Channel Encoding & Decoding
Viterbi Algorithm

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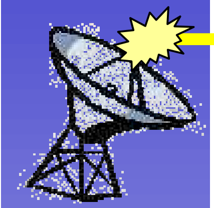
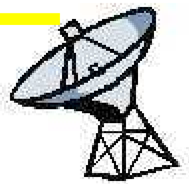
Channel Encoding & Decoding

1. Digital Communication System
2. Viterbi Algorithm
3. Advantages of the Viterbi Algorithm
4. Presentation of a Demonstration Software

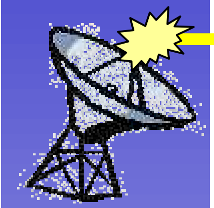
1. Digital communication system





- Definition of Viterbi algorithm
- Historical background of viterbi-coding
- Parts of a digital communication system
- Use of the Viterbi algorithm

Digital communication system



- Problem of digital communitcation
  - Transmit much data via a noisy channel
  - Detect and correct errors
- Solution
  - Convolutional coding with
  - Forward error correction (FER)

Viterbi Algorithm

*The **Viterbi-Algorithm** is a basic part of the **coding and modulation** method of the digital data transmission.*

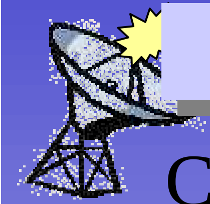
*With the help of the Viterbi-algorithm it is possible to **recognise data errors** and **correct** them at the receiver. [9]*

Viterbi Algorithm

"…efficient methode of ***optimum sequence estimation*** *of a* ***finite-state process*** *“.*

„finding the shortest path through a weighted graph“

Development



< 1955

Channel Encoding was implemented by

- Block codes
- Linear block codes

1955

Elias P. introduced

- Convolutional codes
- Fixed decoding time
- First real-time coding

Development

1967

Andrew J. Viterbi

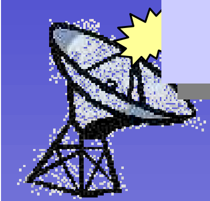
- Founder of Qualcomm Corporation
- Developed the Viterbi Algorithm

...

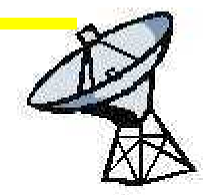
Other researchers improved the channel coding methodes

- Found new convolutional codes
- Improved the performance limits
- Designed implementations in hard- & software

Development



1993



Turbo coding merged

–Parallel concatenated convolutional technique

–Improves performence by chaining up:
Viterbi decoder and Reed-Solomon decoder
(data recycle through the decoder several times)

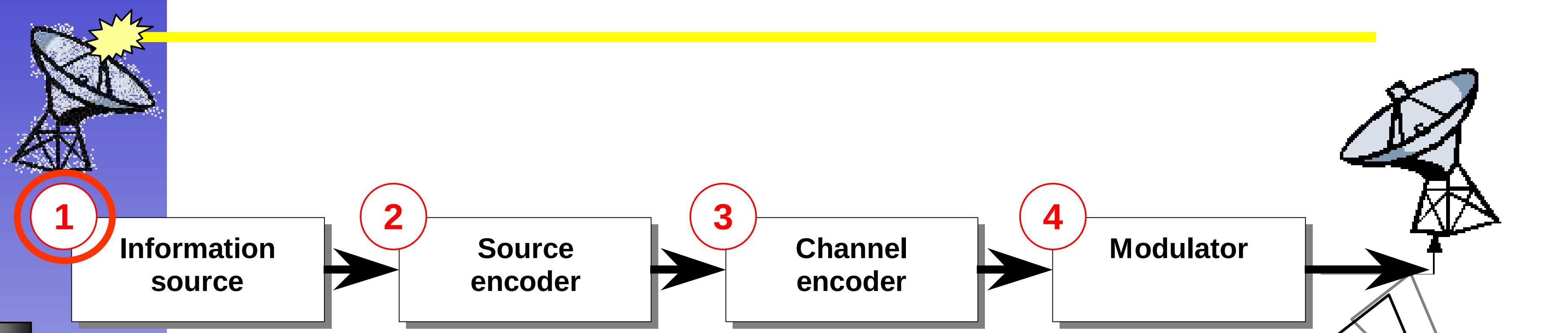
1995

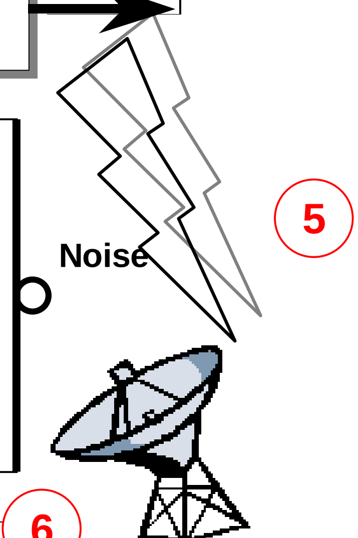
Viterbi & Reed-Solomon decoding

– Used in space communication

– geostationary satellite communication

Digital communication system

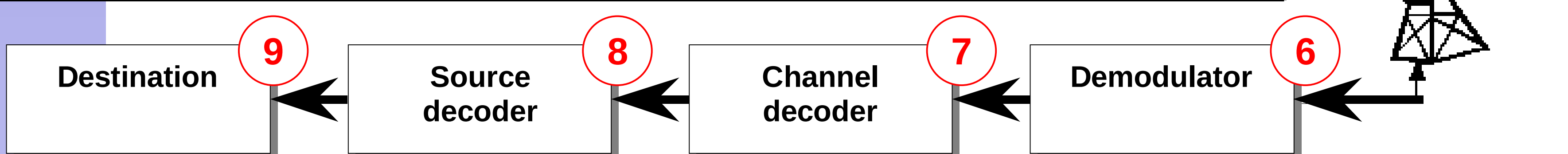




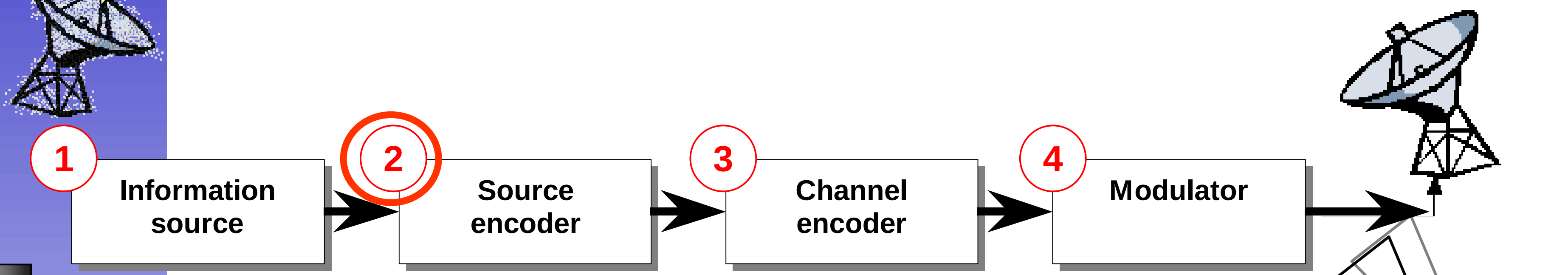
1. Information source

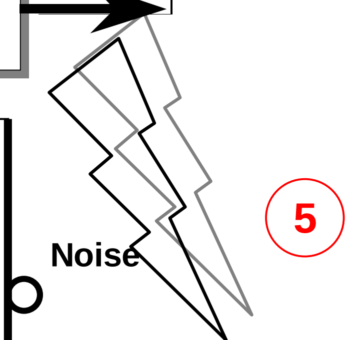
- Speech of a person
- Binary data of a machine e.g. computer

