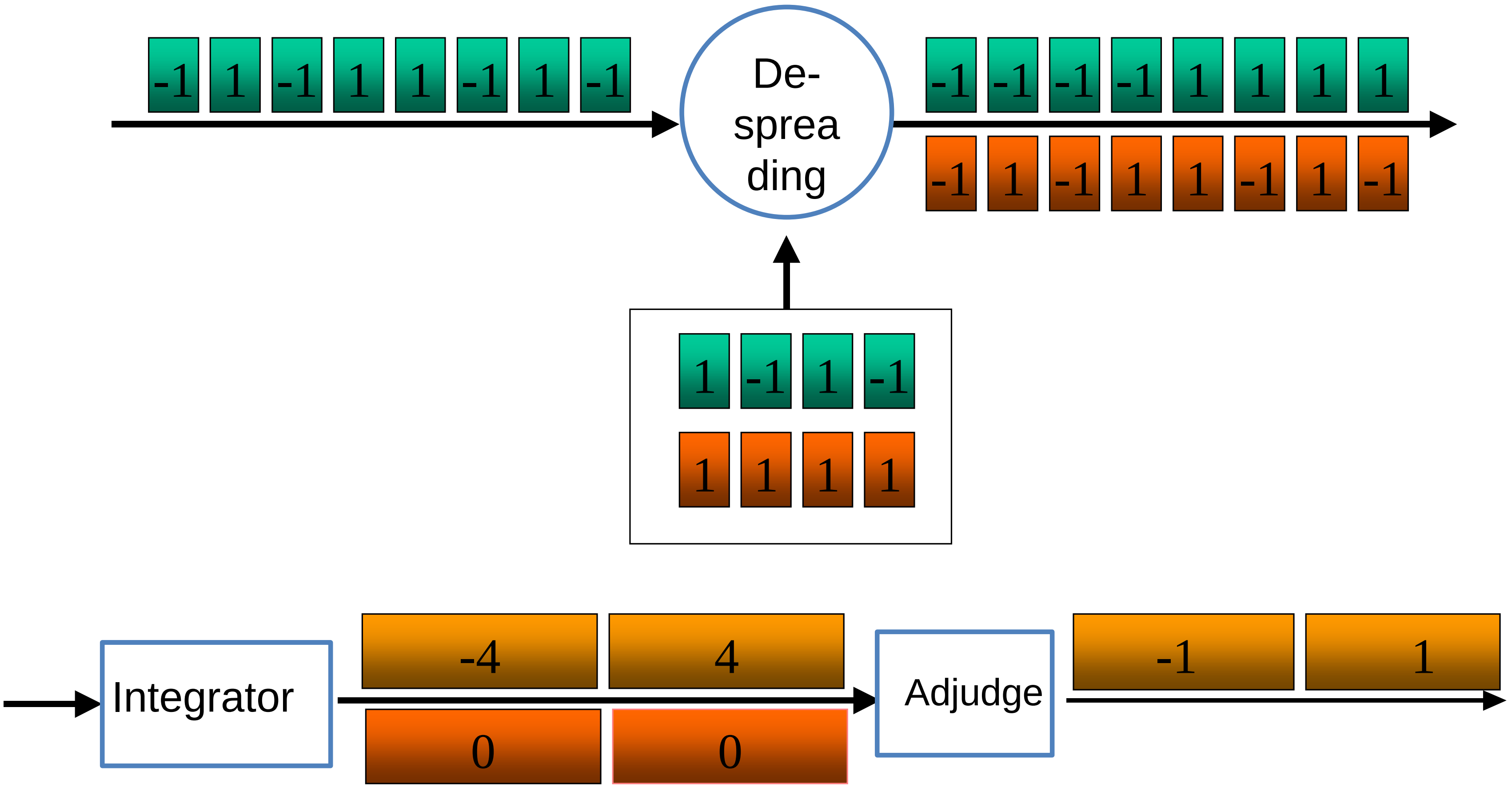
Definition:Spread spectrum technique ,employ a transmission bandwidth that is several orders of magnitude greater than the minimum required signal bandwidth.

- Sender combines data with a fast spreading sequence,transmits spread data stream
- Receiver intercepts the stream,uses same spreading sequence to extract original data

Spread Process



De-spread Process



Spread Spectrum Principles

SHANON Formula

$$C=B*\log_2(1+S/N)$$

Where,

C is capacity of channel, b/s

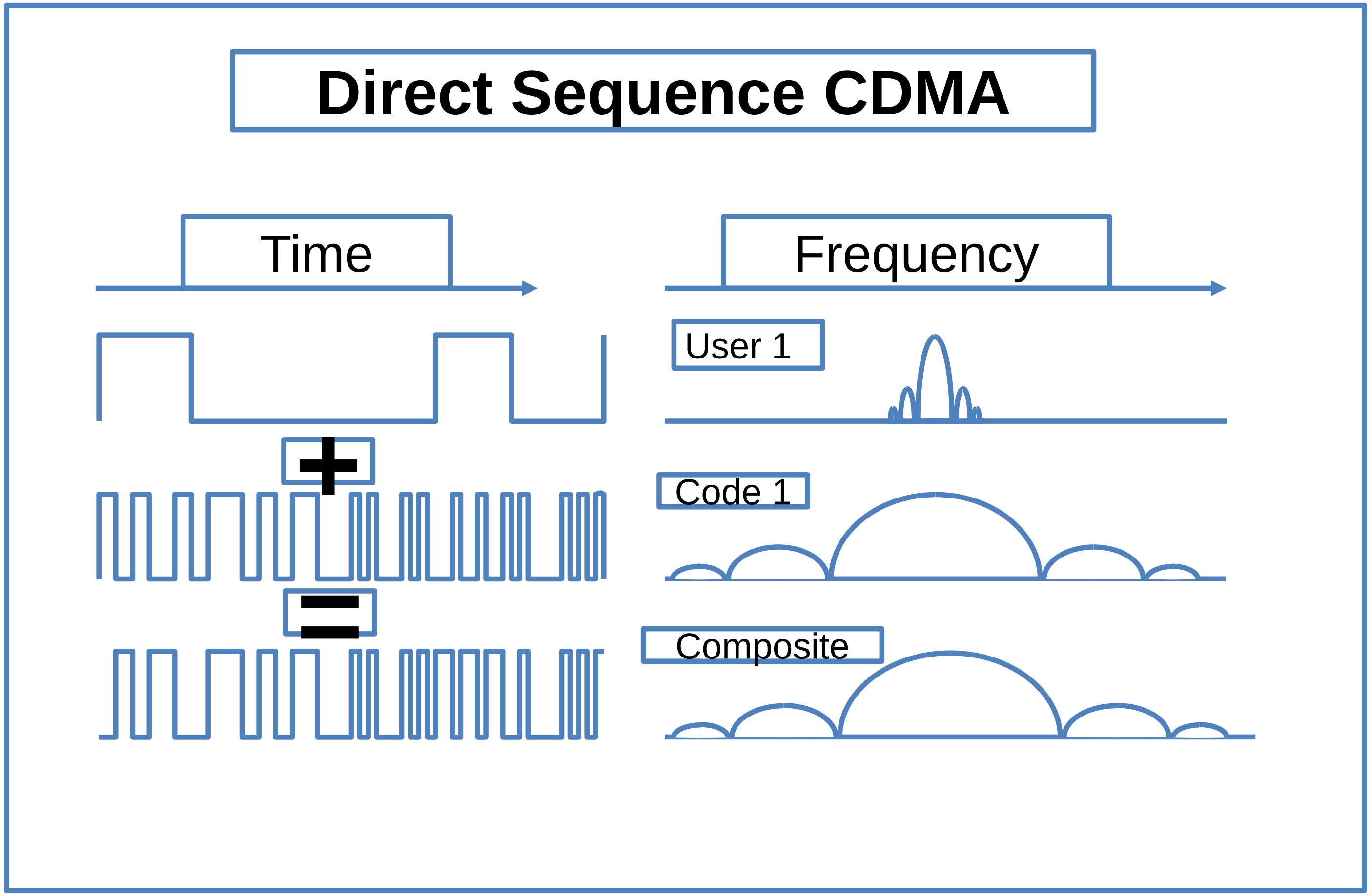
B is signal bandwidth, Hz

S is average power for signal

N is average power for noise

It is the landmark paper of information theory, a mathematical theory of spectrum communication.

How DSSS Spectrum Change



Spectrum Variation of Spread & De-spread

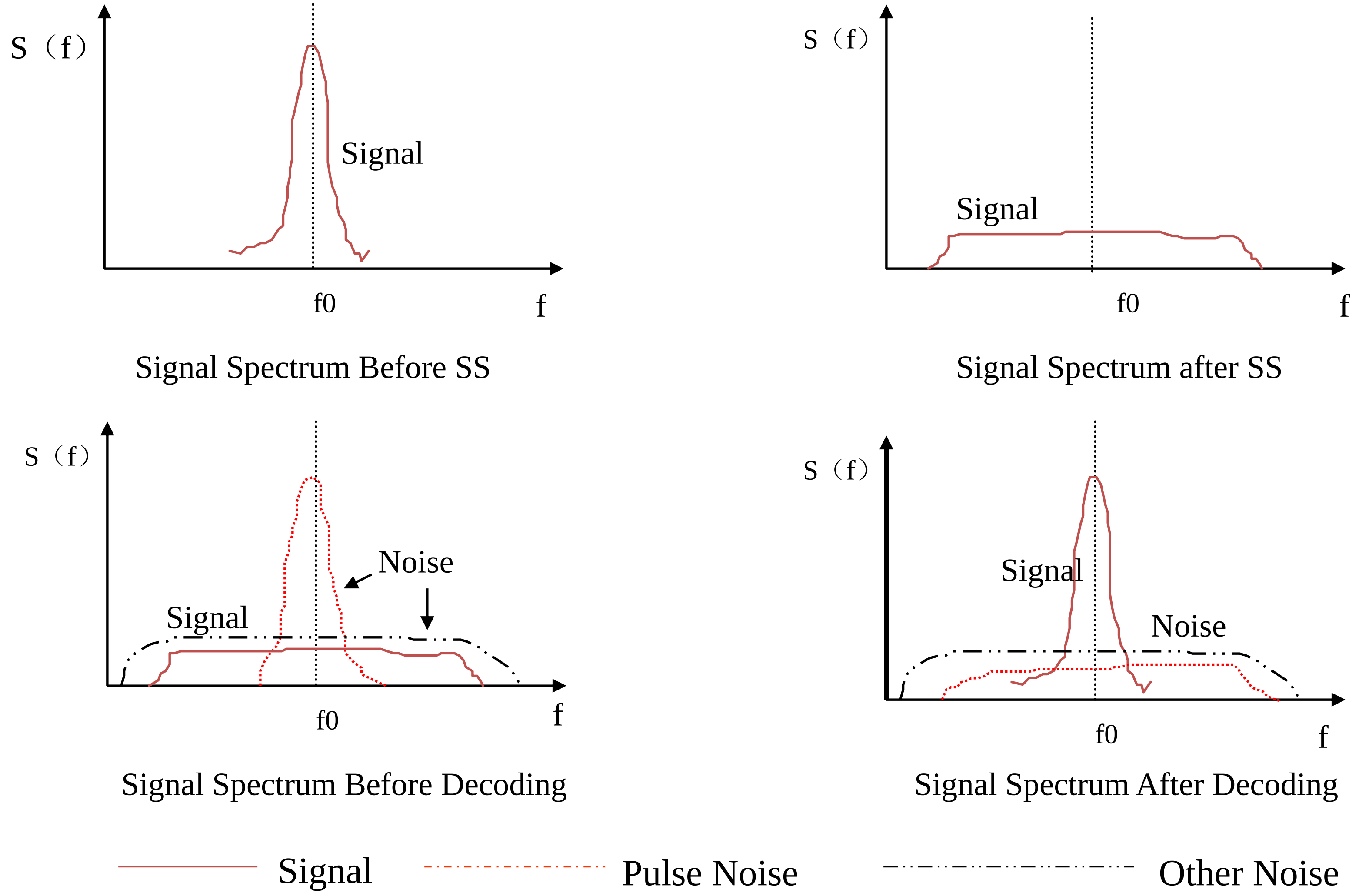


Illustration to SS Principle(1)

