Exercise 4: Signal Analysis

The objective of this exercise is to measure the influences of real (non-ideal) transmitter amplifiers and mixers onto the signal quality. The exercise is carried out using a vector signal generator and a signal analysis system.

Exercise preparation

The exercise is based on Chapters 5 and 6 of the lecture notes of "RF Techniques". You should also be familiar with the substance of "Modulation and Detection Techniques", in relation to the properties of GMSK and QAM. A good overview is also provided by the application notes available at the laboratory website. Work out the following additional topics out of them: EVM, I/Q impairments, PDF, CDF, CCDF and Crest factor.

As a preparation, have a look on the product website "http://www.keysight.com/find/89601b" to get familiar with the possibilities and basic concepts of signal analysis. Due to the complexity of the signal analysis software, its details can be explained only in the context of the laboratory exercise.

Hardware Used

- Signal Analyzer:
  - Software: Keysight 89601B
  - Hardware (Receiver): Agilent N4010A, 2.38–2.52 GHz center frequency, 40 MHz bandwidth, 500 kSamples memory

- Signal Source:
  - Rhode & Schwarz SMBV100A with internal baseband modulator

- Test amplifier:
  - Mini-Circuits HPS-30 W-252-S+:
    - Frequency range: 700 MHz – 2.5 GHz
    - Output Power: 30 W (!)
    - Gain: typ. 50 dB

- Power attenuator

Exercise Tasks

1. Measurement of the output signal quality of the RF signal generator

Perform the following measurements on different kind of signals. Therefore, connect the signal generator directly to the signal analysis system. Select a center frequency of 2.45 GHz and an appropriate output power with low distortion!

Use the following test signals:

- GMSK, 2 Mbit/s, BT = 0.3
- QPSK, 4 Mbit/s, 0.5 RRC
- 16-QAM, 8 MBit/s, 0.5 RRC

Answer the following questions for each of the test signals:

- What shape has the spectrum of the transmitted signal?
- What can be said about PDF and CCDF? What is the Crest-factor?
- How is the transmission spectrum linked with the transmission filter?
- What effect has a change of the symbol rate?
- What effect has a change of BT on the bandwidth and ISI?

Additional questions:

- Which parameters change when comparing a 16-QAM to a 64-QAM?
- How does the eye diagram of a 16-QAM look like (with RC and RRC filter)?
- Interpret the phase trellis of a GMSK signal!

2. Analysis of non-ideal modulation signals

Connect the signal generator directly to the signal analysis system. Select a center frequency of 2.45 GHz and an appropriate generator output power. Use a 16-QAM, 8 MBit/s, 0.5 RRC modulation format!

Measure the quality of the generator in terms of:

- EVM (Error Vector Magnitude)
- carrier suppression
- I/Q phase imbalance and I/Q amplitude imbalance

Create an imperfect modulation by using the signal generator's impairments menu! Discuss the effect of different impairments onto the constellation/spectrum and how they impairments can be measured!

Additional question:

- Interpret the spectrum of the EVM signal!

3. Measurement of the constellation change by a nonlinear amplifier

Connect the amplifier (Mini-Circuits *HPS-30W-252-S+*) followed by a power attenuator between signal source and signal analysis system. Use a center frequency of $f = 2.45$ GHz and a **maximum input power into the amplifier of 0 dBm**. Use the spectrum analyzer as mixer and connect its IF out to the VXI-sampler. Determine the spectrum analyzer's IF frequency as accurate as possible!

When setting up the following steps:

a. **Do not** connect the power amplifier initially to the power supply.
b. Turn off the RF source.
c. Limit the power of the RF source to 0 dBm.
d. Wire the entire structure.
   Note: the power attenuator must be installed in the correct orientation.
e. Check that all RF connectors are proper connected (with nominal torque).
f. **Ask your supervisor for power-on admission!**
   Do not turn on before it has been approved by your supervisor!
g. When you got the permission to power your setup, connect the amplifier to the power grid and strictly keep the following on/off sequence!

For RF amplifiers always follow this power on/off sequence:

Power on	Power off
1.) Connect inputs and outputs to 50 Ω 2.) Turn on DC power supply 3.) Turn on RF power	1.) Turn off RF power 2.) Turn off DC power

Investigate your setup at an input power of –30 dBm into the amplifier:

- Did the SNR change compared to the direct connection (generator to analyzer)? Why?
- Does the constellation diagram show phase noise?

Use the following signals…

- GMSK, 2 Mbit/s, BT = 0.3
- 16-QAM, 8 MBit/s, 0.5 RRC

…and measure the effects of amplifier saturation onto the following parameters:

- Constellation diagram
- Output spectrum
- Error Vector Magnitude (EVM)
- PDF and CCDF

Interpret the measurement results!

Digital demodulation in the signal analysis software

The demodulator is implemented in software including all the features like carrier recovery, filtering, synchronization, etc. For correct operation it is required that the modulation parameters (modulation type, symbol rate, filter, etc.) are proper set. The following setup block diagram is used for all digital modulation formats (except FSK) and introduces the signal names used in the vector signal analysis software.