=> Analog wave / sequence of discrete symbols



Digital communication system



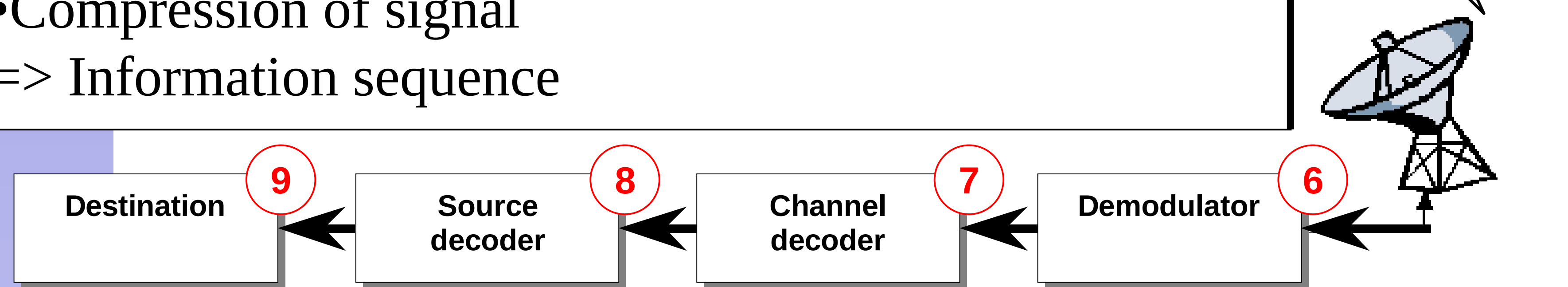


2. Source encoder (A/D converter)

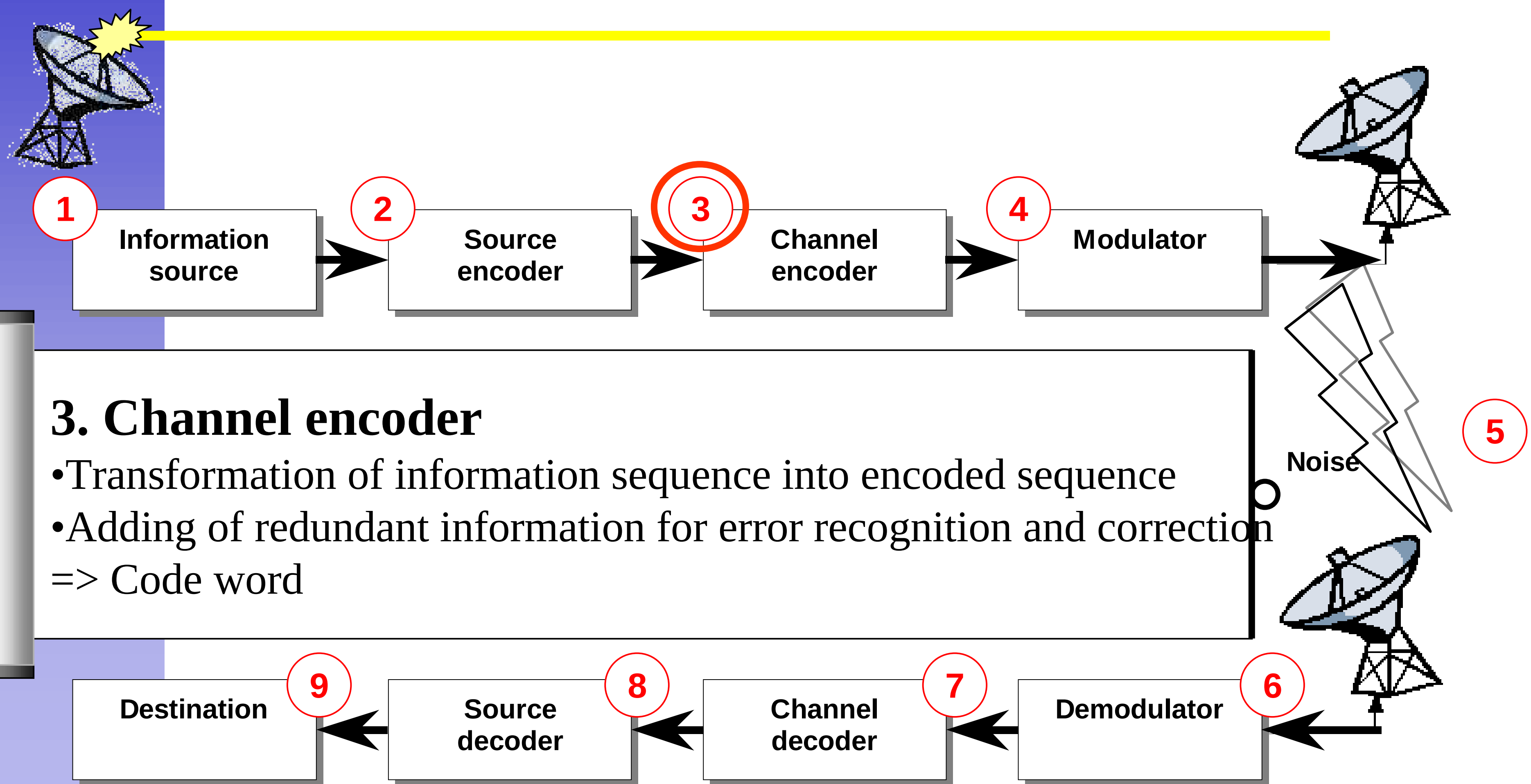
•Transformation of analogue signal into digital signal

•Compression of signal

=> Information sequence



Digital communication system

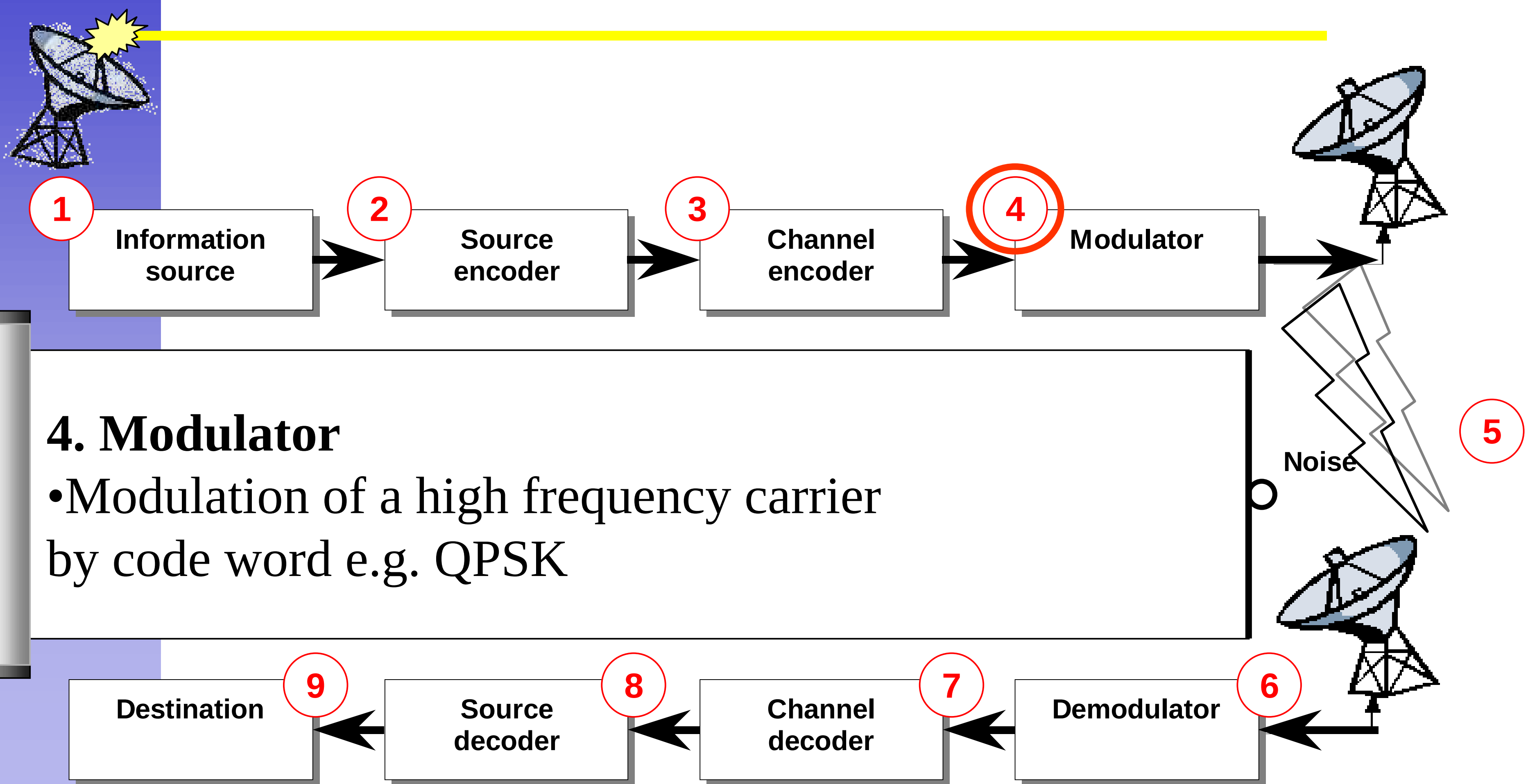


3. Channel encoder

- Transformation of information sequence into encoded sequence
- Adding of redundant information for error recognition and correction