Power is “Spread” Over a Larger Bandwidth

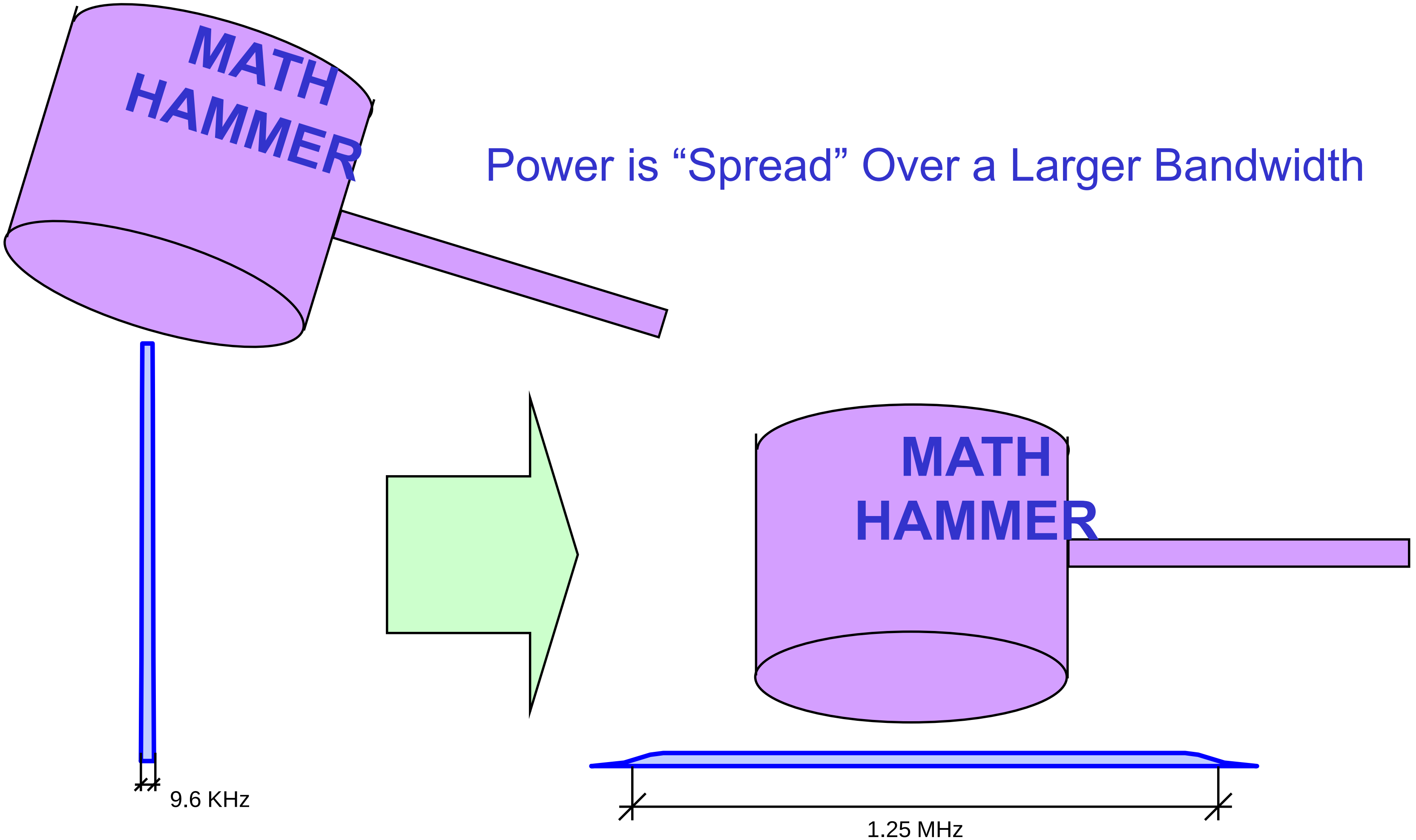
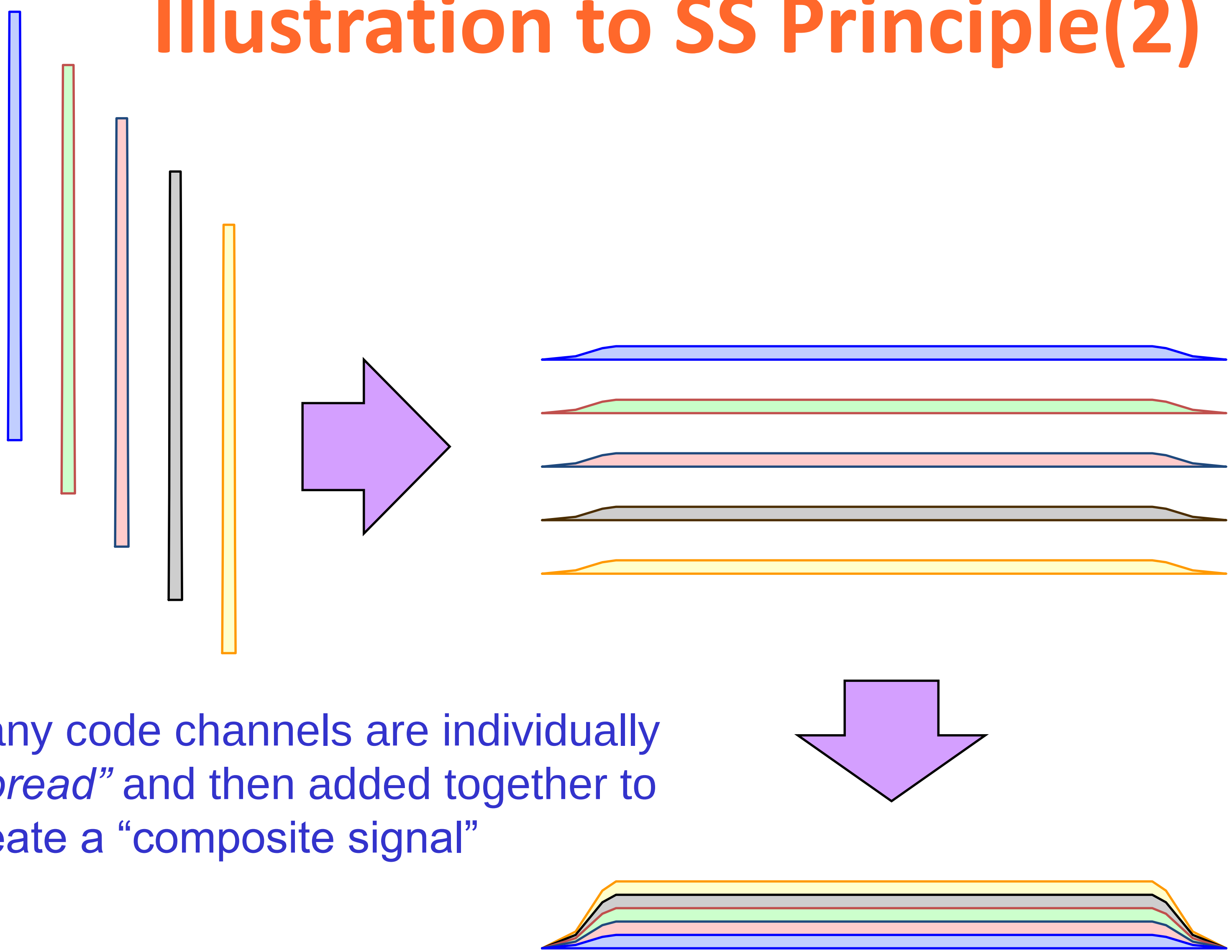


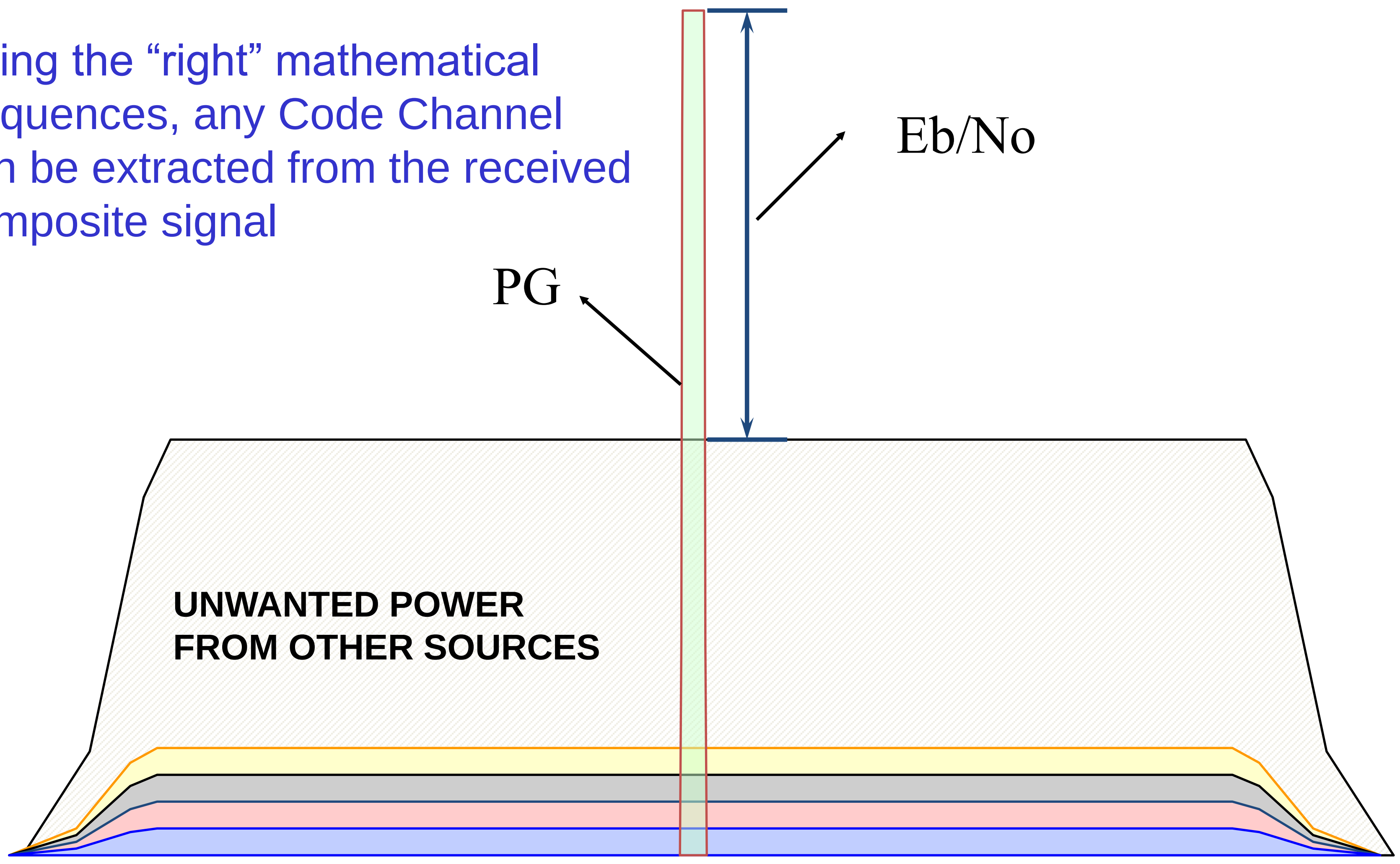
Illustration to SS Principle(2)



