Mobile Communications (Lab)
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February - May 2017

Lab 2: Generation, transmission and reception of GSM signals on FRAMED-SOFT based on the Software Defined Radio environment NI LabVIEW and NI USRP-2920 hadware.

(4 hours)

Objectives
The objectives in this lab session are:

- Reinforce the knowledge about the burst formation in traffic and control channels of a GSM system.
- Reinforce the knowledge about the GSM standard.
- Learn how to manage equipment of a communication laboratory, like transceivers to work in a Software Defined Radio (SDR) environment, as well as getting used to the NI LabVIEW development environment.

After this lab session, the student must have understood how the GSM system works, from the composition of a signal to its transmission. Besides, the student will be more used to managing hardware equipment of a communication laboratory.

1 FRAMED-SOFT

The Flexible Radio Access Mobile Environment Defined by SOFTware (FRAMED-SOFT) is a platform designed in The University Carlos III of Madrid with the aim of getting closer to the students the mobile communication standards. The platform is divided into three parts, namely, the hardware, the base stations and the receivers. The hardware part is composed of the NI USRPs, usually two of them for each software part. Although the same USRP could work simultaneously as transmitter and receiver (one antenna for transmission and the other one for reception), this design uses two different USRP connected by the provided interconnection wire. This way, the design of each part is simpler, it allows the use of less powerful computers for controlling the USRP.

FRAMED-SOFT allows the modification or optimization of the transmission/reception parts independently, what is very useful for practical work. Thus, a base station needs two USRPs, one for transmission and the other one for reception. Since both are controlled by different LabVIEW designs (even running in different computers although this is not mandatory), they interchange information by using the interconnection wire provided with the USRP bundle.

The base station part allows one to select the GSM or the UMTS standard. Depending on which one is chosen, the adequate LabVIEW design is executed. Since both standards are completely different from the physical layer point of view, two different designs have been implemented. However, from the logical point of view, both of them have several similarities.

It should be noted here that within the LabVIEW interface, there is the NI LabVIEW MathScript RT that allows the use of Matlab code directly into the LabVIEW designs. This can be used when a complex algorithm needs to be evaluated first in order to decide if it will be implemented or not.

In this lab work, the student will receive a incomplete version of FRAMED-SOFT and he/she, after studying the corresponding standard, must program the parts that are required. This way, the student becomes aware of the functioning of mobile communication technologies.

In further lab sessions, the student will be asked for an open ended-design experience that consists in developing important parts of a communication system: the channel estimation, equalization, rake receiver, synchronization, etc.

2 Lab work description

The objective is to generate, using the development software NI LabVIEW, the transmission of 2 control channels and 1 traffic channel of the GSM standard. Once these sequences are created, the student must form the suitable bursts to transmit these formed channels.

Finally, the last part of the session consists in managing two Base Transceiver Stations (BTS) GSM, namely the transmitter of a BTS and the receiver of another. Thus, the FRAMED-SOFT platform will be used together with the hardware NI USRP-2920 in order to transmit and receive the signals. The channels previously created will be transmitted and the student will observe and analyze their constellations and spectrums. The results must be discussed.

For the correct realization of this lab, it is highly recommendable to read the supplied tutorial about LabVIEW.

3 Generation of the transmission in GSM

As you have seen in the lectures of Mobile Communications, the transmission in GSM is made in one only slot of the 8 that are available in each frame [1], using a GMSK modulation [2]. In this lab session, you are asked for creating two of the GSM control channels, concretely the SCH (*Synchronization CHannel*) and the FCCH (*Frequency Correction CHannel*), and one traffic channel TCH. With the aim of learning the whole procedure from the information bits creation that will be transmitted, to the transmission itself, also you will be asked for designing and implementing the bursts formation, namely the NB (*Normal Burst*), FB (*Frequency Correction Burst*) and SB (*Synchronization Burst*).

Note: Due to the special characteristics of the FCCH, this channel will be formed directly in the module *Burst_Practices.vi* that must be created and will be explained later.

