**S-26.3120Laboratory course in Radio Engineering, autumn 2013–spring 2014**

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# GSM-receiver

## 1. The purpose of the laboratory work

The receiver part of the GSM base station will be measured. The measurements will cover the RF-parts of the heterodyne receiver, the pre-amplifier, and the diplexer. The purpose of this work is to get acquainted with a GSM base station, understand the effect of noise and non-linearities in the different parts of a heterodyne receiver, and to practice RF measurements with commonly used measurement equipment.

The important parameters of the GSM receiver are gain, stability (thermal and time stability), low-noise requirements such as noise temperature or noise figure and low influence of non-linearity on noise performance (desensitization).

The dynamic range of the receiver is limited by several margins. Minimal detectable power (MDP), or sensitivity of the receiver, shows the minimal detectable signal strength. MDP by its self does not ensure successful transmission of data, thus to ensure the desired bit-error ratio, the minimal signal-to-noise ratio (SNR) has to be added to the noise floor to obtain the MDP. Theoretically the MDP can be calculated with formula:

$$P_{MDP}[-] = F \cdot kT_0 \cdot B_{RF} \cdot SNR_{MIN}$$

which after some simplification reduces to:

$$P_{MDP}[\mathrm{dBm}] = -174 + F[\mathrm{dB}] + SNR_{MIN}[\mathrm{dB}] + 10\log_{10} B_{RF}$$

Typical values of $P_{MDP}$ are as low as -100 dBm, the measurement equipment used in our laboratory though has limits to minimal detectable power and these must be considered.

The upper limit of dynamic range is maximum input power at which the receiver is not saturated yet, or, the one dB compression point.

Dynamic range can be determined as a ratio of these two power limits:

$$DR[\mathrm{dB}] = P_{1dB} - P_{MDP}$$

The dynamic range can be described also graphically:

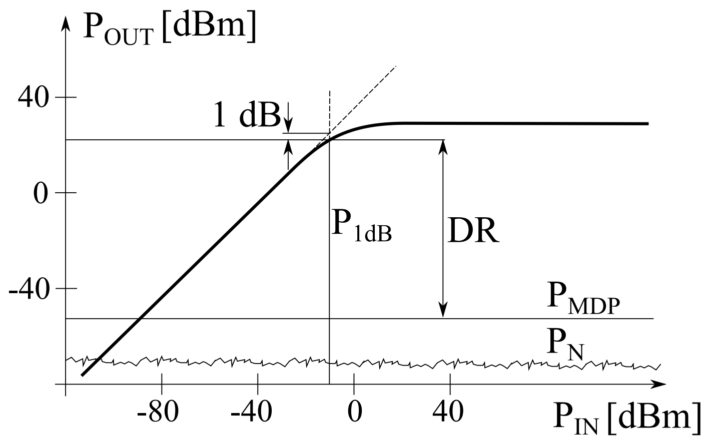


*Figure 1. Graphical determination of the dynamic range of a receiver. $P_N$ is the noise power, $P_{MDP}$ is the sensitivity and $P_{1dB}$ is the one dB compression point.*

**Receiver under study**

The block diagram of the RF parts of the GSM base station studied in this lab experiment is presented in Fig.2. The receiver chain of the base-station contains a filter (bias Tee), diplexer and a pre-amplifier. With producer specified sensitivity of around -112.5 dBm. Since the base-station is fully integrated we cannot access the demodulator, local oscillator or baseband signal. Instead we will concentrate on the input receiver chain consisting of the bias Tee, diplexer and LNA. The minimum SNR required by the GSM standard is around 10 dB, this value will be used later with the calculation of the sensitivity of the receiver from the measured data.

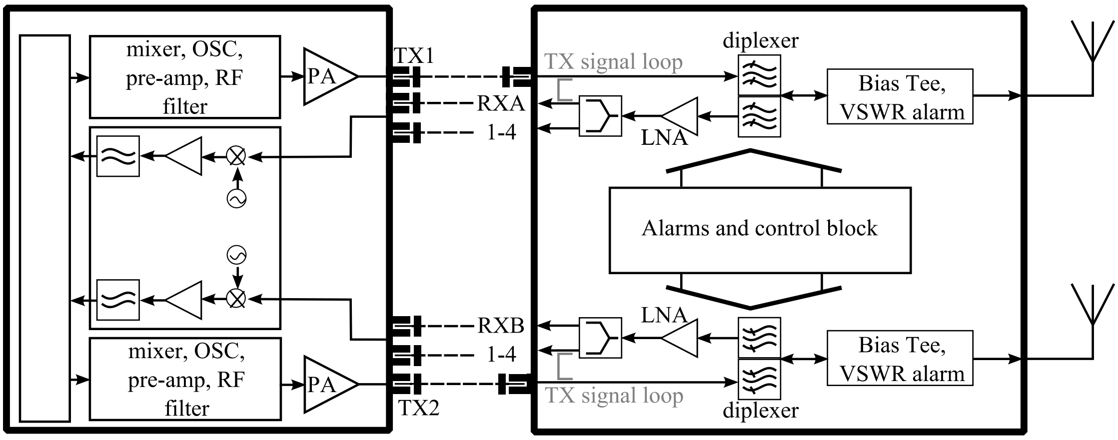


*Figure 2.The block diagram of the RF parts of the GSM base-station studied in this measurement lab.*