Many code channels are individually *"spread"* and then added together to create a "composite signal"

Illustration to SS Principle(3)

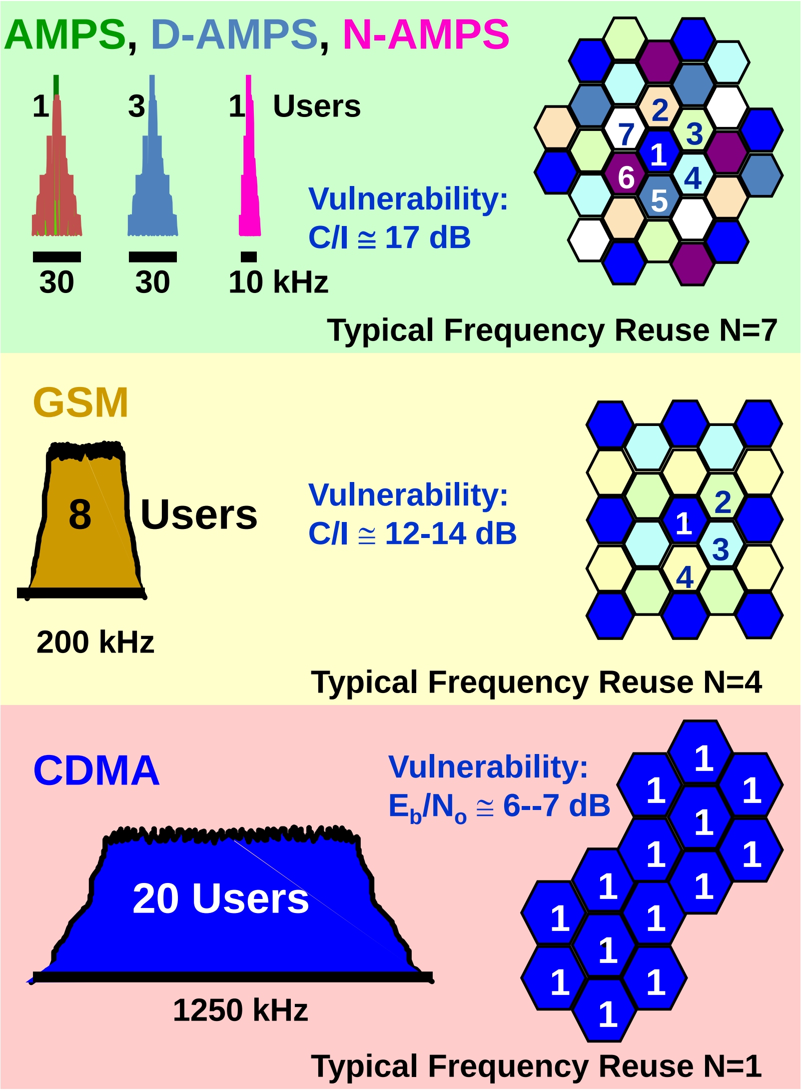
Using the "right" mathematical Sequences, any Code Channel can be extracted from the received composite signal



Spectrum Usage and Capacity:

- Each wireless technology (AMPS, NAMPS, D-AMPS, GSM, CDMA) uses a specific modulation type with its own unique signal characteristics
- The total traffic capacity of a wireless system is determined largely by radio signal characteristics and RF design
- RF signal vulnerability to Interference dictates how much interference can be tolerated, and therefore how far apart same-frequency cells must be spaced
- For a specific S/N level, the Signal Bandwidth determines how many RF signals will "fit" in the operator's licensed spectrum

$$17 \text{ dB} = 10^{1.7} \cong 50$$
$$14 \text{ dB} = 10^{1.4} \cong 25$$
$$12 \text{ dB} = 10^{1.2} \cong 16$$



Relationship Between E_b/N_0 and S/N

$$E_b = \left(\frac{\text{Signal Power}}{\text{Bit Rate}}\right) = \left(\frac{S}{R}\right) = \left(\frac{E/t}{B/t}\right)$$

$$N_0 = \left(\frac{\text{Noise Power}}{\text{Bandwidth}}\right) = \left(\frac{N}{W}\right)$$

$$\frac{E_b}{N_0} = \frac{\left(\frac{S}{R}\right)}{\left(\frac{N}{W}\right)} = \left(\frac{S}{R}\right) \times \left(\frac{W}{N}\right) = \left(\frac{S}{N}\right) \times \left(\frac{W}{R}\right)$$

Signal to Noise

Processing Gain

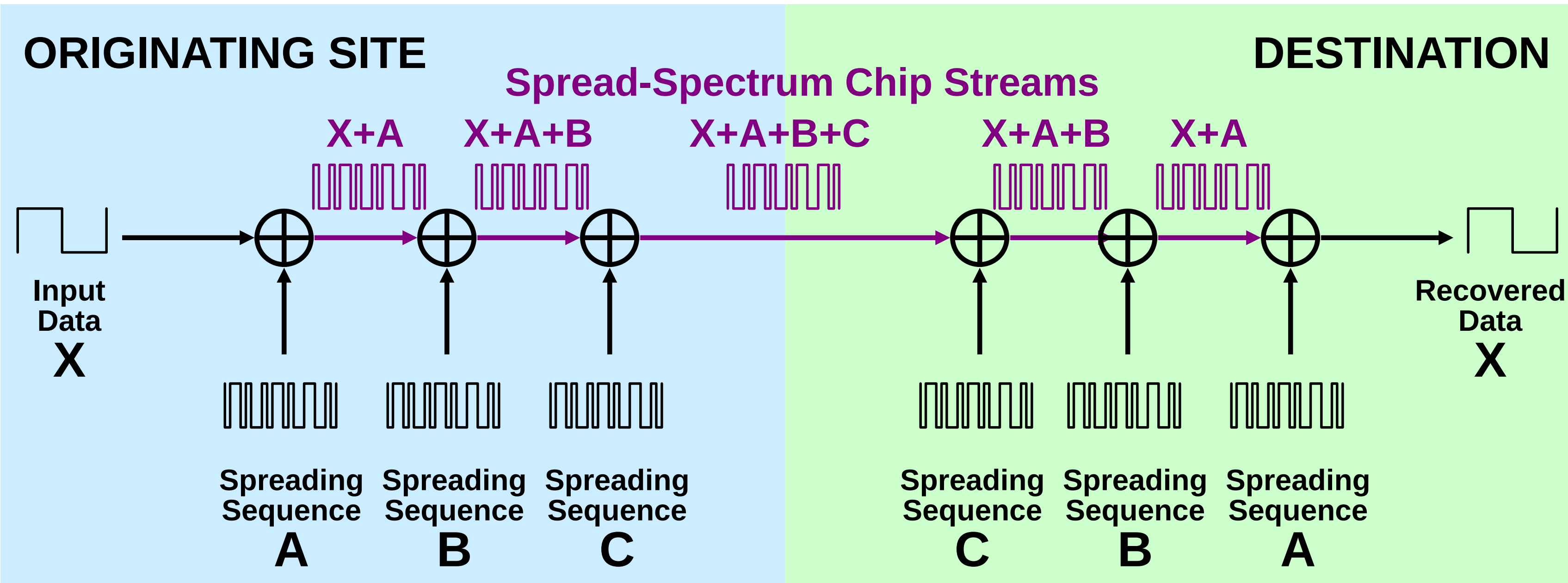
8 Kb vocoder (Full Rate)

$$\frac{W}{R} = \frac{1{,}250{,}000}{9{,}600} = 130 = 10^{2.11} = 21.1\,dB$$

13 Kb vocoder (Full Rate)

$$\frac{W}{R} = \frac{1{,}250{,}000}{14{,}400} = 87 = 10^{1.94} = 19.4\,dB$$

CDMA Spreading Principle Using Multiple Codes

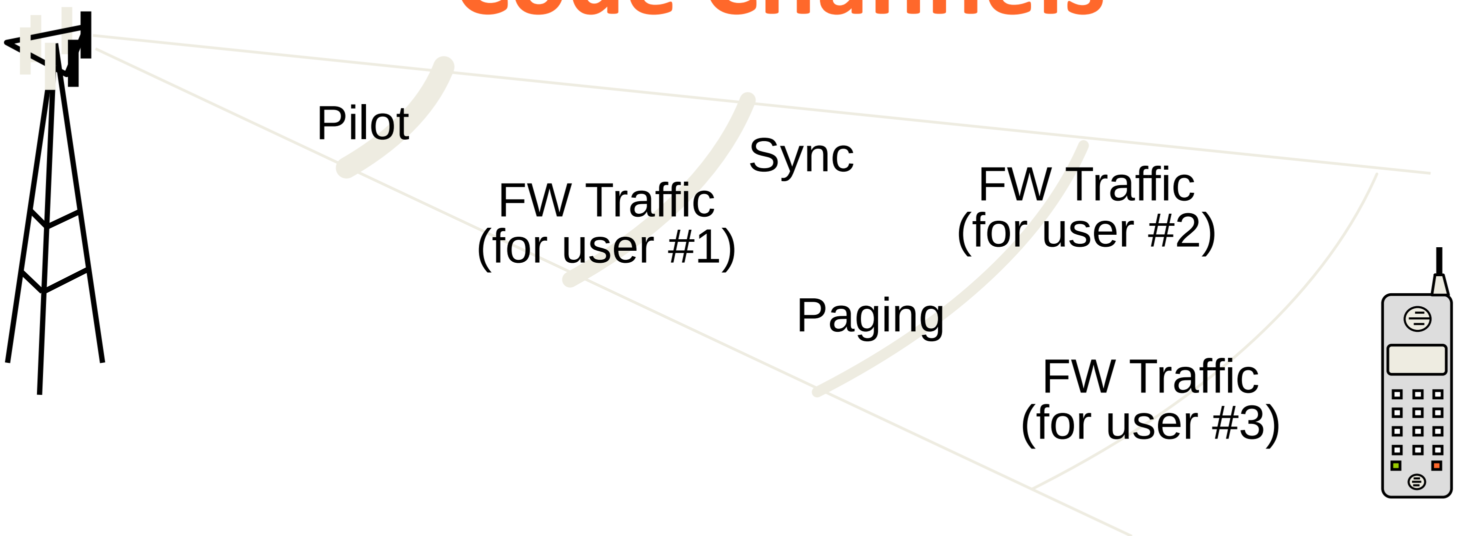


- Multiple spreading sequences can be applied in succession and then reapplied in opposite order to recover the original data stream.
- The spreading sequences can have different desired properties.
- All spreading sequences originally used must be available in proper synchronization at the recovering destination.