3.1 SCH channel (*Synchronization CHannel*) [3, 4, 5]

Generate this first control channel, which is used to allow the mobile station to idenify a near base station and to make a temporal synchronization of the frames.

Generate the 78 encrypted bits corresponding to such channel, knowing the information corresponding to the Table 1 and that the base station will transmit continuously the frame $15000 + 600 \times (Group + 1)$.

Group	**Country**	**BS**
1	Spain	0
2	United Kingdom	1
3	Portugal	2
4	France	3
5	Spain	0
6	United Kingdom	1
7	Portugal	2
8	France	3

Table 1: Table of values

Use the function *check_SCH.vi* to check if you have generated the information bits of this channel correctly. There are two ways of invoking this function:

1. To check the bits before the convolutional encoder $u(0) \ldots u(38)$. You can use it like a guide to check if the construction of the burst is correct so far.
2. To check the coded bits after the convolutional encoder $e(0) \ldots e(77)$.

The input parameters that the VI *check_SCH.vi* receives are (in the same order):

1. Group number: $1 - 6$
2. Input array with the corresponding bits: 39 or 78 bits depending on each case.
3. Type of the information that wants to be checked: SCHp for the first call mode or CSCH for the second one.

The message appearing in the screen will inform if the bits generation are correct or incorrect for the specified group.

3.2 TCH channel (*Traffic CHannel*) [3, 4]

Due to the short time available for the lab session, and once the coding procedure of the SCH is made, the student is asked for forming a burst of TCH. To this effect, change the pattern $Grupo \times 2$ in the Table 2. Simply, you must copy this pattern that has been previously coded and encrypted to generate a suitable number of bits in the burst.

Use the function *check_TCH.vi* to check if you have correctly generated the information bits of this channel. The inputs to this VI are (in the same order):

1. Group: corresponding to the group number that the student belongs to.
2. An array containing the information bits that conform the TCH (116 bits).

3.3 Creation of bursts [3]

Create the module *Burst_Practices.vi* correponding to the generation of bursts, which receives the information bits of the channels SCH and TCH[1] and obtains the burst of 148 bits (the 8.25

[1]For the FCCH chanel it is not necessary to introduce a bits array. The whole burst will be created within this module because it does not contain information bits.

Number	Pattern
0	11110000
1	00001111
2	11001100
3	00110011
4	10101010
5	01010101
6	11100111
7	00011000
8	11111111
9	00000000
10	11101110
11	00010001
12	10001000
13	01110111
14	10011001
15	01100110

Table 2: Possible patterns for TCH

bits of the guard period are included after the modulation process, so yout must not take on it). Concretely, you must generate the burst corresponding to these channels:

- *Synchronization Burst (SB)* for SCH.
- *Normal Burst (NB)* for TCH.
- *Frequency Correction Burst (FB)* for FCCH.

For the TCH, suppose that it is always transmitted in the TN (*Timeslot Number*) equal to the number of Group. The student must invoke to the function *check_Burst.vi* to check if the he/she has correctly created the burst SB, NB and FB. This function receives as inputs the following (in the same order):

1. Type of burst: Character array corresponding to the kind of burst that wants to be checked. Possible values: NB, SB, FB.
2. Burst: 148 bits that conforms a complete burst (keep in mind that in the case of FCCH, it is not necessary to introduce any bit because the whole burst will be created inside).
3. Group: group number to which the student belongs.

The result of this module must be an array of 148 bits, regardless of the kind of burst.

4 Transmission and reception of GSM channels with the transceiver NI USRP-2920

To make this section, consult the teacher to install all the harware required.

You are going to configure the transmitter of a GSM Base Transceiver Station (BTS) to transmit exactly the same channels implemented in the practice. The transceiver will be the NI

USRP-2920. Besides, a GSM receiver of a Mobile Station (MS) will be configured in order to receive these same channels by using another transceiver NI USRP-2920.