**2. Pre-study**

2.1 Present all the required measurement setups (draw a figure) and procedures .Take into account the attenuation of the cables. In which range is the attenuation of coaxial cables at 900 MHz? Pick the most suitable measurement equipment if there are several options to choose from.

2.2 A signal generator is connected to the input of the RX pre-amp block. The VSWR (voltage standing wave ratio) of the pre-amp is 2.0 and the VSWR of the output of the signal generator is 1.6.

a) What is the range of additional attenuation due to this mismatch in the measurement of the pre-amp block?
b) In what range is the attenuation due to mismatch, when an ideal 10 dB attenuator is connected between the signal generator and the pre-amp block? What is the benefit/drawback of inserting this attenuator?

2.3 The noise temperature of the pre-amp block is determined using the Y-coefficient method. The noise level of the spectrum analyzer HP8596E is $P_{SA}$< -125 dBm when the input is matched and the resolution bandwidth is 30 Hz.

a) How much gain is required from the LNA-amplifier in order to measure the noise temperature with the HP8596E? The noise figure of the amplifier is 2.8 dB and the attenuation of the bias Tee and the diplexer (see Fig. 2) is 0.7 and 0.4 dB respectively.

b) Does the order (i.e. which is first in the chain) of the amplifier, bias Tee and the diplexer in the pre-amp block have any influence on the result of Y-coefficient measurement? If yes, say why.

2.4 Discuss briefly the major changes in the requirements for the RF performance of the blocks in the RX chain when we move from 2G to 3G to 4G systems.

## 3. Measurement tasks

Before the measurements, the assistant will introduce the parts of the base station and show how the base station transmitter can be turned on and off through a PC that controls the base station. **NOTE: While connecting cables, the base station transmitter must always be turned off (stop transmission in the software). The TX-output/antenna connector must always be terminated with a matched power attenuator (30dB). This is to protect the power amplifier in the base station and also to protect the spectrum analyser or power meter when measuring the output power or spectrum of the base station.**

*3.1 Measurement of 1-dB compression point of the RX pre-amplifier block ($f_{RF}$ = 900 MHz).*

The compression point is a measure of maximum power at which the input amplifier works in linear mode and sets limit to the received signal power level. The frequency of 900 MHz is conveniently around the center of the RX band.

*3.2 Measurement of the RX pre-amplifier block gain*

The bandwidth of the RX block should account for the GSM specification for the RX band limits. Measure the 3dB bandwidth of the block and determine approximately the equivalent noise bandwidth (graphically using the additional material) and the TX-band (stop band) attenuation.

*3.3 Noise temperature of the RX pre-amplifier block*

Determine the noise temperature of the RX block (consisting of bias Tee, diplexer and pre-amplifier) with the Y-coefficient method. Use the noise diode as active noise source (and as passive noise source at room temperature when supply voltage is switched off).

3.4 Sensitivity *of the RX pre-amplifier block*

Measure the sensitivity of the RX block using suitable equipment.

### Equipment used

- Cables and attenuators
- Spectrum analyzer HP8596E
- Signal generator Rohde&Schwarz SML03
- Noise diode HP346C, *ENR* around 20 dB

## 4. Final report

The final project report should contain following information: what was measured (and how), clearly described results from the measurements, analyze where needed, error estimates, and conclusions about the operation of the base station and its components based on the results. In addition, it would be good to comment the measurement method and equipment, for example: was there enough measurement equipment for the work. We are always open to constructive criticism on how to improve this exercise.

**Specific task:**
Calculate the value of dynamic range of the RX pre-amp block based on the measured data and compare it with theoretical one (the 1 dB compression point is obtained from measurement for both cases since the producer does not specify this value).

## 5. Deadline for pre-study and final report (please return all reports by e-mail)

1. Pre-study deadline is **16. 01. 2014** (subash.khanal@aalto.fi ).
2. **Based on experience we recommend you start writing the final report shortly after the actual measurements!** Final report deadline is **10. 02. 2014.**

## References

[1] Räisänen A., Lehto A.: *Radio Engineering for Wireless Communication and Sensor Applications*. Norwood 2003, Artech House, Inc..

[2] Pozar D. M., *Microwave engineering*, John Wiley & Sons, Inc., 1998.