Advantages of Spread Spectrum

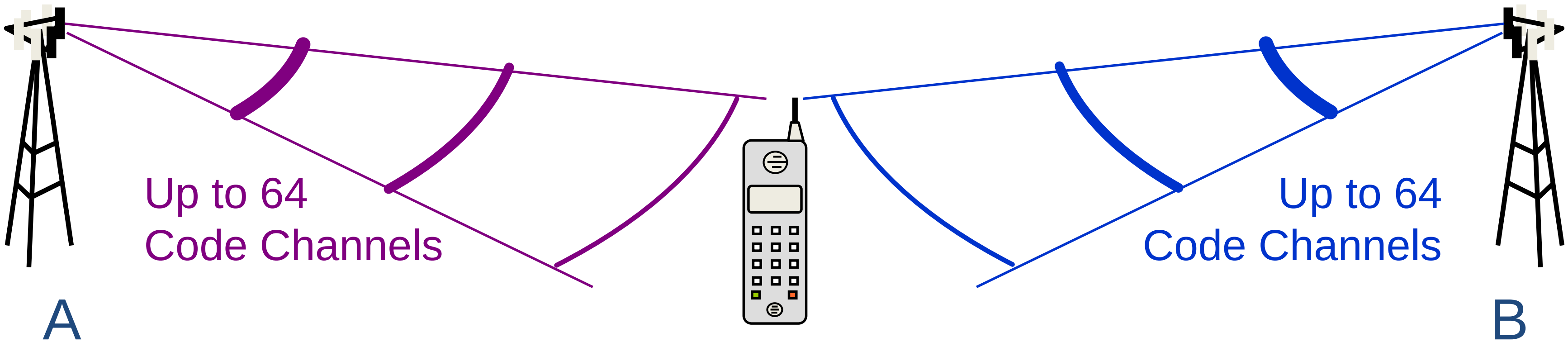
- Avoid interference arising from jamming signal or multi-path effects
  - SS and demodulation, noise is suppressed and filtered
- resist intercept and capture: difficult to detect
- Achieve Privacy: Difficult to demodulate
- Implement Multiple Access
  - Improve Frequency Reuse
  - Enlarge Capacity

Discriminating Among Forward Code Channels



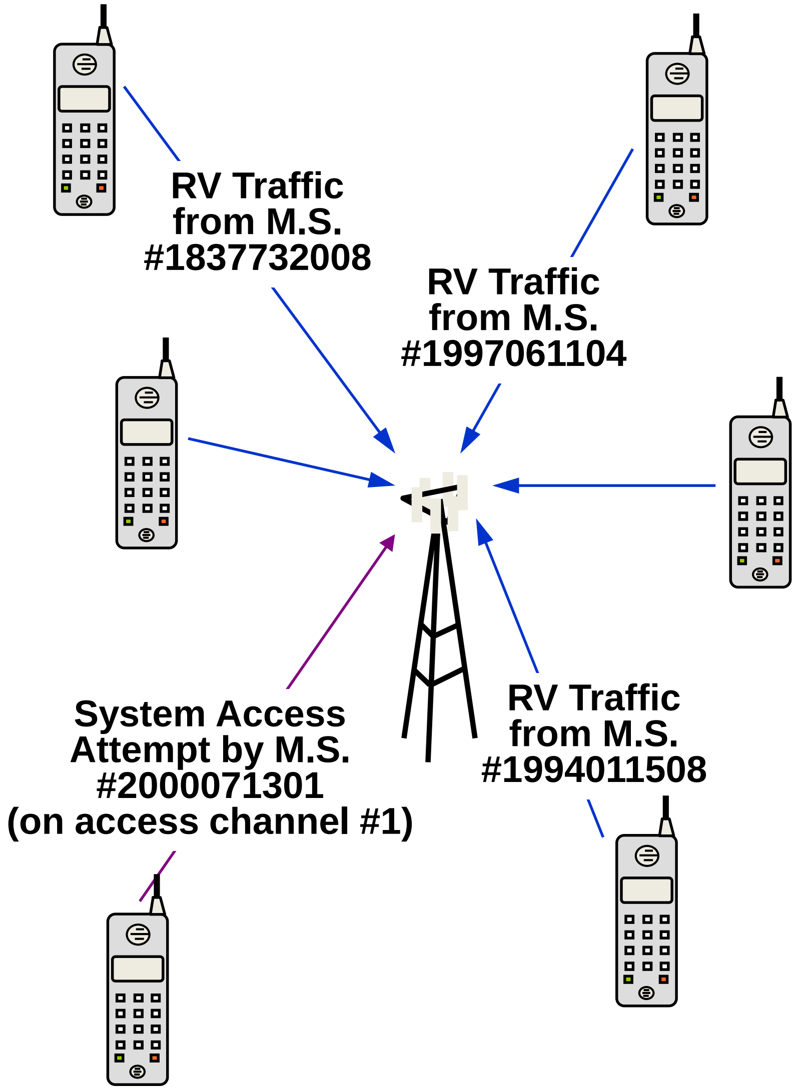
- A Mobile Station receives a Forward Channel from a sector in a Base Station.
- The Forward Channel carries a composite signal of up to 64 forward code channels.
- Some code channels are traffic channels and others are overhead channels.
- A set of 64 mathematical codes is needed to differentiate the 64 possible forward code channels.
  - The codes in this set are called “Walsh Codes”

Discriminating Among Base Station



- A mobile Station is surrounded by Base Stations, all of them transmitting on the same CDMA Frequency.
- Each Sector in each Base Station is transmitting a Forward Traffic Channel containing up to 64 forward code channels.
- A Mobile Station must be able to discriminate between different Sectors of different Base Stations.
- Two binary digit sequences called the I and Q Short PN Sequences (or Short PN Codes) are defined for the purpose of identifying sectors of different base stations.
- These Short PN Sequences can be used in 512 different ways in a CDMA system. Each one of them constitutes a mathematical code which can be used to identify a particular sector.

Discriminating Among Reverse Code Channels



- The CDMA system must be able to identify each Mobile Station that may attempt to communicate with a Base Station.
- A very large number of Mobile Stations will be in the market.
- One binary digit sequence called the Long PN Sequence (or Long PN Code) is defined for the purpose of uniquely identifying each possible reverse code channel.
- This sequence is extremely long and can be used in trillions of different ways. Each one of them constitutes a mathematical code which can be used to identify a particular user (and is then called a User Long Code) or a particular "user Reverse Traffic channel".

CDMA Spread Code Selection

Type of Sequence	How Many	Length	Special Properties	Forward Link Function	Reverse Link Function
Walsh Codes	**64**	64 chips 1/19,200 sec.	Mutually Orthogonal	User identity within cell's signal	Orthogonal Modulation (information carrier)
Short PN Sequences	**2**	32,768 chips 26-2/3 ms 75x in 2 sec.	Orthogonal with itself at any time shift value except 0	Distinguish Cells & Sectors	Quadrature Spreading (Zero offset)
Long PN Sequences	**1**	242 chips ~41 days	near-orthogonal if shifted	Data Scrambling to avoid strings of 1's or 0's	Distinguish users

Definition of Walsh code

- Walsh function is formed by recursion relationship of Hadamard matrix.
- Hadamard matrix is an orthogonal square matrix.It is just composed of +1(0) and –1(1).

$$0 \rightarrow \begin{matrix} 0 & 0 \\ 0 & 1 \end{matrix} \rightarrow \begin{matrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{matrix}$$

$$\boxed{H_{2n} = \begin{matrix} H_n & H_n \\ H_n & \overline{H_n} \end{matrix}}$$

Walsh Codes

- 64 Sequences, each 64 chips long
  - A chip is a binary digit (0 or 1)
- Each Walsh Code is Orthogonal to all other Walsh Codes
  - This means that it is possible to recognize and therefore extract a particular Walsh code from a mixture of other Walsh codes which are “filtered out” in the process
  - Two same-length binary strings are orthogonal if the result of XORing them has the same number of 0s as 1s

EXAMPLE:

Correlation of Walsh Code #23 with Walsh Code #59

```
#23   0110100101101001100101101001011001101001011010011001011010010110
#59   0110011010011001100110010110011010011001011001100110011010011001
XOR   0000111111110000000011111111000011110000000011111111000000001111
```

Correlation Results: 32 1’s, 32 0’s: Orthogonal!!

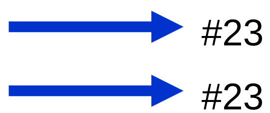
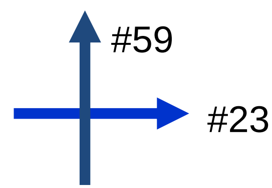
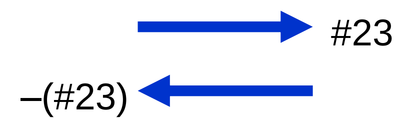
WALSH CODES

#	64-Chip Sequence
0	0000000000000000000000000000000000000000000000000000000000000000
1	0101010101010101010101010101010101010101010101010101010101010101
2	0011001100110011001100110011001100110011001100110011001100110011
3	0110011001100110011001100110011001100110011001100110011001100110
4	0000111100001111000011110000111100001111000011110000111100001111
5	0101101001011010010110100101101001011010010110100101101001011010
6	0011110000111100001111000011110000111100001111000011110000111100
7	0110100101101001011010010110100101101001011010010110100101101001
8	0000000011111111000000001111111100000000111111110000000011111111
9	0101010110101010010101011010101001010101101010100101010110101010
10	0011001111001100001100111100110000110011110011000011001111001100
11	0110011010011001011001101001100101100110100110010110011010011001
12	0000111111110000000011111111000000001111111100000000111111110000
13	0101101010100101010110101010010101011010101001010101101010100101
14	0011110011000011001111001100001100111100110000110011110011000011
15	0110100110010110011010011001011001101001100101100110100110010110
16	0000000000000000111111111111111100000000000000001111111111111111
17	0101010101010101101010101010101001010101010101011010101010101010
18	0011001100110011110011001100110000110011001100111100110011001100
19	0110011001100110100110011001100101100110011001101001100110011001
20	0000111100001111111100001111000000001111000011111111000011110000
21	0101101001011010101001011010010101011010010110101010010110100101
22	0011110000111100110000111100001100111100001111001100001111000011
23	0110100101101001100101101001011001101001011010011001011010010110
24	0000000011111111111111110000000000000000111111111111111100000000
25	0101010110101010101010100101010101010101101010101010101001010101
26	0011001111001100110011000011001100110011110011001100110000110011
27	0110011010011001100110010110011001100110100110011001100101100110
28	0000111111110000111100000000111100001111111100001111000000001111
29	0101101010100101101001010101101001011010101001011010010101011010
30	0011110011000011110000110011110000111100110000111100001100111100
31	0110100110010110100101100110100101101001100101101001011001101001
32	0000000000000000000000000000000011111111111111111111111111111111
33	0101010101010101010101010101010110101010101010101010101010101010
34	0011001100110011001100110011001111001100110011001100110011001100
35	0110011001100110011001100110011010011001100110011001100110011001
36	0000111100001111000011110000111111110000111100001111000011110000
37	0101101001011010010110100101101010100101101001011010010110100101
38	0011110000111100001111000011110011000011110000111100001111000011
39	0110100101101001011010010110100110010110100101101001011010010110
40	0000000011111111000000001111111111111111000000001111111100000000
41	0101010110101010010101011010101010101010010101011010101001010101
42	0011001111001100001100111100110011001100001100111100110000110011
43	0110011010011001011001101001100110011001011001101001100101100110
44	0000111111110000000011111111000011110000000011111111000000001111
45	0101101010100101010110101010010110100101010110101010010101011010
46	0011110011000011001111001100001111000011001111001100001100111100
47	0110100110010110011010011001011010010110011010011001011001101001
48	0000000000000000111111111111111111111111111111110000000000000000
49	0101010101010101101010101010101010101010101010100101010101010101
50	0011001100110011110011001100110011001100110011000011001100110011
51	0110011001100110100110011001100110011001100110010110011001100110
52	0000111100001111111100001111000011110000111100000000111100001111
53	0101101001011010101001011010010110100101101001010101101001011010
54	0011110000111100110000111100001111000011110000110011110000111100
55	0110100101101001100101101001011010010110100101100110100101101001
56	0000000011111111111111110000000011111111000000000000000011111111
57	0101010110101010101010100101010110101010010101010101010110101010
58	0011001111001100110011000011001111001100001100110011001111001100
59	0110011010011001100110010110011010011001011001100110011010011001
60	0000111111110000111100000000111111110000000011110000111111110000
61	0101101010100101101001010101101010100101010110100101101010100101
62	0011110011000011110000110011110011000011001111000011110011000011
63	0110100110010110100101100110100110010110011010010110100110010110

