DIGITAL COMMUNICATIONS

PRESENTATION OF PROGRAMMING WORK

SUBJECT: CRC IMPLEMENTATION

ERROR DETECTION CODES

Cyclic Redundancy Check (CRC)

- For each data block D of k bits, the transmitter generates a Frame Check Sequence (FCS) of n-k bits,
  - such that **the resulting total sequence T of n bits is exactly divisible by a predetermined number P of n-k+1 bits.**
- When the sequence T of n bits reaches the receiver,
  - then its correctness is checked by dividing it by the predefined number.
  - **If this division does not result in a balance**, then the box is accepted.
  - **If there is a remainder**, then it is concluded that the frame has been corrupted and a retransmission is requested.

ERROR DETECTION CODES

- It is worth noting that **modulo-2 arithmetic is used** to calculate the FCS as well as to verify the correctness of the received frame.
  - That is, binary arithmetic in which there are no prisoners or loans.

- **Reasons for using modulo-2 arithmetic**
  - the simplicity that characterises this arithmetic and the resulting ease of implementation.
  - The modulo-2 division leaves a remainder 1 bit smaller than the normal division
    - which leads to a slight reduction in transmitted bits error control errors that overload the communication system.

ERROR DETECTION CODES

modulo-2 arithmetic

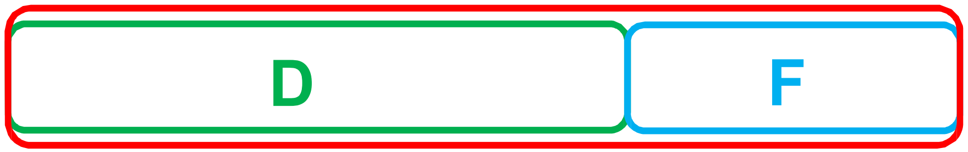
- Binary addition/subtraction without a prisoner
  - **This is essentially the XOR operation**

```
  1111          1111          11001
+1010         -1010            x11
  --------       --------      ----------
  0101          0101          11001
                             11001
                             ------------
                             101011
```

ERROR DETECTION CODES
CRC calculation

- Let's say:
  - **D** is the sequence of **k bits** of data to be transmitted,
  - **F** is the FCS sequence of **n-k bits**,
  - **T** is the sequence of **n bits** to be transmitted
  - **P** is the predefined number of **n-k+1 bits** by which the sequence T should be divisible.
    - The first and last bit should obviously be 1

- The sequence **T** can be written as: $T = \boxed{2^{n-k} D + F}$
  - Before the T sequence is transmitted, a control sequence F must be calculated.



ERROR DETECTION CODES

CRC calculation

- To calculate the error control sequence **F** the following algorithm is used:
  - We place n-k zeros to the right of D so as to obtain $2^{n-k}D$
  - Divide $2^{n-k}D$ by P
  - We use as **F** the **remainder R of** the above division

$$\frac{2^{n-k}D}{P} = Q + \frac{R}{P}$$

$$T = 2^{n-k}D + R$$

ERROR DETECTION CODES

CRC calculation

EXAMPLE OF CALCULATION OF THE FCS AT THE TRANSMITTER AND CORRECTNESS CHECK AT THE RECEIVER

Let's say:

