Lab 4. Single parameter dynamic system

Goal: to extend theoretical knowledge on dynamic systems development end evolve skills in their implementation, basing on single adjustment parameter compensation.

1. Home task

Define compensation application and cost function for the following dynamic systems. Derive compensation algorithm using stochastic gradient:

1. DC offset canceller.
2. Automatic gain control.

2. MATLAB simulations

For all simulation in this laboratory work, use the following tips:

- Create baseband model made for the sampling frequency $f_s = 100$ MHz.
- Implement 4-PAM modulated signal generation with value spacing equal to $\Delta V = 2$, i.e., symbols are from the set $\{-3; -1; 1; 3\}$. The number of samples per symbol has to be chosen to ensure 25 Mbaud high symbol rate.
- If not stated differently, use a single raised-cosine filter to form the signal.
- The length of the simulation is $N = 100\,000$ symbols.

1. DC offset implementation

- Create a DC-offset signal and add it to the generated one. The signal should be equal to $S = 0$ at the beginning of the simulation; after $n = 2\,500$ symbols (not samples), it should jump to $S = 1$.
- Create dynamical DC-offset canceller. Adjust the step-size coefficient so that the acquisition process after $\Delta S = 1$ jump would settle in $n = 20\,000$ samples. On the other hand, in the steady-state, the output signal of the dynamic system should have as low residual error as possible.

- Create a sine wave and fit three its periods in the simulation length. An amplitude of the signal should be $S = 0.5$.

- Replace the original DC-offset signal with the sine wave and try to compensate it with the dynamic DC-canceller. Adjust the step-size coefficient to minimize residual error. Make conclusions on the relation between the spectrum of the distorting signal and the step-size coefficient.

2. Automatic gain control

- Create a gain signal and apply it to the original PAM signal. The gain should be equal to $S = 1$ at the beginning of the simulation; after $n = 2\,500$ symbols, the gain hops to $S = 1.5$.

- Create automatic gain control (AGC) block. Use simplified gain adaptation expression:

$$a[n] = a[n-1] - \mu(y^2[n] - PW),$$

  where $a[n]$ is the current gain, $y[n]$ is an output of the AGC block, and PW is a power reference level. Adjust the step-size coefficient to fit the acquisition process in $n = 20\,000$ samples. On the other hand, in the steady-state, the output signal of the dynamic system should have as low residual error as possible.

- Create the following gain signal. It should be equal to $S = 1$ at the beginning of the simulation; after $n = 12\,500$ symbols, the gain starts linear rising and achieves $S = 1.5$ after $2\,500$ symbols.

- Create a PAM signal with the same parameters as the original one. Use it to modulate a sine wave of the frequency $f_0 = 0.65$ (use balance modulation). Ensure the power of the signal 3 dB lower than that of the original signal. Add two signals and build the spectra (for each of them and their sum).

- Using the signal from the previous paragraph, construct the following system. Both signals are shaped with the root raised-cosine filter in the transmitter. The distorting gain is applied not to the original signal but to the modulated signal. The receiver consists of the AGC block, matched filter (root raised-cosine filter), and the second AGC block. Adjust the step-size coefficients to minimize residual error at the output of the second AGC block.

3. Task of increased complexity[1]

Define compensation application for the receiver quadrature-phase imbalance (phase difference between sine and cosine is not equal to 90 degrees). For the cost function definition, assume that, in the ideal compensation, in-phase and quadrature components are uncorrelated. Apply stochastic gradient approach to develop compensation algorithm. Create a dynamic system that compensates the phase imbalance and show its operability. Develop the experiment yourself.

4. Report structure

1. Home task.
2. Block diagrams of the developed dynamic systems.
3. Distorting effect and the compensation parameter time diagrams.
4. Time diagrams of the input and output signals of a dynamic system at the beginning of the adaptation and in the steady-state.
5. Listings.
6. Conclusions, including your consideration about:
    - The relation between the spectrum of the distorting signal and step-size coefficient;
    - The necessity of two AGC blocks.

[1] Necessary to get mark higher than 8 (eight)