Correlation and Orthogonality

Correlation is a measure of the similarity between two binary strings

Code #23	0110100101101001100101101001011001101001011010011001011010010110
−(Code #23)	1001011010010110011010010110100110010110100101100110100101101001
Code #59	0110011010011001100110010110011010011001011001100110011010011001

		
PARALLEL	**ORTHOGONAL**	**ANTI-PARALLEL**
XOR: all 0s	XOR: half 0s, half 1s	XOR: all 1s
Correlation: 100% (100% match)	Correlation: 0% (50% match, 50% no-match)	Correlation: –100% (100% no-match)

Properties of the Walsh Codes

$$\begin{array}{cccc} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{array}$$

- When a Walsh code is XORed chip by chip with itself, the result is all 0's (100% correlation)
- When a Walsh code is XORed chip by chip with its logical negation, the result is all 1's (–100% correlation)
- When a Walsh code is XORed chip by chip with any other code or its logical negation, the result is half 0's and half 1's (0% correlation)

$$\begin{array}{cccc} 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ \hline 0 & 1 & 0 & 1 \end{array} \qquad \begin{array}{cccc} 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ \hline 0 & 0 & 0 & 0 \end{array} \qquad \begin{array}{cccc} 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ \hline 0 & 1 & 1 & 0 \end{array} \qquad \begin{array}{cccc} 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ \hline 0 & 0 & 1 & 1 \end{array}$$

$$\begin{array}{cccc} 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 \\ \hline 1 & 0 & 1 & 0 \end{array} \qquad \begin{array}{cccc} 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ \hline 1 & 1 & 1 & 1 \end{array} \qquad \begin{array}{cccc} 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ \hline 1 & 0 & 0 & 1 \end{array} \qquad \begin{array}{cccc} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ \hline 1 & 1 & 0 & 0 \end{array}$$

Walsh Code Table

	0123	4567	11 8901	1111 2345	1111 6789	2222 0123	2222 4567	2233 8901	3333 2345	3333 6789	4444 0123	4444 4567	4455 8901	5555 2345	5555 6789	6666 0123
0	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101
2	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011
3	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110
4	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111
5	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010
6	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100
7	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001
8	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111
9	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010
10	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100
11	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001
12	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000
13	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101
14	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011
15	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110
16	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111
17	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010
18	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100
19	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001
20	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000
21	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101
22	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011
23	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110
24	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000
25	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101
26	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011
27	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110
28	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111
29	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010
30	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100
31	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001
32	0000	0000	0000	0000	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111
33	0101	0101	0101	0101	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010
34	0011	0011	0011	0011	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100
35	0110	0110	0110	0110	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001
36	0000	1111	0000	1111	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000
37	0101	1010	0101	1010	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101
38	0011	1100	0011	1100	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011
39	0110	1001	0110	1001	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110
40	0000	0000	1111	1111	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000
41	0101	0101	1010	1010	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101
42	0011	0011	1100	1100	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011
43	0110	0110	1001	1001	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110
44	0000	1111	1111	0000	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111
45	0101	1010	1010	0101	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010
46	0011	1100	1100	0011	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100
47	0110	1001	1001	0110	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001
48	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111	0000	0000	0000	0000
49	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010	0101	0101	0101	0101
50	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100	0011	0011	0011	0011
51	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001	0110	0110	0110	0110
52	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000	0000	1111	0000	1111
53	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101	0101	1010	0101	1010
54	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011	0011	1100	0011	1100
55	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110	0110	1001	0110	1001
56	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000	0000	0000	1111	1111
57	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101	0101	0101	1010	1010
58	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011	0011	0011	1100	1100
59	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110	0110	0110	1001	1001
60	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111	0000	1111	1111	0000
61	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010	0101	1010	1010	0101
62	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100	0011	1100	1100	0011
63	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001	0110	1001	1001	0110

the Application of Walsh code

64-rank Walsh code

- Forward Link: spread spectrum and indicate forward channel
- Backward Link: Orthogonal modulation

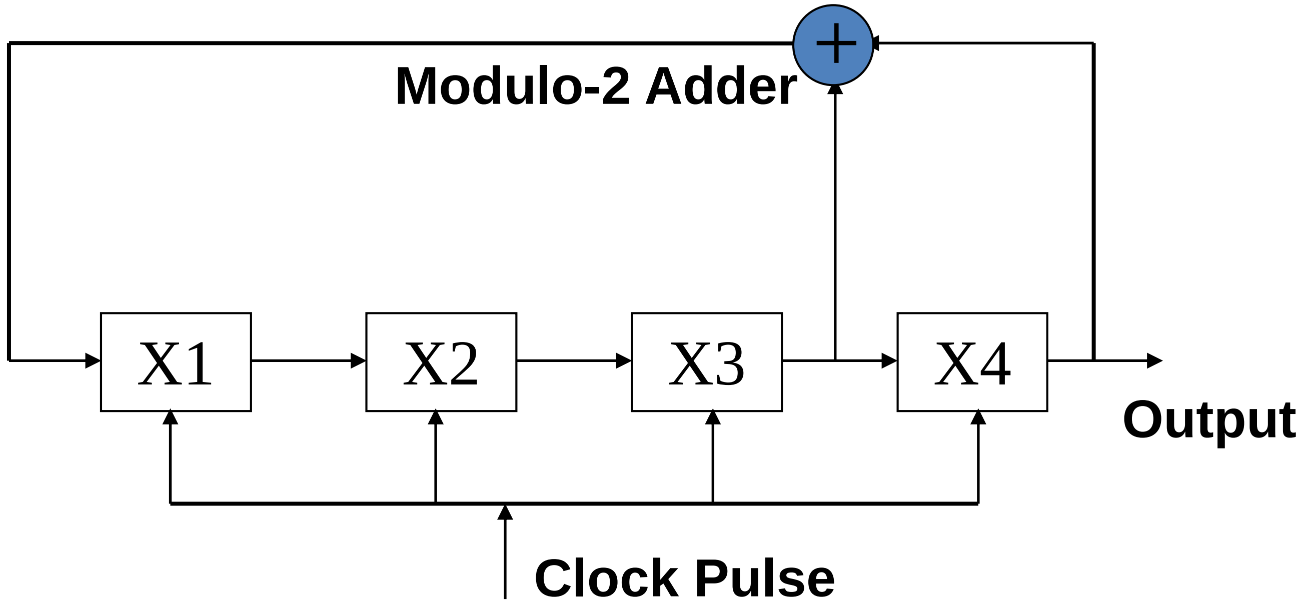
PN Sequence

- Similar with noise sequence property
- Seemingly like random sequence,but it is regular and periodic binary code sequence

m Sequence Definition

- m sequence is an important binary pseudo noise sequence
- m sequence is the short term of “Maximal-Length linear feedback shift register sequence”
- Definition:If the output sequence period of r-stage linear feedback shift register is $P=2^r-1$，Then this sequence is m sequence
- m sequence generator consists of three parts:shift register, modulo-2 Adder, feedback path

Four-Stage Linear Feedback Shift Register



Output

$X = X1 \oplus X2 \oplus X3 \oplus X4 = 100010011010111110$

We suppose the initial state of the register

$X1X2X3X4 = 0001$

Orthogonal

Orthogonal Definition

From the standpoint of mathematics,two lines plumb each other

From the standpoint of analogical,compare with two random line or row,if the number of the same digits and different digits are equal,we call it orthogonal.

In CDMA system,in order to protect less interference between signals,signals between each other should be orthogonal

Sequence 1: 1 0 0 1 1 0 0 0

$\Rightarrow$ Orthogonal

Sequence 2: 0 0 1 1 0 0 0 1

Self-correlation & Cross-correlation

Self-correlation refers to the degree of correspondence or comparability between a sequence and a phase-shifted replica of itself

In CDMA system,should select the good Autocorrelation code to insure demodulation and distinguish at the receiver side

Cross-Correlation refers to the correlation or comparability between two different signals

In CDMA system,different user should select less Cross-correlation signal as a code

Two conceptions

Mask:

- Different mask can make the different phase for m sequence.
- In CDMA system,the mask of different user is calculated by the ESN in the mobile phone

Phase:

- Different phase of difference sequence identify different base station and user

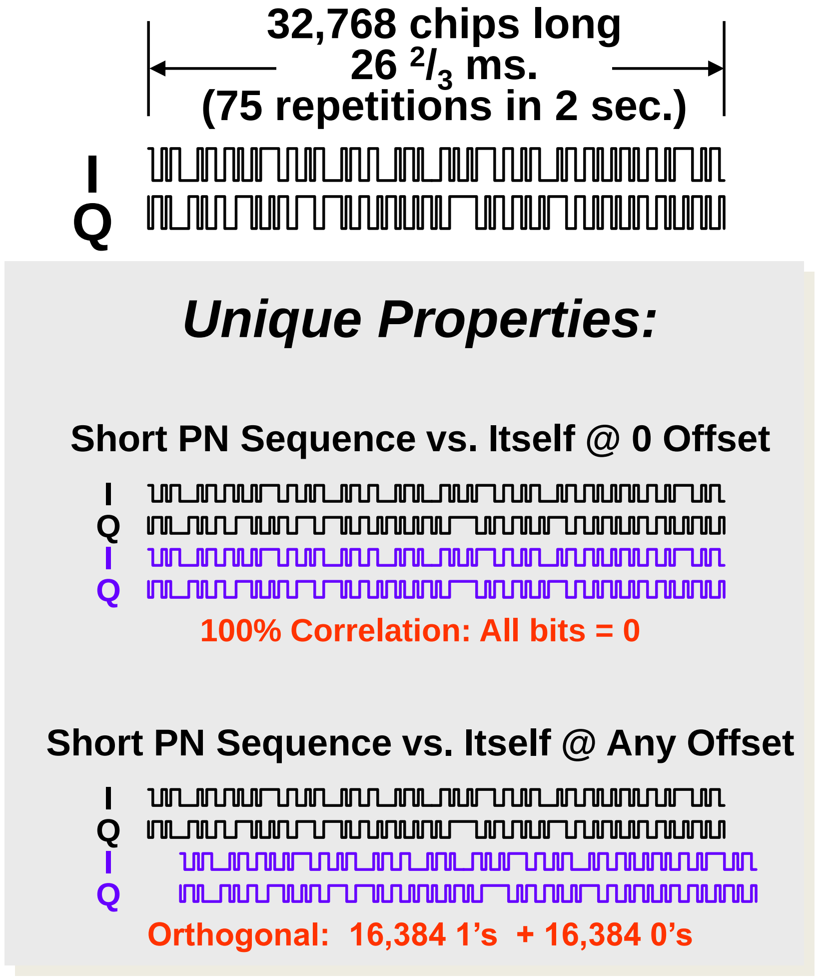
The basic property of m sequence

- ❑ Pseudo noise sequence
- ❑ Period： $P=2^r-1$， r is the stage of shift register
- ❑ When the period is very long, m sequence is almost orthogonal
- ❑ The self correlation of m sequence is very well but the cross correlation is weak.That means if two m sequence with different phase,it is almost orthogonal