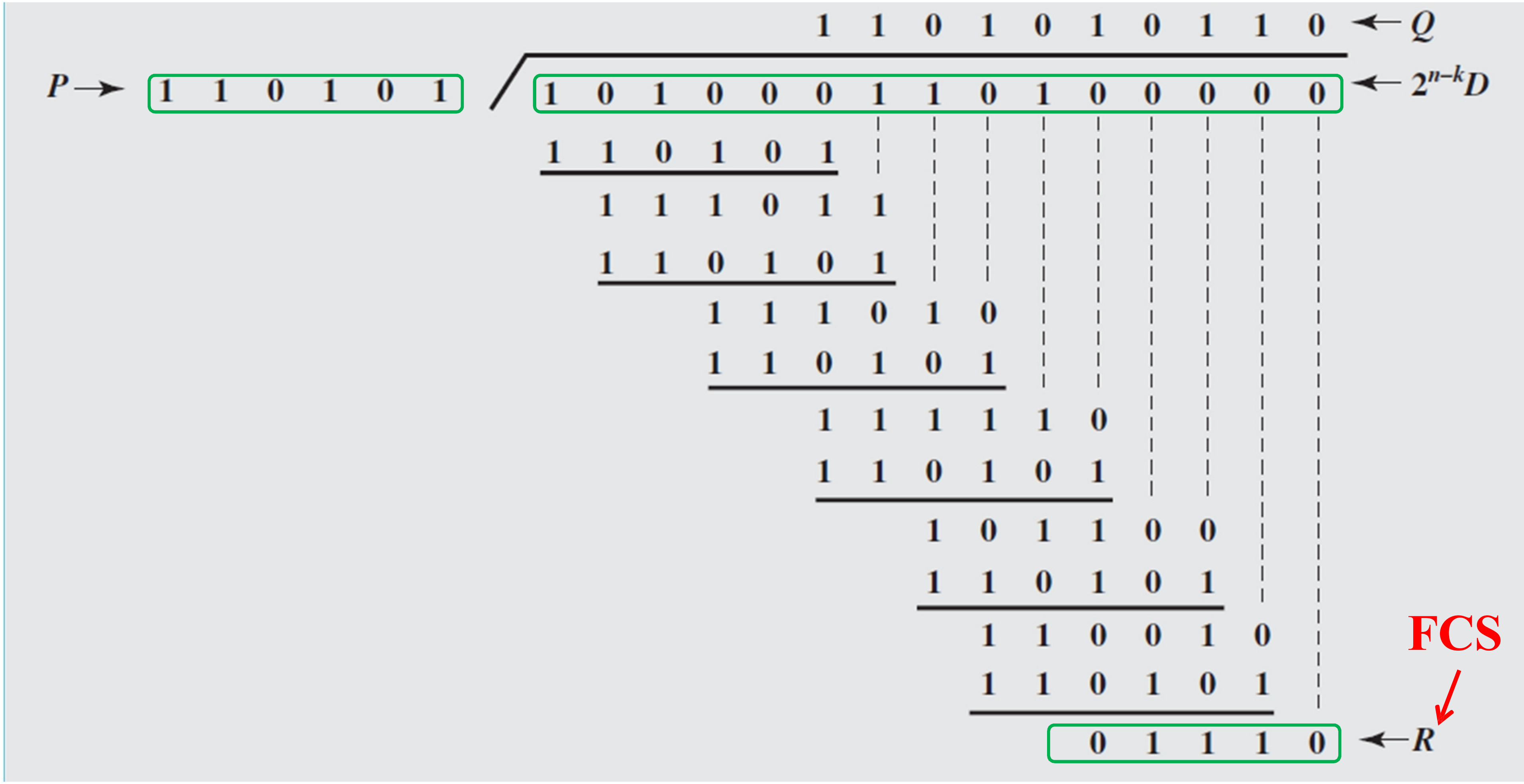
$$D = 1010001101 \text{ (10 bits)}$$
$$P = 110101 \text{ (6 bits)}$$