After the creation of the bursts, the FRAMED-SOFT platform makes all the signal processing to transmit (it generates the Gaussian pulse conforming, differential coding, GMSK modulation, inclusion of 8.25 bits that are the guard period, burst composition, setting of the transmission parameters, etc.).

The student is provided with two applications called *BTS-Transmitter App.exe* and *MS-Receiver App.exe*[2]. In the figures 1 and 2 you can observe the front panel of them.

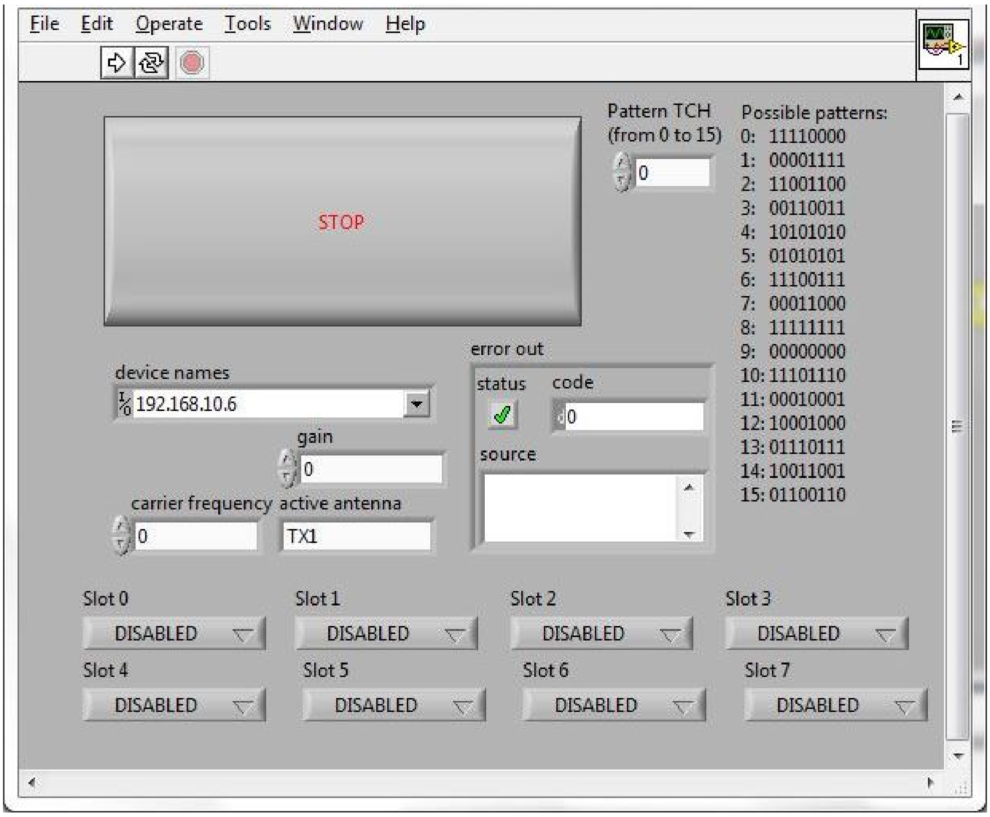

Figure 1: Front panel of the BTS transmitter

With these applications, the student is going to customize the BTS transmitter and MS receiver in order to obtain what is asked:

a) Transmit a frame formed by the corresponding channels in order that the terminals synchronize their PLLs to the appropriate frequency. Besides, the terminals must receive data information in the $TN4$ and $TN6$ (*Timeslot Number* 4 and 6).

b) Transmit a frame formed by the corresponding channels in order that the users can synchronize the frames in time. Besides, they must receive data information in the $TN4$ and $TN6$ (*Timeslot Number* 4 and 6).

In both cases, you must suppose that there is little traffic in the cells, that the frequency transmission is $600MHz$ and a transmission gain of 10 dB. This carrier frequency is used in order not to interfere to other GSM signals coming from real base stations.