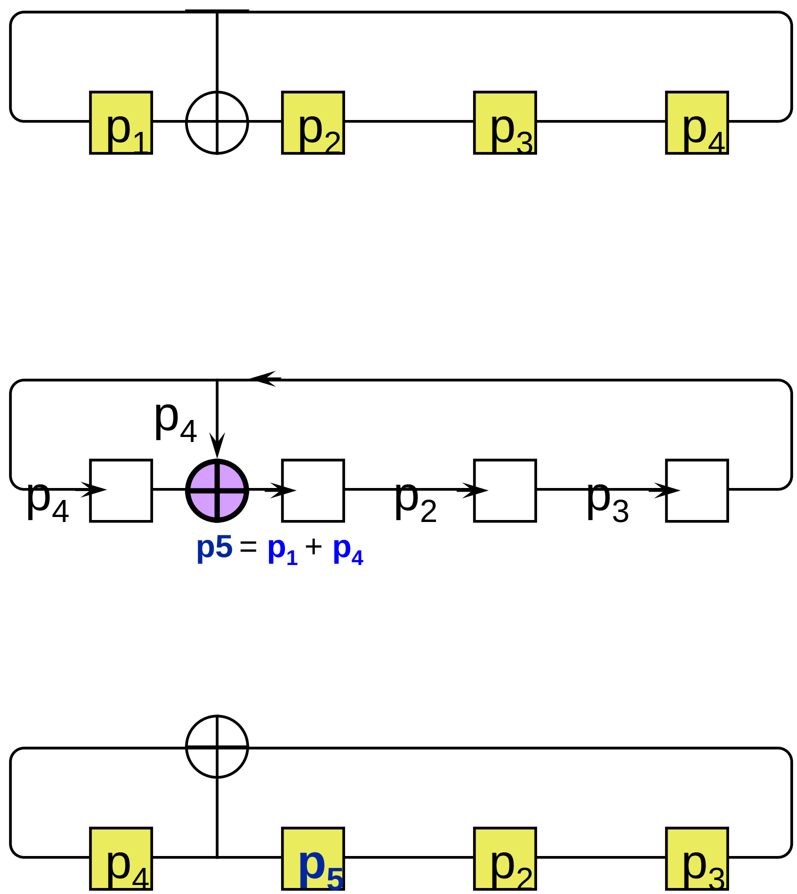
Short PN Sequences

The two Short PN Sequences, I and Q, are 32,768 chips long

- Together, they can be considered a two-dimensional binary “vector” with distinct I and Q component sequences, each 32,768 chips long
- Each Short PN Sequence (and, as a matter of fact, any sequence) correlates with itself perfectly if compared at a timing offset of 0 chips
- Each Short PN Sequence is special: Orthogonal to a copy of itself that has been offset by any number of chips (other than 0)



Short PN: 4-bits register example

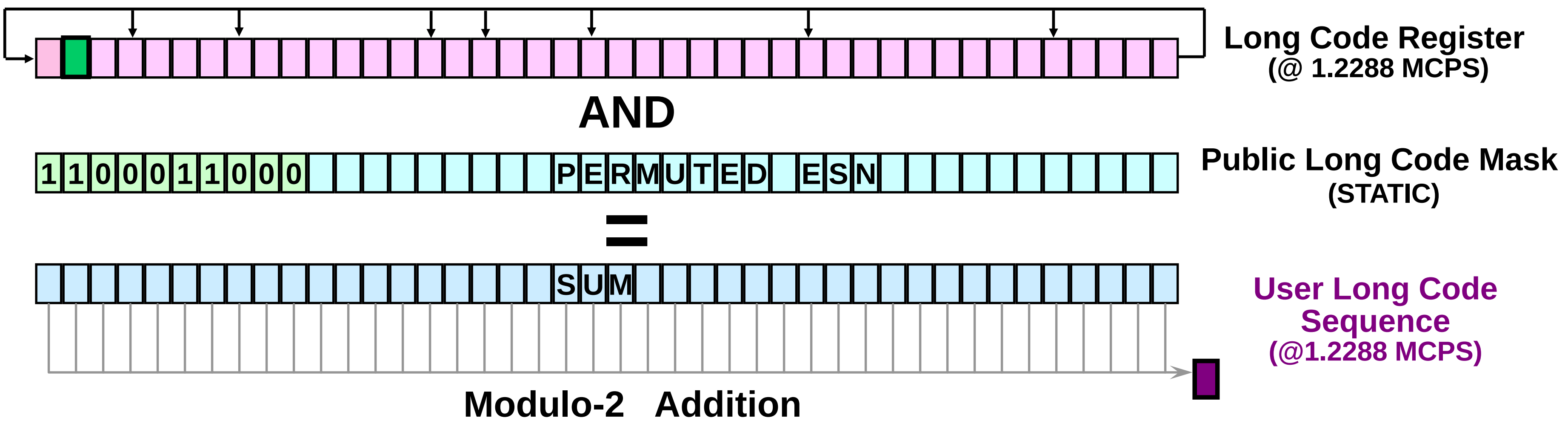


0	0	0	1
1	1	0	0
0	1	1	0
0	0	1	1
1	1	0	1
1	0	1	0
0	1	0	1
1	1	1	0
0	1	1	1
1	1	1	1
1	0	1	1
1	0	0	1
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

The PN sequences are deterministic and periodic.

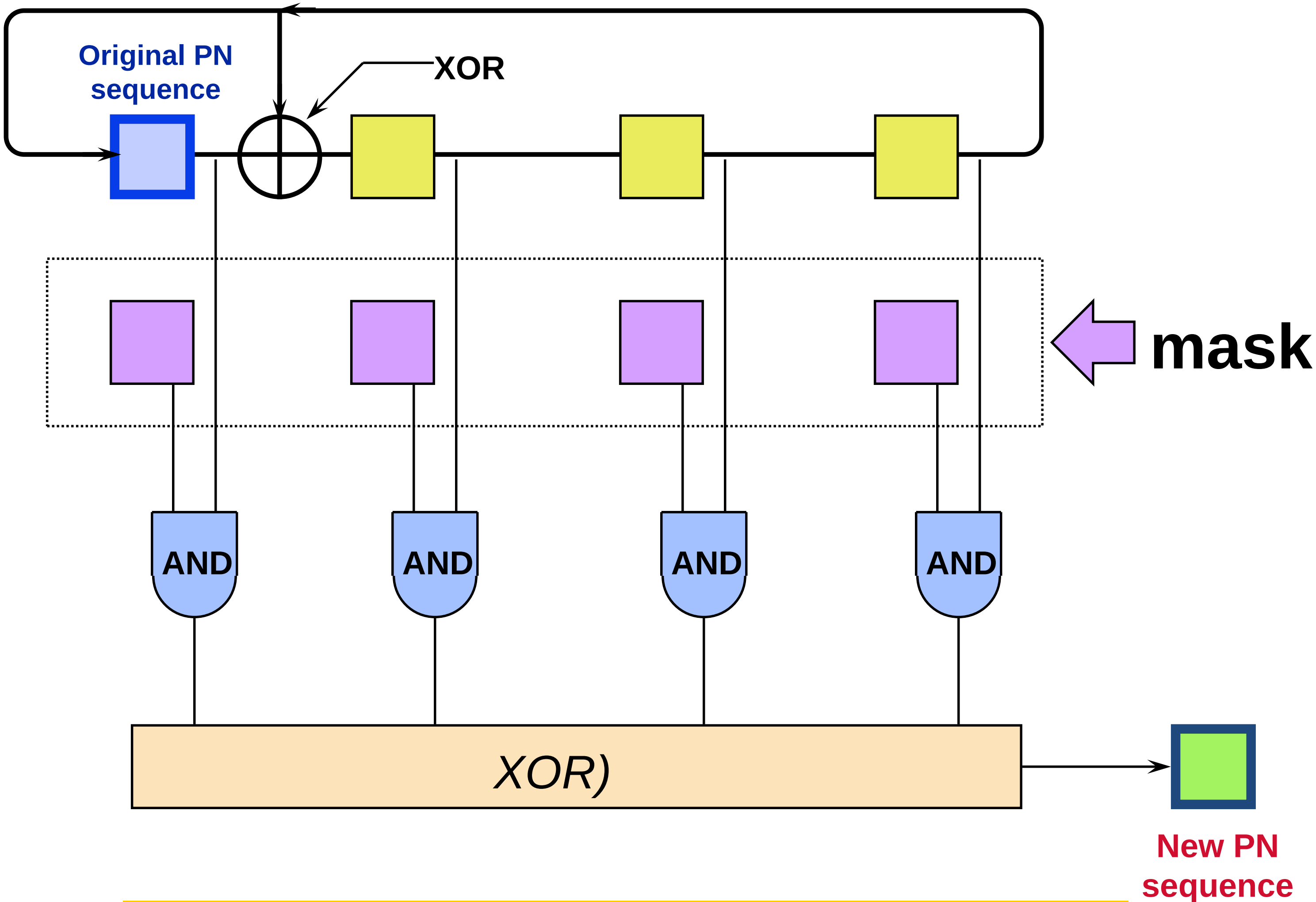
- The length of the generated string is 2^n-1, where “n” is the number of elements in the register
- The number of zeroes in the sequence is equal to the number of ones minus 1

The Long PN Sequence



- Each mobile station uses a unique User Long Code Sequence generated by applying a mask, based on its 32-bit ESN, to the 42-bit Long Code Generator which was synchronized with the CDMA system during the mobile station initialization.
- Generated at 1.2288 Mcps, this sequence requires 41 days, 10 hours, 12 minutes and 19.4 seconds to complete.
- Portions of the User Long Codes generated by different mobile stations for the duration of a call are not exactly orthogonal but are sufficiently different to permit reliable decoding on the reverse link.