$n = 15, k = 10$ $(n - k) = 5.$

TRANSMITTER: CALCULATION OF R (5 bits) TO BE USED AS ERROR CONTROL BITS **F**

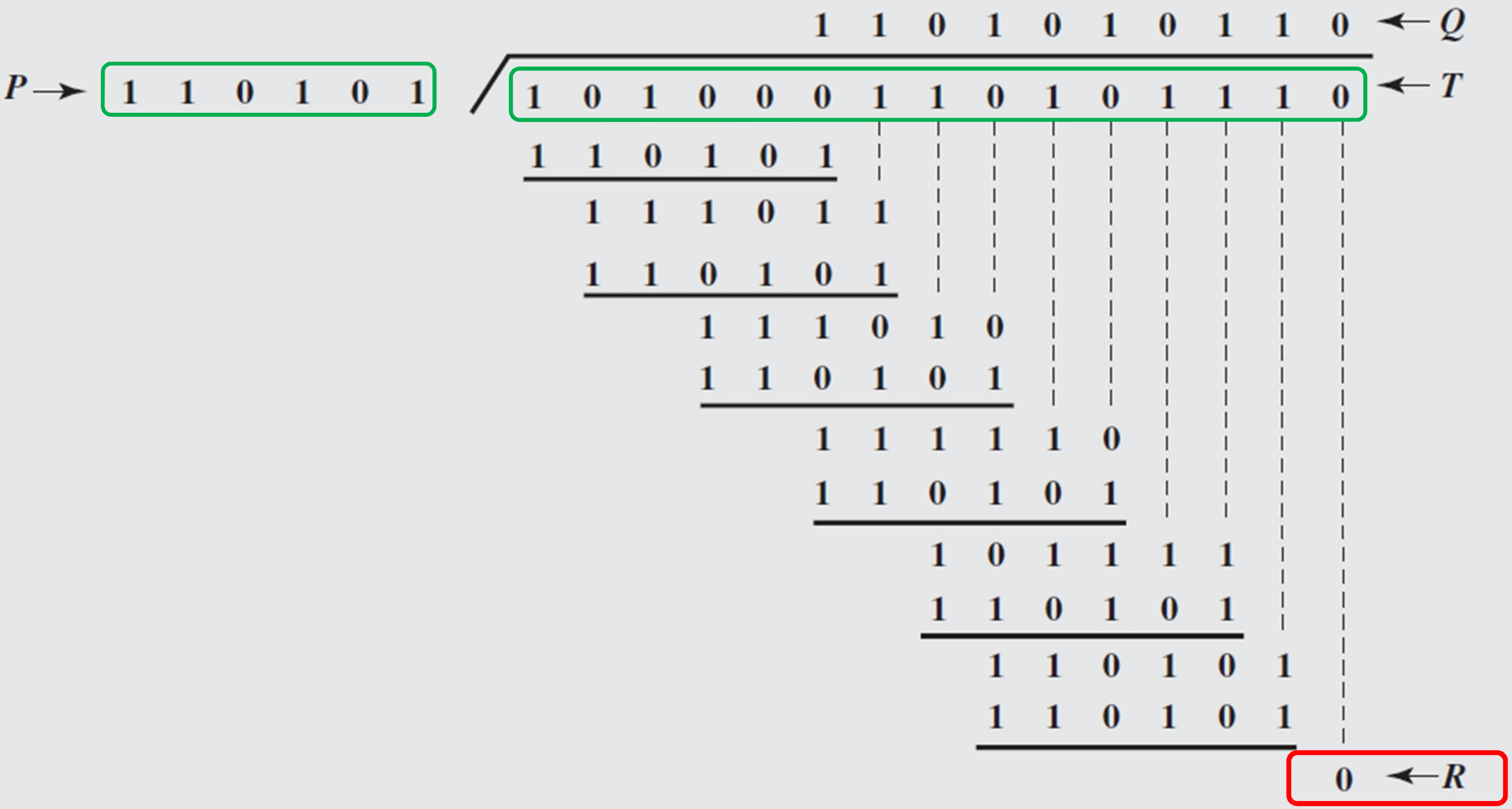
ERROR DETECTION CODES

CALCULATION OF THE FCS AT THE TRANSMITTER



ERROR DETECTION CODES

CONTROL ON THE RECIPIENT



PRONOUNCEMENT OF PROGRAMMING WORK

- As part of the assignment, you are asked to implement the CRC error detection algorithm.
- Build a program in the programming language of your choice, which includes the following functions:
  - Generation of randomly selected binary messages of *k* bits, in the transmitter (data blocks of k bits, in each bit of which 0 and 1 have equal probability of occurrence).
  - Calculation of the CRC (FCS) corresponding to each message. A binary number *P* given by the user will be used as a template for calculating the CRC.
  - Transmission of the message and the CRC through an open channel with Bit Error Rate *BER* and reception of the "corrupted" message at the receiver.
  - Check the CRC on the receiver.

WORK STATEMENT

- Deliverables: Report which will include:
  - a) The program you built, examples of how it works and a brief description of the most important parts of your code.
  - b) For $k=20$, P=110101 and BER=10^{-3} , calculate:
    - The percentage of messages that arrive with an error (in the data block or CRC) to the recipient.
    - The percentage of messages detected as incorrect by the CRC.
    - The percentage of messages that arrive with an error at the recipient and are not detected by the CRC.

Tip: To get reliable results, create as many messages as possible.