=> Code word

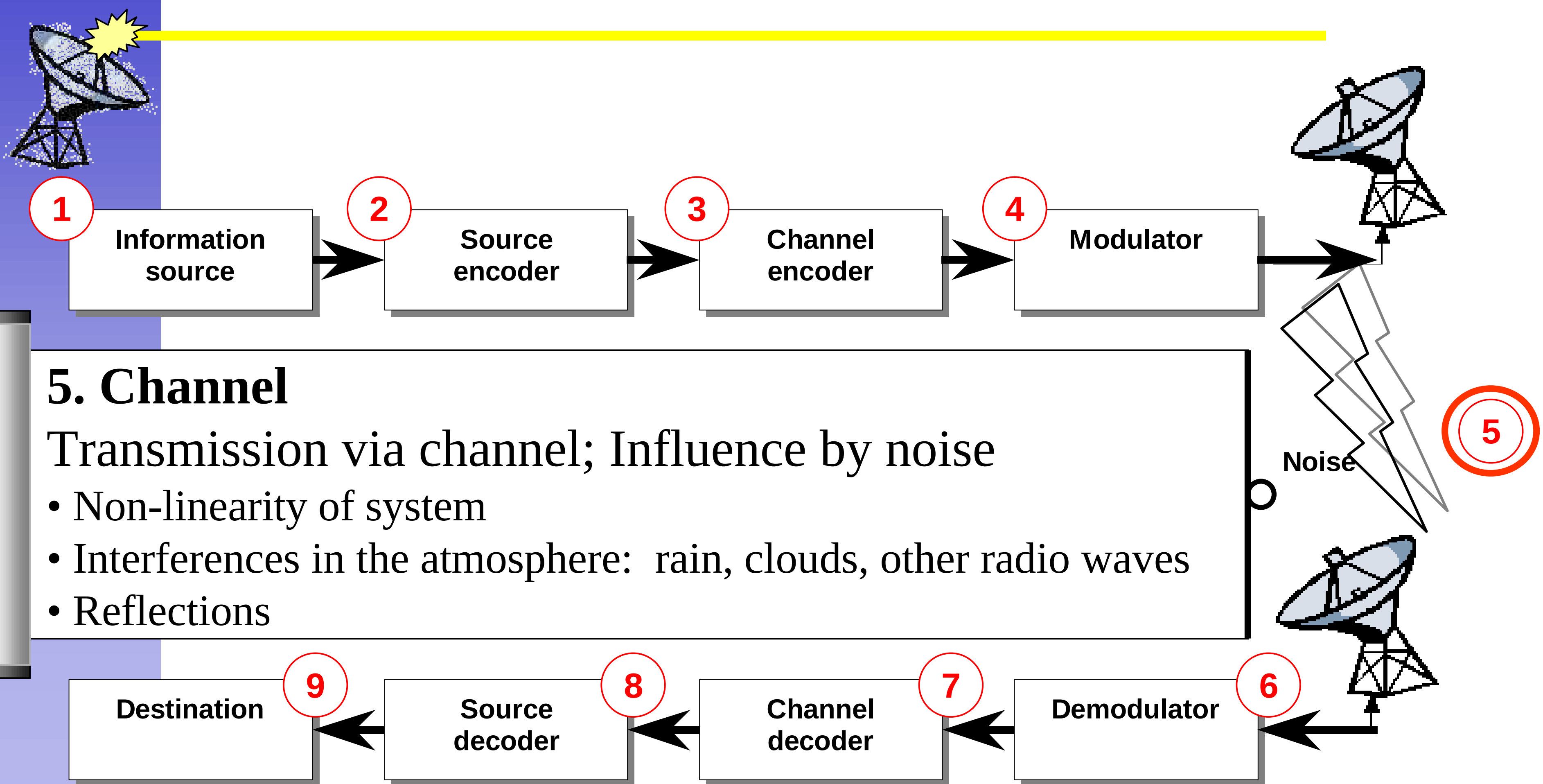
Digital communication system



4. Modulator

•Modulation of a high frequency carrier by code word e.g. QPSK

Digital communication system

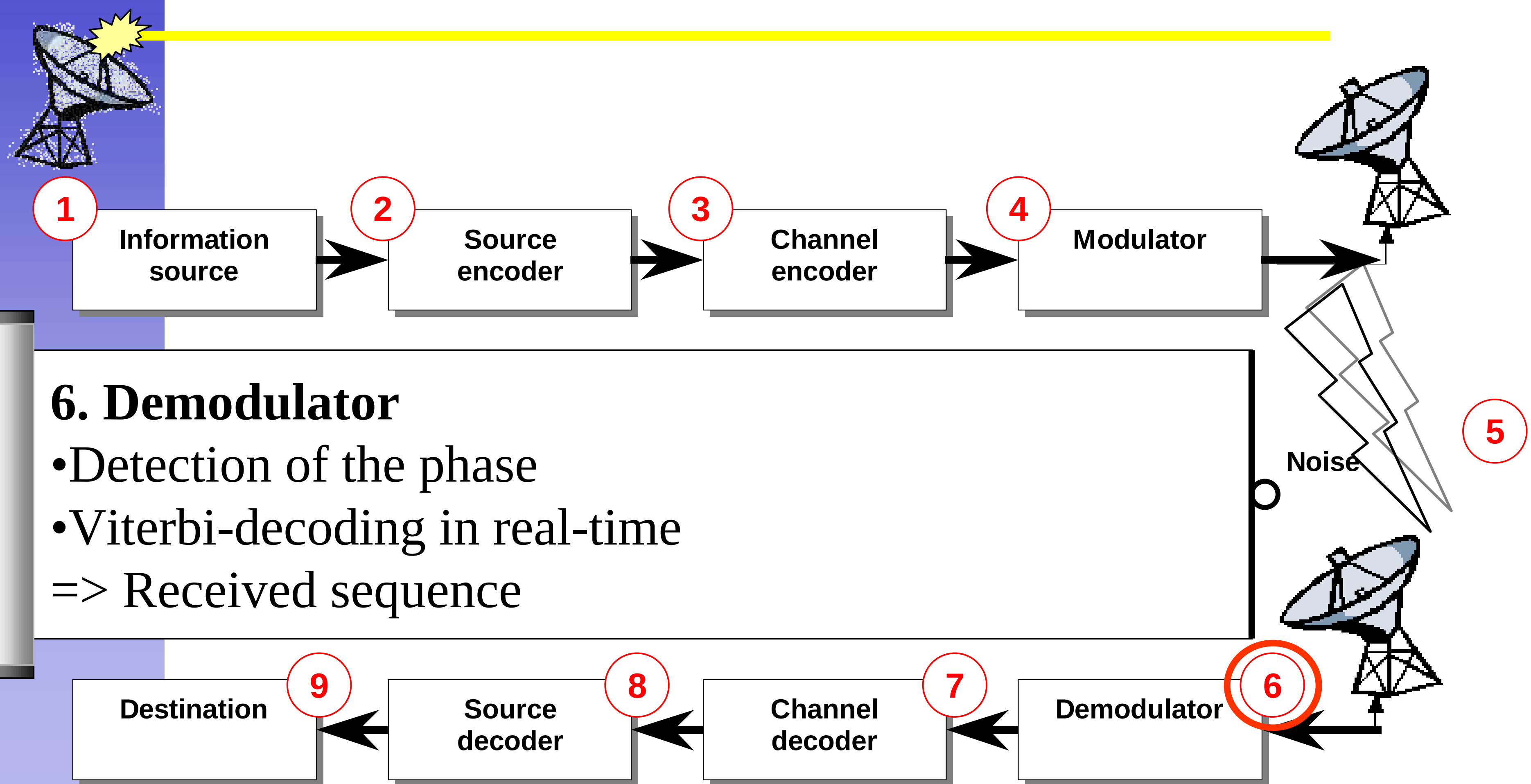


5. Channel

Transmission via channel; Influence by noise

- Non-linearity of system
- Interferences in the atmosphere: rain, clouds, other radio waves
- Reflections