[2]These applications can be executed only in computers with the LabVIEW Run-Time Engine 2010 version installed. Besides, drivers are needed to interface the program with the hardware NI USRP

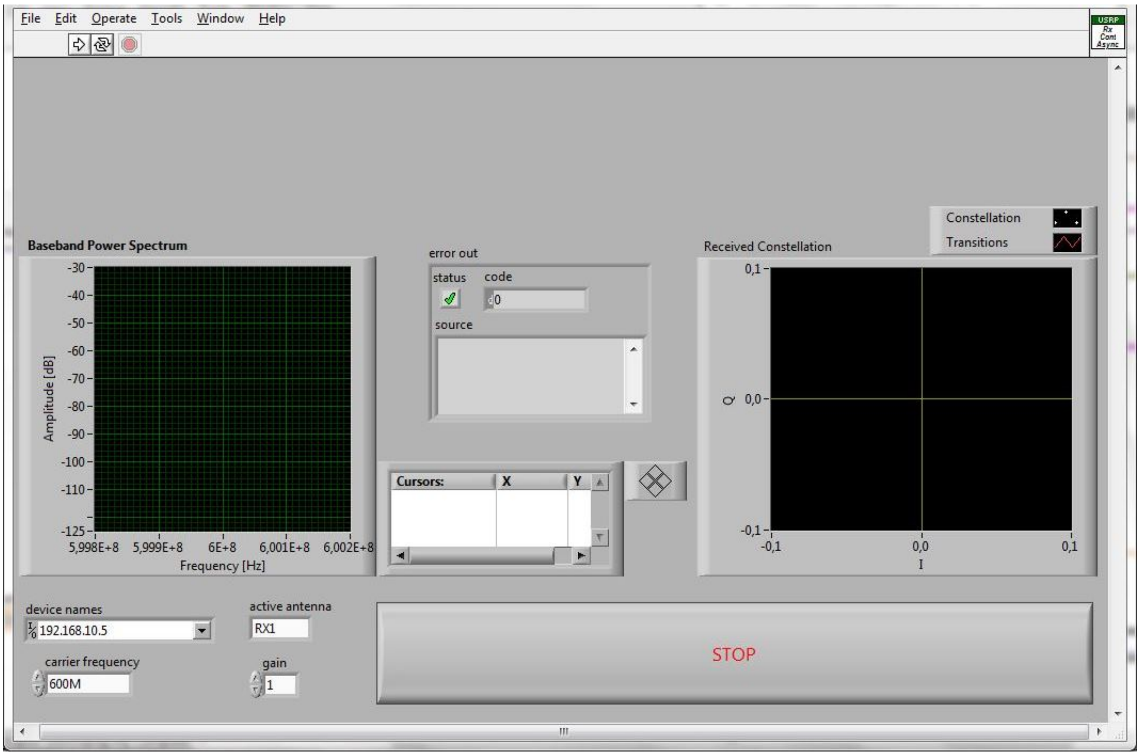

Figure 2: Front panel of the MS receiver

Capture at the receiver the constellation and frequency spectrum of the three diffent slots. Comment the results. If you are not able to capture the signals independently when you are transmitting them all together, customise it and transmit channel by channel.

Note: To introduce a new cursor in the graphic of the frequency spectrum, follow the next steps: Right button → *Create Cursor* → *Single-Plot* → Write in the X axis the frequency where you want that the cursor is initially, and after change it manually.

Optional: Observe what happens when you modify in real time the patterns of data bits sent in the transmitter. Configure the transmission of a data channel with the pattern number 4 or 5 and explain what happens and the reason.

5 Evaluation

The evaluation of this practice will be made in the post of practices. There, the students will have to show the obtained results. (Same procedure for all the lab sessions).

