# EITP30: Lab 1 - 2022

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The objective of these laboratory sessions is to make you understand how a device first gets connected to the cellular network from a more hands-on point of view. We will technically refer to the device acting as a user as the User Equipment (UE). On the other hand, we will refer to the device that is part of the cellular network as the Base Station (BS). In the 3rd Generation Partnership Project (3GPP) context, a BS receives different names. For LTE, the technical denomination is eNodeB (eNB). For NR on the other hand, it is gNodeB (gNB).

## Pre-lab Section

To start with it, we will need to understand how to generate the first pieces of information that will be recognized from the device side. These pieces are called synchronization signals, and we will focus on the generation of NR synchronization sequences in this lab. The procedure is similar for Long-Term Evolution (LTE) and New Radio (NR), so it is up to the student to explore on the generation of LTE synchronization sequences. As pre-tasks, you should do the following:

1. Please read Chapter 11 of the 4G book [1] and Chapter 16 of the 5G book [2].
2. Read about Maximum Length Sequences (MLS, m-sequences) from different sources.
    a. Optional: Read about Linear-Feedback Shift Registers (LFSRs)
3. Read 3GPP 38.211 [3], Section 7.4.2 (pp. 118-119).
    a. Optional: Read Section 7.4.3 (pp. 119-121).
4. Are the formulas for PSS generation in 3GPP 38.211 and the 5G book equivalent? If so, in which way?

Notice from the 5G book and the figure down below (taken from the book) that, for PSSs, there are contributions from previous bit states ($x(n + 4)$ here) and the immediate input bit state $x(n)$ . These contributing bit states are called register taps. For the figure down below, we have contributions from the 3rd and 7th tap.
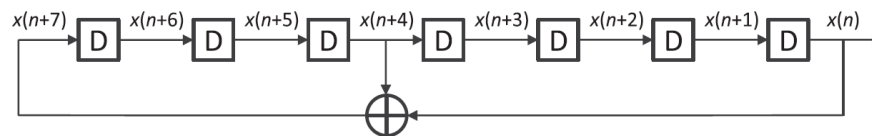


Initial value: [$x(6)$ $x(5)$ $x(4)$ $x(3)$ $x(2)$ $x(1)$ $x(0)$] = [1 1 1 0 1 1 0]

**Fig. 16.5** Generation of basic $M$-sequence from which three different PSS sequences are derived.

5. Can you explain why the tap order and the index $x(n + index)$ do not coincide in value?

## Lab Calculation Section

We will start with simplified hand calculations for a short m-sequence, namely a 3rd-order m-sequence. In the following figure, a Primary Synchronization Signal (PSS) generating scheme is given:
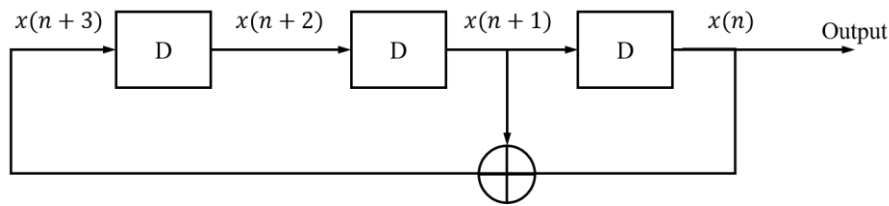


Fig 1. Generation of basic M-sequence: $x(k) = x(k-2) \oplus x(k-3)$

Initial sequences for the scheme are determined as follows:

- PSS = 0 has initial sequence $[x(2), x(1), x(0)] = [0\ 1\ 1]$;

- PSS = 1 has initial sequence $[x(2), x(1), x(0)] = [1\ 0\ 0]$;

- PSS = 2 has initial sequence $[x(2), x(1), x(0)] = [1\ 0\ 1]$.

After a UE is switched on, it starts the procedure of cell search. During the synchronization phase, it detects a PSS sequence $[p(6), p(5), p(4), p(3), p(2), p(1), p(0)] = [1\ 0\ 0\ 0\ 0\ 1\ 1]$. Assume that one value of the received sequence is detected incorrectly (either 0 or 1) due to the channel influence. **Note:** keep in mind that the ordering must be correct.

**Tasks:**

6. Calculate basic m-sequences based on the initial sequences (you should obtain 3 m-sequences).

7. By defining which sequence has been received by the UE, specify the value of the considered PSS ID, $N_{ID}^{(2)}$, and calculate the Physical Cell Identity (PCI), $N_{ID}^{cell}$, based on the given SSS ID $N_{ID}^{(1)} = 53$.

**Hint!** Scalar product between the detected PSS sequence and the basic m-sequences can be helpful.


## Lab programming section

We use MATLAB as our programming tool. Pay attention to the indexing when coding. The tasks for this lab are the following:

8. Build the NR Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS) sequences given in 3GPP 38.211 Section 7.4.2, with the help of Chapter 16 of the 5G book.
9. Build a PSS with arbitrary parameters given for each student at the beginning of the lab session.
10. For PSS generation, answer the following questions:
    a. Is it reasonable to change the initial sequence to all zeros? What are the implications of doing this?
       i. Test with your MATLAB sequence generator.
    b. Is it reasonable to change the initial sequence to any other values than all zeros? What are the implications of doing this?
       i. Test with your MATLAB sequence generator.
    c. Is it reasonable to move the last register tap (7th for PSS) to one less bit state (6th)? What are the implications of doing this?
       i. Test with your MATLAB sequence generator.

      d. Is it reasonable to move any of the other register taps (3rd for PSS) to any other position? What are the implications of doing this?
          i. Test with your MATLAB sequence generator.
    e. What are the implications of increasing the range of the parameter $N_{ID}^{(2)}$?

**References**

[1] Dahlman, Erik, Stefan Parkvall, and Johan Skold. 4G: LTE/LTE-advanced for mobile broadband. Academic press, 2013.

[2] 5G NR: The next generation wireless access technology. Academic Press, 2020.

[3] 3GPP TS 38.211 version 17.1.0 Release 17. Physical channels and modulation. 2022. Available online:
https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/17.01.00_60/ts_138211v170100p.pdf