Digital communication system

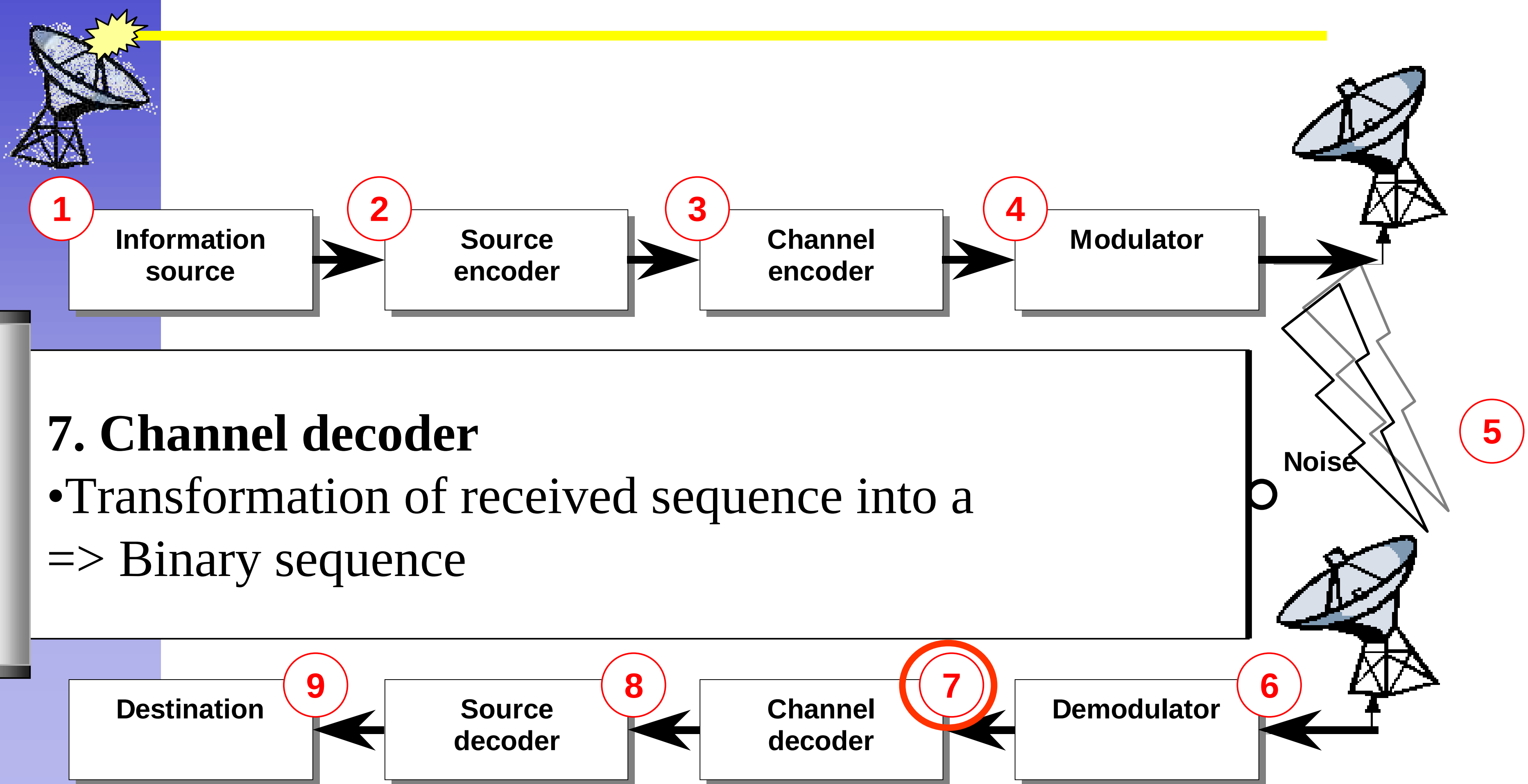


6. Demodulator

- Detection of the phase
- Viterbi-decoding in real-time

=> Received sequence

Digital communication system

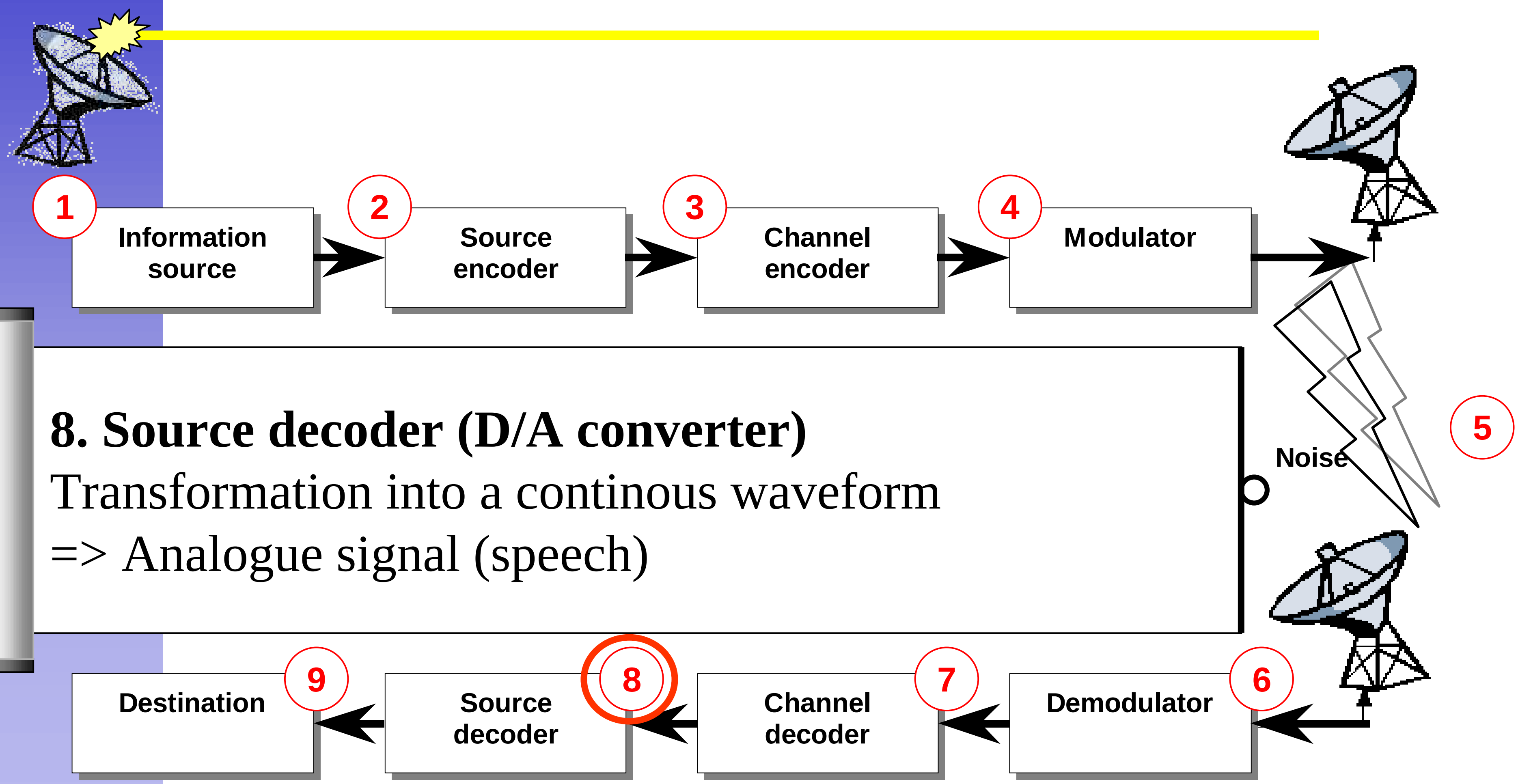


7. Channel decoder

•Transformation of received sequence into a

=> Binary sequence

Digital communication system



8. Source decoder (D/A converter)

Transformation into a continous waveform

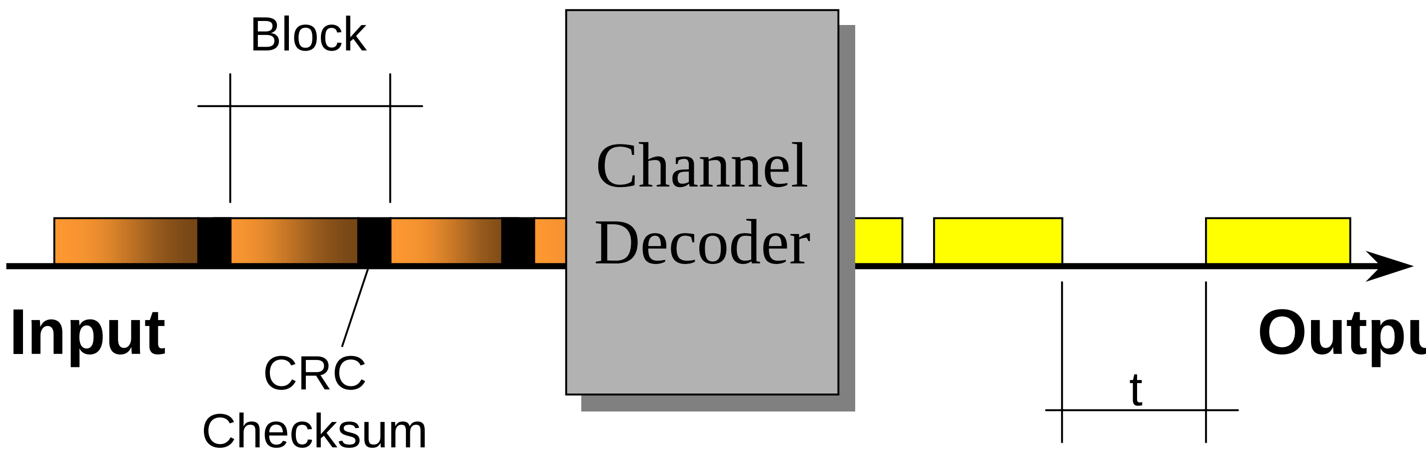
=> Analogue signal (speech)