Besides, it is necessary to present a report where all the obtained results must be described and commented. Also, the students must expose the found troubles during the practice and they have been solved. Finally, the students must send to the instructor the source codes produced, concretelly three (or more if it is the case):

- VI that creates the encrypted information bits of the SCH (78 bits).
- VI that creates the encrypted information bits of the TCH (116 bits).
- VI(s) that conform the bursts NB, SB and FB (148 resulting bits).

To facilitate the understanding of the steps that must be followed, block diagrams to obtain the final bursts of the channels FCCH, SCF and TCH are included in the Figures 3, 4 and 5).

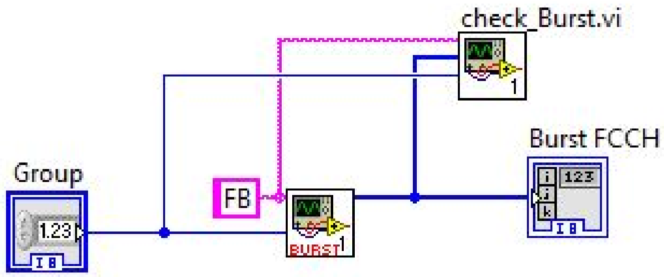

Figure 3: Block diagrams of the complete creation of FCCH

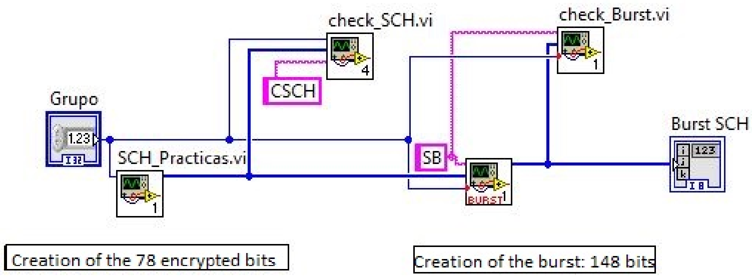

Figure 4: Block diagrams of the complete creation of SCH

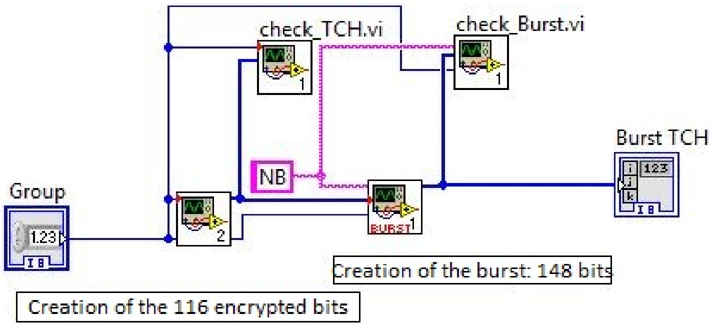

Figure 5: Block diagrams of the complete creation of TCH

References

[1] ETSI. ETSI TS 100 573 v8.4.0 (2000-07) Digital Cellular telecommunications system (Phase 2+); Physical layer on the radio path; General description (GSM 05.01 version 8.4.0 Release 1999). Technical report, ETSI, July 2000.

[2] ETSI. ETSI EN 300 959 v7.1.1 (2000-06) Digital Cellular telecommunications system (Phase 2+); Modulation (GSM 05.04 version 7.1.1 Release 1998). Technical report, ETSI, June 2000.

[3] ETSI. ETSI EN 300 908 v8.5.1 (2000-11) Digital Cellular telecommunications system (Phase 2+); Multiplexing and multiple access on the radio path (GSM 05.02 version 8.5.1 Release 1999). Technical report, ETSI, November 2000.

[4] ETSI. ETSI EN 300 909 v8.5.1 (2000-11) Digital Cellular telecommunications system (Phase 2+); Channel Coding (GSM 05.03 version 8.5.1 Release 1999). Technical report, ETSI, November 2000.

[5] ETSI. ETSI EN 300 927 v5.4.1 (2000-12) Digital Cellular telecommunications system (Phase 2+); Numbering, addressing and identification(GSM 03.03 version 5.4.1 Release 1996). Technical report, ETSI, December 2000.