Long PN:4-bits shift register example



0	0	0	1
1	1	0	0
0	1	1	0
0	0	1	1
1	1	0	1
1	0	1	0
0	1	0	1
1	1	1	0
0	1	1	1
1	1	1	1
1	0	1	1
1	0	0	1
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

Attention:different mask lead to different offset!

PN code application in CDMA

- PN code used in CDMA system

  Long code： $2^{42} - 1$ (r = 42)

  Short code： 2^{15} (r = 15)

- Different purpose

  ---Forward channel

  long code : scramble

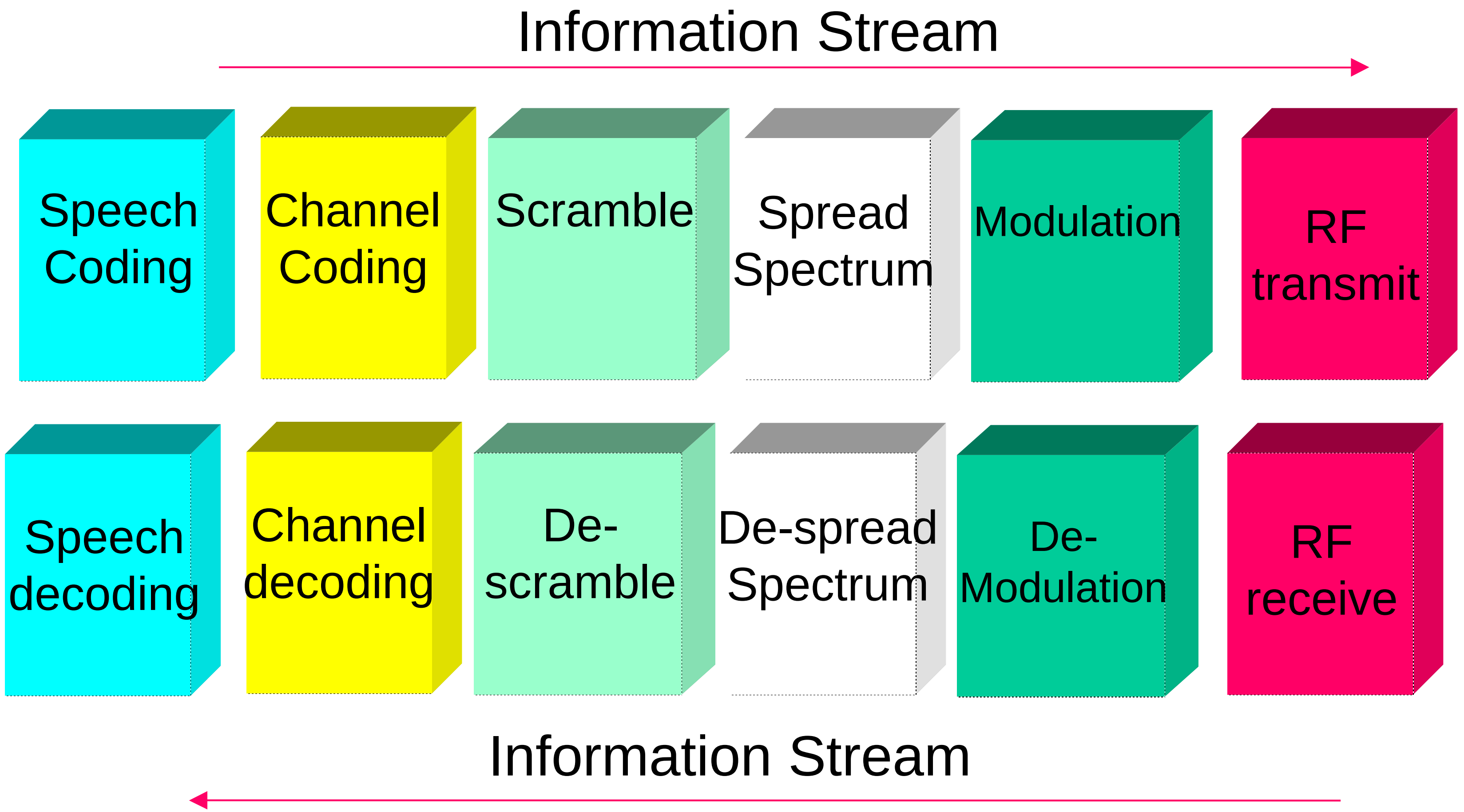
  short code :orthogonal modulation and identify base station

  ---Reverse channel

  long code :spread spectrum and identify user

  short code :orthogonal modulation

CDMA Communication Model



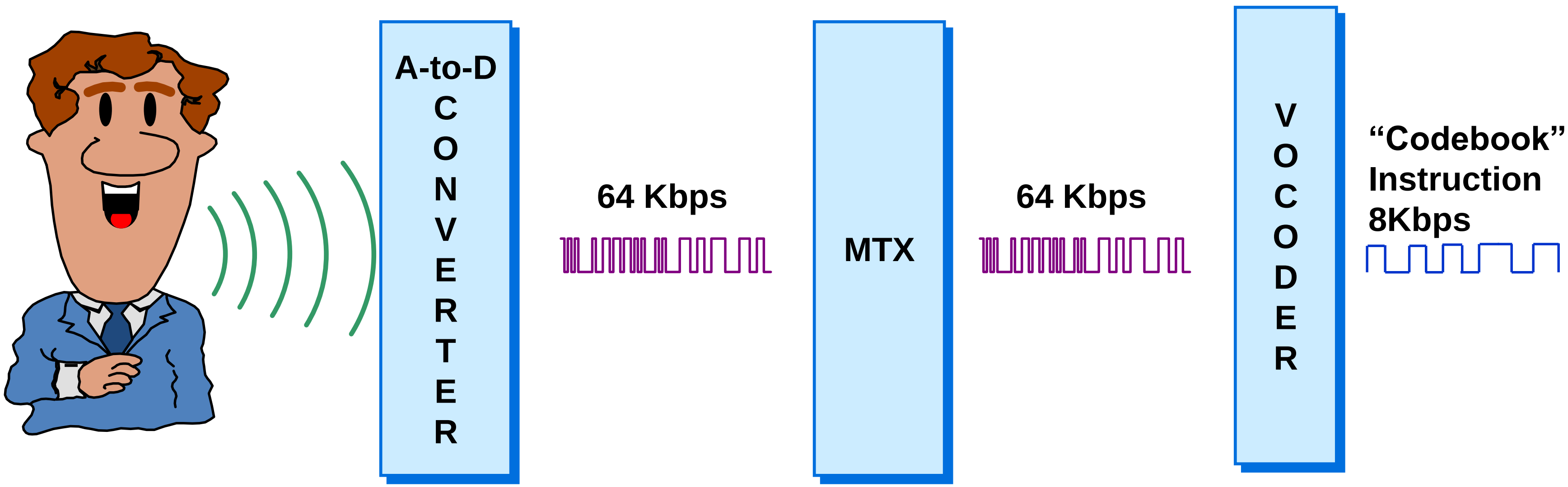
Coding Technology

In Digital communication coding technology,include two types:

- ❑ **Speech coding** is critical to digital transmission.CDMA system use an efficient method of speech coding and extensive error recovery techniques to overcome the harsh nature of the radio channel.
  The objective of speech coding is not only to maintain speech quality but also to reduce the quantity of transmitting data.

- ❑**Channel coding** usually falls into two classes:Block interleaver codes and Convolutional codes.
  The objective of channel coding is adding additional supervising bits in the information stream to ensure get correct signal at receive side.

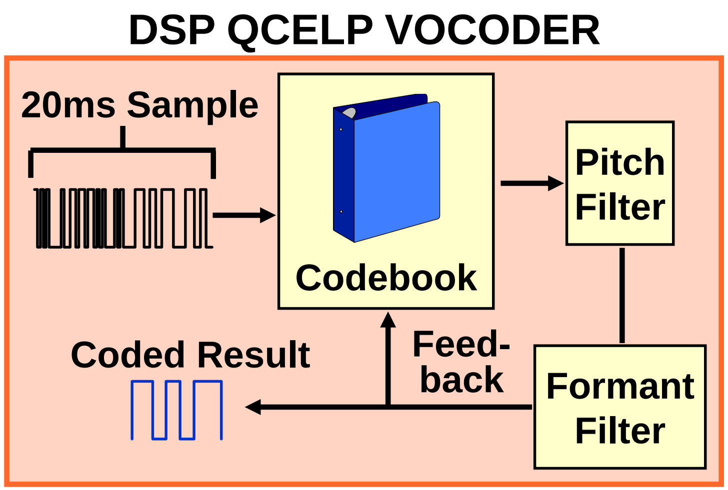
Speech Coding



- Speech coding algorithms (digital compression) are necessary to increase cellular system capacity.
- Coding must also ensure reasonable fidelity, that is, a maximum level of quality as perceived by the user.
- Coding can be performed in a variety of ways (for example, waveform, time or frequency domain).
- Vocoders transmit parameters which control reproduction of voice instead of the explicit, point-by-point waveform description.

Variable Rate Vocoding

- CDMA uses a superior Variable Rate Vocoder
  - Full rate during speech
  - Low rates in speech pauses
  - Increased capacity
  - More natural sound
- Voice, signaling, and user secondary data may be mixed in CDMA frames