Channel coding: Code Types

Code Types:

- Block coding
- Convolutional coding

1. Block coding



- Input:
  - Large message blocks with CRC
- Output:
  - Block code with different lenght and breaks

1. Block coding

Example of Block Coding:

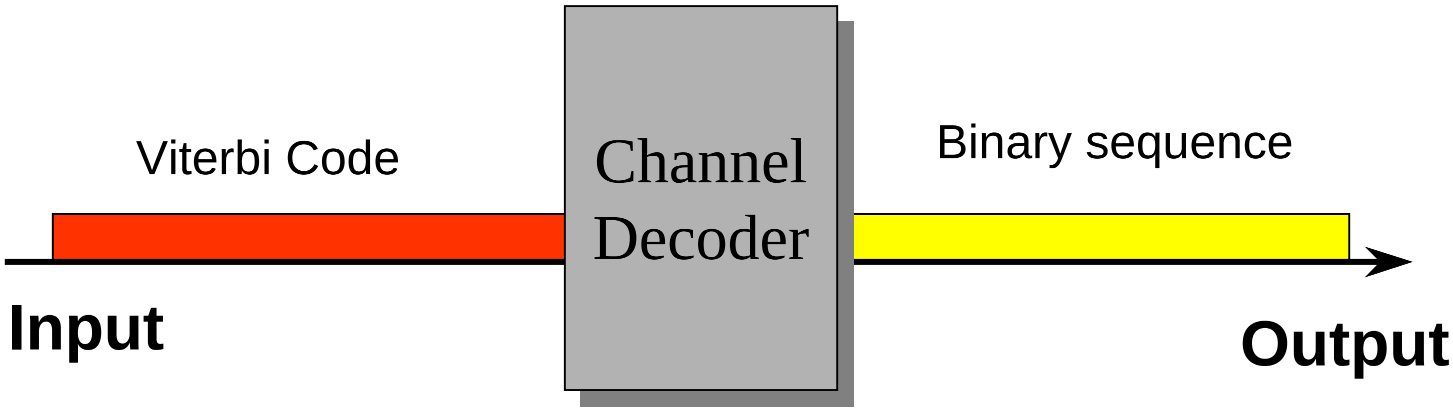
- Reed-Solomon Block:

Viterbi-coded block + CRC-block

188 bytes	16 byte

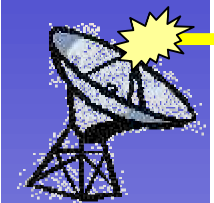
- Recognition and correction of 8 error-bytes

2. Convolutional Coding



- Input:
  - Serial data stream with includes redundant information
- Output:
  - Decoded binary data stream

Use of the Viterbi Algorithm



- Low Signal to noise ratio ratio

- Radio link
- Satellite connection
- Digital TV (MPEG-2/DVB)
- Geostationary satellite networks (VSAT)
- Speech recognition
- Magnetic recoring
- Direct broadcast satellite systems (DBS)

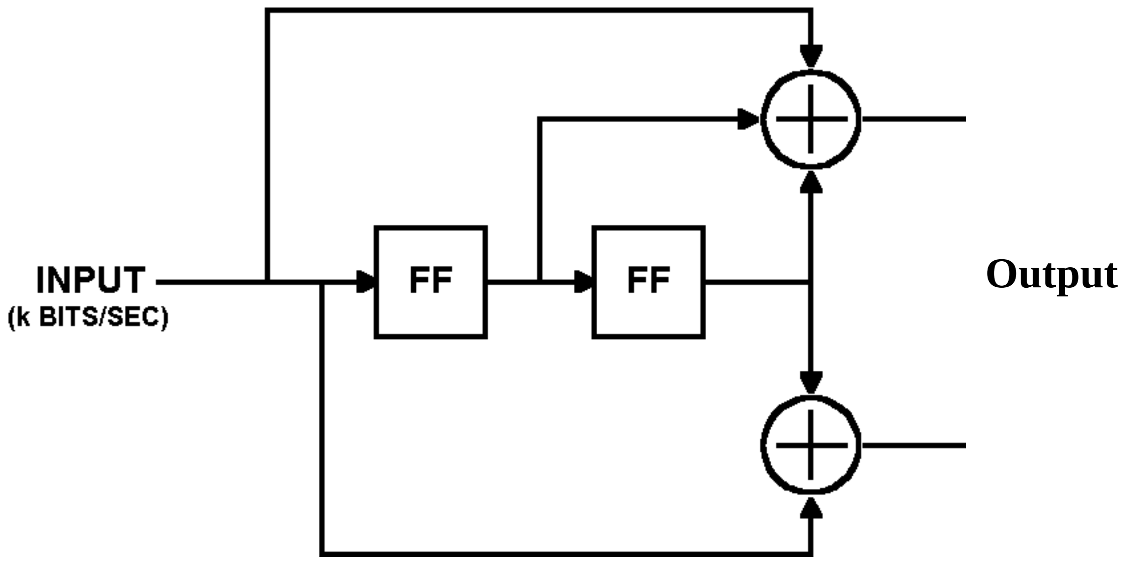
2. Description of the Algorithmus

- Generation of the data
- Convolutional encoder
- Parameters
- Channel symbols mapping
- Noise adding
- Channel symbol quantizing
- Viterbi Decoding

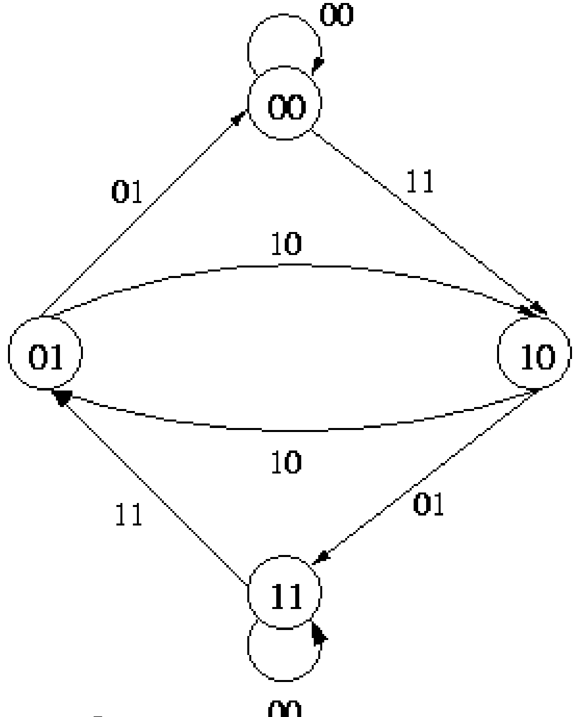
Generation of the data

- needed for simulation
- eg. using a random number genarator
  - eg. rand (); in C
  - value less than half of the maximum value is a zero
  - any value grater or equal to half of the maximum value is a one

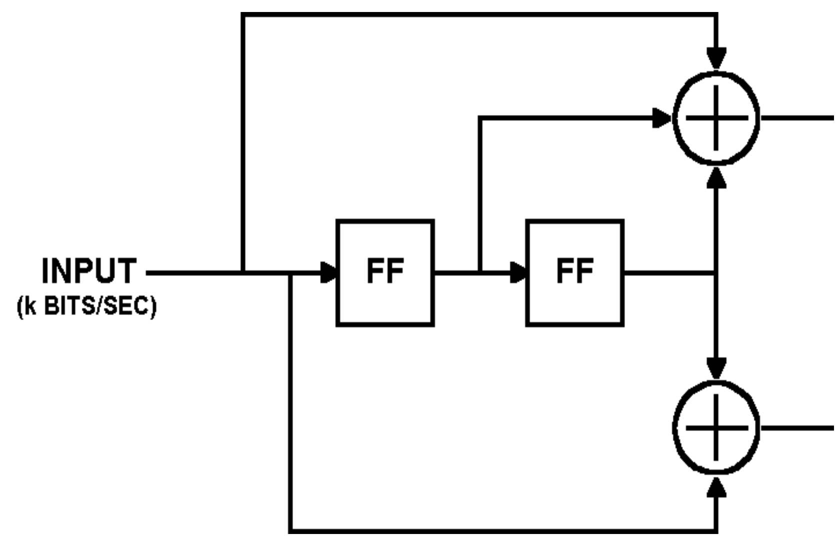
Convolutional encoder



Convolutional encoder



State diagram

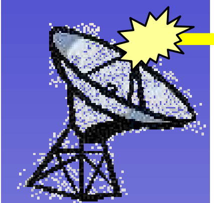


Encoder

Parameters

- eg. k=3
  - represent the code generator polynomials
- eg. m=2
  - number of shift-register
- eg.R=1/2
  - code rate (one inputbit → two outputbits)

Channel symbols mapping

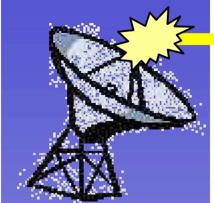


- Is simply a matter of translating:
    - zeros to +1
    - ones to –1

  – method is called living zero

This can be accomplished by performing the operation: **y = 1-2x**

Noise adding



- generating Gaussian random numbers
- adding the scaled Gaussian random numbers to the channel symbols values

Channel symbol quantizing

- Hard-decision
- Soft-decision

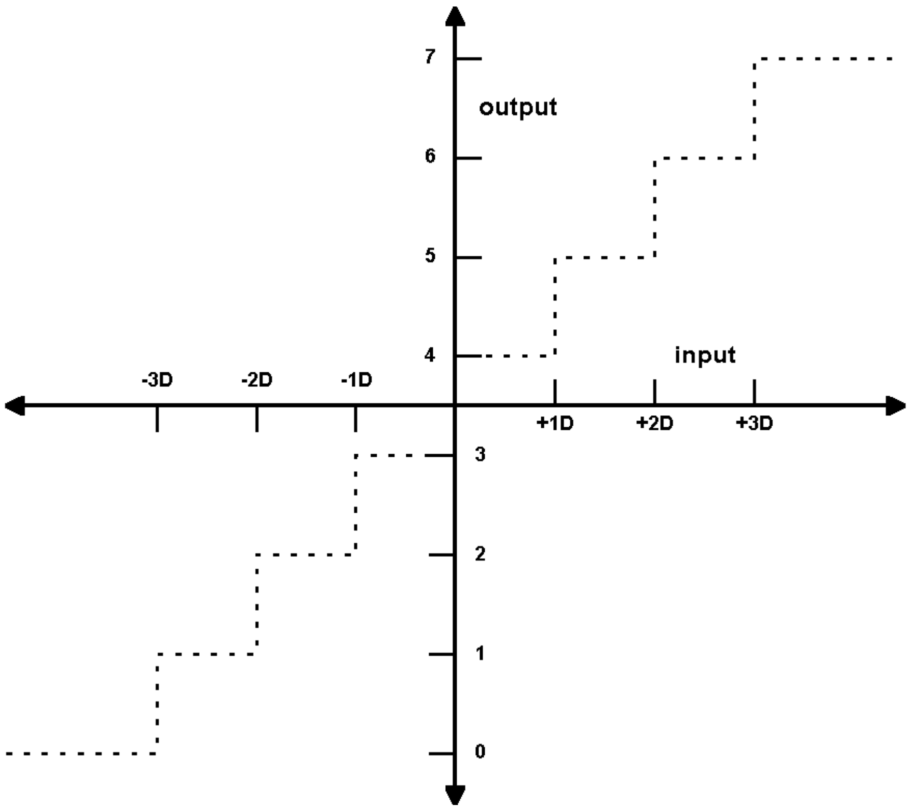
Hard-descision

- quantized to one-bit precision
  - < 0V = 1
  - > 0V = 0

Soft-decision

- quantized with more than one bit of precision
- three or four bits of precision can perform about 2 dB better than hard-decision
- the usual quantization precision is three bits

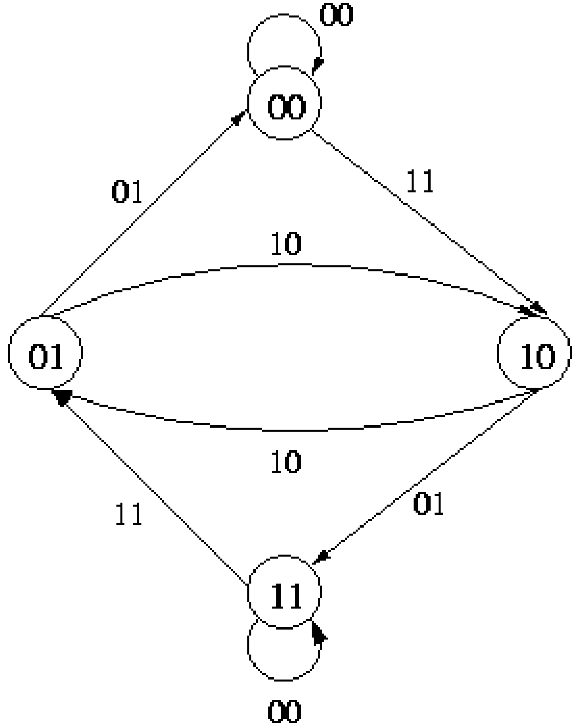
3 Bit Quantizer



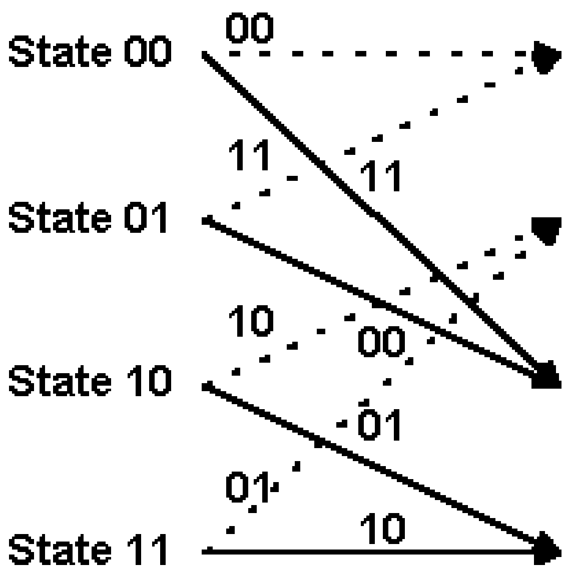
Viterbi Decoding

- Diagrams help to understand the algorithm
  - State diagram
  - Trellis diagram