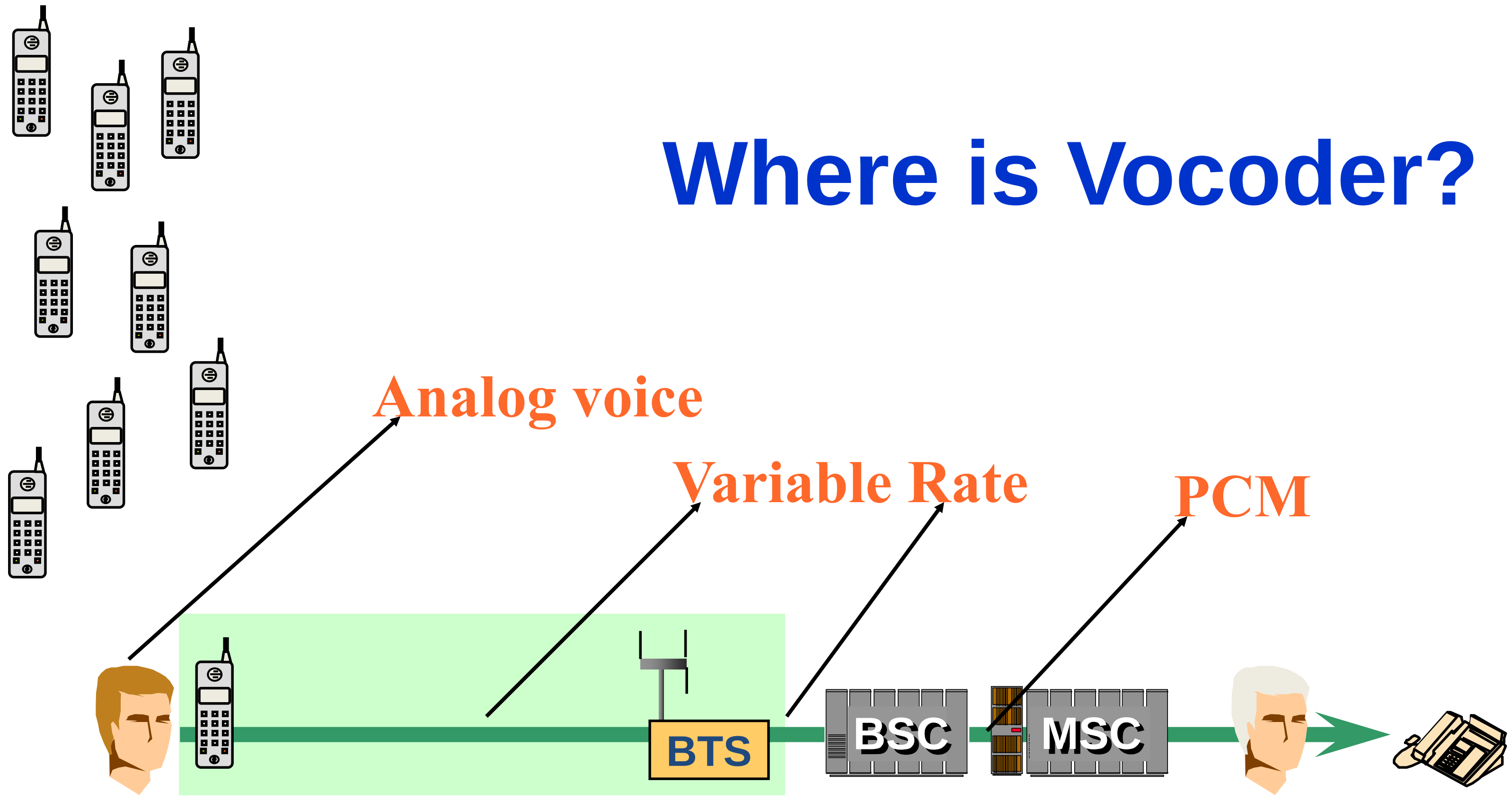
Variable Rate Vocoding

bits	Rate Set 1 Frame Sizes
192	Full Rate Frame
96	1/2 Rate Frame
48	1/4 Rt.
24	1/8

bits	Rate Set 2 Frame Sizes
288	Full Rate Frame
144	1/2 Rate Frame
72	1/4 Rt.
36	1/8

- The output is 20 ms frames at fixed rates: Full Rate, 1/2 Rate , 1/4 Rate , 1/8 Rate, & Blank
- CRC is added to all the frames for the 13 kb vocoder, but only to the Full and 1/2 rate frames for the 8 kb vocoder.
- CRC is not added to the lower rate frames in the 8 kb vocoder, but that is ok because they consist mostly of background noise and have a higher processing gain.
- Current vocoder rates are 8kbps, 13kbps, and 8kbps EVRC (Enhanced Variable Rate Coder)

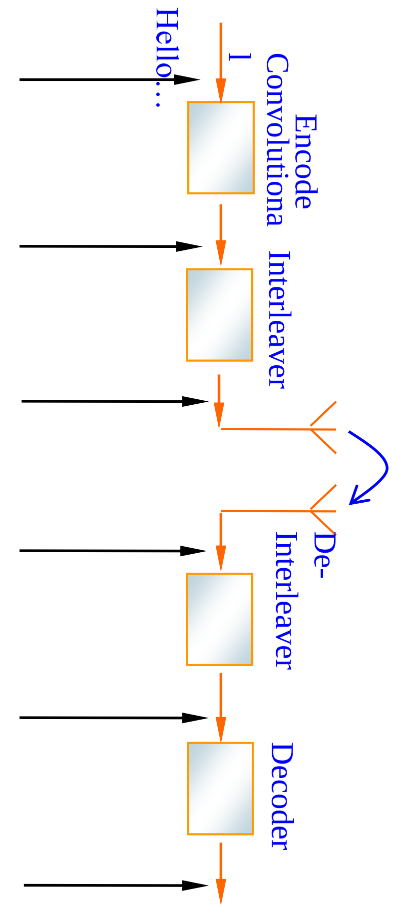
Variable Rate Voice Bit and PCM



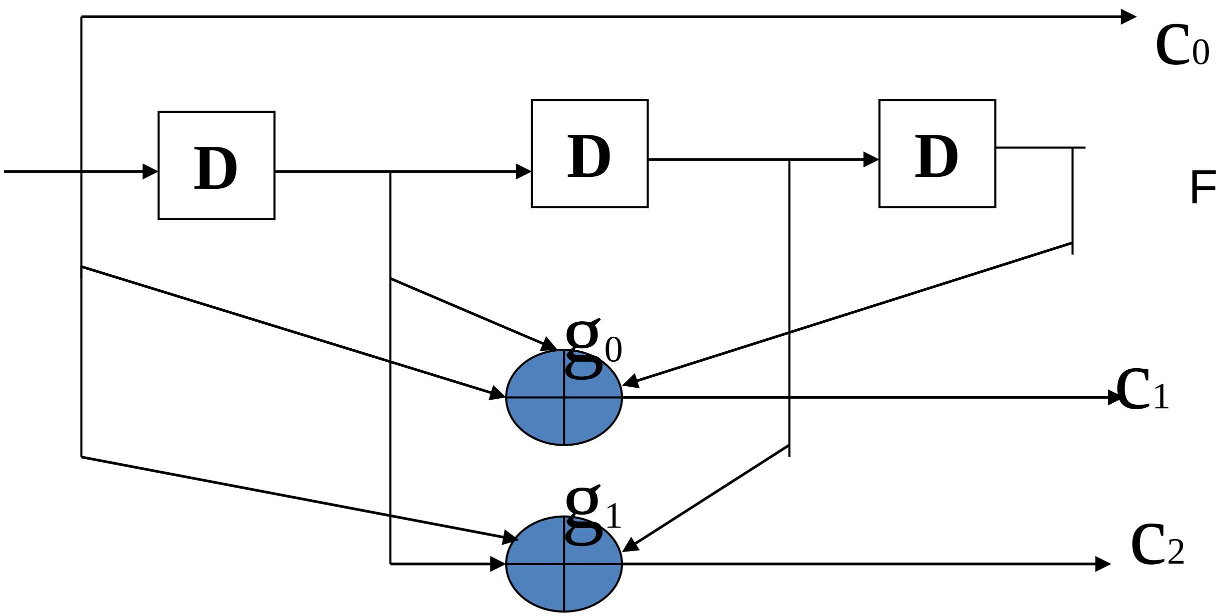
Convolutional Coding & Interleaving

Example:

Bits to be Txed:	**HELLO**	**FOLKS**
Convolutionally Encoded:	**HHEELLLLOO**	**FFOOLLKKSS**
Interleaved:	**ELSOLHLOFK**	**LEOLSHOLKF**
Bits Rxed:	**EL SOL HLOFK**	**LEOLSHOLKF**
De-Interleaved:	**HHEELLL – OO**	**FFO – LLKK- S**
Viterbi Decoded:	**HELLO**	**FOLKS**



Channel Coding
-Convolutional Encoder



From this figure:

Constraint length(K) = 4

Code length(N) =3

Code rate=1/3

- ❑ Constraint length(K) = Shift Register Number + 1
- ❑ Code length(N) = input information bit + supervising bit
- ❑ Code rate(R) = input information bit/code length

Channel Coding
-Block Interleaver Encoder

Block Interleaver principle:input according to row and output according to columns

For example: An Origination stream 1 1 0 1 0 0 1 1 0 1 0 0 1 1 1 0,arrange in 4 by 4 matrix

1	1	0	1
0	0	1	1
0	1	0	0
1	1	1	0

1	x	0	1
0	x	1	1
0	x	0	0
1	x	1	0

Interference sequence: 1 0 0 1 x x x x 0 1 0 1 1 1 0 0

Output from receiver matrix：1 x 0 1 0 x 1 1 0 x 0 0 1 x 1 0

Convolutional Encoder & Interleaver Encoder

Convolutional Encoder: increase the reliability but reduce the transmitting efficiency,because each code stream adds supervising bit for rectified

Block Interleaver Encoder: not change the efficiency but have some delays,because the transmitter and receiver must process to writing first and then reading

Scramble

The paging channel also includes many import information such as user’s IMSI,In order to keep the user’s information secret ,we use the data scrambling.

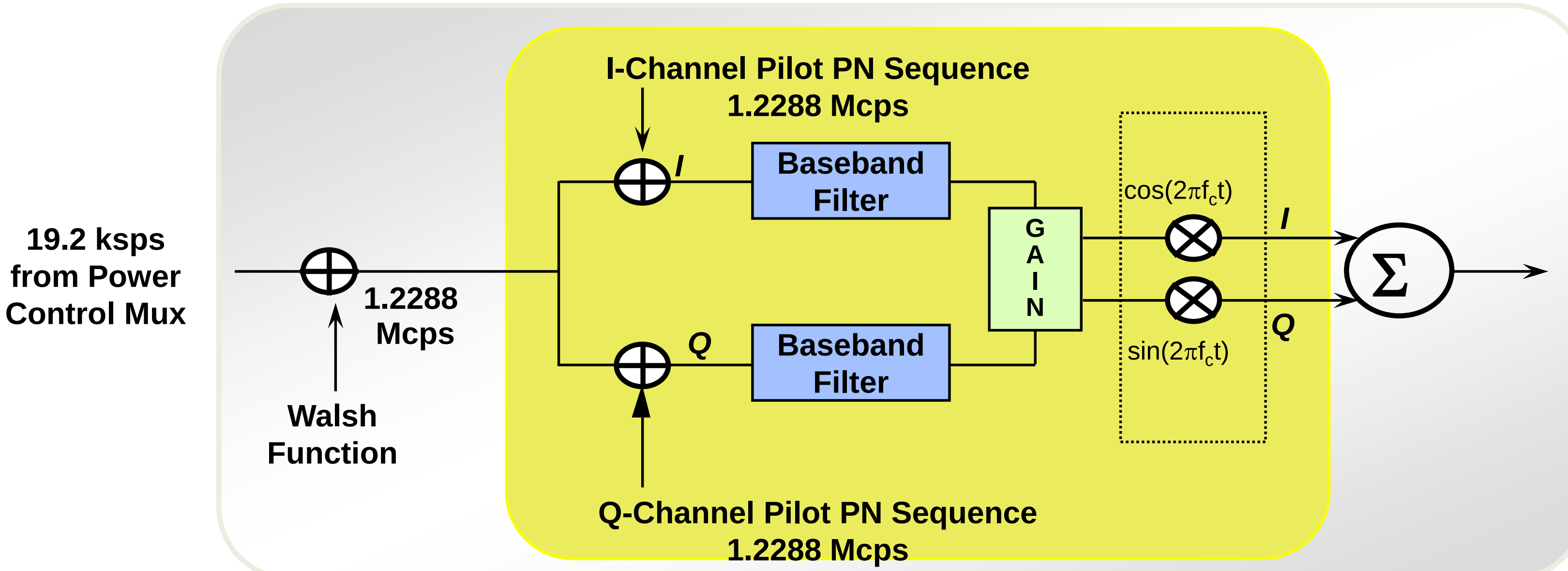
Spread Spectrum

- Spread code rate: 1.2288Mcps
- Spread code

    Forward Link:Walsh code

    Reverse Link: Long PN code

Modulation-QPSK&OQPSK



- The forward traffic channel is combined with two different PN sequences: “I” and “Q”
- Baseband filtering ensures the waveforms are contained within the 1.25 MHz frequency range
- The final step is to convert the two baseband signals to radio frequency (RF) in the 800 MHz or 1900 MHz range