State diagram / Trellis diagram

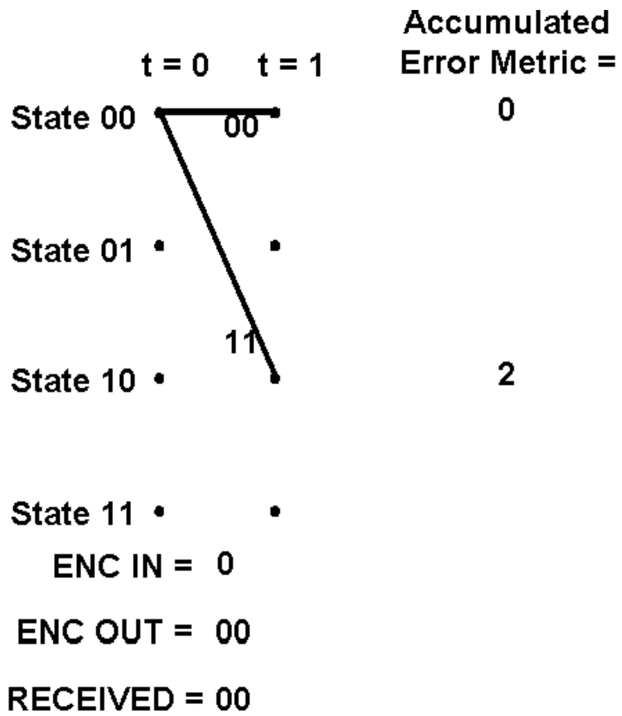


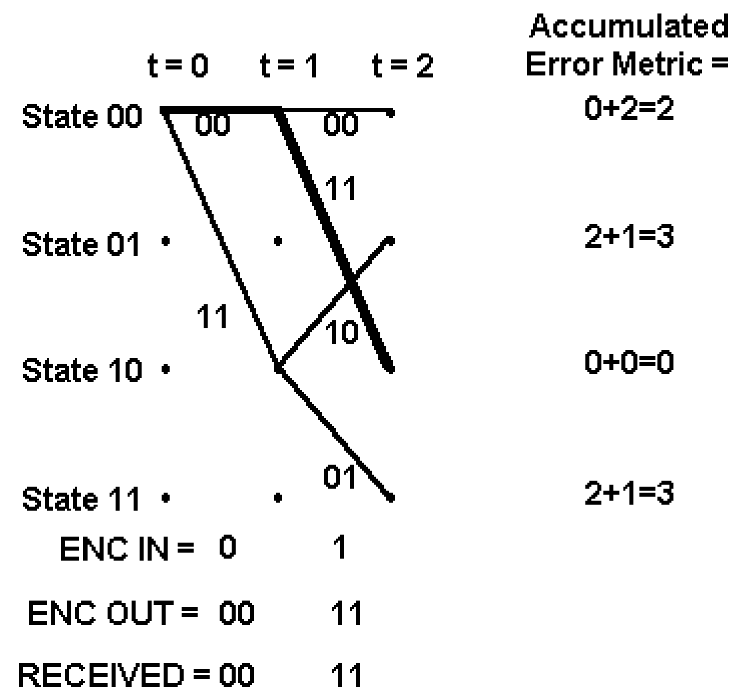
State diagram



Trellis diagram

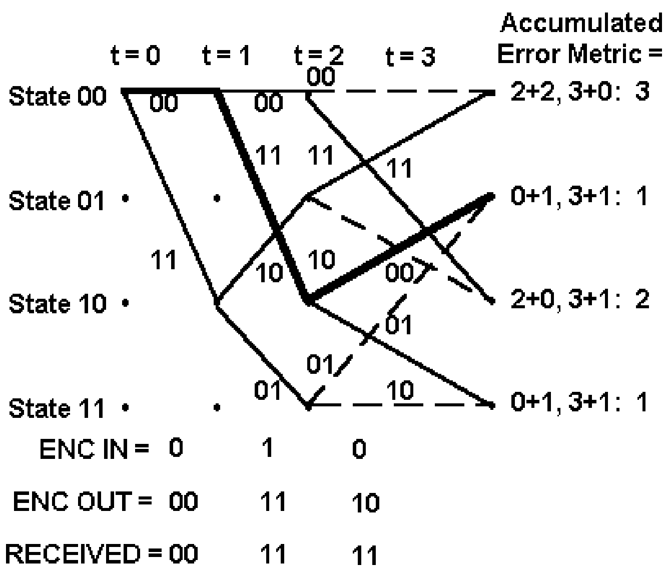
Viterbi decoding 1

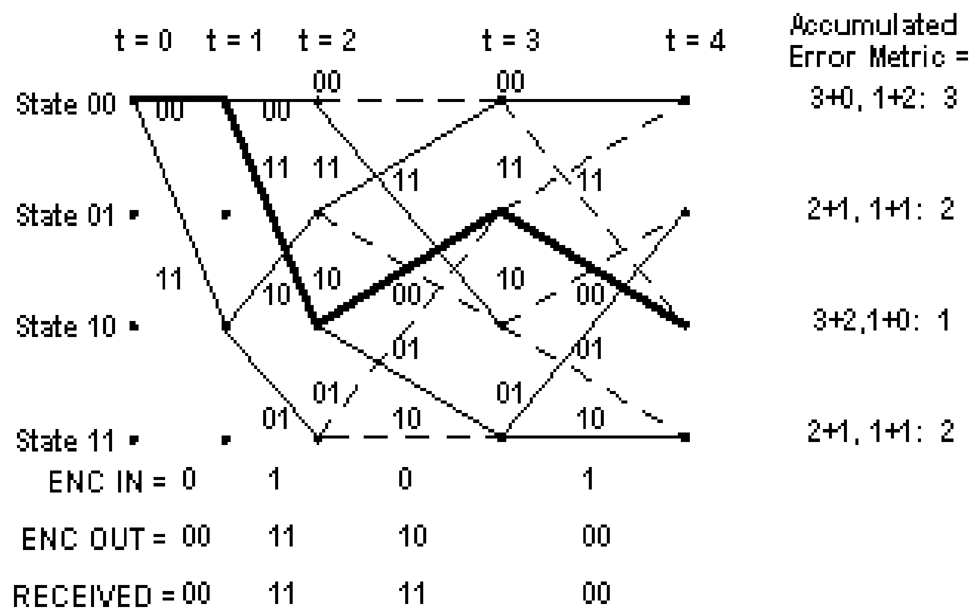




2. Description of the Algorithm

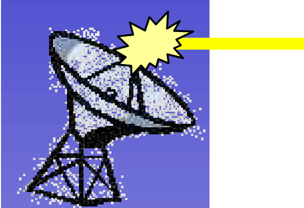
Viterbi decoding 2

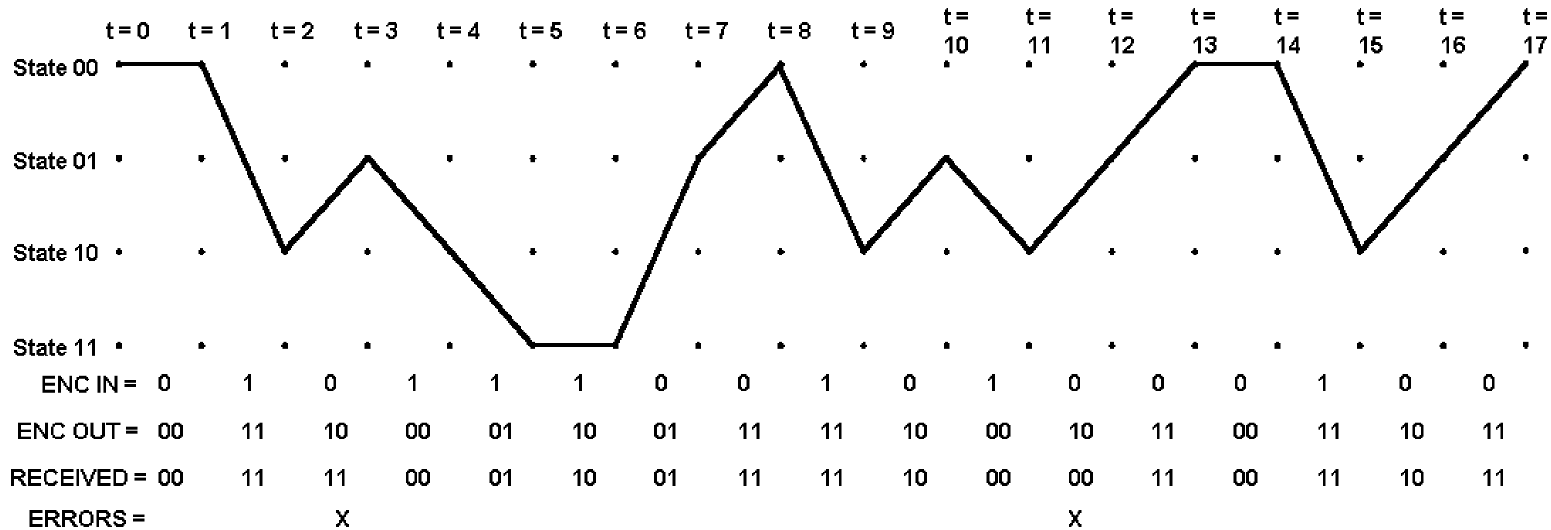




Trellis diagram

2. Description of the Algorithm





current	next	sended bit
00	00	0
00	10	1
10	01	0
10	11	1
01	00	0
01	10	1
11	01	0
11	11	1

3. Advantages of the Viterbi Algorithm

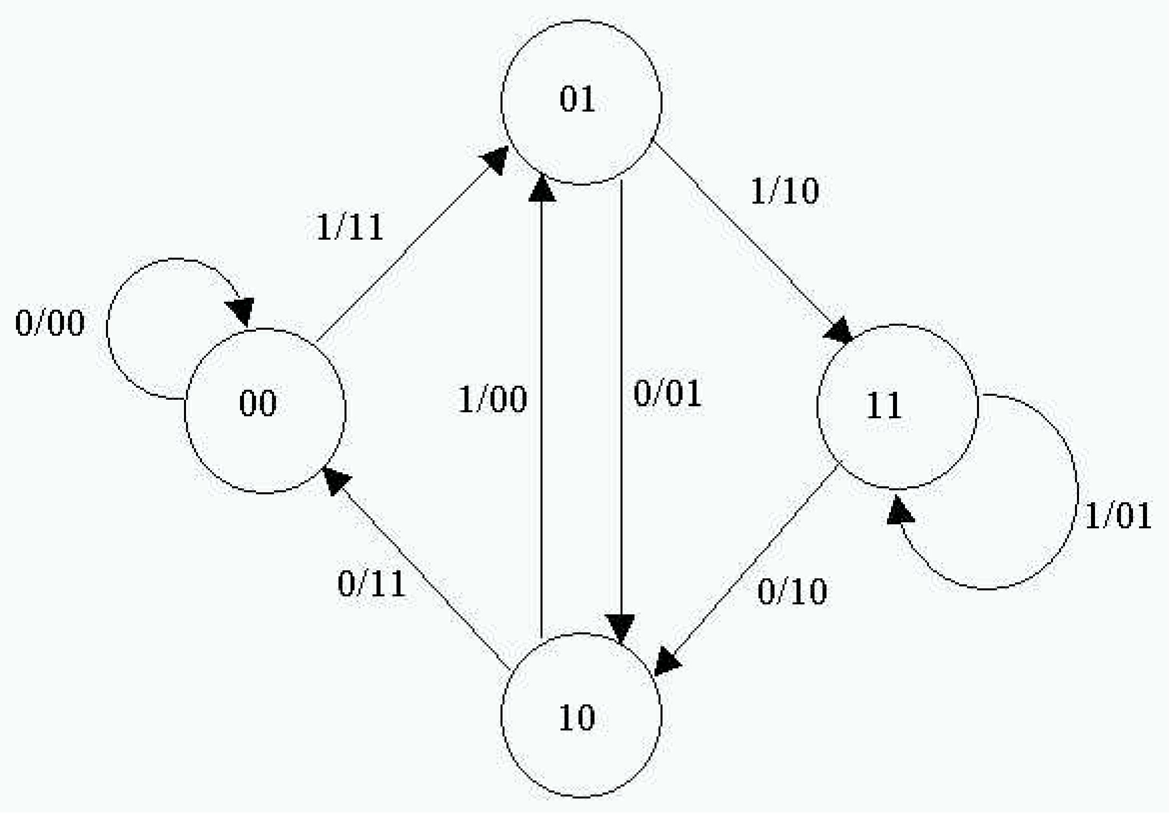
- Self-Correction of the Code
- Minimization of the Transmitting Energy
- Minimization of the Bandwidth
- Other Advantages

Self-Correction of the Code

- very good ability to correct wrong transmitted bits $\Rightarrow$ forward error correction
- done by adding of a redundant information
- state diagram offers a complete description of the system

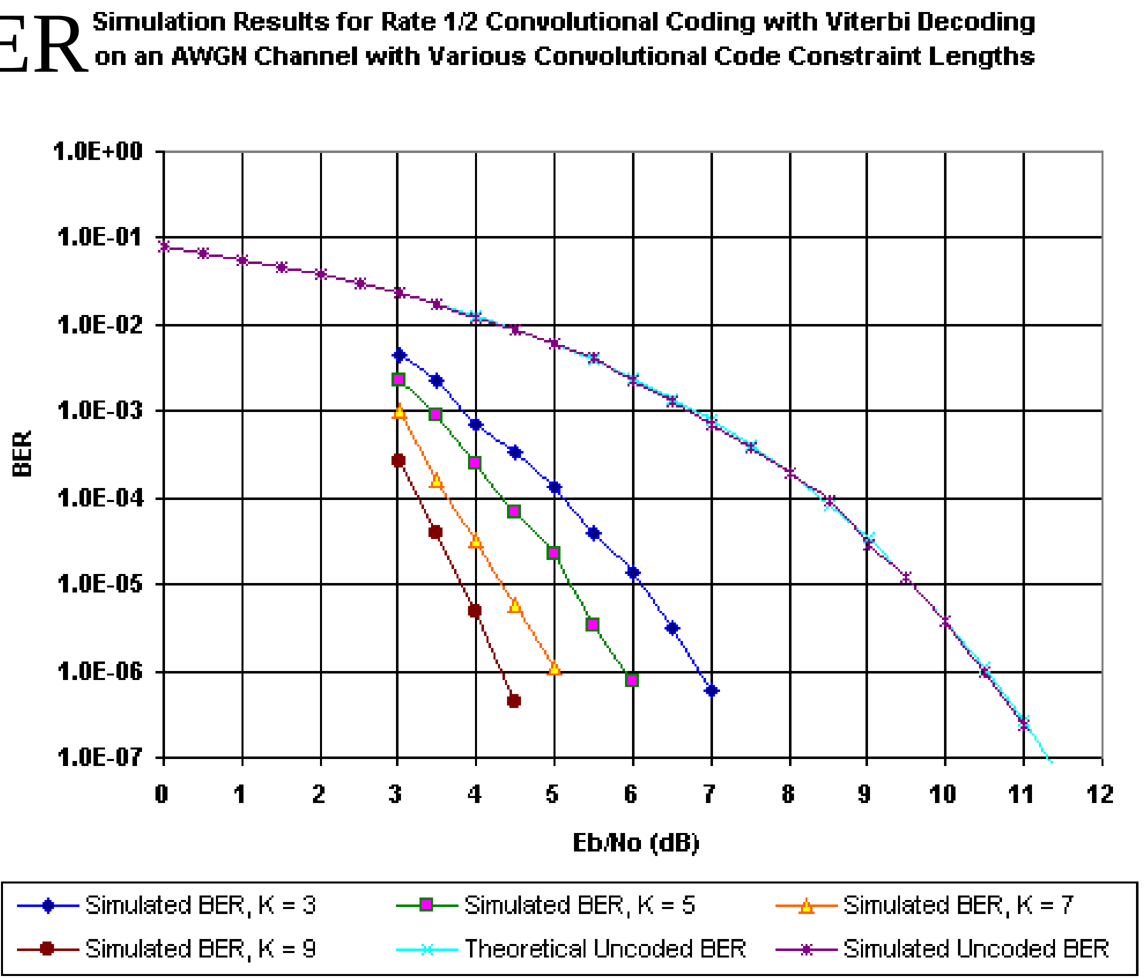
Self-Correction of the Code

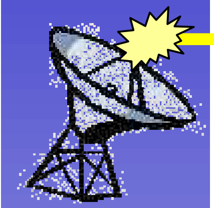
- State diagram



Minimization of the Transmitting Energy

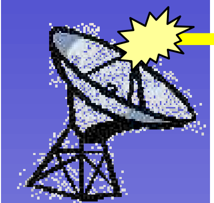
- BER





3. Advantages of the Algorithm

Minimization of the Transmitting Energy



- good designed satellite transmissions: BER< 10^{-6}
- professional transmissions: BER < 10^{-10}
- transmitting power: 4 Watt

Minimization of the Bandwidth

- possible to reconstruct lost data ⇒ used to save bandwidth
- more bandwidth needed, because of all the redundant information
- rate 1/2 ⇒ double of the bandwidth
- don’t send every third bit ⇒ able to reconstruct the dropped data

Minimization of the Bandwidth

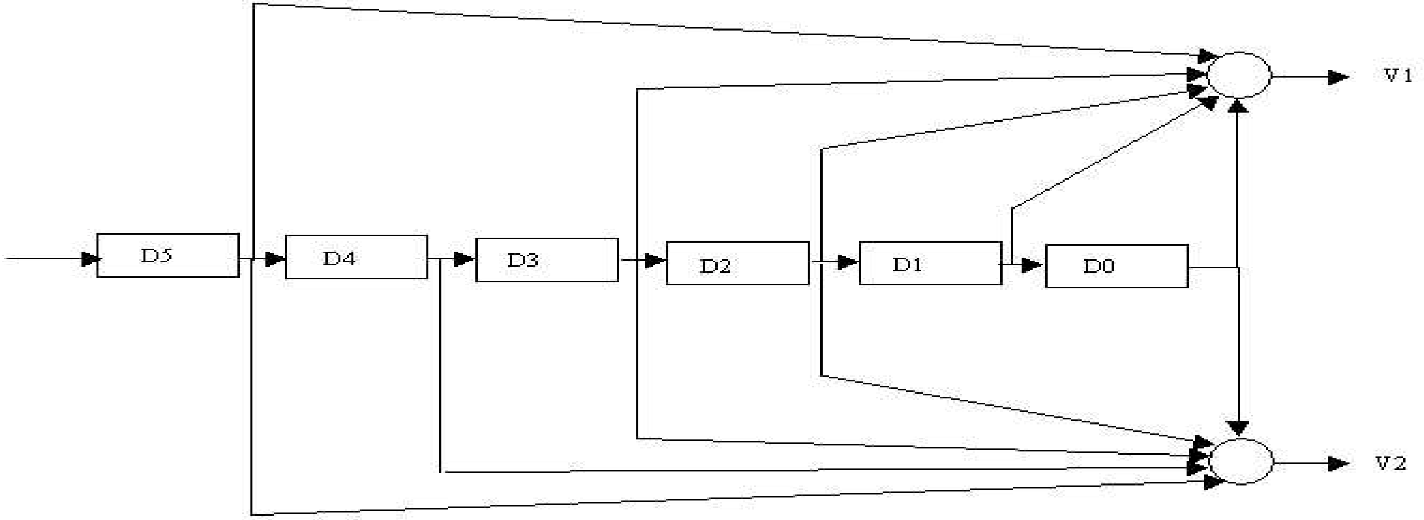
- called puncturing of the code
- disadvantage: the transmitting energy have to been increased

Other Advantages

- fixed decoding time
- high transfer rate, up to 2 Mbps
- implementation in hardware and software

4. Presentation of the Software

- task:
  - constraint length: 7
  - code rate: 1/2
  - soft decision: 3 bit quantizer



Viterbi Algorithm

Thank You for Your Attention!